CARTOGRAPHIC VISUALIZATION OF MORPHOLOGICAL AND HIERARCHICAL RELATIONS IN CITY NETWORKS: A BASIS FOR UNDERSTANDING THE URBAN SYSTEMS OF THE QUADRILÁTERO FERRÍFERO

Visualização Cartográfica De Relações Morfológicas e Hierárquicas em Redes De Cidades: Uma Base Para Entender Os Sistemas Urbanos Do Quadrilátero Ferrífero

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ABSTRACT

The present work investigates the urban agglomerates that compose and structure the urban system of Quadrilátero Ferrífero region, which is part of the peri-metropolitan space of Belo Horizonte. Analysis like these are very important to understand the regional space and network from the point of view of its urban structure, fulfilling at the same time the lack of further studies on regional scale in Brazil, and mainly about the importance of Quadrilátero Ferrífero (Iron Ore Quadrangle), known for the important role in the national economy since the XVIIIth century with the discovery of gold and, nowadays, with iron mining. Particular attention is given to the study of the functional morphological aspects of the urban agglomerates, analyzing mainly the road axes that connects the cities, characterizing them as new urbanizations along the borders, as well the processes in course of urban growth. As an essential tool for understanding the characteristics and the structure of such space, cartographic visualization is used for the synthesis of the information resulted from the research. In this way, a set of diagrams is elaborated for each urban agglomerate, concerning the evolution stage of its axes. The visualization is organized in maps that depict the structure of the regional urban system, the relations among the cities, the agglomerates and there relation with the metropolis of Minas Gerais. Cartographic visualization becomes an indispensable instrument to clarify the importance that the urban agglomerates have for the urban system of the Quadrilátero Ferrífero, as well as the importance that this system has for the peri-metropolitan space of Belo Horizonte.

Keywords: visualization, city networks, regional planning, Quadrilátero Ferrífero.

RESUMO

O presente trabalho investiga os aglomerados urbanos que compõem e estruturam o sistema urbano da região do Quadrilátero Ferrífero, que faz parte do espaço perimetropolitano de Belo Horizonte. Este tipo de análise é indispensável para entender este espaço regional e a rede urbana urbana, preenchendo, ao mesmo tempo, a ausência desse tipo de

estudos em escala regional no Brasil, e sobretudo a respeito do Quadrilátero Ferrífero, conhecido pelo seu importante na economia nacional desde o século XVIII, quando do descobrimento do ouro, e na atualidade com o minério de ferro. Neste trabalho há interesse particular nos estudos sobre os aspectos morfológico-funcionais dos aglomerados urbanos, analisando principalmente os eixos viários que unem as cidades, e caracterizando-os quanto às novas urbanizações e os processos de crescimento urbano em curso. Como ferramenta essencial para a compreensão das características e da estrutura de este espaço, adota-se visualização cartográfica para a síntese das informações determinadas ao longo da pesquisa. Com isto, são elaborados diagramas para cada aglomerado urbano indicando o estágio de evolução dos seus eixos. A organização das informações se baseia em mapas que retratam a estrutura do sistema urbano regional, dando visualização às relações entre as cidades, os aglomerados e a metrópole mineira. A visualização cartografia se torna um instrumento indispensável para esclarecer a importância que os aglomerados urbanos têm para o sistema urbano do Quadrilátero Ferrífero e a importância que esse sistema tem para o espaço perimetropolitano de Belo Horizonte.

Palavras-chave: Visualização cartográfica, redes de cidades, planejamento regional, Quadrilátero Ferrífero

1. INTRODUCTION

Current Brazilian urbanization is the result of a process that presents strong signs of the exhaustion of urban concentration on metropolitan bases. National and regional metropolises have shown a decrease in growth rates and, on the other hand, it is possible to see the strengthening of cities of a smaller dimension, notably, those classified as medium-sized cities.

According to Monte-Mor (2003), on a national scale, this process takes place in a diffuse way, although more specifically in regional spaces with more articulated and complex urban networks. In such regions, medium-sized cities play an important role on urban and regional polarization by connecting rural spaces with larger cities and, ultimately, national and regional metropolis. (AMORIM FILHO, 2007) .

The particular aspects of growth within medium-sized cities, on regions that have structured and complex urban networks, such as Brazil's southeast region, are particularly interesting because of their influence, on both urban and regional scales.

As a result, peri-urban spaces or peri-urban zones are increasingly more complex with the incorporation of predominantly residential settlements, such as gated communities (AMORIM FILHO, 2007). Or, on the other hand, through the strengthening and growth of preexisting urban settlements that are close to the city, such as old districts that incorporate and expand non-residential uses, thus bringing urban functions to parts that used to be exclusively rural areas. The dynamic of changes on regional scale is characterized by the integration of neighboring cities, creating urban agglomerations that results in strengthening of horizontal relations through spaces/zones, or resulting in conurbations. Such processes are especially observed in urban systems that are close to peri-metropolitan spaces, located immediately after the metropolitan area and under direct influence of the metropolis.

Conti (2009) points out the presence of several urban agglomerations in peri-metropolitan area of Belo Horizonte. According to the author this area comprises five regions with specific characteristics: two of them are predominantly rural and three of them present a consistent urban structure (Fig. 1).

The two predominantly rural regions, considered depressed areas due to their geographical isolation, located on landforms that are not easily transposable, are:

- The northern depressed region, on Espinhaço Hill, with sharp slopes and significant elevations. An area very difficult to be occupied, since the hill constitutes an obstacle that is not ease to overcome. Urban centers are less numerous and the ones that do exist are small-sized cities. The only center that can be highlighted, and that keeps a relationship with Belo Horizonte Metropolitan Region (henceforth BHMR), is the city of Conceição do Mato Dentro, that increasingly polarizes this area, even in micro-regional degree.

- The southwest depressed region is delimited by a set of mountains in the north and in the south, what makes very difficult the articulation with BHMR's regional space and with the agglomerations on eastern and southeastern sides. To the west, the Rio Manso dam delimits the space. In the south, the federal highway BR-381, which connects Belo

Horizonte and São Paulo, can be a solution to extend the influence towards south, that is polarized by Lavras and São João Del Rei, two important medium-sized cities in Minas Gerais.

The three main regions that comprise peri-metropolitan space of Belo Horizonte are and present a more consistent urban structure are:

- The midwest region, headed by the city of Divinópolis, is the most important one, due to its dimension and complexity, but also because of the articulation and maturity of its urban system. The network is composed of a significant number of medium-sized cities that polarize specific sub-regions, occasionally developing relationships of horizontal complementarity with nearby cities of the same hierarchical level and, in some cases, forming urban agglomerations;

- The north-northwest region, which has a smaller number of cities and a simpler urban system when compared to the midwest region, presents a network that is similar to a "christallerian" hierarchical model (the Central Place Theory proposed by Christaller). The region is headed by the city of Sete Lagoas;

- The east-southeast region is composed by sub-regions that are almost independent of each other, and polarized by specific urban agglomerations, comprising medium-sized cities. Occasionally the sub-regions present processes of conurbation and urban diffusion in their respective peri-urban spaces, in all medium-sized cities of the region. This area corresponds to Quadrilátero Ferrífero territory.

