Defining Standard Symbols for Street Network Maps for Urban Planning Based on User Requirements

Claudia Robbi Sluter*, Maria Cecília Bonato Brandalize, Corné P. J. M. van Elzakker***, Ivana Ivánová*****

* Federal University of Paraná, Department of Geomatics, CURITIBA, BRASIL and CAPES – Coordenação de Aperfeiçoamento de Pessoal de Ensino Superior, BRASÍLIA, BRASIL
** Federal University of Paraná, Department of Geomatics, CURITIBA, BRASIL
*** University of Twente, Faculty of Geo-Information Science and Earth Observation (ITC), ENSCHEDE, NEDERLANDS

Abstract. This paper describes the first step of a research project which aims to establish a standard set of symbols for the cartographic representations of urban regions. The first step was a case study focused on the street network of *Pinhais* municipality, Paraná, Brazil. To achieve our research goals, we had defined methodological steps such as : (1) studying and learning how urban planners develop the analysis of the streets network, (2) understanding the geographic knowledge the users need in order to verify how is the function of each street in the network, (3) defining the geographic information about the urban area that is necessary for the analysis of the street network hierarchy, (4) designing the maps that will represent this geographic information defined on step 3, (5) defining and applying user test. The test is based on tasks related to scenarios that are defined as the methodological steps the urban planners accomplish when they analyze the function of the streets in the network. The users performed the tasks using maps generated with the proposed standard set of symbols. They were also encouraged to 'think aloud' while performing the tasks of the test. And also, a 'focus group' was set based on the results of the user's test. One important conclusion of this work was the understanding of how the users acquired their spatial knowledge, which served as a base to form their decisions. We got to this conclusion based on our research results as a premise for every cartographic solution design, that is, every design decision demands to take into account the users' needs and requirements.

Keywords: User requirements, standard symbols design, street network system

1. Introduction

The Brazilian Federal Law 10.257 of 2001 (BRASIL 2010) requires that a municipal master plan be the basic instrument for political policies when developing urban areas. According to the Brazilian Federal Constitution (BRASIL 1988) every municipality with over 20,000 inhabitants is required to have a master plan. In Paraná State, Brazil, three groups of professionals are involved when establishing a master plan: state government technicians, municipality technicians, and urban planners. Commonly, during the proposition of a master plan, the municipal executive government needs to hire a commercial enterprise, which employs urban planners. Their plan proposal is first analyzed by municipality technicians and then sent to the council of representatives to be approved as a set of laws.

On our case study the state government technicians, or the users as we refer to them on this paper, work for an institution called *ParanaCidade* which is responsible to providing knowledge support to municipality technicians. According to *ParanaCidade* (PARANACIDADE 2010) a municipal master plan is developed in five stages, being three of them directly tied to geographic knowledge. Those three stages are the analysis of the regional, the municipal and the urban reality, the master plan guidelines and its proposal, and the draft of a set of laws. In these stages it is important that every cartographic representation of different aspects on the urban reality be perfectly understood by each one of these three groups of professionals. However, that is not the current situation in Parana State where urban planners use various classifications for one singular phenomenon, which are not always based on the specifics of the geographic region. Therefore, it can affect the efficiency of both the state government and the municipality technicians on their decision making regarding the urban planning.

The solution to this issue, as we intend to present on this paper, is to create standard for map symbols. The street network was chosen as our research starting point of the topic for its design and construction depend mostly on geographic characteristics, which must be a part of the analysis of municipal reality. Concurrently, the proposals for all of the other aspects of an urban plan depend on the street network.

2. Methodology

As the efficiency of a cartographic solution depends directly on designing it based on the users' needs, our starting point was to elicit the users' requirements (Kotonya and Sommerville 1998)(Bray 2002)(Hull, Jackson and Dick 2005). The solution's efficiency had been confirmed as it was submitted to a test specially prepared in accordance with the user needs.

