A new perspective on street classification towards sustainability

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Abstract: - Roads located in urban areas should take the generic concept of streets that should be studied and analyzed based on their various domains of characterization. However, one difficulty of this process is the high heterogeneity of the features of the different urban environments. Usually, a functional road classification is based on a dichotomous relationship between the functions of mobility and accessibility, although it was not possible to represent all types of roads of a road network in this type of classification or road hierarchies. Since road classification is a fundamental tool of urban planning, this paper presents a new proposal for classification and hierarchy of streets, which takes into account the perspective of sustainable urban development. Thus, this proposal envisages the evaluation of the performance of streets, which allows identifying the key issues and defining a set of strategies for their resolution through an environmental, social and economical perspective.

Key-Words: - Street classification, road hierarchy, sustainability, urban planning, street performance

1 Introduction

Roads and streets are one of the most important factors to ensure the good performance of cities, regions and countries. It is obvious that the requirements imposed by the type and functioning of the environment in which streets are included vary considerably, depending on whether it is rural or urban. In urban areas, most streets must ensure accessibility to local areas, such as neighborhoods, CBD, among others. The traffic generated in local areas is then routed to the different types of the street network, in order to ensure a more fluid and efficient circulation of people and goods.

The study of urban streets is of a complex nature, often limited by traffic engineers to the study of phenomena associated with the mobility that they should provide, as if it were a simple road infrastructure. The complexity of this study emerges from the multi-functionality present in an urban street, usually associated with high population densities, with a wide variety of land uses.

The study of a street requires the use or definition of a road classification. The classification allows, above all, for the identification of groups of streets with homogeneous characteristics in terms of functions or features. Based on the functional hierarchy usually defined by Traffic Engineering, called "conventional hierarchy", and on the study of the functions of mobility and land access that fall in a rural or urban environment, a number of issues could be raised, such as:

- Are two functions enough to evaluate the sustainable street performance?
- Should issues associated with urban life activities that take place in the surrounding space to the carriageway be included in a street classification?
- Which term "street" or "road" is more appropriate when studying road networks in urban areas?
- And finally, how the classifications and hierarchies are used in the study of urban streets?

The study of an urban street has necessarily to be extended to its entire cross-section, i.e. to the overall street. It is this openness and interconnection with the "street character", in the study of streets located in urban areas, which aims to understand and give a contribution to the discussion and definition of strategies in order to achieve the development in economic, social and environmental areas or, in other words, the sustainable development of these streets, which is often lost.

To ensure a sustainable perspective in the study of urban streets requires the need to introduce issues of equity, i.e. equality in the use of street space and respect for the rights and compatibility of different users and stakeholders on the process of evaluating its performance and in the characterization of homogeneous groups of streets by defining different types of streets.

2 "Conventional" street hierarchies

Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the nature of its service. Most journeys involve movement through a network of roads. It becomes necessary then to determine how this travel can be channelized within the network in a logical and efficient manner. Functional classification defines the nature of this channelization process by defining the part that any particular road or street should play in serving the flow of trips within a road network [1].

In the Portuguese case, the functional road hierarchy of a road network located in urban areas was based on two functions: accessibility (land service) and circulation (traffic), which represents a complementary relationship between them, giving rise to four types of roads, usually referred to as Arterial, Main Distributors, Local Distributors and Local Access streets [2]

This classification can be considered similar to proposals developed by some organizations from Australia, United Kingdom and USA, such as AUSTROADS [3], the Institute of Highways and Transportation [4], and the Federal Highway Administration [1], as shown in Table 1.

Table 1: Street categories in different countries

Source	Road/ Street categories			
IHT [4]	Primary distributor	District distributor	Local distributor	Access road
AUSTROADS [3] FHWA[1] AASHTO [5]	Arterial streets	Distributors/ collectors		Local Streets
Portugal [2]	Arterial streets	Main distributors	Local distributors	Local access streets

It can be seen that there are great similarities between the different classes of hierarchical classifications. Thus, in order to make it easier to read and reference each of these types, the designations given in the last line of Table 1 were adopted. Not included are the streets of pedestrians because these represent a very specific case of local access streets.

3 The integration of the sustainability concept in the study of urban streets

Urban transport management and planning often requires an integration of a large number of travel modes, especially when referring to big cities, or major urban environments. However, some smaller cities could also have this scenario and the question is whether the use of different travel patterns is economically possible and sustainable.

The concept of sustainability has a vast diversity of interpretations and applications and for that reason there is some difficulty in getting a practical definition. This concept was primarily formulated by the World Commission on Environment and Development (Brundtland), who defined sustainable development as – "…development which meets the needs of the present without compromising the ability of future generations to meet their own needs" [6].

