TRANSITION ZONES BETWEEN URBAN AND INTER-URBAN AREAS: IDENTIFICATION AND DEFINITION CRITERIA

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ABSTRACT

Discontinuity is defined as a spatial or temporal range that interrupts the continuity of something. In any branch of engineering linked to human behaviour (but not only), discontinuities should always be mitigated. A sudden change of stiffness, strength, trajectory, speed or energy is always a problem to solve, trying to contain and govern the laws of nature.
Italian standards classify roads starting from their division into urban and inter-urban roads. This distinction does not need any further explanation because it is based on knowledge of the concept of the city, which is obvious in modern society. However, everybody also knows that it is not at all easy to establish where a city finishes and where the boundaries of a rural area are.
Moreover, the intuitive distinction between the two types of road is sometimes not sufficient in practical applications. Indeed, there are some roads which although basically interurban, pass through built up areas, even quite large ones, and provide a series of strong administrative and managerial ambiguities. In addition, these roads can also cause behavioural problems to the road users because of the change from one condition to another one. Consequently, they cannot always be easily determined either formally or substantially.
This paper is aimed at highlighting the need for a classification of a new road category for transition zones identifying variables to distinguish urban from inter-urban areas. On this point, the paper provides some indicators and thresholds values, useful to classify transition roads between urban and suburban areas. These indicators and thresholds come from a reasonable logical analysis carried out among the elements that typically characterize the type of a road.

1 INTRODUCTION

A key innovation in road engineering arose many decades ago with the intuition that user behaviour cannot change instantaneously from driving in a straight line to round a curve. Indeed the manoeuvre of the rotation angle of the steering wheel needs time to be completed. Consequently, the trajectory of the vehicle turns into a winding path around the axis. The transverse acceleration must be able to vary gradually while the cross slope of the road surface also varies gradually. For these reasons, road design standards require the insertion of adequate transition curves between straight sections and circular curves, designed to drive the user behaviour in a natural and progressive way from the infinite curvature of a straight section to the specific value of curvature corresponding to the circular curve. It is desirable that the centripetal acceleration or force should increase (or decreases) linearly with the distance travelled on the spiral easement. This principle defines the geometry of the spiral easement: its curvature begins at zero on the straight section (the tangent), increases linearly and ends at the curvature of the horizontal circular curve where the easement meets the curve. In a second stage, it was also understood that geometric adjustment has to be made compatible with an adequate variation of speed. Currently many road regulations require that the speed variation between a straight

section and circular curve has to be controlled through appropriate checks to be carried out using a diagram of speeds along the path that, setting an appropriate value of acceleration (or deceleration), sets the length of the transition curve.
The example described is useful to illustrate a general principle of road safety: most of the time, in order to raise the level of safety it is necessary for road geometry, the trajectory of the vehicle and user behaviour to change as gradually and harmoniously as possible, by inserting the proper transition sections between the elements of discontinuity.
This general principle, now acquired for the planimetric geometry of roads, has not yet been applied for discontinuous road elements related to land use, particularly between urban and inter urban areas. Any careful observer can easily realize the fact that there is a strong analogy between the above described case and the transition of a road between urban and inter urban areas. On the contrary, in this area, in the absence of an appropriate transition zone (i.e. in the absence of any regulation), user behaviour, characterized by the selected speed and transversal position of the vehicle, is often forced to make sudden changes, sometimes not supported either by developments in the geometry, or by vertical or horizontal signs.
The need for an appropriate transition zone derives from the observation that the behavioural changes would be obviously made too late if they were made in the urban area, and unsupported by any regulation or enforcement if induced in the inter-urban area. The division between urban and rural areas is actually strongly influenced by planning and administrative needs rather than by road safety and can easily be out of phase with the considered road, both in time and space. Hence, the criteria to identify and define areas of transition cannot refer either to administrative regulations (which often have only formal value) or to existing road regulations (which are unsuitable for the case) or to the urban planning regulations (most of which concern the very future of the territory), because road safety obviously depends on the real behaviour of users and on interaction with the environment.
After a brief summary of the state-of-the-art regarding the transition zones between the urban and inter urban areas, in the first sections, the paper examines the need for new standards able to identify the transition zone and the need for definition criteria for transition roads, scanning the type of road users and their behaviours, the characteristics of the territory at the roadside and the structural characteristics of the network. Then, once the characteristics that generally distinguish an urban road from a rural road have been examined, a set of indicators able to represent every characteristic is given with the same threshold values of reference. Only a rough estimate of the change limits can be made in this study. A more realistic definition requires a statistical investigation, possibly carried out in different countries and contexts, in order to collect information on the factors involved.

