Chapter 253

A symbology proposition for large-scale topographic mapping applied to the municipality of the city of Maputo

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ABSTRACT
This article deals with a proposition of symbology for large-scale topographic mapping. Emphasis was given to the case of the Municipal City of Maputo and public and private institutions that operate in urban mapping. Of the five available topographic maps, visual analysis was carried out, based on legibility and visibility criteria previously proposed by other authors. For each class of features, the graphic primitives used in each card were identified and, in the evaluated sequence, the possibility of maintaining the graphic primitive or modifying its representation in the proposed symbology. In many cases, semantic and geometric generalization was necessary to fit the symbology. The research showed that the library of symbols proposed in table form can be applied in the topographic mapping of urban areas, provided that the precepts of cartographic language and theories of graphic semiology are observed in order not to compromise the process of cartographic communication. A proposition of symbology for large-scale topographic mapping requires the cartographer to comply with the rules and specification criteria for maintaining logical consistency between topographic maps of subsequent scales, such as maps of 1:25.000 and smaller that follow the norms established by CENACARTA.

Keywords: Symbology mapping, Topographic mapping, Cartographic representation.

1 INTRODUCTION

The development of this research is motivated by the scarcity of scientific research on the proposal of symbology for topographic mapping solutions on a large scale in the municipality of the city of Maputo, Mozambique. Cartographic symbology represents natural and cultural aspects of the earth's surface. The proposal can serve as support for the standardization of symbols because different institutions involved in the topographic mapping process in Mozambique have verified discrepancies in the use of symbols when it is intended to represent the features. The ideal would be to standardize so that the production and distribution of geographic data have interoperability between the various systems, facilitating the sharing between the different institutions and organizations, allowing data acquired and processed by different sources to be reused (SLUTER, 2008, SLUTER et al 2018; Notes and Reviews, 2018). Therefore, it is important to develop research that addresses theoretical issues of topographic mapping and verifies its adequacy to the national reality, considering the geographical aspects that should be represented in topographic mapping.

The cartographic language consists of a set of symbols including their meanings, which describe the perceived differences in the symbols to represent the geographical features. The cartographic language according to Slocum (1999:20) and Sluter (2008:9), is based on three aspects of the symbols that are dependent, being: the spatial dimension of the mapped features and the graphic primitive to represent them; the level (or scale) of measures of the phenomenon, defined by the characteristics to be represented of the phenomenon; and the graphic primitives, which will be used to represent the features and their classifications.

Large-scale topographic mapping is of general use that should serve any uses and users, being the reference base for several applications, including other types of mapping (SLUTER et al., 2018:362; HOPFSTOCK, 2010:6). Being of general use, the cartographic language must be clear for the understanding for all users. Therefore, unlike thematic maps, each map to be built must be designed according to the needs of its users, however, each map is defined as a cartographic language.

The features of topographic mapping are classified according to the spatial dimensions in which the geographical phenomena are perceived in their real environment and can be: punctual, linear area and primitive are the respective forms of representation on the map, can be points, lines and areas (SLOCUM, 1999:89; SLUTER, 2008:9; RODRIGUES & SOUSA, 2008:8). However, not all features are represented by the graphic primitive identical to the respective spatial dimension (NATINGUE, 2014:43). In all cases, scale is the factor that determines decision-making about the graphic primitives to use.

MacEachren (1994:17), based on the studies of the graphic semiology of Bertin (1983), identified visual variables such as the location in the plane given by the X and Y coordinates that are the horizontal and vertical dimensions of the sheet of paper or even the computer screen, the size, the shape, the value, the tone, the texture, the orientation, the saturation, and the arrangement. The visual variables according to Robbi (2000:46) and Slocum et al. (2009:93), transcribe relationships of similarity, order, and proportionality between the data. Visual variables and their applications enable the understanding of the variables that are best suited to represent data of a certain level of measurement (NATINGUE, DELAZARI & SLUTER, 2018:510).

SSC (1977) and Bos (1984), state that cartographic communication is directly linked to visibility, legibility, and interpretation, Santil (2012) states that symbols should be identified without any mental effort or ambiguity. Visibility and legibility are the elements that define the quality of cartographic communication (COMÉ:2014:14). Readability is about how easily a map can be read and, consequently, understood by the user. Visibility has to do with whether a feature is visible to the user on a map. Concerning the interpretation of a map, this depends on how the features are represented and how the user understands them (COMÉ, 2014). Graphic semiology refers to the use of signs on the map and suggests forms of representation that allow establishing the conditions of legibility and perception of them.

The visual variables allow to highlight of the symbols from each other, reinforcing from the semiotic point of view, studies regarding the combinations of the signs (syntactic), the relations with the objects represented (semantics), and the effects of the signs on the users who use them (pragmatics) (SANTIL, 2012:374). With the assumptions of Bertin (1983), topographic mapping can be proposed on a large scale, determining norms and standards of symbology, which ensures that the relationship between cartographic design and cartographic communication, through cartographic language, is always successful (COMÉ, 2014).

The advent of digital technology has allowed the construction of cartographic symbols and enables important advances through software that allows speed in the use of spatial data, enabling numerous benefits and generating new needs. Cartographic science starts to dedicate itself to automation in the construction of maps, which in turn directly influences the symbology, by the new needs of representation allowed by computational technologies. For example, it is common to use images to scan features on cards, as well as you can independently use the *Ersi* or *NPS* symbol library to search for symbology. This library is the result of the collection of symbols from different countries and cultures. This contributes to the design of the maps, the same feature, represented by different researchers, is identified by different symbols, creating ambiguity in the identification of the meanings of the symbols. Natingue, Delazari, and Sluter (2018:511), understand that in topographic maps, the more standardized the symbols, the better the cartographic communication since these are intended for the general use of professionals from various areas of knowledge.