For example, on the study of urban streets with high performance of traffic and accessibility functions, a problematic street cannot be seen as a single element but as a part of a whole street network system, mainly when sustainable solutions are being carried out for that particular street. That said, for a given system, it should be possible to design and manage individual streets so that they contribute to different aspects of sustainability, in order to accomplish a greater overall sustainability. This may be done by encouraging an appropriate mix of social and economic activity for an area, while minimizing environmental damage [7].

As a methodological guide, the ten "Bellagio Principles" [8] have been proposed to assess progress towards sustainable development. These principles were selected by a group of practitioners and researchers from five continents, and served as guidelines for an assessment process including the choice and design of indicators, their interpretation and the communication of the results,

The treatment of sustainability focusing on tangible and immediate considerations for addressing the design of urban streets should include [9]:

- the accessibility for a range of users;
- the notion of a street as a destination for social and economic activity, and as a conduit providing accessibility elsewhere;
- the promotion of 'greener' modes - bearing in mind not only immediate emissions but also long term environmental consequences;
- the minimization of the environmental impacts (including accident risk and loss of amenity) due to motor traffic.

Some of the key characteristics of urban sustainability often mentioned in the literature and in policy documents are, among others [10]:

- intergenerational equity (including social, geographical and governance);

- protection of the natural environment (and living within its carrying capacity);
- minimal use of non-renewable resources;
- economic vitality and diversity;
- community self-reliance;
- individual well-being; and satisfaction of basic human needs.

The application of sustainability principles on the management and planning of urban mobility, the integration of different visions and expectations of all stakeholders must take into account the definition of strategies and actions that may influence the performance of the entire transportation system of a city.

4 A proposal for street classification

One of the reasons that led to the development and presentation of a new proposed street classification is that it is not possible to study and fit all types of existing streets using conventional classification systems. Thus, the street categories set out above and illustrated in Fig. 1 do not correspond to a point but a spot due to the high heterogeneity of the observed features within each class.

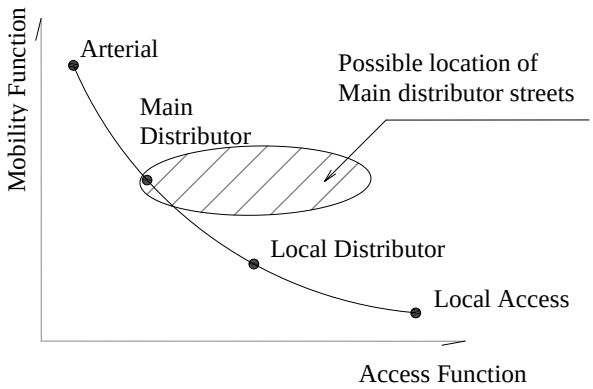

Fig. 1: Possible location of different types of Main Distributors

In order to overcome this difficulty, the use of matrix or 'periodic table' classifications may be the solution. This type of classification was developed in the European project ARTISTS (Arterial Streets towards Sustainability) to serve as a tool in the reconstruction and also in the design and management guidance of arterial streets. This classification was based on the definition of two distinct and independent functions: link (a movement conduit) and place (a destination on its own right) [7] [10], as shown in Fig. 2.

Link status denotes the relative significance of a street section as a link in the network. It is effectively based on its scale of significance within the network. The link status as presented here is effectively a restatement or repackaging of (some) conventional practice. In particular, it follows the underlying principle of conventional road hierarchy. Place status denotes the relative significance of a street locale as an urban place in the whole urban area. There is no direct equivalent to place status in conventional street classifications or road hierarchies. Therefore, the place status is – like link status – related to its geographical scale [9].

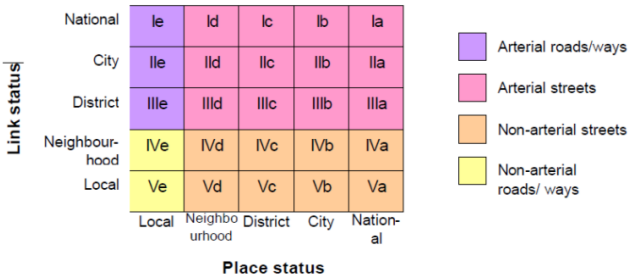

Fig. 2: Classification framework as a matrix

Although a new approach to the formulation of the matrix can include the categories of streets found in conventional hierarchies, as well as explicitly accommodate different types of main distributors, which are not currently recognized on conventional classifications. Indeed, it can incorporate the existing categories (Fig. 2), since in theory the link function is similar to traffic or mobility function; however, the place status is more than just land access or accessibility.