Our methodology's first step was to understand the geographic knowledge on which the users based themselves while accomplishing tasks that would lead to a proposal for a street network system. The techniques applied at that point were also based on background reading, as well as on opened and structured interviews (Suchan and Brewer 2000)(van Elzakker 2004). We had established the reading objectives as a set of questions that had guided us through this task:

- What is the definition of a municipal master plan in Brazil?
- How is the methodology adopted by our users while developing master plans in the Paraná State?
- What is the relation between a street network design and a master plan?
- How is the methodology adopted by our users while defining a street network hierarchy?

We had prepared the interviews based on the acquired knowledge from reading in two steps. Initially we had formulated an opened interview, as our purpose at that moment was to talk to those users about some specific topics related to the conception of a master plan and street network design, so we could have a better understanding on that matter. Secondly, we prepared a structured interview intended to refine our understanding about the geographic knowledge the users need to make decisions about defining a street network hierarchy.

The interviews were chosen over questionnaires as a result of our doubts about some of the methodological steps when proposing a master plan, the related geographic knowledge and the way users think while defining a street network. The description of the necessary geographic knowledge was the basis for designing our cartographic solution.

Our decisions about the maps designing were based on the seven stages of the analysis of the street network conditions (defined in section 3). For each and every stage we had defined geographic information that the users' need. Established by the characteristics of the geographic information we had decided which maps would be designed and built. At that stage of our research the cartographic representations are defined as paper maps.

We had applied a qualitative user's test so we could evaluate some significant aspects of the map design, which includes the set of symbols, its scales, and consequently its levels of generalization. The tests were based on tasks related to scenarios defined by a methodology divided into steps that the urban planners had to accomplish so they can understand the hierarchy of the street network. The municipality used in our case study is *Pinhais* (Figure 1).

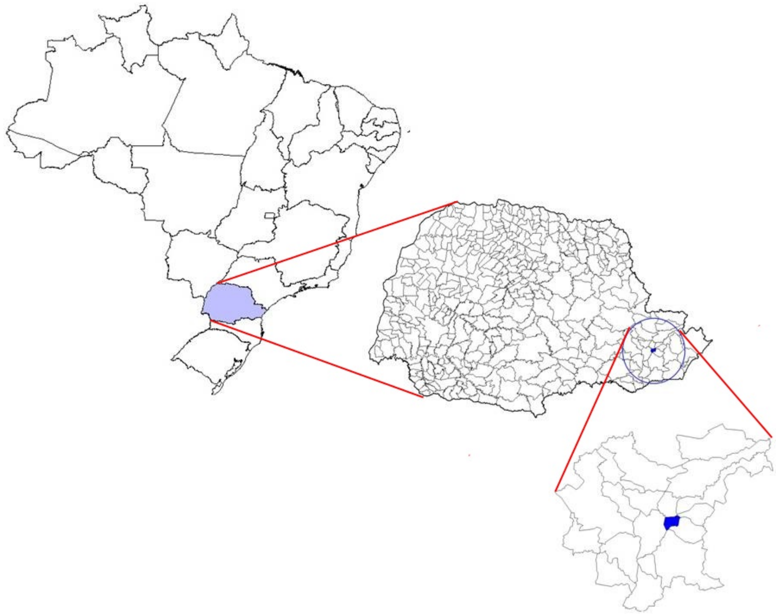

Figure 1. The geographic location of Paraná in Brazil and *Pinhais* in Paraná State.

We described the scenarios' elements based on: (1) the geographic characteristics of an urban area that must be taken into account so the aspects of the street network can be understood, (2) the characteristics of the municipality of the case study, and (3) the scales of analysis. Users performed the tasks using maps designed with a proposed set of symbols, scales and, geographic information and its classification. They were also encouraged to 'think aloud' while performing those tasks. In addition, a 'focus group' was prepared based on the results of the user's test as a way to improve our proposition for a cartographic standard solution.

3. Results

The knowledge acquired from background reading and interviews was organized in two topics: (1) the users' profile and (2) the design of the street network. The first one was described according to their expertise, their professional duties and responsibilities in respect to a master plan proposal.