In Mozambique, the cartographic information used for topographic mapping is the result of historical antecedents from colonial times and is currently the responsibility of some mapping institutions and organizations at the national level. The national mapping institution is the National Center for Cartography and Remote Sensing (CENACARTA). The main series of maps produced are known as the topographic map series which includes five major scales: the topographic chart at 1:25,000 scale, the topographic map of land use and land cover at 1:50,000 scale, the topographic chart at 1:100,000 scale, the topographic map of land use and land cover at 1:250,000 scale, the topographic chart at 1:500,000 and 1:1,000,000 scales. Institutions focused on topographic mapping emerged, but rather on the use and consumption of cartographic information resulting from the topographic mapping carried out by CENACARTA, being the National Institute of Statistics (INE), Electricity of Mozambique (EDM), Maputo City Municipal Council (CMCM) and Geography Laboratory of Eduardo Mondlane University (GEOLab). A series of symbology for large-scale topographic mapping produced by these institutions is not standardized with the cartographic principles of Keates (1973, 1989), Bertin (1983), MacEachren (1994), and MacEachren (1995). Therefore, they did not establish a classification for the elements to be mapped and, consequently, did not follow methodological and systematic reasoning (SLUTER et al., 2018).

National surveys that proposed methods and solutions based on the cartographic generalization of large-scale topographic mapping were conducted by Comé (2014); Comé & Sluter (2015); Natingue (2014); Natingue, Delazar &Sluter (2018) and supported by foreigners such as Kirkowski, (2002); Nalini (2005); Taura (2007); Castro (2014); Sluter et al. (2018); Silveira (2019) and Pisetta (2021). The last three authors presented symbology solutions for large-scale topographic maps, considering urban and rural characteristics. However, research involving the criteria of readability and visibility in the context of large-scale topographic mapping in Mozambique is still a challenge (SLUTER et al., 2018; SILVEIRA, 2019; PISETTA (2021).

In the context of symbology in large-scale topographic mapping, the research seeks to answer the following question: how should symbols be defined for application in large-scale topographic mapping? The assertion of the proposal is to contribute to the knowledge about the definition of standardized symbols to represent the features of topographic mapping on a large scale, since in the process of cartographic communication the reading and interpretation of maps lack the appropriate use of cartographic language, for general use.

2 METHODOLOGY

The spatial cutout for the case study is the municipality of the city of Maputo, located in the south of the country, on the western shore of Maputo Bay. The municipality has an area of approximately 347 km² and a population of 1,088,449 according to the 2017 Census (INE, 2017), it is an urban area with different types of features, which were submitted for analysis. We analyzed the information that is part of the topographic maps of Mozambique and, by criteria of classification of features suggested by national institutions. The principles of topographic cartography were considered, in which Keates (1973) maintains that the topographic maps are represented all the identifiable features of the earth's surface, both natural and artificial, and cartographic patterns of Symbols for Digital Topographic Maps on the scale 1:10,000 of the National Center for Cartography and Remote Sensing (CENACRTA, 2012), assisted with the suggestions of the CTCG (2009) regarding the proposal of cartographic conventions for the large-scale topographic mapping.

Five paper letters were made available, being: a letter from the district of Moçimboa da Praia on a scale of 1:50,000 provided by INE; a city and Maputo chart on a 1:5,000 scale provided by EDM; a Maputo city chart on the scale of 1:25,000 provided by CENACARTA; Maputo city chart at 1:2,000 scale provided by CMCM and Maputo city chart at 1:12,500 scale provided by UEM. We worked with the map of the city of Maputo on a scale of 1:25,000 provided by CENACARTA. It was scanned in *tif* format, imported, georeferenced, and edited in *ArcMap* 10.3. The editions aimed to readjust the data so that the project process and the conditions for the occurrence of cartographic communication were. And for the elaboration of the symbols, the visual evaluation of available maps and their symbology was made based on the graphic parameters proposed internationally, which allowed to readjust of the graphic symbology according to the standards of CENACRTA (2012), assisted with the proposal of the SSC (1977), which enabled readability and visibility.

Still, on the definition of graphic symbology, the symbology adopted internationally to represent the features in topographic maps was analyzed, to solve the need for simplified symbols, which makes cartographic legibility effective. To this end, the symbology adopted by the SSC (2002) and the *Ordnance Survey* of Great Britain (2010) was also consulted.

The first step was to determine which elements should be part of large-scale topographic maps of urban areas based on an understanding of the topography defined by Keates (1973). The meaning of each feature of the topographic map was defined according to the functional approach of MacEachren (1995). In the second stage, the criteria for classifying the features were established based on the categories of topographic mapping and their classes of maps related to these features. After establishing the mapping features and their meanings and grouping them into categories and classes, the map symbols were drawn based on the approach of the cartographic language MacEachren (1994) and Bertin graphic semiology (1983).