2 BACKGROUND

During the last two decades, science has become interested in the development and upgrading of road transition zones between urban and inter-urban areas but it has not yet come to a standardization.
The European Transport Safety Council [1] identifies two principles of reference for these transition areas. The first concerns the achievement of maximum efficiency with the cumulative impact of measures progressively introduced in the transition zone (e.g. reducing the width of lanes or locating trees and other vertical elements on the road edge). The second concerning the implementation of traffic calming measures within the urban area in order to reduce speed.
The Dutch regulations [2] provide the possibility of raised pedestrian crossings (or raised intersections) and the planting of trees along the road side at urban accesses.

The Danish regulations allow trees along the margins, installation of lighting and slight narrowing of the carriageway when accessing primary roads and allow speed bumps and other structural measures at the access to secondary roads.
The Irish guidelines [3], besides showing the basic data for good design (traffic, accidents, operating speeds, geometry of the site), are of particular interest for introducing the concept of optical width. This is defined as the ratio of the width of the roadway and the height of the elements placed at the roadside. In fact, in the suburban area, the width of the roadways are generally greater than the heights of the vertical elements bordering the peripheral vision, while in urban areas the ratio is usually reversed. As the operating speeds are higher where the optical width is larger, the use of marginal elements of appropriate height allows a gradual reduction until the urban area.
In the United Kingdom [4] a speed reduction of 10 km/h was found at urban gateways when not followed by further measures and it went up to 15 km/h when other restraint systems were implemented. In addition, reductions in the 85th percentile of speeds of up to 25 km/h were found [5, 6] in case of urban gateways coupled with additional traffic calming measures in the urban area. Further remarks on lowering speeds and reducing accidents can be found in Taylor and Wheeler [7, 8].
The UK Department of Transport [9, 10] considers two conditions in which urban gateways can be especially effective: high speeds on approaching small towns and urban centres where the beginning of the urban area is not clearly recognizable.
Other evaluations regarding the effectiveness of safety measure implementation at urban gateways have been conducted in the USA [11, 12] and in Italy [13,14].
The speed reduction certainly corresponds to a reduction in the severity of accidents [15, 16, 17, 18] but further investigation is needed of this relationship and each safety measures (traffic calming tools, access portals, vertical and horizontal signs, etc.).
It is clear that no standard criterion able to determine transition zone has been identified and therefore there are no related design or management rules that would probably increase road safety, reducing the risk of accidents at black spots where the risk increases rapidly due to a rapid change of the boundary conditions. The FHWA Functional Classification Guidelines [19], that group streets and highways according to the level of service they are intended to provide, also do not specify what happens when a highway enters a city, or when a collector is entering a town. Adequate research should therefore be made to continue, improve and integrate the pioneering work begun in the past [20] to try to identify benchmarks and indicators that define transition zones.

3. THE NEED FOR NEW STANDARDS

The lack of agreed rules able to identify and implement a transition zone between urban and rural areas [21] and the only recent interest from the scientific and academic world in the topic is probably also attributable to the transport model schematization of road networks. Considering a road network to be composed of arcs and nodes can only be effective if the arcs are homogeneous and the nodes are well defined. Each arch is often only defined by its start and end points that generally coincide with nodes of intersection (or urban settlements). It is unusual to take into account the variability of the boundary conditions along the arc. In case of transition from rural to urban areas along the access arcs, the boundary conditions change gradually, often with a gradient not proportional to the user behaviour adaptation.
In this sense, the transition zones cannot be considered either homogeneous arcs or defined nodes. They should serve to define the road space transformation from a suburban to an urban environment, encouraging drivers to adjust their driving behaviour and, of course, improving road safety.

The necessity to define transition roads between urban and inter-urban roads leads to implementing new standards and regulations able to determine and to manage them. The key points on which standards should be developed can be identified as following:

- establish criteria for the identification of transition zones;
- determine how the speed should vary within the transition zones;
- determine the geometry of the transition zones;
- define the safety measures to be implemented in transition zones (traffic calming tools, access portals, vertical and horizontal signs, etc.);
- determine how the accesses should be managed at the edge of transition areas;
- establish the technical and administrative jurisdiction of transition streets.