The backgrounds of the user expertise are: urban planning, civil engineering, geography, business, information technology, economics and geoinformation engineering. Their professional duties are to manage the office's projects, to develop municipal master plans, and to coordinate the *ParanaCidade* regional offices. In relation to a municipal master plan their responsibilities are:

- To propose a basic management organization in the municipal government, which is responsible for monitoring and evaluating the development and also the results of the master plan.
- To gather and organize the information exchange among the *ParanaCidade* technicians, the municipality technicians, and the urban planners.
- To deal with possible disagreement between the technicians and the urban planners referring to master plan goals, to take the geographic characteristics into account, to adopt a methodology, or to meet the expected results of the master plan.
- To guarantee if the master plan's outcome is compatible with the current legislation of Brazilian, Parana State, and municipality.
- To define a guideline while establishing a permanent and a sustainable planning process when training municipality technicians.

3.1. Street Network Design as part of a Municipal Master Plan in Paraná State, Brazil

A master plan is a guide for every law enclosed on an urban planning. It conducts the actions of the municipal policies related to the public institutions, the socioeconomic development, the environment preservation, the landscape management, and the utilities. One of the policies established on a master plan says that the street network system must be related to the land use, to the public transportation and the movement of people.

Among a municipal master plan set of laws there is one for the street network system commandment, which obligatorily includes:

- A street network hierarchical classification in accordance with the Federal Law 9.503 of 1997 (BRASIL 1997), what establishes the Brazilian motor vehicle code;
- The minimum width of streets based on their hierarchy's function;
- The guideline for street network expansion.

Accordingly to the Brazilian Federal Law 9.503 (BRASIL 1997), urban streets are classified as: freeways, arterials, collectors and locals. Freeways do not have any kind of intersection, that is, they are crossed by under or overpasses. Arterial streets make possible the traffic between different regions on an urban area and they are characterized by intersections at a grade usually controlled by traffic light. Collector streets are designed to collect and distribute the traffic that go in and out arterial streets and freeways. Local streets are characterized by the intersections at a grade with no traffic lights, and are designed solely inside districts or restricted traffic areas.

To define a master plan proposal, it is necessary to perform: data survey, an information gathering, and an analysis of the streets network of the municipal reality. In accordance with our users the latter is the most important step for it guides the design of the street network hierarchy. And its accomplished has seven stages:

- Stage 1. Knowing where the limits of the districts are, and their geographic characteristics that are related to the street network and the urban occupation.
- Stage 2. Characterizing the urban regions based on geographic features and the urban land use.
- Stage 3. Verifying which streets connect different urban regions, these are arterial streets.
- Stage 4. Inside those regions, verify which streets connect with different districts.
- Stage 5. Inside every district, verify which streets function as collectors.
- Stage 6. Verifying the streets' width.
- Stage 7. Analyzing the relation between the street hierarchical classes and the urban land use.

Based on these seven stages we had designed our cartographic solution proposition (a set of paper maps) and had prepared the user's test.

3.2. The Design of the Maps

During the process of understanding the user's requirements we had detected two problems that should be explained before designing the set of symbols. The first problem is related to the graphic solution currently adopted in Paraná State for the topographic maps at large scales, 1:2000, 1:5000 and 1:10000 (Figure 2). The second one is the consequence of the lack of indispensible maps at suitable scales for the urban area analysis. To solve these two problems we had decided that our starting point would be to propose a better graphic solution for the topographic maps in two levels of generalization: 1:5.000 and 1:20.000.

Figure 2. Current solution for topographic map symbols at 1:5000 scales in Paraná State, Brazil.

The example showed on Figure 2 illustrates the reason why urban planners cannot find on those maps many of the geographic information they need. Consequently, they cannot know the characteristics of the urban area for which they are supposed to propose an improvement on the street's network. Hence we had proposed a solution based on a new set of symbols for large scale base maps defined by a working group of the Technical Chamber for Cartography and Geoprocessing (CTCG) of Parana State Government (CTCG, 2009). An example of our solution for 1:5000 topographic map of a region of *Pinhais* municipality is shown in Figure 3. Our proposed set of symbols will be adopted, from now o, as a standard solution for large scale topographic map in Paraná State.