As stated earlier in the introduction, there is a dearth in Mozambique of scientific research on symbology proposals for standard topographic mapping solutions looking at the national geographical and sociocultural landscape. Due to this gap, we reviewed research on minimum perceptible graphic parameters about point, line, and polygon symbols (Taura, 2007), the automated detection of map elements that should be simplified in large-scale topographic maps (Castro, 2014), the definition of the sequence of operators that should be applied in the map generalization process to ensure the positional accuracy of features of the Comé map (2014); Comé & Sluter (2015), and the definition of a set of colors to improve map communication for general users (Natingue, 2014). Because Natingue (2014) and Comé (2014) are national researchers, although they have developed work on large-scale topographic maps in urban areas at the international level, they are kinds of literature with significant contributions to Mozambique. They had to identify, verify and analyze all the elements that were proposed by the CTCG (1996) for topographic maps at the 1:2,000 scale and describe their characteristics that should be considered in the generalization of the map. Based on the cartographic solutions of these researches, and the study of the scientific literature related to cartography, the research method that is described below was proposed:

2.1 SET OF ELEMENTS THAT SHOULD BE PART OF THE URBAN TOPOGRAPHIC MAPPING AND THEIR RESPECTIVE SYMBOLS THAT SHOULD BE ESTABLISHED BY THE THEORY OF CARTOGRAPHY

The first task was to define which cartographic elements should be part of topographic maps. We studied the official national cartographic standards (CENACARTA, 2012) and defined a set of elements of the urban map together with proposals established by the INE. The study of patterns aimed to obtain information about the cartographic elements depicted in large-scale maps of urban regions being:

- Topographic elements that should be included in urban maps;
- How the meaning of each element is established; and
- How they classify these elements.

2.2 SEMANTICS: ESTABLISHING THE MEANING OF EACH MAP ELEMENT

This item revolves around establishing the meaning of each element and grouping it into categories and classes according to their meanings. From their meanings, determine their similarities and differences, which was important to define the classes of elements. The meaning of each element was determined based on the fact that a standard for topographic mapping is being proposed, and with this, they should be used and understood by any user. According to Keates (1973:19), a topographic map is an accurate representation of the natural and cultural features of the earth's surface. Therefore, the features represented in the topographic mapping should be those that are visible in the landscape and is familiar to any user.

Sluter et al. (2018:367) say that the meaning defined for each feature should be understood by most users. To establish the meaning of topographic features, we first checked the Mozambican patterns for national mapping at scales 1:25,000 and smaller. With this, the meanings for each feature that was part of the national mapping were defined, and finally, the elements were grouped into categories and classes.

2.3 GROUPING MAP ELEMENTS INTO CATEGORIES AND CLASSES

The symbology of large-scale topographic mapping in Mozambique was not designed with assumptions from the theory of cartographic communication and map design. As a consequence, there is a lack of a classification of elements that should be the basis of systematic reasoning for the design of map symbols. The design of cartographic symbols as testified by Keates (1973); Natingue (2014); Sluter et al. (2018) and among others, should represent similar characteristics or uses and differences between the meanings of the elements through similarities and differences between the visual aspects of the symbols. Therefore, the aspects of the symbols that define their similarities and differences are the criteria for the description and classification of the elements.

The category is the first level of classification, it may have no classes, or be subdivided into classes, and these, by a subclass, to discriminate the features within the same category.

TABLE 1 illustrates the listing of the features of the Mozambican and international standards, to show the degree of differentiation.

Table 1 presentation of different features

MOÇAMBIQUE	BLACHUT; CHRZANOWSKI & SAASTAMOINEN	CTCG
Edificações	Edificações e construções	Edificações
Vias	Estradas e vias férreas	Transporte
Rede eléctrica	Linhas de transmissão	Infra-estruturas
Hidrografia/vegetação	Uso da terra e vegetação	Hidrografia
Pontos cotados	Pontos de referência	Pontos de apoio
Vegetação	Feições de relevo	Vegetação
Limites	Linhas de limite de propriedades	Limites
Relevo/hidrografia	Serviços e utilidades	Altimetria

Source: the author (2023)

2.4 PROPOSAL OF THE SET OF SYMBOLS FOR URBAN TOPOGRAPHIC MAPPING

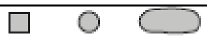
The features were projected on the maps with the assumptions of the cartographic language (SLOCUM, 1999; SLUTER, 2008) and graphic semiology (BERTIN, 1983; MACEACHREN, 1994). It was verified which symbols in the topographic maps made available could be used directly, which symbols should be modified to suit the purpose, and which symbols should be represented, that is, the symbols that would represent the features of the map that were not represented in the topographic maps available.

First, the graphic primitive (point, line, and polygon) was determined to represent each geographical element, the level of measurement for the category was nominal, and the visual variables to define the characteristics of each symbol of the map (ROBBI, 2000; SLOCUM et al., 2009). To this end, the concept of a color association was adopted (KEATES, 1973, 1989). Next, it was determined which categories should be included in the maps, and for these categories, the symbols were represented at the ordinal measurement level. Also, the visual characteristics of the national topographic mapping patterns at scales 1:25,000 and smaller were assisted for the design of symbols.

2.5 EFFICIENCY OF TOPOGRAPHIC SYMBOLOGY

Keates (1973), Comé (2014), Natingue (2014), Castro (2014), and among others, adopted readability and visibility as quality criteria to verify the efficiency of the results. In this way, an effective map is one in which people process the information presented to them and how well this transfer of information is facilitated by the map (ANDRADE, 2014:3). So, it was decided to use these criteria because this is the first study in Mozambique that aims to propose a set of large-scale symbols of topographic mapping as a result of a systematic approach. It was understood that these criteria should be the first to be checked because anyone, as a potential user of the map, should be able to perceive each symbol and quickly discriminate them among the other symbols on a map. The purpose of this set of symbols in topographic mapping is to facilitate the user of the map, through the reading of the map, spatial reasoning that allows the user to understand the geographical environment of urban areas. The readability of symbols on the map is a necessary condition for the efficiency of the map. So it was decided to use the minimum standards of symbols that are noticeable to users, as illustrated in TABLE 2.