It is necessary to establish criteria for defining transition areas and therefore what happens when a road passes from a rural area to an urban area in order to develop new standards.

4. THE NEED FOR DEFINITION CRITERIA

It is thus necessary to determine some rational and generalized criteria which allow the definition of an urban or inter-urban road so as to remove any kind of administrative, managerial, planning or design doubt.
The aims of this paper are to tackle the problem and propose a solution, leaving the definition of the thresholds of the change from one type of road to another study when the results of the necessary experimentation are known in the different contexts.
The two types of road usually differ according to the type of road user (e.g. pedestrian or cyclist on an urban road), the user's behaviour (e.g. people who move into town and people passing through), the characteristics of the land bordering the road (e.g. many lateral activities in the case of urban areas), and the characteristics of the network (e.g. a lot of access in an urban road network). The differences are obviously not always clear and we deliberately refer to the comparison between two roads, one typically urban and the other one inter-urban, in order to highlight this point. After examining these differences, the appropriate indicators will be determined to characterize an urban or an inter-urban road.

5. CHARACTERISTICS OF ROAD USERS

The difference in the characterization of the users of the two types of road is clear The reason of the differences is clearly connected to the different reasons for travelling [21, 22, 23].

5.1 Pedestrians

The urban road is characterized by a certain number of pedestrians, which depends on the surrounding conditions (length of the trip, climate and weather, distribution of car parks, efficiency of the public transport and multimodal relations), but also on those of the subject (available time, reason for travelling, economic conditions).

On the other hand, the number of pedestrians on inter-urban roads is very limited and occasional.

Pedestrians are the category most at risk when adequate transition zones between urban and rural roads are absent. For this reason, specific pedestrian-oriented methodologies have to be implemented in order to analyse and evaluate the effectiveness of each safety measure.

5.2 Two-wheeled vehicles

Two-wheeled vehicles are distributed between urban and inter-urban roads in a similar way to pedestrians but there might also be a reasonable number on inter-urban roads, obviously depending on the climate and the weather. A larger number of motorbikes and mopeds than bicycles might reasonably be expected on inter-urban roads.

5.3 Motor vehicles

There are motor vehicles in reasonably large numbers on both types of road. However, a greater number of larger and more powerful vehicles is expected on inter-urban roads, whereas small cars should be more numerous on urban roads.

5.4 Traffic with heavy vehicles

Heavy traffic due to freight transport is certainly greater on inter-urban roads. However, the presence of buses connected to public transport must not be neglected on urban roads.

6. ROAD USER BEHAVIOUR

The reason for a journey has a great influence on road user behaviour. Indeed it varies significantly from one type of road to the other.

6.1 Average speed

The expected average speed on inter-urban roads should be higher than that on urban roads due to better traffic flow, less interference and above all due to the greater need to match the actual travel time with the expected time. This does not take commercial speed into consideration as it is obviously different.

6.2 Level of attention

The level of attention depends on two factors other than the psychophysical state of the subject: habit and negligence. The former is caused by the absence of new elements, it lowers the level of attention and it is generally more common on inter-urban roads. The latter, on the contrary, occurs when the equilibrium is broken by something of great interest which distracts the driver from his or her driving. Distraction is more common on urban roads due to the greater possibility of interest.

7. CHARACTERISTICS OF THE TERRITORY AT THE ROADSIDE

The two types of road are strongly characterized by the surrounding environment, such that, as mentioned in the last point, it is even able to influence road user behaviour.

7.1 Residential settlements

The presence of residential settlements should obviously be a specific feature of urban roads. The presence of dwellings along inter-urban roads is unexpected and thus potentially dangerous because it provokes different driver behaviour and levels of attention. This circumstance should thus be avoided, although it cannot always be obtained with limited costs.

7.2 Services and production plants

Services and production plants should not be present along inter-urban roads because they could affect the behaviour of some road users, who might perform manoeuvres which are unexpected by other road users. It is necessary to insert a second level distribution roadway between the inter-urban road network and such plants. The presence of services and production plants near a road gives it intermediate and ambiguous characteristics which should be analyzed carefully.

7.3 Access roads

Similar consideration should be given to access roads as to those in the previous point. The presence of access roads is, in any case, typical of urban districts and local streets.