As a consequence of not knowing that most of geographic information is already depicted on maps, users are also unaware that a cartographic generalization could also fulfill part of their needs. In other hand some of the street network's characteristics can only be understood by the users when they can visually relate the topographic features on both scales, that is, 1:5000 and 1:20000 (Figure 4 and 5). Therefore the set of symbols for generalized maps must be visually related to the cartographic symbols for 1:5000 maps.

Figure 3. Our solution for topographic map symbols at 1:5000 scales.

From the methodology's understanding for street network analysis, we had learned that the users need cartographic representations relating to three kinds of geographic features: the street network hierarchy, and both the decisions making about the streets' continuation and its network's expansion.

Thus, besides the topographic maps at 1:5000 and 1:20000 we had designed and had tested thematic maps on which we had depicted the width of the street network elements, and the impact caused on the traffic flow by the urban land use. Urban planners need to know the width of three elements of the streets design: sidewalk, traffic lane, and both together, which is the street itself. We had designed the symbols for these three maps based on size visual variables (Figure 6).

The design of the street network also requires a solution for urban regions where some activities (land use) can cause traffic congestion. For this map we had considered that every land use can be located inside a block and it can also be depicted as a point symbol. Therefore, we had defined a 1:5000 scale for this map and a thematic solution with pictorial symbols (Figure 7). The map of the land use completes the set of maps for the analysis of the street network.

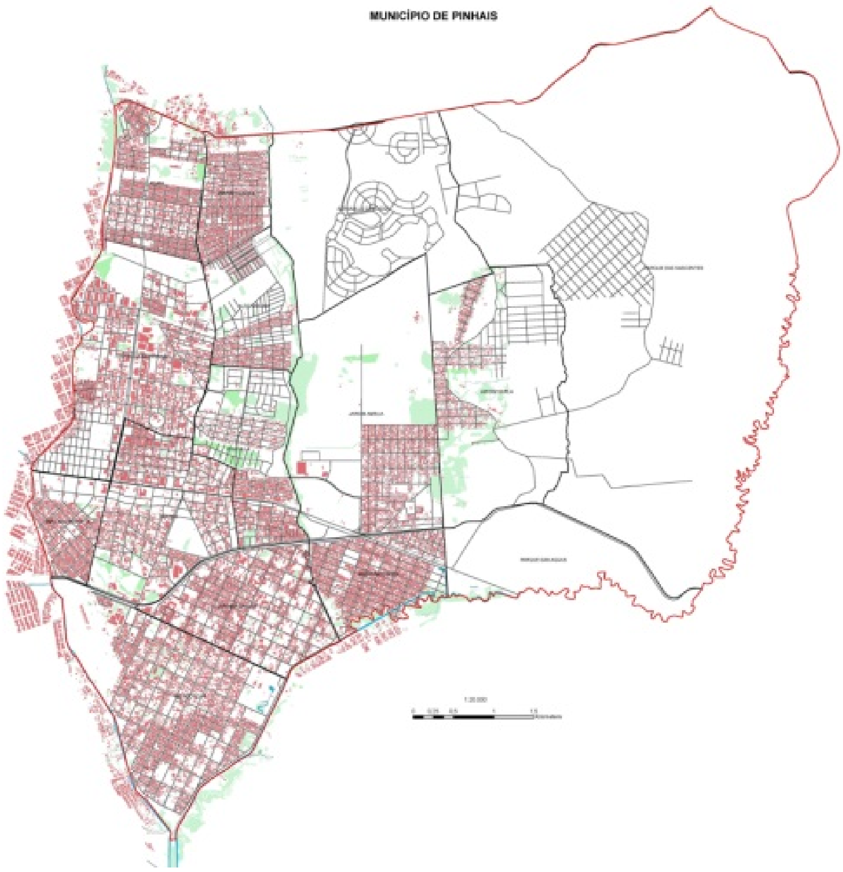

Figure 4. Illustration of a 1:20000 topographic map of *Pinhais* urban area.