Studies about Quadrilátero Ferrífero focused on urban network, conurbations and new agglomerations have never been done before, thus making this an unprecedented work. The region is usually studied on geological and economic aspects, due to the importance it has and has had on Brazilian national economy. Studies about current urban issues on a regional scale are practically non-existent, and those that do exist are usually limited to the area of historical cities, such as Congonhas, Ouro Preto and Mariana, focusing the colonial gold mining period. So far, the only study available, regarding the evolution of this urban network has a focus on that specific period (MORAES, 2006).
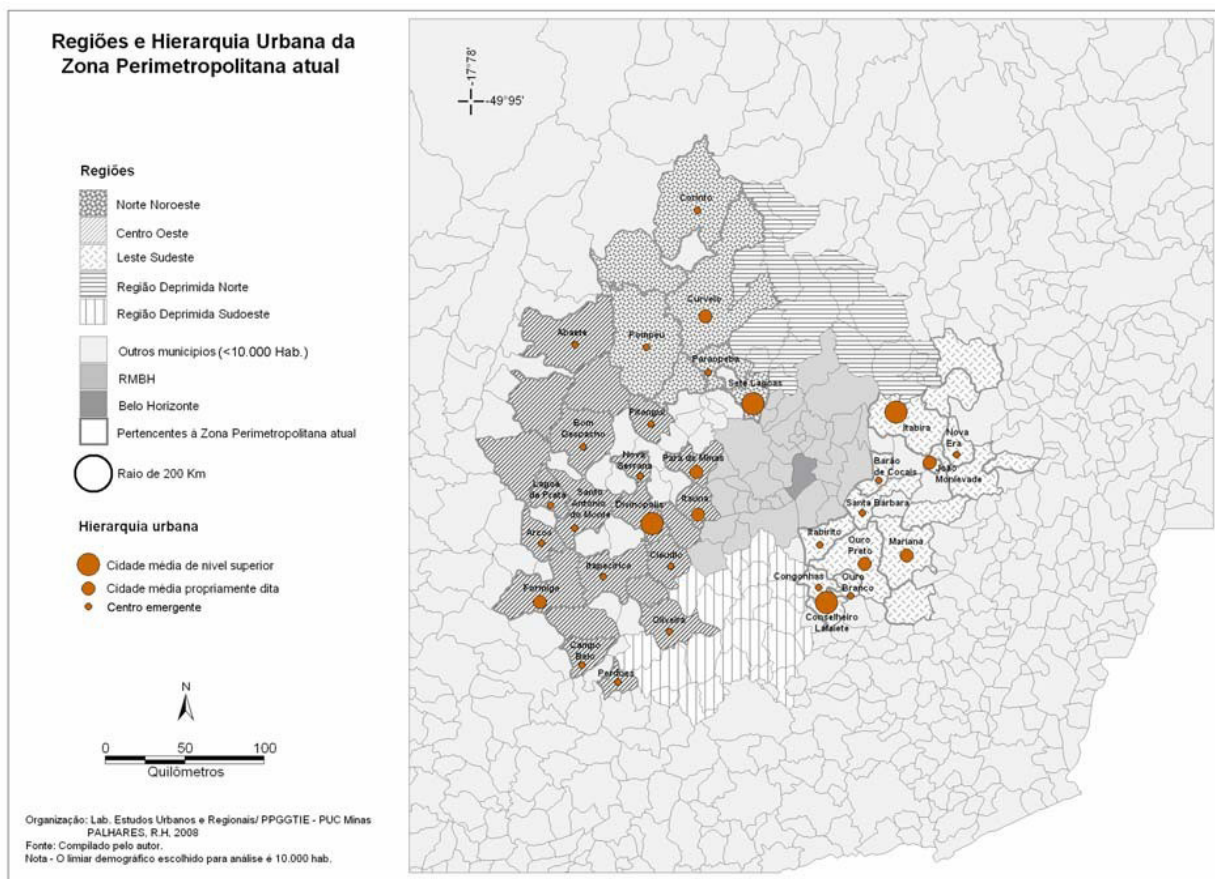

Fig. 1 - Peri-metropolitan area of Belo Horizonte. Source Created by Alfio Conti and Ricardo Palhares

The methods of visual representation and definitions of elements and relations can be used as a reference in other studies with the same goal, and it`s a contribution about cartographic representation of spatial relations.

This work intends to present a visualization about this regional space as a whole. The Quadrilátero Ferrífero region is the least homogeneous portion among those that comprise Belo Horizonte's peri-metropolitan space. It is so heterogeneous that it's hard to acknowledge it as a specific region. Its structure is not defined by a single urban system, but rather by a group of small urban systems. The small urban systems located in the north, central and southern sub-regions of Quadrilátero Ferrífero are polarized by urban agglomerations headed by cities that are currently experiencing different stages of growth, but all of them belong to the category of medium-sized cities (AMORIM, 2007; AMORIM, RIGOTTI & CAMPOS, 2007).

All these tiny urban systems are polarized by Belo Horizonte, and a possible integrations amongst these smaller urban systems are still shallow. Apparently, this condition stimulates the development of horizontal relationships of complementarity, what is demonstrated through a strengthening process that takes place in a two-dimensional manner: an internal one, relative to the urban agglomeration itself, and an external one, that strengthens the domination of the regional space which it polarizes (CONTI, 2009; 2012; 2015).

Regional integration in Quadrilátero Ferrífero is still very difficult, due to two determining factors:
- The geographical conformation of the regional space, that bears landforms that are difficult to transpose;
- The radial conformation of the regional road network.

In order to identify and characterize the thresholds of sub-regions that are polarized by urban agglomerates, the research adopted the criteria proposed by Conti (2009). He defines these thresholds based on geographical and functional terms, and the existing connections are classified as weak or strong.

The strength or weakness of geographical, physical or functional thresholds is attributed by assessing the inertia of its transformations and/or by the presence of changes in the thresholds, case by case. Data used to construct this classification is collected from field research.

With that in mind, these sub-regions are delimited (Fig. 2):
- the northern sub-region is composed by the urban agglomerations of Itabira, João Monlevade, Nova Era, São Gonçalo do Rio Abaixo and Bela Vista de Minas. It also includes the tiny urban agglomerates of Santa Bárbara, Barão de Cocais and Catas Altas, area that is bordered by the highway BR262 and, on its west and southeast sides, by the geographical limits of Espinhaço Hill and Caraça Massif. The southern and southeastern parts bear a weak geographical-functional threshold, since it is an area of contact with the central sub-region and with the region polarized by the city of Ponte Nova. On the eastern part, the threshold is strongly defined by Rio Doce State Park. On the northeastern part the threshold is once again of a strong geographical-functional type because it's a region polarized by the Metropolitan Vale do Aço Region (MVAR). On the northern area there is a weak geographical-functional threshold, since it's an area of contact with the region polarized by Guanhães;
- The central sub-region is composed by the urban agglomerations of Ouro Preto, Mariana and Itabirito. This region is bordered by the highway BR356. It has a strong geographical threshold in the western, southern and eastern sides, constituted by Espinhaço Hill, Ouro Branco Hill and Itacolomi State Park. On the northwestern and northern sides, there is a weak geographical-functional threshold, since it is an area of contact with the region polarized by Ponte Nova and the northern sub-region.
- The southern sub-region is composed by the urban agglomerations of Conselheiro Lafaiete, Congonhas and Ouro Branco, bordered by the highway BR040. On the west side there is a strong geographical threshold, constituted by Espinhaço Hill. The southwestern, southern and eastern parts have a weak geographical-functional threshold, constituted by the area of contact with the polarization of the cities São João del Rei, Barbacena and Viçosa. On the northern part, there is a strong geographical threshold constituted by Ouro Branco Hill.
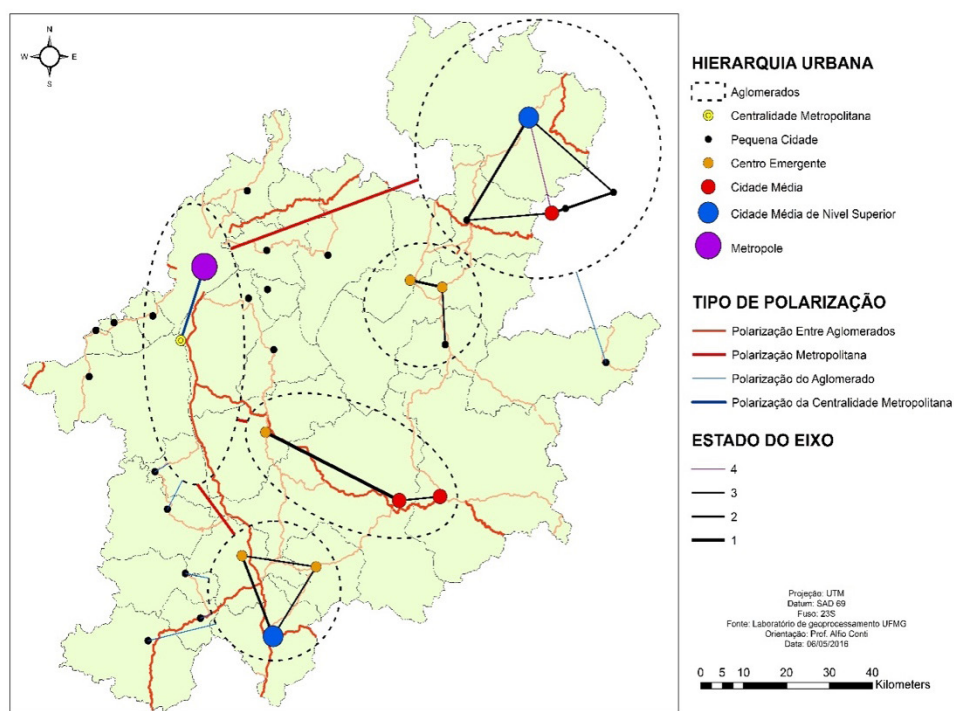
Fig. 2 - Subregions of Quadrilátero Ferrífero. Source: Created by Alfio Conti and Gustavo Tinoco