Table 2 Minimum standards of perceptible symbols

Símbolo	Detalhe	Tamanho mínimo (mm)	
		Resultado do teste (Taura, 2007)	SSC (1977; 2002)
●	Círculo sólido	0,50	-
○	Círculo vazado	0,50	0,30
▲	Triângulo sólido	0,80	-
△	Triângulo vazado	0,80	1,00
■	Quadrado sólido preto	0,30	0,30
□	Quadrado vazado preto	0,50	-
□	Quadrado vazado vermelho	0,50	-
	Linha continua	0,20	0,25
	Espaçamento entre linhas continuas	0,20	0,25
	Espaçamento entre áreas	0,25	0,25
	Areas com detalhes nos polígonos	0,30	-
	Areas com detalhes internos	-	0,40
	Areas com preenchimento sólido	0,08	0,08
	Area com preenchimento de textura	1,00	1,00
Vias/Ruas	Letra fonte *arial* e *time new roman*	1,00	1,2

Source: Adapted from SSC (1977; 2002) and Taura (2007)

The steps and task sequence of this method were adapted from Sluter et al. (2018), who proposed a systematic approach to formalize and identify the topographic styles of different countries based on Kent &Vujakovic (2009) and Ory et al. (2013). The authors sought an understanding of topographic styles, comparing the set of elements and their semantics and symbols designed for European topographic mapping, the aim here is to define a topographic style for large-scale urban maps in Mozambique.

3 RESULTS AND DISCUSSIONS

3.1 ESTABLISHMENT OF THE SET OF URBAN ELEMENTS FOR MAPS AT THE SCALE 1:10,000

With the documentary research, it was understood that the patterns of map symbols (CENACARTA, 2012), are defined as a table of elements and their related symbols (TABLE 3). However, for these standards, CENACARTA has established a definition for each element. CENACARTA assumed that the meaning of each element of the topographic map is common knowledge and that all users would understand the use.

Table 3 part of symbols for digital topographic maps at scale 1:10,000

No.	Feature Class	Data Class	Feature Name	Code Number F.C	D.C	No.		Data Typ	Definition	Acquisition Criterion	Data Acquisition Method	Symbol (Shape and Size)
	Constructions	Building	Casas isoladas (Independent Building/House)	6	1	1	6101	polygon	Single or double stories building/house.	The building whose short side length is more than 4 m should be plotted.	The data will be acquired by photo interpretation. The edge of building shall be plotted at scale. The direction of plotting shall be clockwise.	Colour : Black70% (C70%M70%Y70%) width : 0.1mm
	Constructions	Building	Construções dominantes, predios (Prominent Buildings)	6	1	2	6102	polygon	More than 3 stories permanent building	The building whose short side length is more than 4 m or equivalent should be plotted.	The data will be acquired by photo interpretation/field identification. The edge of building shall be plotted at scale. The direction of plotting shall be clockwise.	Filling Colour : Gray50%(C25%M20%Y15%) outline:Black70% width : 0.1mm
	Constructions	Building	Casas (Building, house minimum)	6	1	3	6103	point	The building/house that the short side less than 4 m or equivalent.	All building/house whose short side less than 4 m or equivalent should be plotted.	The centre of the building/ house shall be plotted as a point data.	Colour : Black70% (C70%M70%Y70%) width : 0.1mm 1.0x1.5
	Constructions	Building Symbol	Igreja católica (Catholic church)	6	2	2	6202	point	A place where Catholic Christian prays.	All Catholic church should be plotted.	The information will be collected by the field identification. The centre of the main building shall be plotted.	Colour : Black 0.4 1.2 2.5
	Constructions	Building Symbol	Escola (School)	6	2	16	6216	point	A place where children or student are taught.	All school (elementary, Junior high, high) should be plotted with the same symbol.	The information will be collected by the field identification. The centre of the main building for school (elementary, Junior high, high) shall be plotted.	Colour : Black 2.5 1.6
	Constructions	Building Symbol	Hospital (Hospital)	6	2	30	6230	point	A building which sick or injured people are taken care of and receive medical treatment.	All hospital should be plotted.	The information will be collected by the field identification. The centre of the main building of hospital shall be plotted.	Colour : Black 2.0 2.5

Source: cenacarta (2012)

Also from the research done on the five topographic maps made available by the national institutions, there were discrepancies in the establishment of the definition for each element, the categories of predominant classes, and other information that are crucial in the design of urban maps (TABLE 4). Consequently, map design decisions were not made based on similarities and differences between the elements, which could only be determined from the meanings of the elements. As Sluter et al. (2018:367) argue, this method of projecting a set of map symbols is a weakness associated with such a map and patterns.