The 'place status' is influenced by the following set of factors: a) location, which generally reflects the historical identity of the place; b) the types of existing uses in buildings and on public space; c) the shape, i.e. the characteristics of the buildings, the presence of vegetation, meeting places, the appearance of the road, urban furniture, among others.

Table 2 presents a possible adaptation of a matrix structure, where the letters that characterize the type of a street are based on the existing road/street categories of the conventional hierarchies (link function), e.g. road (A)rterial, and the numbers correspond to categories defined by the place function.

In this example, the categories defined from the "link function", must match the different categories defined based on the role of place; however, this fact seems somewhat mismatched with reality, which can cause a large set of inconsistent types.

For example, if number 5 corresponds to a typical residential space, it is practically impossible to have, in fact, the type A5.

Table 2: Potential functional classification in a matrix structure

Link function					
Arterial roads – A	A 1	A 2	A 3	A 4	A 5
Main distributor street – DP	DP 1	DP 2	DP 3	DP 4	DP 5
Local distributor street - DL	DL 1	DL 2	DL 3	DL 4	DL 5
Local access street – AL	AL 1	AL 2	AL 3	AL 4	AL 5
	1	2	3	4	5
	Place function				

In order to avoid missing pairs of combinations, and so that the classification reflects only the reality, instead of the idealized hypothetical types of streets, a tree diagram classification is proposed. At a primary level, the streets are distinguished by the link function, which are subsequently divided into subclasses, representing a secondary level of division, through its place function. This clearly indicates the relative importance of the two functions and the sequence of the classification process (Fig. 3).

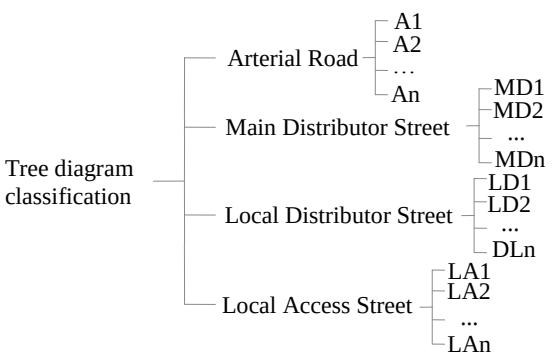

Fig. 3: Tree diagram classification

In this case, the letters of the classes correspond to the type of street, e.g. (A)rterial road, and the numbers correspond to the subclasses created based on the urban character of the place. Another advantage of using a tree diagram is the independence of the subclasses among different classes, i.e. subclass (1) from class A (Arterial) may not correspond to any subclass of other classes.

This structure has the advantage of being understood as a natural evolution of conventional classifications, where the first level is already defined, requiring only the definition of the different types of places. Then segments of the street, or streets, with different configurations of urban spaces that cross these are defined as links, allowing for the analysis of each of these segments in a more "personalized" perspective, where the knowledge of its basic features relating to various domains of the street, as well as the evaluation of the performance of similar streets can indicate scenarios of possible solutions for some existing problems.

In relation to the basic characteristics, such as the space between buildings, type of cross-section and typology of buildings, some streets included in the same category in classical classifications are completely different. It is important to clarify that the classification and evaluation of street performance do not aim to improve the urban characteristics of the street, such as the facades of buildings, nor to identify the types of uses that certain streets should possess or not. In terms of transport policy, this problem is analyzed and thought of differently, resulting in the formulation of measures at the level of public space or traffic management, which should be applied to promote patterns of mobility consistent with the activities that take place in the street.

4.1 Methodology

The methodology to define a tree classification of streets requires three steps (Fig. 4), as follows:

- Step 1 - Definition of the street type by examining its role in the overall road network of streets in the area;
- Step 2 - Evaluation by type, defined in the 1st step, the place status of different sections of a street;
- Step 3 - Conclusion of the definition of the subclasses defined in the 2nd step, through the characterization of aspects of the mobility function of the various sections of the streets.

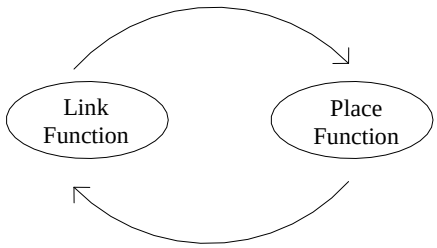

Fig. 4: Steps of the classification

With the definition of these three steps, it is possible to represent the types of streets that actually exist. Although in the first step, the physical characteristics of the streets are of little relevance to the classification, this phase is crucial for the

functional characterization of the subclasses. This methodology can also be seen as an "upgrade" of the conventional road hierarchy defined by the various local authorities, especially municipalities, with the advantage of getting a deeper knowledge about the various street types that may exist.