2. METHODOLOGY

The representation of spatial information of geographic phenomena using maps or graphics requires that correct transmission of the message about the phenomena between transmitter and receiver. As Pereira (2007) states about maps: they "have specific functions for specific groups of users, but their greater function is communication". To achieve the goal of "greater function", it is required that the cartographer determines the techniques, signs and symbols to be used in the transmission of the message. This makes the visualization method effective and quickly discernible to achieve an understanding of the phenomena, symbolically expressing the concepts and values that determine the spatial relationships existing in concrete spaces.

In this way, for Santos, quoted in Pereira (2007), cartographic visualization is "the process of translating spatial information into maps using cartographic methods and techniques". In the same way, the map as a model for the interpretation of the organization, conformation, arrangement and decoding of the characteristics of geographic space. It is, according to Passini quoted in Pereira (2007) "a symbolic representation of a real space, using a complex semiotic language: signs, projections and scales".

It`s important to understand that representation of the territory can be done by systematic and thematic cartography. For Archiela (1999) systematic cartography constitutes the science responsible for the representation of Earth surface, using standard conventions and scales, producing basic mappings about altimetry and planimetry of natural and cultural elements. On the other hand, Silva (2005) defines thematic cartography as representation of geographic phenomena or themes, using best graphic composition to facilitate the understanding of the message to be transmitted through its clarity and effectiveness.

Considering this subdivision, this research is based on the development of thematic maps, with the goal to present a proposal of symbols and elements of representation that, based on graphs, blocks, diagrams and sketches can reach better condition of communication and information.

These thematic maps and diagrams of representation are the result of the in-depth investigation of urban characteristics on the regional scale of the space. The research was structured in two moments. In the first moment, the cities and urban agglomerates in Quadrilátero Ferrífero were classified according to their urban and functional hierarchy, and according to their importance in regional structure. In

the second moment, the axes that compose the urban agglomerates were analyzed, mapping and characterizing the urbanizations located in them. The typological characterization and the analysis of the urbanization growth process allowed to evaluate the situation of each axis to understand the current dynamics associated to each of them. The joint analysis of the cities and the axes made it possible to draw up a diagram for each urban cluster and allowed an overall view of the urban systems of Quadrilátero Ferrífero.

The analytical representation of the different categories of medium-sized cities, as well as of the new urbanizations found along the axes, was done using size and color, identifying and relating the different hierarchical levels of medium-sized cities with a variation in the scale of the same symbol. This allowed to determine the spatialization and visual hierarchy of the clusters.

The cartographic representation determined for the hierarchy of medium-sized cities was the visual order by the size of the symbol (in this case circles), and by the chromatic variation using the colors red, yellow and blue for different hierarchical levels.

The visual representation is based on topological rules, presenting main nodes, their areas of influence and the existing connections. It`s a simplification of very complex relations, searching for presenting the main information. The topological representation in cartography, according to Theobald (2001), aims to compose the information according to spatial relations, presenting spatial adjacency and connectivity, and considering hierarchy among the components.

The methodology used in this work can be adopted for similar works to investigate regional urban structures, and brings the transformation of data into information, and information into knowledge. Cartography, thus, plays a substantial role since it allows the proposition of shared visual codes creating a common base of understanding.

3. THE URBAN AGGLOMERATIONS OF QUADRILÁTERO FERRÍFERO REGION

Urban agglomerations are, broadly speaking, constituted by the association of three or more centers that are geographically close to each other and that belong to the category of medium-sized cities. This specific category of cities is somewhat peculiar, in the sense that it has a few important subdivisions within itself.

Amongst the several studies that focus on the medium-sized cities of Minas Gerais, written since the 1970's (LELOUP, 1970; IGA, 1980; FJP, 1988; AMORIM FILHO and ABREU, 2000; AMORIM FILHO and ARRUDA, 2002), more recent studies point to the existence of three levels within this category. The first level refers to emerging centers, characterized as an incubator for medium-sized cities. They consist of smaller urban centers that begin to have their own demographical and spatial dynamic, once they overcome the threshold of 20.000 inhabitants. Once this threshold is passed, it is possible to identify, within these urban centers, an intense demographical growth, associated with a morphological-functional transformation (an increase on the complexity and degree of specialization of its parts and functions) and an increase in polarization, regarding its regional surroundings. Such growth and strengthening in intra-urban and regional terms is concluded with the emergent center's access to the second level of the subdivision (AMORIM FILHO, 2007).

The second level is the one of properly medium-sized cities, given their demographical dimension, their morphological-functional characteristics and their role in regional polarization.

The third level corresponds to medium-sized cities of a higher level. These are cities that have experienced a demographical growth that borders on the hundreds of thousands of inhabitants and have a higher morphological-functional complexity than the regular medium-sized cities. They also have a further reach in terms of their regional polarization, what makes them regional centers.

The urban agglomerations found in Quadrilátero Ferrífero comprise medium-sized cities from these three levels. Medium-sized cities of high level include Itabira (northern sub-region) and Conselheiro Lafaiete (southern sub-region), located in the lower threshold of this hierarchical level. Properly medium-sized cities include João Monlevade (northern sub-region), Ouro Preto and Mariana (central sub-region), all of them in the lower threshold of this hierarchical level. As emergent centers,

there are the cities of Santa Bárbara and Barão de Cocais (northern sub-region), headed by a small urban agglomeration polarized by the agglomeration headed by Itabirito (central sub-region). The emergent center of Itabirito is in the superior threshold of this hierarchical level, and is about to enter to the level of properly medium-sized cities. Furthermore, the group of emergent centers also includes Congonhas and Ouro Branco (southern sub-region). Congonhas is in the superior threshold of this hierarchical level, about to enter to the level of properly medium-sized cities.

Once the growth rates were analyzed, it resulted plausible to present some hypotheses regarding the existence of a relationship between geographical and hierarchical proximity, since the growth rates of these cities point to a very positive tendency overall. The cities with the highest rates are emerging centers that, located within the higher threshold of this hierarchical level, are close to becoming properly medium-sized cities. Medium sized-cities and medium-sized cities of a higher level maintain relevant growth rates and contribute to an increase in the population of the agglomerations, reaching an average value of 200.000 inhabitants.

The urban agglomerations of Quadrilátero Ferrífero were analyzed from a morphological and functional perspective that considered some aspects as being more important and structural, so that to define the regional network structure.