Table 4 features categories

Carta	Feições	Escala
INE	Limites Hidrografia Vias Vegetação	1:30.000
EDM	Rede eléctrica Vias Calçadas	1:5.000
UEM	Limites Edificações Vias	1:12.500
CENACARTA	Edificações Vias Vegetação Hidrografia	1:25.000
CMCM	Edificações Vias Limites Vegetação Lazer Calçada	1:2.000

source: the author (2023)

3.2 SEMANTICS: ESTABLISHING THE MEANING OF EACH MAP ELEMENT

It was decided that for each topographic element that is included in the national topographic mapping, one should adopt the same meaning that is published for the national mapping standards. For elements that are not mapped on national topographic maps, the main challenge was to establish a balance between what CENACRTA (2012) established and the common meanings of each element. For example, the definition of the path in the dictionary Infopedia of the Portuguese language is a strip of land that allows traffic between two places (https://www.infopedia.pt). On the other hand and according to the CTCG (2009), the path is a passable road in good and dry weather. Although the two definitions do not differ much, there are essential differences when looking for path types. The Mozambican standards for the 1:10,000 scale describe fifteen types of paths, for example: improved and profiled dirt roads under construction, standing paths, unpaved automobile paths, single-track railway, railway or single-track tranvia (CENACRTA, 2012). These examples show the different semantic levels in the Mozambican topographic mapping patterns and other CTCG patterns on different types of paths. Sluter et al. (2018) say that determining the semantic level concerning topographic mapping patterns is one of the most difficult decisions to make.

3.3 GROUPING OF MAP ELEMENTS INTO CATEGORIES AND CLASSES

Based on the analyses carried out on the national standards, and the criteria for the classification of features in Mozambicans (CENACARTA, 2012), adjusted with internationally established standards, as well as on the theories of topographic cartography based on authors referenced in TABLE 1, eight categories of features are suggested in this work to compose the urban topographic cartography in Mozambique: administrative division, municipal register, transport and communications, buildings and constructions, vegetation, hydrography, landmarks, and relief. These suggestions were made based on the analysis of the letters made available and the classification criteria adopted by them because these are alternative means that have been used due to the lack of national cartographic conventions. Then it is necessary to give some value to the means used until there are cartographic conventions oriented to topographic cartography on a large scale.

TABLE 5 illustrates a total of 97 features, which were grouped into eight categories as a result of this step, which is a list of features that must be represented in urban topographic mapping.

Table 5 total features grouped into categories

Categorias	Número de feições
Divisão administrativa	5
Cadastro municipal	2
Transporte e comunicações	17
Edificações e construções	43
Vegetação	7
Hidrografia	9
Hidrográfica	9
Relevo	5

Source: the author (2023)

The patterns for urban topographic mapping were the main reference for grouping the features into categories in this article. These criteria were established with the premise that urban topographic mapping should be understood by any user, as emphasized by Sluter et al. (2018:369), as long as the user is literate.

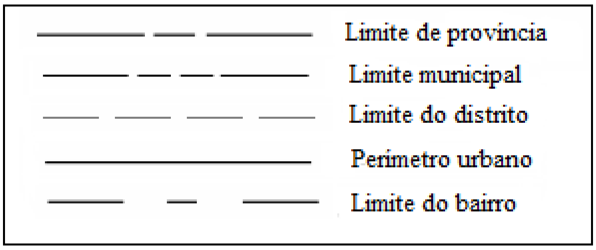
3.4 PROPOSAL OF THE SET OF SYMBOLS FOR URBAN TOPOGRAPHIC MAPPING

3.4.1 Administrative division

This category contains a proposal for the development of symbology related to the cartographic representation of provincial, municipal, district, urban perimeter, and neighborhood boundaries. In the analysis of the features on the maps, it was not possible to distinguish the sizes of the thicknesses used, only the shape and colors. It was found that the symbology adopted to represent the administrative division was represented by continuous and dashed linear symbols, differentiated through brown, red, and blue colors, without following any pattern.

In this research, the design of symbols for this category followed its distinction respecting the hierarchy, starting from the feature of largest to smallest division, and the shape of the tracing of the symbols, resembling only in the thicknesses as explained below: as for the shape of the symbol in the case of limits, the primitive graphic line was applied, dashed, with a thickness of 0.35mm for the provincial limit, municipal and district, while for the urban perimeter, the continuous and dashed trace was chosen for the neighborhood limit, both with 0.18mm, as shown in FIGURE 1.

Figure 1 proposed symbols for the administrative division



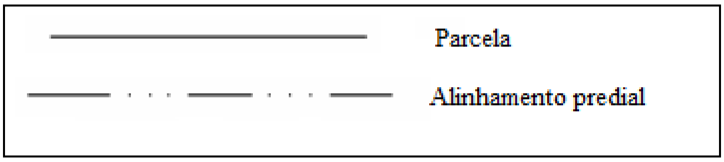
Keates (1989), argues that the representation of features based on levels of hierarchy constitutes one of the basic rules for the success of cartographic communication. For it allows symbols, even with a tendency to be similar, in hierarchy and form, to contribute to the distinction between them. Concerning the shape, Bos (1984) suggests that the minimum size of the applicable thickness when drawing the linear symbol is 0.1mm, while Raisz (1969) suggests 0.2mm, and CTCG (2009), proposed a minimum size of 0.35mm, coinciding with the one proposed in this work.

3.4.2 Municipal register

This category makes the cartographic representation of symbols referring to the parcel and building alignment materialized. These features are integral elements of the municipal cadastre and the cartographic delimitation can be materialized when these delimitations are materialized on the ground it can be called real limits.

In the design of symbols, the materialization or not of the elements was not considered. Being elements that represent delimitations, we opted for the primitive graphic line for the drawing of the symbol. As for the shape of the symbols, we opted for the primitive continuous linear graphic for the plot and dashed for building alignment, both with a thickness of 0.18mm. The design of the symbols was made respecting the minimum thicknesses proposed in item 5, as illustrated in FIGURE 2.