4.1.1 Description of the classification process

The classification process can be described as detailed below [11]:

- Phase I - Define the type of street by the assessment of its role in the overall road network

I.1 - Analyze the structure of the urban layout and define the type of streets in accordance with the level of performance of the mobility function

I.2 - Split the streets of the same type in homogeneous sections regarding the characteristics of buildings and public space (should be done based on plants and site visits).

- Phase II - Create subclasses, according to the performance of the place function

II.1 - Set the sample of streets or sections of streets;

II.2 – Collect data on the shape of each section through variables like the height of buildings, width of public space between buildings, among others;

II.3 - Apply statistical methods to obtain homogeneous groups of streets.

This is another innovation compared to conventional classifications since the definition of the street types depends on the characteristics and in the existing situation of the streets. Thus, the application of statistical methods, e.g. cluster, principal components and discriminant analysis, is required since it can consider simultaneously more than one variable in the definition of subclasses.

- Phase III - Set the typology

III.1 - apply statistical analysis using measures of central tendency, to check the level of significance of the solution;

III.2 - define quantitatively the variables that characterize the place function of a section;

III.3 - define quantitatively the characteristics of the mobility function (closing the cycle).

Once the subclasses are defined and characterized for the various street domains shown in Table 3, it is then possible to study the type of relations between them and the domains of sustainability (environmental, economic and social).

The relationships found may provide a major contribution to the development of planning and design strategies for the street, e.g. the effect of a change in the conditions of traffic regulation may have a strong impact on the speed of movement, or noise, or other variables for a given subclass. Therefore, the knowledge of these trends may allow the technician to make more appropriate decisions.

Table 3: Street domains associated with place and mobility function

Street type	DP1	…	DPn
Place function			
Buildings & space between buildings	…	…	…
Mobility function			
Traffic	…	…	…
Management and Regulation of the street space	…	…	…
Patterns of use	…	…	…

Another possible use of the classification is to evaluate the relative performance of the streets. Once the subclasses are defined, i.e. the groups that have a lower heterogeneity in relation to the whole class, it is of great interest to evaluate and compare the performance of the streets against others of the same kind, especially when the classification is oriented towards the identification of the existing problems in the street in order to promote and increase sustainability in the streets and in the city itself.

5 Main results of a case study

In the context of this work, this methodology was applied, having been selected some streets of various cities in eight European countries that had a similar performance in relation to the link function in the street network. Thus, 41 main distributors were selected, which were then divided into 172 sections according to its street character, in order to achieve a homogeneous set of streets namely in relation with specific variables of the characterization domains.

For each section an exhaustive survey of about 200 variables was carried out, with the aim of characterizing the domains related with the structure of urban space, types of use, regulation and management of the street space and modes of transport, as well as the sustainability aspects used to evaluate the street performance.

Based on the collected data and by the application of statistical techniques, a set of variables were selected as most representative of each domain of characterization of the streets, allowing to define and characterize the different subclasses of main distributor streets in relation to

the link and place function. Four types of main distributor streets have been encountered [11].

- narrow with low levels of activity;
- intermediate;
- wide with high levels of activity;
- wide with low levels of activity.

These types of streets were characterized considering the following variables:

- Place function: height of buildings; width of streets, ratio between the width of the street and height of buildings; number of doorways per 100m; percentage of active facades; and, percentage of the space between buildings (along the street).
- Link Function: volume of daily traffic, travel speed (V85); and, the ratio between the movement of people and motorized traffic.

6 Conclusions

The study of an urban street must cover all the dimensions of the street. Thus, the definition of strategies that envisage sustainable development of the entire city depends largely on how the streets perform different functions namely the link and place function. These functions represent not only the mobility or land access function of the conventional classifications but also integrate the perspective that a street is a conduit for movement and simultaneously a locale where living activities take place. Therefore, for developing strategies, policies and plans in order to achieve better patterns of sustainability for a city, a street cannot be seen as a single element of a network, but a set of sections with different characteristics and specificities with its own functioning problems, which need to be addressed with different and suitable solutions.

The integration of sustainability in terms of the study and classification of streets implies the introduction of equity issues in terms of the use of street space, and the respect for the rights and compatibility of different users and stakeholders in the definition of street types and study of the overall functioning of the streets and the entire street network.

In the process of looking for new ways to use functional classifications, three aspects should be pointed out, which should be continuously evaluated, namely: the update of the functional classification of streets over time, the undefined classification of some streets, and the impact of land use in the functions to be performed by the streets.

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