7.4 Parking

The presence of parking areas is also typical of urban roads. On inter-urban roads, the parking areas must be physically separated from the road and must be reachable by means of intersection areas or secondary roads.

8. STRUCTURAL CHARACTERISTICS OF THE NETWORK

A road network has structural characteristics which define it [24]. The salient features able to do so are listed below.

8.1 Distance between nodes

The distance between the nodes of a road network is rather limited. Therefore, many alternative routes can be taken into consideration in order to reach a destination from a given origin: the network is generally two-dimensional. On the contrary, the distances between the nodes are much greater in an inter-urban road network and the distances are in most cases determined by only one dimension which coincides with the number of kilometres travelled.

8.2 Length of the journey

The average journey length is much greater for the inter-urban road user than for the urban road user. This, as mentioned above, has great consequences on expectations and on driving behaviour.

8.3 Administrative classification

Unfortunately the administrative classification hardly ever indicates the difference between an urban and an inter-urban road. Motorways, state highways, regional and provincial highways are all considered inter-urban roads and municipal roads are considered urban roads, but this is contradicted in certain circumstances and this makes the behaviour of road users rather uncertain.
However, when an alternative route is designed and made in a town, the previously existing bypassed road section is generally changed into an urban road and comes under the municipal administration's jurisdiction, therefore in this case the functional distinction coincides with the administrative one.

9. THE INDICATORS FOR DEFINING URBAN AND INTER-URBAN ROADS

In the previous sections the main characteristics of the differences between urban and inter-urban roads have been examined. The numerical parameters to measure the urban or inter-urban type for a given road section must now be investigated. For each parameter, the threshold for changing from the urban condition to the inter-urban one can also be established.

9.1 The type

We now go on to determine the indicator for each characteristic.

9.1.1 Pedestrians

The most appropriate indicator for a given section of road would seem to be the number of transits pp in the average hour. For an inter-urban road it is:

$$pp < (pp)lim \qquad \text{(Eq. 1)}$$

9.1.2 Two-wheeled vehicles

In this case too, the most appropriate indicator for a given section of road would seem to be the number of transits pb in the average hour. For an inter-urban road it is:

$$pb < (pb)lim \qquad \text{(Eq. 2)}$$

9.1.3 Motor vehicles

The most appropriate indicator for a given section of road would seem to be the percentage of small cars pu compared to the total number of vehicles??. For an inter-urban road it is:

$$pu < (pu)lim \qquad \text{(Eq. 3)}$$

9.1.4 Traffic with heavy vehicles

The most appropriate indicator for a given section of road would seem to be the percentage of heavy vehicles pt compared to the total traffic. For an urban road it is:

$$pt < (pt)lim \qquad \text{(Eq. 4)}$$

9.1.5 Mean speed

Considering recent studies on the distribution of speeds in vehicle flows, the most appropriate indicator for a given section of road would seem to be eighty-five percent (the eighty-fifth percentile) of the vehicle speeds v85. For an urban road this is:

$$v85 < (v85)lim \qquad \text{(Eq. 5)}$$

9.1.6 Level of attention

At the present time it is not possible to determine an elementary and measurable parameter which can summarize the road user’s condition. However, because the level of attention is undoubtedly affected by traffic composition, speed and the characteristics of the territory alongside the road, the level of attention is considered, even if only partially and indirectly.

9.1.7 Residential settlements

The most appropriate indicator for a given section of road would seem to be the number of residents a150 within an area of land 150 m from each road edge. For an inter-urban road this is:

$a150 < (a150)lim$ (Eq. 6)

9.1.8 Production plants and services

The most appropriate indicator for a given section of road would seem to be the number of production plants p150 within an area of land 150 m from each road edge. For an inter-urban road this is:

$p150 < (p150)lim$ (Eq. 7)

9.1.9 Access roads

The most appropriate indicator for a given section of road would seem to be the number of access roads I within a kilometre either side of the section being examined. For an inter-urban road this is:

$i < (i)lim$ (Eq. 8)

9.1.10 Parking areas

The most appropriate indicator for a given section of road would seem to be the number of lay-bys in direct contact with the road in the kilometre either side of the section of road being examined. For an inter-urban road this is:

$s < (s)lim$ (Eq. 9)

9.1.11 Distance between the nodes

The most appropriate indicator for a given section of road would seem to be the distance d between the two nodes either side of the section being examined. For an inter-urban road this is:

$d > (d)lim$ (Eq. 10)

9.1.12 Length of the trip

The most appropriate indicator for a given section of road would seem to be the mean trip length l of the passing vehicles. For an inter-urban road this is:

$l > (l)lim$ (Eq. 11)

9.2 Change thresholds

Only a rough estimate of the change limits can be made in this study. A more realistic definition requires a statistical investigation, possibly carried out in different countries and contexts, in order to collect information on the factors involved.