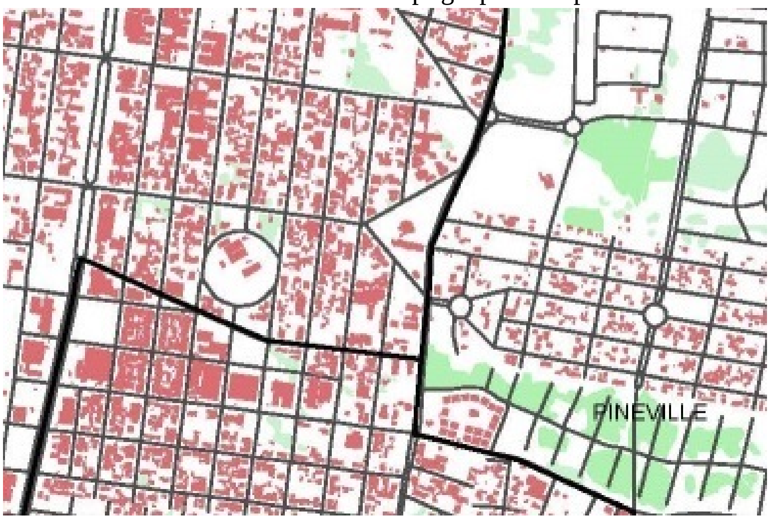

Figure 5. One region of a topographic map of *Pinhais* municipality at approximately 1:20000.

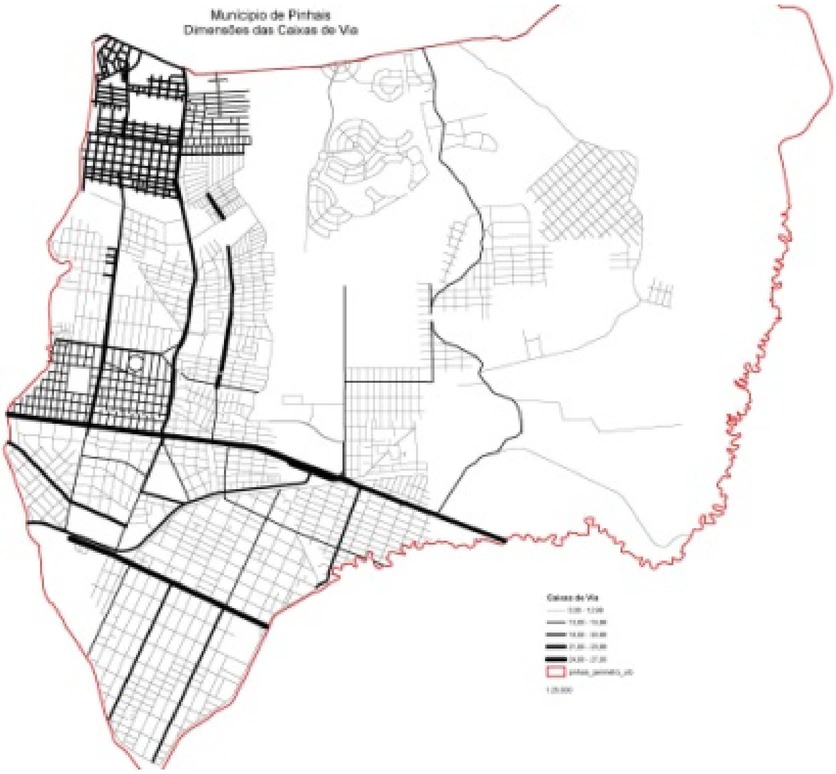

Figure 6. Illustration of the street width map of *Pinhais* urban area.

Figure 7. Some of the pictorial symbols for representing urban land use.