Figure 2 proposed symbols for municipal registration

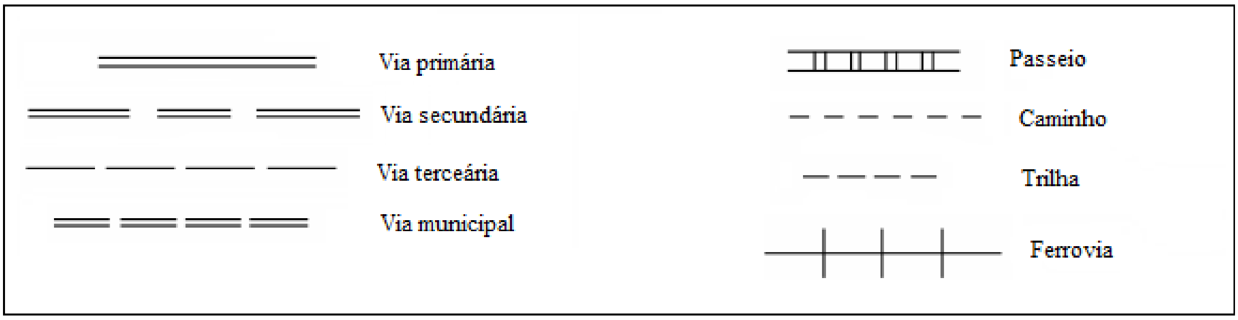


3.4.3 Transport and Communications

This category represents symbols referring to the road network, airport, viaduct, tunnel, bridge, path, trail, railway, port, and related elements such as power transmission line, power substation, power pole, antenna, and high voltage pole.

In the analysis of the road network, it was found that the lines had different thicknesses, which makes them imperceptible, the same occurs with the colors used to represent the roads, there was a differentiation in the shades. For a better understanding and organization of the symbols, it was necessary to group them into different categories and distinguish them hierarchically, based on the proposed classification, as illustrated in FIGURE 3.

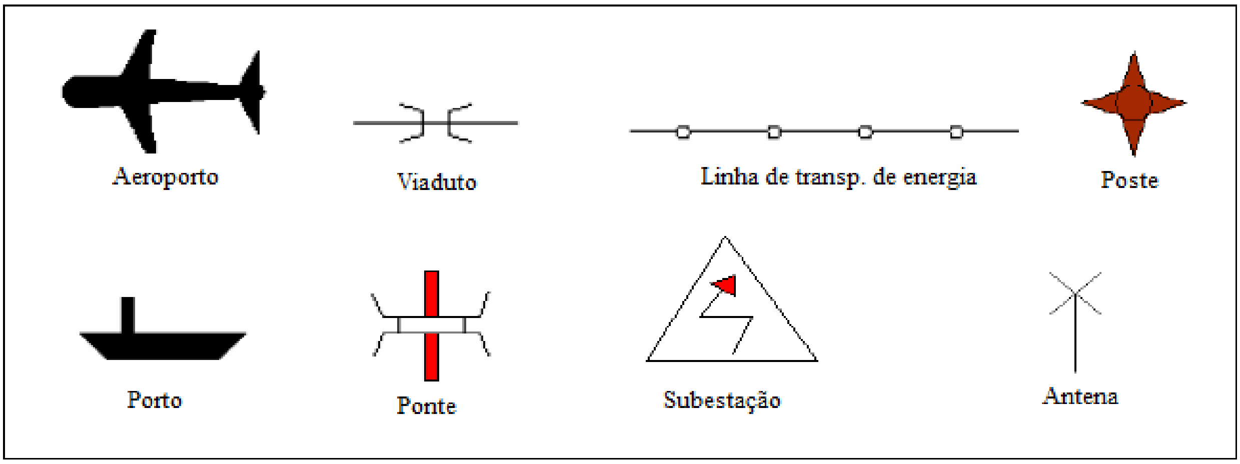
Figure 3 proposal for symbols for transport and communications



It was proposed as the solution for the design of parallel and simple linear symbols with spacing and without spacing with black color, which can be continuous or dashed, as well as considering the hierarchy and grouping between them. The line tracing for all cases was 0.18 mm and the spacing was 0.50 mm. The SSC (1977; 2002) and Taura (2007) conducted studies regarding the minimum spacing between lines for different tracings. Based on the results of the visual perception of the spacing between parallel lines of different thirds, they concluded that the spacings are different for each type of trace since the perception takes place at a distance of 0.25mm. As for the minimum thickness that a line should have Bos (1984), it suggests 0.1mm, while Raisz (1969), suggests 0.2mm and CTCG (2009) proposed 0.18mm as the minimum size.

The following elements were included within the transport and communications category: airport, viaduct, tunnel, bridge, power transmission line, power substation, power pole, and antenna. The design of these symbols was made, as far as possible, to preserve the proper appearances and proportions between the value of the elements represented and the scale of the map, to indicate the approximate area that they may occupy on the ground, as illustrated in FIGURE 4.

Figure 4 proposal for transport and communications symbols



A thickness of 0.18mm was applied to the drawing of the outlines of the symbols as well as the symbols without an outline. This layout is suggested by CTCG (2009) in its standardization proposal.

We opted for the use of pictorial and geometric symbology in the sense of not trying to distance too much the appearance of features from their reality. According to Andrade (2014) and Bos (1984), these symbols contribute to the perception of features regarding their spatiality, dimensions, and position in geographic space.