These aspects include:
- The conformation of agglomeration, considering the spatial disposition of the centers and the links they have with each other;
- The urban hierarchy and functional typology of the centers, considering that these characteristics derive from investigations of a morphological and functional nature;
- The morphological and functional analysis of the axes, with the mapping of new urbanizations located alongside them as a necessary condition for defining the hierarchy and functional typology of each of them.

The axes of agglomeration were considered important element of the structure, composed of several arterial roads that connect the urban centers amongst themselves, performing two functions:
- Allowing for the circulation of people and goods amongst the cities within the urban agglomeration;
- Catalyzing the process by which urban functions are diffused.

The constitution of the axes contributes to determining the importance and complexity of the urban agglomeration, and indicates the degree of integration between the urban centers that are part of it. The table summarizes the functional typology, the morphological characteristics and current processes regarding the axes of agglomerations (Table 1).

Table 1: Axes of urban Agglomeration, stages, functional typology, morphological characteristics and the presence of a specific process.

	Stages	Functional typology	Morphological characteristics	Process is in course
1	1	Consolidated	Conurbation between urbanizations and urban centers	No
	2	Consolidated	Conurbation between urbanizations	No
2	1	Dynamical	Conurbation between urbanizations and urban centers	Yes
	2	Dynamic	Conurbation between urbanizations	Yes
3	1	Currently in formation	Significant formation of urbanizations	Yes
	2	Currently in formation	Significant formation of urbanizations adjoined to the centers	Yes
4		Stationary	No significant urbanizations	No

3.1 The urban agglomeration of Itabira, João Monlevade, Nova Era, São Gonçalo do Rio Abaixo and Bela Vista de Minas

The first agglomeration polarizes the northern sub-region composed by the cities of Itabira, João Monlevade, Nova Era, São Gonçalo do Rio Abaixo and Bela Vista de Minas. Itabira is a medium-sized city of a high level and heads the urban agglomeration, with a total population of 236.659 inhabitants, making it the larger amongst the three agglomerations in the east-southeast region. It is also the one with the most complex dynamics, resulted from spatial articulations inside the agglomeration itself, but also with the northern sub-region polarized by it.

Within this area there is also a second, a smaller urban agglomeration that is, nevertheless, subordinate to and polarized by the first one. João Monlevade is the most dynamical urban center, consolidated as a properly medium-sized city. It is the second center of the agglomeration, establishing an important relationship with the city of Itabira, regarding the exchange of people and goods. Itabira stands out as a more dynamical urban center, with a significant growth rate.

Other centers that are part of this urban agglomeration have smaller dimensions and face different situations. It`s possible to point out steel working and mineral extraction as the most important economic activities of this urban agglomeration. The city of São Gonçalo do Rio Abaixo stands out due to its high growth rate and dynamic economy, resulted from massive investments made by the mining company Vale and the opening of the Brucutu mining complex.

Regarding the cities of Nova Era and Bela Vista de Minas, there are no dynamics worth noting. The first has gradually lost its economic relevance and experienced a demographic decline in recent years, apparently due to a crisis in the local steel industry. The second one is worth noting due to its location, which is very close to João Monlevade.

Within the perspective of a functional hierarchy proposed by Conti (2009), the city of Itabira is constituted as an associated regional center, because of the regional polarization that it creates in other centers of lower urban hierarchical position in this urban agglomeration.

This is especially true regarding to the urban center of João Monlevade, which plays the role of a level 1 associated regional sub-center. Since the remaining urban centers are small cities, they integrate the urban agglomeration as associated urban centers.

The roads that connect these centers are well preserved and properly paved. Despite the proximity between João Monlevade and Bela Vista de Minas, it`s not observed a process of conurbation in the area. In fact, conurbation is not happening in this urban agglomeration, since the conditions of landscape are not adequate for occupation. The proximity of these cities results in strengthening of horizontal relationships without leading to an impoverishment of the functional characteristics of smaller urban centers. Amongst the urban agglomerations, this is the one with the most complex structure, formed by two parts:

- The lower west part, which comprises the cities of Itabira and São Gonçalo do Rio Abaixo;
- The southeast part, where are the cities of João Monlevade, Bela Vista de Minas and Nova Era.

This agglomerate presents a visual conformation of a quadrangle, with the most important centers of Itabira and João Monlevade located in opposite vertices, and the configuration of the road structure. Close to João Monlevade vertex there is also a small urban center, which is the aforementioned city of Bela Vista de Minas, part of the axis João Monlevade to Nova Era. (Fig. 3).

Located on the opposite vertex are the smaller-sized urban centers of Nova Era and São Gonçalo do Rio Abaixo. The agglomeration has five axes. Beside the axes that connect the edges of the quadrangle, there is also one that connects diagonally the cities of Itabira and João Monlevade, but it's not a very relevant one.

The Itabira to São Gonçalo do Rio Abaixo axis, which comprises the west part, is among the most complex ones within the urban agglomeration, presenting several new urbanizations and an interesting road distribution, since the axis is composed of two pathways. On the outward region, the axis is composed by two parts, the first one partially constituted by the federal highway BR381, which stretches from São Gonçalo do Rio Abaixo to the point where
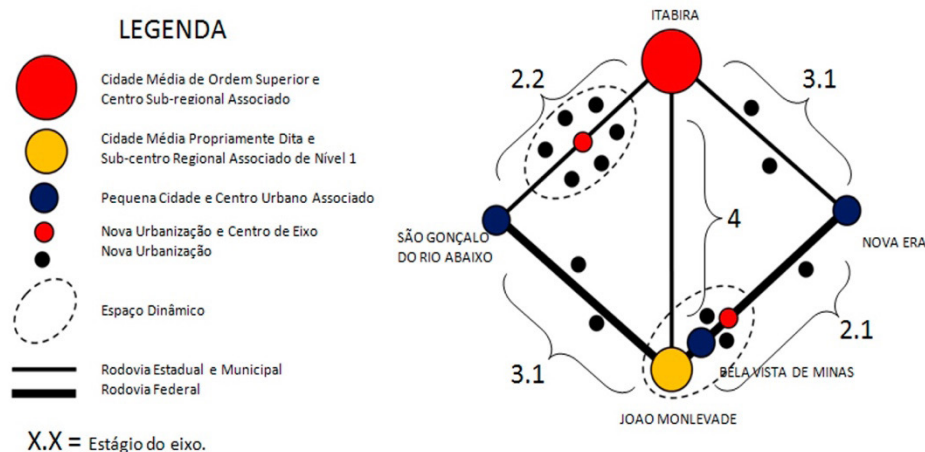
Fig. 3- New urbanizations on the agglomerations of Itabira, João Monlevade, Nova Era, São Gonçalo do Rio Abaixo and Bela Vista de Minas

it intersects with the state highway MG434. The second one is constituted by the state highway MG434, stretching from the intersection with the federal highway BR381 to the outskirts of Itabira, where it intersects with the state highway MG129. The inward part is constituted by the state highway MG129, which starts in São Gonçalo do Rio Abaixo and intercepts the state highway MG434 on the outskirts of Itabira. The external part presents several punctual settlements and filaments across the highway, most of them located within the county of Bom Jesus do Amparo, located far from the federal highway BR381. There are also new settlements near the intersection between BR381 and MG434. Within the outskirts of São Gonçalo do Rio Abaixo, in the space between BR381 and MG129, there is an urbanization surrounded by punctual settlements and new settlements. This internal part axis, structured by MG129, is the most complex. It includes different types of both new and older urbanizations, with the older ones being located a bit farther from the agglomeration of urban centers and highways that help to catalyze the establishment of new urbanizations of different types and constitute the center of the axis. Around them and especially alongside the state highway MG129, there is a significant number of punctual settlements and filaments, as well as within the area close to the intersection between MG434 and MG129, which concentrates a number of new urbanizations of

less relevant role. These include filaments and punctual settlements, currently in the process of conurbation with signs that indicate growth through urban sprawling. Due to its complexity and the processes that are in course, the axis is currently at stage classified as 2.2.