3.3. The User Test

According to our users the main objective of the street network analysis is to understand the hierarchy of the streets within the urban area. The users organize the steps of the methodology of street network analysis based on specific objectives. Therefore, we had decided that the main objective should be the major scenario and the specific objectives should be the scenarios of every step of the test, as follows:

- Each specific objective is defined as one scenario and it is also one step of the test.
- For each scenario the user has to accomplish some tasks.
- The tasks have to be accomplished based on maps.

- We define the maps the user has to use as well as the purpose of using that specific map.

The test is described below:

1. Step 1: We had provided the user one topographic map, *Pinhais* map at 1:20000 scale and their tasks were:

- Task 1. To describe the relation between the street network spatial patterns and the urban districts' geographic limits.
- Task 2. To describe the relation between the street network and the urban occupation pattern.

2. Step 2: We had provided the users a series of topographic maps of *Pinhais* urban area at 1:5000 scale. The users' tasks were:

- Task 3. To identify the spatial locations where it was supposed to have a traffic flow obstruction and to discriminate the geographic elements that may have caused it.
- Task 4. Based on the knowledge acquired from developing the task 3, to verify if there were regions in the city that were different from each other by the pattern of the geographic elements in relation to the traffic flow obstruction.
- Task 5. To delineate those regions on the map.

In the next three steps of the test we had asked the users to employ the series of 1:5000 topographic maps and the topographic map at 1:20000 of *Pinhais*.

3. Step 3: The users tasks were:

- Task 6. To identify the longer streets in the urban area.
- Task 7. To verify the relationship between the streets which was the result of Task 6 and (1) the street network patterns, and also (2) the districts limits.
- Task 8. To verify the connections and bottlenecks in the traffic flow of the streets indentified on Task 6.

4. Step 4. The users duties were:

- Task 9. To identify streets which connected districts inside one region.
- Task 10. To verify the relationship between the streets identified on Task 9 and (1) the street network pattern, as well as (2) the regions defined at the second step of this test.
- Task 11. To verify the connections and bottlenecks in the traffic flow of the streets indentified on Task 10.

5. Step 5: At this stage of the test the tasks were:

- Task 12: To verify the streets that had not been identified as connectors between regions or districts.
- Task 13: To identity the spatial relationship between the streets defined on Task 12 and the streets defined on the third and the fourth steps of this test.

At that moment the users might had defined the hierarchy of the streets, which was one of the characteristics they needed to understand while developing the street network analysis.

6. Step 6: The maps to be used are the three maps that depict the width of the streets (Figure 6), of the travel lanes and of the sidewalks. We had defined the following task:

- Task 14: to verify if the streets hierarchy that is the result of the steps 3, 4 and 5 is compatible with the width of the streets and their elements.

7. Step 7: We had defined the following tasks:

- Task 15: To identify the land uses that were represented in the urban land use map.
- Task 16: To verify the relation between the land use and the streets hierarchy' s result (fifth step of this test).
- Task 17: To identify the regions of the city where there was a great possibility of vehicle concentration or traffic jam.

The group of people that had participated in the test was formed by: two urban planners, one economist and two cartographers. Although we had planned the tasks to be accomplished by drawing on the maps, the participants asked to solve them by explaining us how they would do it. Their request was accepted as we asked them to orally describe their decisions and conclusions while accomplishing the tasks (i.e. think aloud). We had organized this test in two groups of people. Each one of them was lead by one urban planner and assisted by one member of the research team.

The urban planners had solved every task using the maps we suggested. This result showed us that the maps as we had conceived them were suitable to analyze the street network. The test's development and the accomplishment of its tasks were the motivation for the focus group. Considering that every step of the test had been defined as an objective to be achieved by the end of a few tasks, we had proposed to develop the focus group based on those steps. The results of the focus group were organized according to every kind of map we had designed for this project.

During the test and from the results of the focus group we had learned that to start the street's network diagnosis, urban planners need to be acquainted to a general view of the urban area exactly as we had proposed on the first task. Therefore, the first map to be used was a topographic map at 1:20000 scale. It was clear that the 1:20000 topographic map has to be generated as a generalization of 1:5000 map as the representation of the geographic features has to be related in both scales. Another conclusion was that the representation of the terrain relief is only necessary in 1:20000 scale.