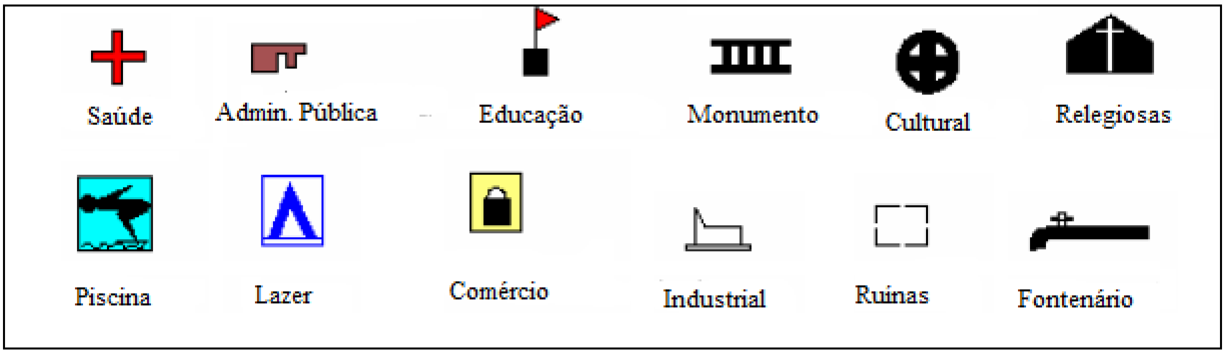
3.4.4 Buildings and Constructions

This category deals with the cartographic representation of symbols referring to buildings of health, education, commerce, industry, culture, religion, public administration, leisure, ruins, monuments, swimming pools, and fountains.

The design of symbols was based on the patterns of perceptible symbols referring to the diameter, side, and height that each feature should have, as referenced in item 5. For all cases, the side, height, and diameter were not less than 0.5mm. We opted for the use of geometric symbols since these are strongly associated with the representation of cultural features. It was considered important to use pictorial symbology in some cases to facilitate the identification of some services, as shown in FIGURE 5.

Concerning the details of the area features about the minimum standards of the symbols that users can perceive, according to Taura (2007), it was found that an area feature, the size is 0.30mm. For solid and hollow circles the diameter is 0.50mm, the discrimination of solid and cast triangles is 0.80mm on the side, and for discrimination tests of solid and cast squares is 0.50mm of minimum noticeable size.

Figure 4 proposal for building and building symbols

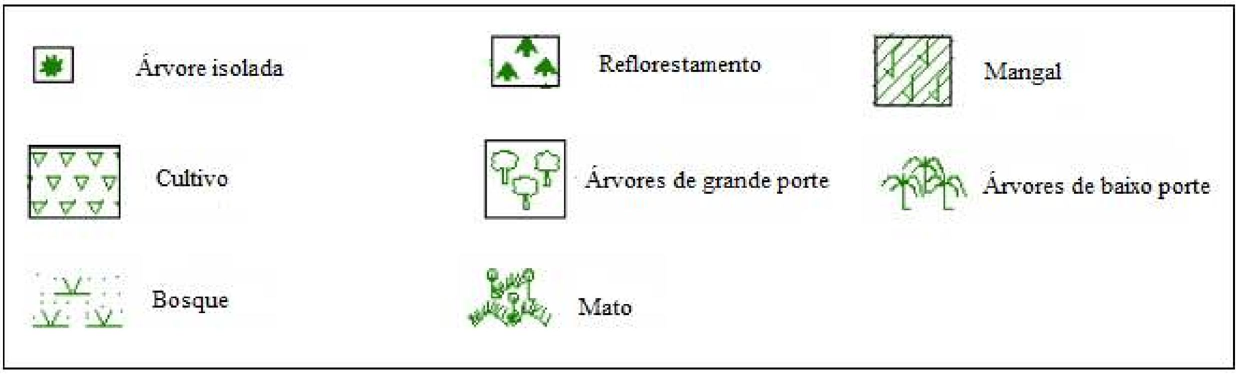


3.4.5 Vegetation

This category is dedicated to the cartographic representation of symbols referring to vegetation cover, being: isolated trees, large vegetation, low vegetation, cultivation field, reforestation, mangrove, forests, and bush. The vegetation is important in the topographic map because it indicates the index of vegetation cover that a given geographical area has, also providing elements for reading the map.

The symbols form is drawn in the color green which is the conventional color for the representation of vegetation. The basic principle of topography suggests that the colors green, white, and yellow represent the vegetation according to Imhof (1982). FIGURE 6 illustrates the symbols for vegetation.

Figure 6 proposed symbols for vegetation

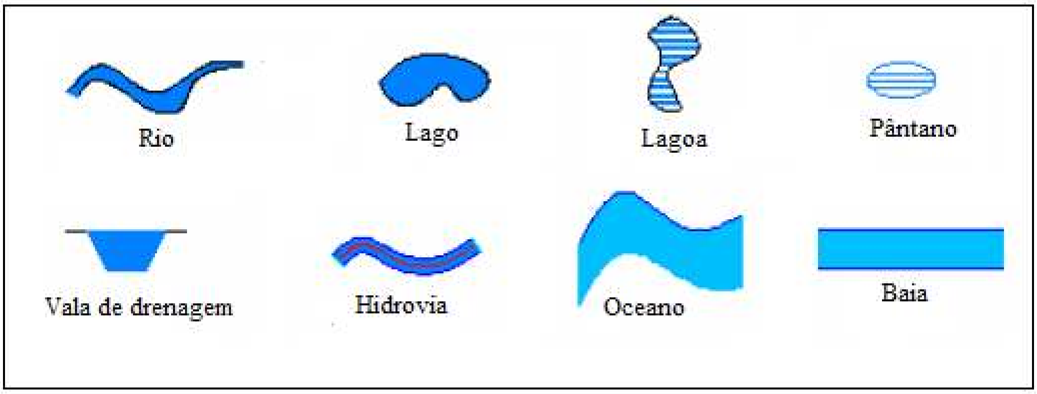


3.4.6 Hydrography

This category deals with the cartographic representation of symbols referring to hydrographic zones of the interior being river, lake, lagoon, swamp, well, drainage ditch, hydrography, ocean, and bay.