However, for each of the indicators, we can suppose an interval characterised by intermediate conditions defined by two limit values (k)inf and (k)sup (fig. 1) and a central value (k)lim (fig. 2), which is better able to represent the change conditions from one type of road to another [23, 25]. The thresholds indicated result from an initial analysis of local roads carried out by the authors. Therefore they should not be considered exhaustive but just an indication that only describes the area analyzed. In the future, values can be confirmed or modified by further and more consistent analysis.

One initial hypothesis of a numerical value to be given to the indicators is the following.

9.2.1 Pedestrians

(pp)inf = 2 n/h; (pp)sup = 30 n/h; (pp)lim = 6 n/h (Eq. 12)

9.2.2 Two-wheeled vehicles

(pb)inf = 6 n/h; (pb)sup = 120 n/h; (pb)lim = 30 n/h (Eq. 13)

9.2.3 Motor vehicles

(pu)inf = 10 %; (pu)sup = 65 %; (pu)lim = 50 % (Eq. 14)

9.2.4 Heavy traffic

(pt)inf = 3 %; (pt)sup = 8 %; (pt)lim = 5 % (Eq. 15)

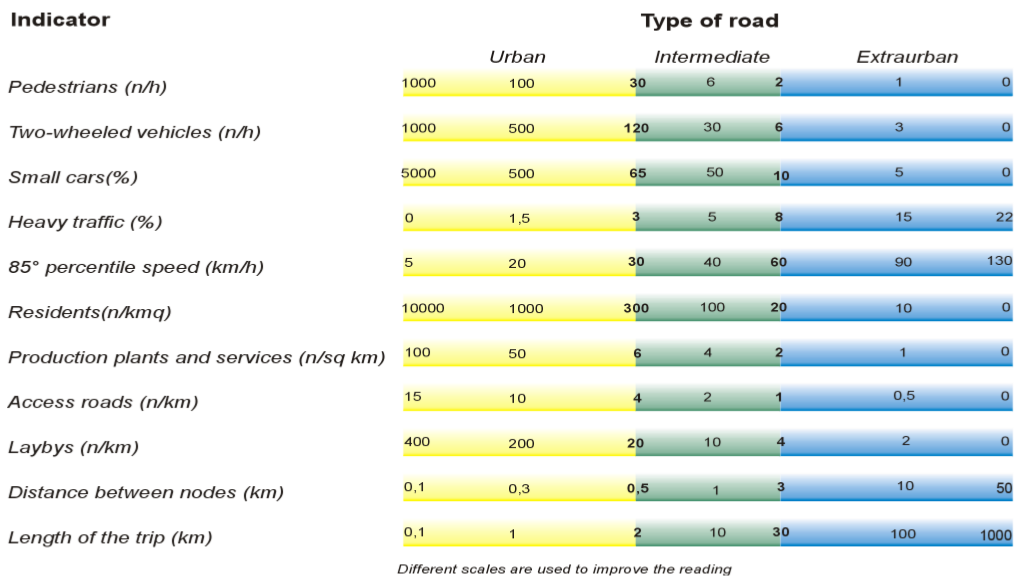

Figure 1 - Possible intervals characterizing each indicator.