The 1:5000 topographic map is suitable for most of the visual analysis of the urban area. One important remark about this map is that the analysis of the street network requires that some geographic features be easily seen and understood. Those features are road civil elements, tunnels and bridges and their connections to the streets (or roads) lanes, the districts and the urban area limits, and the street names.

The solutions we had designed for the street and travel lane width were useful and efficient for the street network diagnosis. However the sidewalk width needs to be represented on both side of the street as they may be different from one another.

The land use map was the last one to be discussed during the focus group. About that there are two observations: to redefine the classification of the land uses and to use hue color as a visual variable for the point symbols instead of representing each class by pictorial symbols.

4. Conclusion

The objective of our paper was to propose a standard set of symbols for the street network hierarchy as part of a municipal master plan. The results of the elicitation of the users' requirements had showed us that it may be necessary to establish a standard solution for the maps that may support the analysis of the street network. Another conclusion was that the standard solution for the maps should include geographic information to be depicted in every map, its classification, the scale of every map, and only then, the set of symbols. This conclusion could only be achieved through understanding the users' needs as presented in our paper.

Requirements elicitation is an interactive process between cartographers and urban planners. It stimulates the cartographers to understand how the urban planners visualize the urban reality, and how they organize in a systematic way their tasks when proposing improvements for the street network system. As a consequence we were able to propose a cartographic solution that may help them to efficiently accomplish their professional tasks.

The interactive process that was a requirement for the understanding the users' needs made possible the validation of the cartographic solution. Every map design decision was based on the users' requirements as well as the map use tests. The users' tests were defined in accordance with the tasks they need to achieve during their professional activities, for example the analysis of the street network. The definition of these tasks was part of the results of the requirements elicitation. Therefore the results of the users' tests had to be analyzed in accordance with the results of the requirements elicitation which made possible to verify the efficiency of the cartographic solution.

References

BRASIL (2010). Estatuto das Cidades. Lei n° 10.257, de 10 de julho de 2001, e legislação correlata. 3rd ed.

BRASIL (1997). Código de Trânsito Brasileiro. Lei n° 9.503, de 23 de setembro de 1997.

BRASIL (1988) CONSTITUIÇÃO DA REPÚBLICA FEDERATIVA DO BRASIL - Senado Federal, Secretaria Especial de Publicações e Editorações, Brasília, Brasil.

Bray, I. K. (2002) An Introduction to Requirements Engineering, Pearson Education Ltd. UK.

CTCG – Câmara Técnica de Cartografia e Geoprocessamento do Estado do Paraná (2009) Relatório Técnico Preliminar: Proposta de Convenções Cartográficas para o Mapeamento Topográfico em Grande Escala no Estado do Paraná.

Hull, E.; Jackson, K. and Dick, J. (2005) Requirements Engineering. Second edition Springer-Verlag, Berlin, 198 p.

Kotonya, G. and Sommerville, I. (1998) Requirements Engineering: Processes and Techniques, John Wiley and Sons Ltd. London, 294 p.

PARANACIDADE (2010) Processo licitatório de Convite n°008/2010 - Plano Diretor Municipal - Município de Lunardelli - Termo de referência padrão elaborado pelo Paranacidade que atende a lei 15229/2006. Serviço Social Autônomo Paranacidade, Curitiba, Brasil.

PARANACIDADE (2012) Compilação das diferentes classificações para a hierarquia da estrutura do sistema viário nos município do estado do Paraná. Serviço Social Autônomo Paranacidade, Curitiba, Brasil.

Suchan, T. A. and Brewer, C. A. (2000) Qualitative Methods for Research on Mapmaking and Map Use, Professional Geographer, 52(1), pp.145-154.

Van Elzakker, P. J. M. The Use of Maps in the Exploration of Geographic Data. PhD Thesis. ITC/University of Twente, Enschede, Netherlands.