When coloring, blue was used, conventionally used, for elements of hydrography. As for the shape, the primitive graphic area was used, with horizontal hatches and solid filling. Some differences in terms of color were found regarding the thickness of the lines that surround the areas of the elements, and the thickness was 0.18mm for all cases, as illustrated in FIGURE 7.

Figure 7 proposed symbols for hydrography

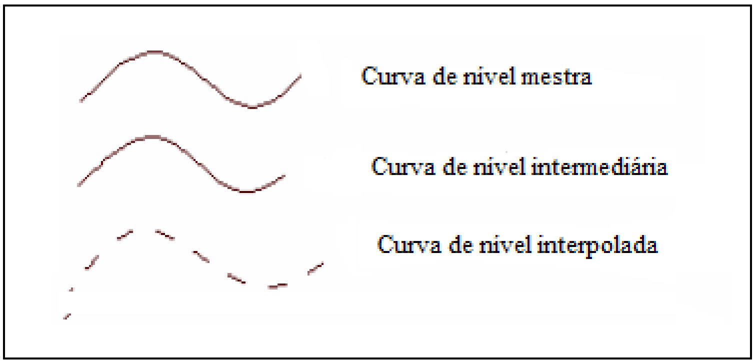


3.4.7 Level curves

This category cartographically represents the symbols referring to the master, intermediate, and interpolated level curves. The level curves were represented by continuous and dashed lines of brown color to illustrate the differences in elevations and depressions. The master level curve was drawn with a stroke with a thickness of 0.25mm, which allows the rapid perception of the different altitudes and the shape of the terrain, while the intermediate and interpolated level curves were drawn with a thickness of .18mm, differing in their tracings.

The vertical interval between level curves is 5 meters and the tightest curvature allows in a curve is 0.25mm between the center of the Imhof lines (1982). This author states that in topographic maps used for construction and engineering design purposes, the intervals of the level curves vary according to the scale in the following proportions: on the scale of 1:1,000, the interval is 0.1 meters; on the 1:2,000 scale, the range is 0.2 meters; on the 1:5,000 scale, the range is 0.5 meters; and on the 1:10,000 scale, the range is 1 meter. FIGURE 8 illustrates the proposal of symbols for the contour lines.

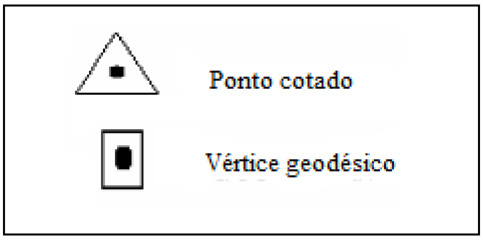
Figure 8 proposed symbols for contour lines



3.4.8 Landmarks

This category refers to the cartographic representation of symbols referring to the reference points, being geodesic vertices and quoted points. The reference points were drawn using a specific convention for the systematic mapping of Mozambique, plus the legend corresponding to altitude, both with side and height of 2mm and 0.18mm thickness of the trace in black and white, as illustrated in FIGURE 8.

Figure 8 proposed symbols for landmarks



4 CONCLUSION

The development of this research began with the search for solutions to problems demanded by the scarcity of scientific research on the proposal of symbology for large-scale topographic mapping of the municipality of the city of Maputo, Mozambique. Are the problems addressed in this work related to how the symbols should be defined for application in large-scale topographic mapping? The solution to this problem assumes as assertion the main objective of this research, which was the proposition of symbology for topographic mapping solutions on a large scale of the municipality of the city of Maputo. The analysis of the similar characteristics of the national standards (five maps), and the criteria for the classification of features in Mozambicans (CENACARTA, 2012), adjusted with internationally established standards, as well as, in the theories of cartography, resulted in the proposition of eight categories being: administrative division, municipal cadastre, transport and communications, buildings and constructions, vegetation, hydrography, level curves, and reference points.

The solutions of the set of urban elements for maps on the scale of 1:10,000 were proposed based on the similarities and differences between the elements, which were determined from their meanings.

The design of symbols for the administrative division followed its distinction respecting the hierarchy, starting from the feature of largest division to smallest, and the shape of the tracing of the symbols, resembling only in the thicknesses, for the limits, the primitive graphic line was applied, dashed, with a thickness of 0.35mm for provincial, municipal and district limit, while for the urban perimeter, it opted for the continuous and dashed trace for the neighborhood limit, these with 0.18mm.

The design of symbols of the category buildings and constructions were based on the patterns of perceptible symbols referring to the diameter, side, and height that each feature must have the side, height, and diameter not less than 0.5mm. It was proposed The use of geometric and pictorial symbols since these are strongly associated with the representation of cultural features.

The graphic parameters used in the proposed solutions are the readability criteria adopted for cartographic efficiency because this is the first study in Mozambique that aims to propose a set of large-scale symbols of topographic mapping as a result of a systematic approach.

It is recommended that for future research that follows this line of reasoning, the proposed solutions are applied. Thus, the solutions found can be compared in different products and later a proposal is presented to solve such differences.

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