The João Monlevade to Bela Vista de Minas and to Nova Era axis, which comprises the southeastern part of the agglomeration, is structured by the federal highway BR381. It also bears a significant degree of complexity, manifested through its proximity with João Monlevade and Bela Vista de Minas, almost composing a conurbation. It is plausible to think that this particular situation is responsible for the appearance of new urbanizations within the outskirts of county roadways, along with the indication that growth is directed towards the urban centers. Amongst these new urbanizations, one stands out due to its size: Lajes. Lajes is located alongside BR381, towards Nova Era. It includes some several hundred buildings and is diametrically divided by the federal highway. This urbanization is currently in the growth and consolidation stage, especially in its northwestern part. It can play an important role in the near future, in case it manages to become a center within the axis. But to achieve it, the urbanization has to incorporate uses and functions that'll turn it into a reference point for the surrounding area along the axis. The axis from within João Monlevade to Bela Vista de

Minas is close to the stage 2.1, having a partial conurbation process established between the urban centers of the agglomeration and nearby, new urbanizations.

The João Monlevade to São Gonçalo do Rio Abaixo axis, structured by the federal highway BR381, has a significant number of new urbanizations, although there is also an absence of urbanizations that could be able to make this area more dynamic. The predominant typology are punctual settlements and aggregations, located next to the urban center of São Gonçalo do Rio Abaixo. The rough topography constitutes an important inhibition factor, preventing the instalation and growth of new urbanizations. The axis is currently at stage 3.1, in the process of forming itself and bearing a significant number of new urbanizations.

The Itabira to Nova Era axis is structured by the federal highway BR120 and the Vitória-Minas railroad, both along the Rio do Peixe River, an affluent of the Piracicaba River. Its particular topography constitutes a factor that contributes to the inertia regarding the development of the few new urbanizations that exist in the area, that where classified as typologies of new settlements and filaments. The axis is currently at stage 3.1, in the process of forming itself, with the possibility of a higher number of new urbanizations.

The Itabira to João Monlevade axis is the least complex one. It is structured by a county roadway that was established in a region with important topographic features that are responsible for reducing the presence of new urbanizations, as well as the possibility for the installations of new ones. The new urbanizations observed were characterized as a few filaments and some aggregations on the outskirts of Itabira, where topographic conditions area more suitable to land use. This axis is currently stationed at stage 4, without the presence of significant urbanizations.

3.1.1 The urban agglomeration of Santa Bárbara, Barão de Cocais and Catas Altas

The second urban agglomeration found in this sub-region is composed by the cities of Barão de Cocais, Santa Bárbara and Catas Altas. It has a smaller dimension and a total population of 67.338 inhabitants. The existence of this urban agglomeration must be observed, since it polarizes the southeastern portion of the northern sub-region. The cities that head these agglomerations have very similar characteristics in urban contexts, as emergent centers of an intermediary level. They have some of the most elevated growth rates amongst the east-southeastern region and a very similar demographic dimension. They are urban areas located very close to each other, makes us believe there is a conurbation process currently taking place, and this process contributes to fostering mutual growth on regional scale. The third center that is comprised in this agglomeration is Catas Altas, a small city with a high growth rate. Despite its varied economic base, industry can be pointed out as its main economic activity. From a functional perspective, the urban centers of Barão de Cocais and Santa Bárbara can be considered the centers of associated sub-regional articulation, and the city of Catas Altas, an associated urban center.

This urban agglomeration has a linear shape, structured by MG129, and Santa Bárbara has a central position. Barão de Cocais and Santa Bárbara belong to the hierarchical level of intermediary emergent centers. From a functional point of view, they are both associated regional articulation centers, polarizing the southeastern portion of the northern sub-region, that is also polarized by the urban agglomeration headed by Itabira. Catas Altas is a small city, and from a functional point of view, an associated urban center (Fig. 4).

The state highway MG129 is the connection axis north-south, linking the urban agglomerations of the east-southeast region. The flows of people and goods alongside this highway are quite limited on a regional scale.

The Santa Bárbara to Barão de Cocais axis is the smallest one, lengthwise, but the most complex. Alongside its area, which is nearly six kilometers long, there are several new urbanizations of different types. The Barra Feliz urbanization stands out among them, because it is located along the margins of MG129, currently on a growth stage due to the opening of new expansion areas. Brumal is currently growing alongside a county road in which there also other new urbanizations. The Barra Feliz urbanization is at the center of this axis, and is bolstered by the presence of the Brumal urbanization. The

dynamics currently in course, which allows for the conurbation process between the two existing urbanizations to take place, is responsible for putting this axis in stage 2.2.

The Santa Bárbara to Catas Altas axis, approximately ten kilometers long, is structured by MG129 and has new urbanizations alongside its extension, most of them filaments that are currently on the growth stage. The topographic conditions do not constitute significant obstacles to the urbanization process. This axis is dynamic and is currently on the development stage, what explains why new urbanizations of a more complex nature are not seen in the region. Since there is also a significant presence of new urbanizations, this axis is currently at stage 3.1.
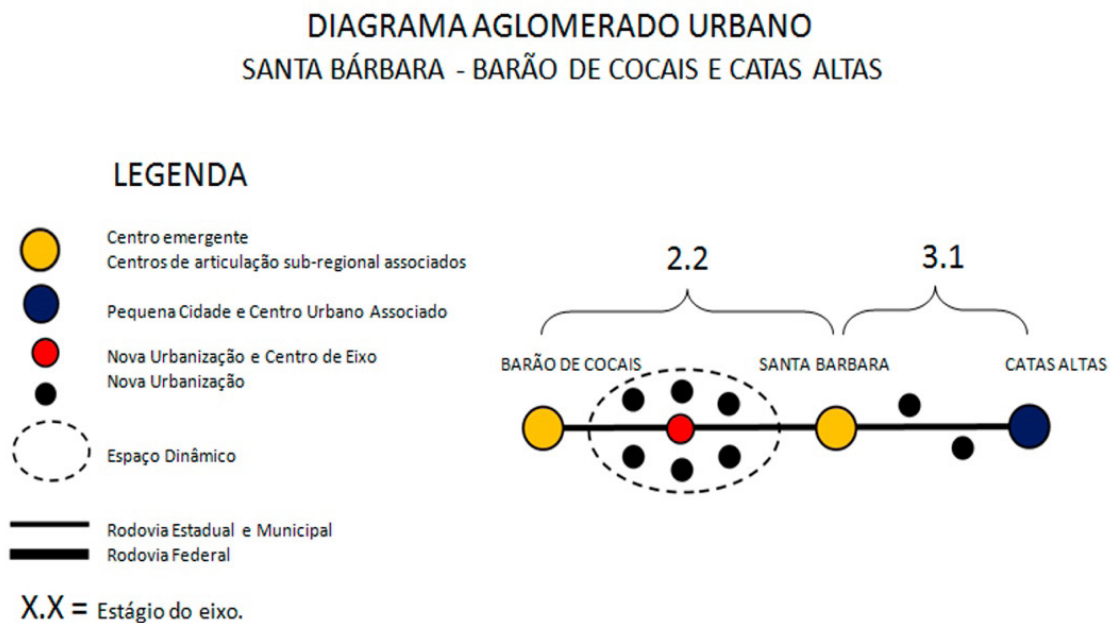

Fig. 4 - Diagram of the urban agglomeration of Santa Bárbara, Barão de Cocais and Catas Altas.