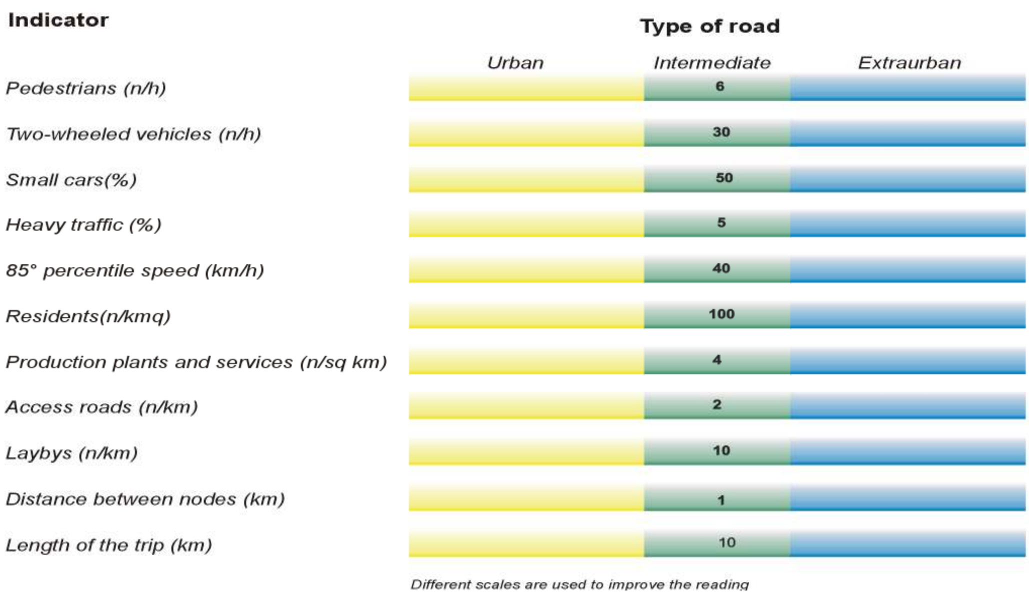

Figure 2 - Central values of each indicator.

9.2.5 Mean speed

$(v85)_{inf}$ = 30 km/h; $(v85)_{sup}$ = 60 km/h; $(v85)_{lim}$ = 40 km/h (Eq. 16)

9.2.6 Level of attention

As mentioned above no elementary and measurable indicator to summarise the road user's condition has yet been determined.

9.2.7 Residential settlements

$(a150)_{inf}$ = 20 n/sq km; $(a150)_{sup}$ = 300 n/sq km; $(a150)_{lim}$ = 100 n/sq km (Eq. 17)

9.2.8 Production plants and services

$(p150)_{inf}$ = 2 n/sq km; $(p150)_{sup}$ = 6 n/sq km; $(p150)_{lim}$ = 4 n/sq km (Eq. 18)

9.2.9 Access roads

$(i)_{inf}$ = 1 n/km; $(i)_{sup}$ = 4 n/km; $(i)_{lim}$ = 2 n/km (Eq. 19)

9.2.10 Parking areas

$(s)_{inf}$ = 4 n/km; $(s)_{sup}$ = 20 n/km; $(s)_{lim}$ = 10 n/km (Eq. 20)

9.2.11 Distance between the nodes

$(d)_{inf}$ = 0.5 km; $(d)_{sup}$ = 3 km; $(d)_{lim}$ = 1 km (Eq. 21)

9.2.12 Length of the trip

$(l)_{inf}$ = 2 km; $(l)_{sup}$ = 30 km; $(l)_{lim}$ = 10 km (Eq. 22)

CONCLUSIONS

The need to identify and then to manage the transition zones between urban and interurban roads leads to the idendification of the most appropriate parameters able to describe the transition between the two types of road in an optimal manner. In the previous sections some indicators are listed which were selected after a logical analysis and able to describe the situation analyzed (a city in southern Italy). The aim of this paper is to emphasize more the methodology able to identify transition zones and not so much the value of the indicators that may vary for other areas or situations.

The simple methodology proposed is divided into two steps. In the first it is necessary to determine the indicators mentioned for a given section of road. Later, by comparing the threshold values, it is easy to check whether the characteristics of the road are typically urban, inter-urban or intermediate, to determine the presence of any anomalies, plan road improvement and safety or modify the road network.

The procedure can be easily passed onto the decision makers by means of simple graphs (fig. 3 - 4) in which the numerical values are highlighted in defined intervals which indicate the abnormality conditions.