3.2 The urban agglomeration of Ouro Preto, Mariana and Itabirito

The second agglomeration polarizes the central sub-region and is formed by two properly medium-sized cities: Ouro Preto and Mariana. The first has belonged to this category for longer than Mariana, which has just recently entered this hierarchical level. In addition, there is also the emergent center of Itabirito, currently in the upper threshold of said hierarchical level and bearing a high demographical growth rate. The most important part of this agglomeration is its central nucleus, which comprises the cities of Ouro Preto and Mariana, currently in the process of conurbation with each other. Both cities have a positive growth rate. This agglomeration becomes even more interesting once we analyze the role played by the city of Itabirito, since it is the most dynamical center among the three from an economic and demographic point of view. The main economic activity of the agglomeration is industrial steel and mineral extraction. The total population is 184.004 inhabitants. Regarding functional hierarchy, Ouro Preto plays the most important role in the agglomeration, considered an associated regional center, with Mariana and Itabirito playing the role of associated regional sub-centers.

From a morphological standpoint, this urban agglomeration has a linear shape, developing itself alongside the federal highway BR356. The edges are the cities of Itabirito, an emergent center of a higher level and level 2 associated regional sub-center, and Mariana, a properly medium-sized city and level 1 associated regional sub-center. In a central position, closer to Mariana, there is Ouro Preto, a properly medium-sized city and associated regional sub-center (Fig. 5).

DIAGRAMA AGLOMERADO URBANO
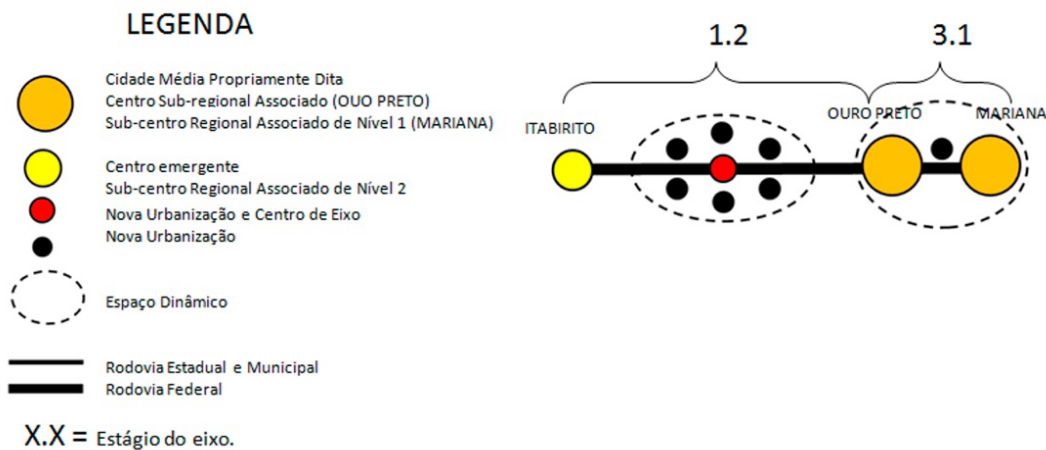**OURO PRETO - MARIANA E ITABIRITO**

Fig. 5 - Diagram of the urban agglomeration of Ouro Preto, Mariana and Itabirito.

The Ouro Preto to Mariana axis is the smallest in length, having around three kilometers and a simple conformation, due to the presence of an older urbanization within its center: the Passagem de Mariana district. In the portion close to Ouro Preto, there is an urban aggregation currently in formation. It is composed of a neighborhood called Liberdade, a linear aggregation that runs alongside BR356; and one new settlement, a condominium that was recently created in the area of Mariana. The more peripheral areas of both urban centers conform a conurbation with these new urbanizations. However, the conurbation among these urban centers are not constituted yet, due to the difficulties of geographical conformation, with sharp slopes and in the borders of Ribeirão do Carmo River. This axis is currently at stage 3.1, still in formation and bearing a significant presence of new urbanizations.

The Ouro Preto to Itabirito axis has a larger dimension and degree of complexity. With an extension of approximately 30 kilometers, it presents numerous urbanizations. Most of these were recently formed, thanks to an ancient supporting structure that dates back to the XVII century and is intimately linked to gold mining activities. This supporting structure is formed by an articulated road network that has its nodes located in several urban areas that have, over the course of history, evolved into districts. The largest one is Cachoeira do Campo district, which stands out as the largest

and most important urbanization in this axis, bearing a total population of approximately 10.000 inhabitants. Besides its historical area, with buildings that date to the XVII and XVIII centuries and are listed as historical heritage sites, it also supplies goods and services to other urbanizations across the axis. Another important urbanization is the Santo Antonio do Leite district, located southwest from Cachoeira do Campo and accessible through the state highway MG030, where there are some other punctual settlements, as Engenheiro Correia and Miguel Burnier. Aside from it, there is also Glaura district, in the north. Both districts are close to each other, forming the center of the axis, which is enforced by the presence of the Amarantina urbanization. This urbanization has nearly completed its conurbation process with Cachoeira do Campo, due to the existence of new settlements of condominiums. Around the central area of this axis, there are numerous punctual settlements and filaments that enforce the centrality and complexity of this space. In the area close to Ouro Preto the mountain prevents further occupation, composing a free space between Cachoeira do Campo and Ouro Preto. The smooth topography of Itabirito allows the new urbanizations to reach the peripheral outskirts of the city. In fact, considering expansion process of Itabirito, within the area close to its eastern expansion vector, there are punctual settlements and new settlements, indicating the diffusion of its urban functions alongside this

axis. Regarding this space, Acuruí district has its importance, surrounded by new settlements in the form of condominiums, making it an element that pushes urban expansion towards Itabirito in the northeast direction. This axis is currently at stage 1.2: consolidated and with urbanizations that form conurbations, bearing a concrete possibility to develop, in medium terms, a process of conurbation with Itabirito.

3.3 The urban agglomeration of Conselheiro Lafaiete, Congonhas and Ouro Branco.

The third urban agglomeration polarizes the southern sub-region of the east-southeast region, and is composed of three cities. Conselheiro Lafaiete is the largest center and is a properly medium-sized city of a high level, in which Congonhas is an emergent center of a high level and Ouro Branco is an intermediate emergent center. The agglomeration has a total population of 218.369 inhabitants. The growth rate of the cities is high and positive, and among them growth rate of Conselheiro Lafaiete is indeed surprising, since it is a medium-sized city of a higher level. This dynamicity is due to the location, alongside the BR040 highway, that connects the metropolitan areas of Belo Horizonte and Rio de Janeiro. The growth rates point to the imminent access of both Congonhas and Ouro Branco to the category of properly

medium-sized cities. The main economic activity of the agglomeration is varied, since each city has a predominant economic activity. Such diversity can be seen as a positive factor regarding the development and growth of the region. Unlike other agglomerations in Quadrilátero Ferrífero, the predominant economic activity is the industry and services related to it. Regarding the functional hierarchy, the main urban center, Conselheiro Lafaiete, is an associated regional center, along with the other two centers, which are, in turn, level 2 associated regional sub-centers.

From a morphological and functional perspective, it is relevant to point out that the spatial distribution of the three urban centers, with each one located on the edges of a triangle that has highways as its sides and the Gerdau Açominas plant as its center, contributes to an increase on circulation and the establishment of horizontal relationships amongst them (Fig. 6).