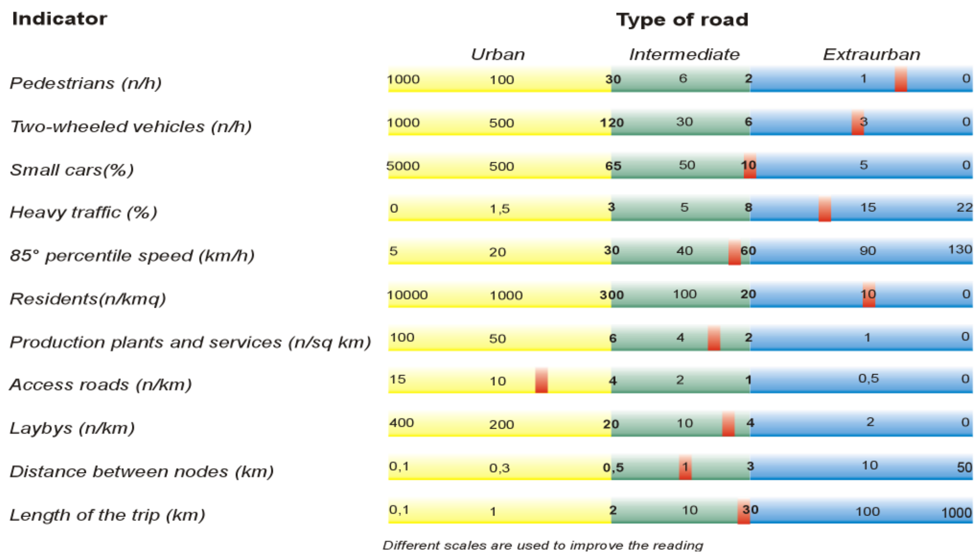

Figure 3 - Typical use of the graph

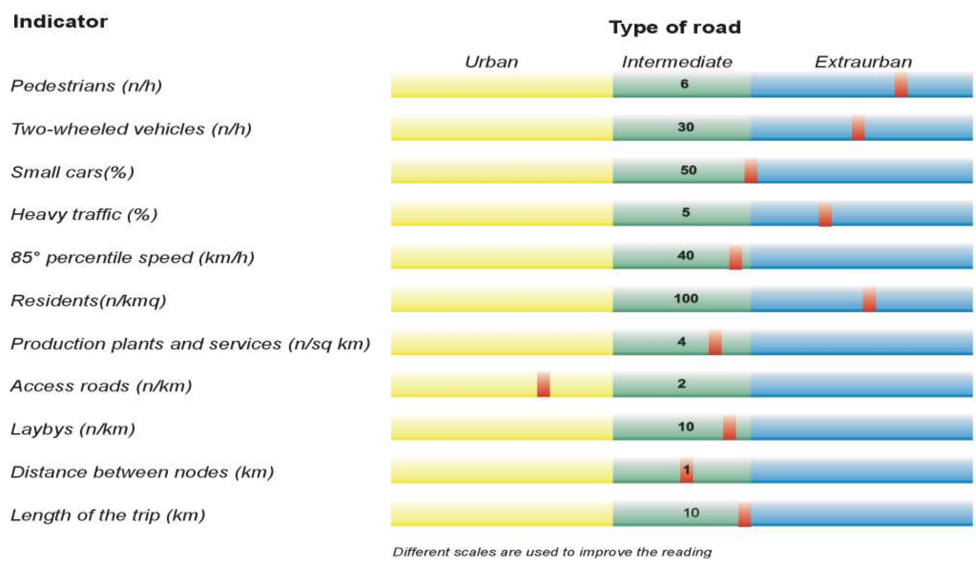

Figure 4 - Typical use of the graph.

The comparison of the graphs regarding subsequent sections of the same road should give useful information on the stability of the characteristics and on their rate of change, which could either be gradual or sudden.

It is then possible to plan the decisions of technical improvement, updating the signs and correct administrative categorization, also clearing up who should have decisional power in planning the transport infrastructures concerned, as mentioned above.

Obviously, since the classification of a section of road as “urban” or “inter-urban” depends on numerous indicators, it may be carried out, not only in the qualitative manner illustrated, but also by using other decisional instruments and techniques, such as fuzzy mathematics, multi-criteria analysis, before and after studies, etc. However it is important to not incur unacceptable simplifications due to regression to the mean, to traffic volume variations or other surrounding conditions, etc.

Adequate research should therefore be carried out to continue, improve and integrate the pioneering work begun in the past [20] to try to identify benchmarks and indicators that define these transition zones, but it is already clear that some considerations can be expressed:

- the definition of transition zones should be updated regularly, as suburban areas are the most dynamic in terms of transformation of a territory.
- a specific appendix of road regulations should be developed for the new rules for the adaptation of existing roads, which are certainly strongly influenced by the problem in question.
- specific technical rules should be developed for newly constructed roads and suburban services (such as shopping centres, interport, etc.), until the regulations are adequate.

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