The three axes that are part of this agglomeration have distinct characteristics. The Conselheiro Lafaiete to Congonhas axis stands out because it is the most complex one and with the majority of new urbanizations of different types. It is approximately 15 kilometers long when it reaches the discontinuous peripheries of the urban centers, and is characterized by the presence of the federal highway BR040, that
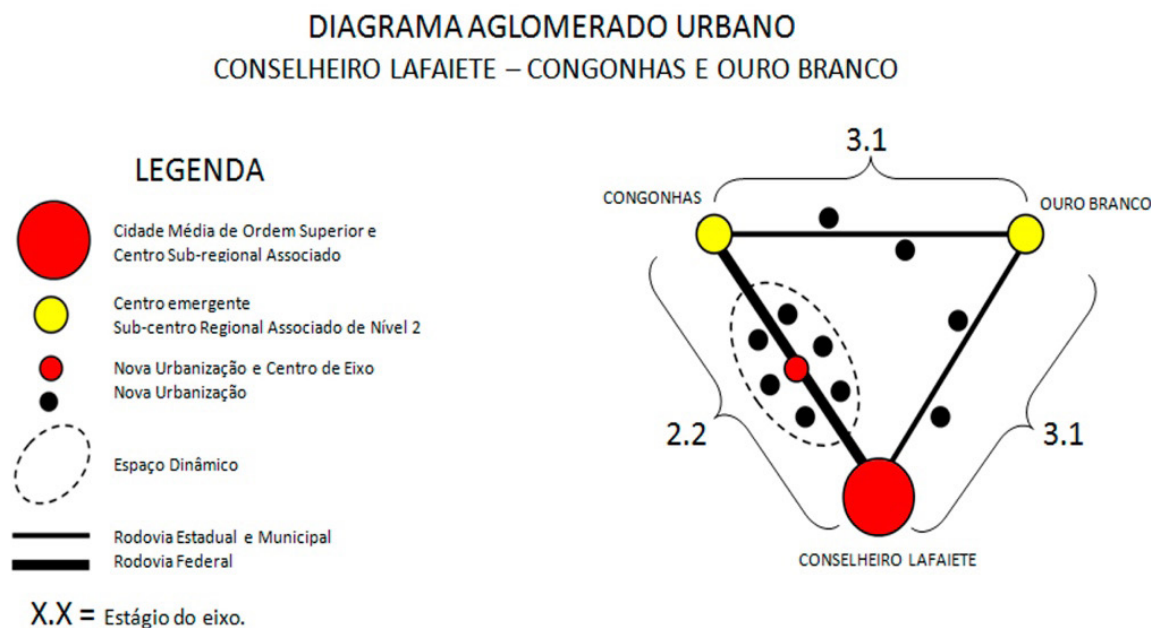

Fig. 6 - Diagram of the urban agglomeration of Conselheiro Lafaiete, Congonhas and Ouro Branco.

connects Brasília to Rio de Janeiro, also passing through Belo Horizonte, and by the presence of the railroad of Central do Brasil.

It is the most urbanized axis and the one with the largest flows of people and goods. Joaquim Murtinho stands out amongst the new urbanizations, located in the connection between highways BR040 and BR383. Two factors contribute to the installations and development of this new urbanization: the topography that is very plane and the geographical position, located in the connection between two federal highways.

This new urbanization came from preexisting ones and developed rapidly as new possibilities of urban areas. This urbanization growth process is currently in course and has a centrifugal nature, occupying the blocks that were already installed, as they distance themselves from the highways. The allotments that are currently established are in the southwestern portion of the road interchange, where there also two small hills. Commercial activity as well as service-related businesses, of different dimensions, are found alongside both roads. Service-related activity is mostly found alongside BR040 and is often related to road-based transportation. Sportive and educational equipment are always found within this portion of the urbanization. Older and more consolidated urbanizations are found on the northwestern portion, whereas the district's older nucleus is to be found on the right margin, located further north, alongside BR040, in the direction of Congonhas. The relevance of this urbanization goes beyond its dimensions because it constitutes the center of this axis and since the other neighboring new urbanizations, that are located alongside BR040 and directed towards the city of Conselheiro Lafaiete, form a group that is currently still on the growth, consolidation and conurbation stage.

In terms of urban occupation, the southern part of the axis is the most articulated, complex and developed one; the northern part has a simpler disposition and a significant number of new urbanizations. This particular situation results from the presence of the Gerdau Açominas plant, which inhibits the appearance, within the northern portion, of new urbanizations on the outskirts of Congonhas. The axis is currently at stage 2.2, because it is considered

dynamical and bears a conurbation process among its urbanizations.

The Conselheiro Lafaiete to Ouro Branco axis is simpler, and has several new urbanizations currently experiencing the growth and consolidation stage. The Gerdau Açominas plant is a factor that inhibits growth, when it comes to the area outlining the MG129 highway, at least in respect to its left margin, which leads to Ouro Branco. Along the right margin, there is a possibility that new urbanizations might come along and, in fact, several filaments can be found within its northern portion. Regarding the axis in the southern portion, the punctual settlement of Rancho Novo, a Conselheiro Lafaiete district, is the most important point.

Unlike the districts that belong on the other axes, this is one is different from a morphological perspective, due to its organic type of outlining, resulted from filling the spaces left between different roads and to urban and rural areas. This organic outlining links the growth process to the establishment of new allotments, without the creation of reserve-areas or unoccupied spaces, what is usually what happens in this situation, that may become an inertia factor for the occupation, but ultimately does not influence the establishment of new allotments and buildings, which continuously take place. Within this new urbanization, there are diffuse processes of improvement on the housing conditions, as well as improvements on the urban conditions (infrastructure and equipment). The consolidation of these settlements also corresponds to a consolidation of its functional characteristics, with the presence of commerce, essential services and basic educational equipment. Another distinguishing characteristic of this axis is the presence of new equipment, on a municipal and regional level, which, as elements of the peri-urban space, attract, redirect and lead growth towards the edges of peripheral urban areas. In this axis, those parts that belong to Conselheiro Lafaiete, thanks to a greater supply of health and higher education equipment, is currently at stage 3.1 because it is still forming itself and bears a significant number of urbanizations.

The Congonhas to Ouro Branco axis is the simplest among the three, bearing few new urbanizations. The Lobo Leite urbanization, a

district of Congonhas located on the intersection between the highways MG443 and MG030, stands out from the others. It is an urban area dated from the XVIII century. It is squeezed between the intersection of the highways and the railroad path. The district is currently experiencing a growth process, with the establishment of new streets to the east, continuing the regular outlining that characterizes the areas that were built more recently. Buildings in this new area are generally smaller, usually build with a single floor and low construction standards. The analysis of the axis, it is so far the one with the least appearance of new urbanization, due to the presence of strong local conditioners, such as the Gerdau Açominas plant, the Soledade water reservoir and barriers associated with the railroad structure. Currently, the most likely scenario involves the consolidation of the existing urbanizations, and the axis is at stage 3.1, because it is still forming itself, with the presence of new urbanizations.

4. CONCLUSIONS

The urban system of Quadrilátero Ferrífero comprises a group of smaller urban systems, headed by a set of urban agglomerations that are significantly autonomous amongst themselves. The unifying element of these tiny urban systems is the polarization exhorted by Belo Horizonte, the city upon which they all depend. Hence, urban agglomerations are urban structures of a regional scale, that bear a high degree of complexity and that propose a new form of geographical and spatial arrangement. This is particularly challenging in the sense that it seems plausible to understand it as a new urban form.

Furthermore, the urban agglomerations of Quadrilátero Ferrífero bear some characteristics that rely upon some very important factors:

- The cities that are part of it, regardless of their total number and considering their urban hierarchy and functional typology, as a group they polarize the geographical space that surrounds them;

- The connection axes, which may be at different stages of evolution depending on the number of new urbanization, can create conurbation with other axes as well as with the
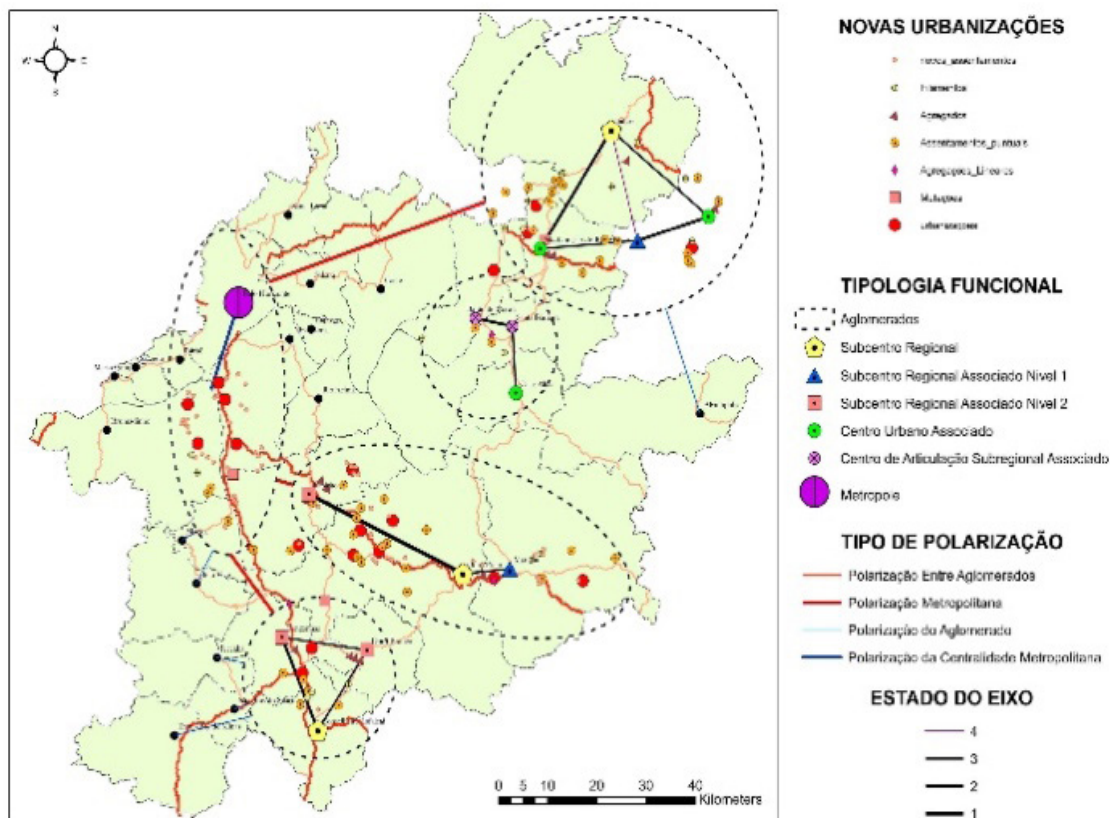

Fig. 7 - The new urbanizations associated with the urban agglomerations that are present in Quadrilátero Ferrífero region.

urban areas that are located on the axis' edges (Fig. 7).

Physical and functional integration between the agglomerations of urban centers, on a regional scale, is a tangible process that takes place in different speeds and over different periods. It is specially manifested through the characteristics of the axes in question. In such sense, we were able to verify that most of the axes that structured the urban agglomerations were at the development stage, forming a group of urban agglomerations of the continuous type. For most of them, these processes will lead to conurbation amongst the new urbanizations and urban centers.

Other important elements of the axes that contribute to the progression towards this scenario of conurbation between urban centers and new urbanizations:

- The disposal of the road structure, which is particularly important, as infrastructure such as duplicated federal highways not only support but also stimulate the establishment and development of new urbanizations;

- Physical-geographical characteristics, which in many cases present themselves as obstacles to the establishment and growth of new urbanizations.

A great variety of situations were found, resulting in a set of possibilities regarding its organization. These possibilities clearly do not exhaust themselves in the situations that were observed and analyzed and, hence, they demand a wider investigation, especially since this phenomena is not exclusive to Quadrilátero Ferrífero. Based on that, we suggest further investigation on other agglomerations that exist in the peri-metropolitan area of Belo Horizonte, notably the mid-west region. (Fig. 8)

We understand that studies of this thematic can contribute to the understanding of regional spaces, their specific dynamics and processes. Eventually, they might be able to give support to public administration to construct their local planning instruments in order to account for a regional dimension, which currently is not taking into account in Brazil.

Also, the regional studies contributes to the optimization of urban space management by improving and integrating cities that share

urban functions on a regional scale. Considering the existence of available data and technologies of geospatial information, studies of this nature allow us to visualize the dynamics of transformation and brings forth the possibility to further refine the urban planning instruments that can be used in different scales.
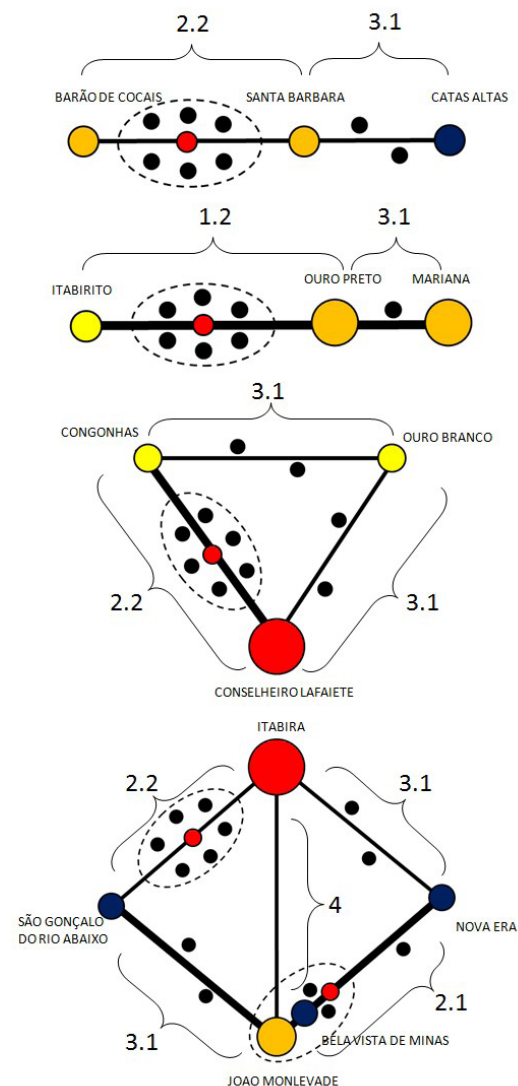

Fig. 8 - Set of diagrams containing the urban agglomerations of Quadrilátero Ferrífero.

Through the representation of spatial information, elaborated from the collected data and with this the categorization of the information for each urban agglomerate of the Quadrilátero Ferrífero, it was possible to develop an analysis about the spatial relations existing in this space.

The interpretation of the characteristics identified allowed the systematized elaboration

of a language of symbols, used in all graphic sets, which made possible a general reading of the existing urban conformation. This language of symbols, expressed in the elaborated diagrams, defines the different categories of medium-sized cities, as well as their degree of articulation and the structure of each axes of connection.

The elaboration of this type of diagrams supports the interpretation and analysis of the regional space, helping the processes of territorial planning, since these diagrams are based on codes that are shareable and easy to understand, and stimulate analytical and critical observation of the processes existing in regional scale.

Thus, cartographic visualization elaborated in an appropriate way allows the construction of diagrams and synthetic schemes, based on topological simplifications, using as elements the relative position of urban areas and the network among them.

The symbologies proposed favored the construction of a common understanding that can be shared. These schemes, transposed to cartographic base, added location + information + justifications and explanations, which is ultimately the role of cartographic visualization.

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BIBLIOGRAPHY

AMORIM FILHO, O. B.; ABREU, J. F. Ciudades intermédias y tecnópoles potenciales em Minas Gerais - Brasil. **Tiempo y Espacio, Chillán,** Universidad del Bío-Bío, v. 8, n. 9-10, p. 23-32, 2000.

AMORIM FILHO, O. B.; ARRUDA, M. A. Os Sistemas Urbanos. In: BDMG, **Minas Gerais do Século XXI: reinterpretando o espaço mineiro**. Belo Horizonte, BDMG, v. 2, cap. 5., p. 185-248, 2000.

AMORIM FILHO, O. B. A **morfologia das cidades médias.** Goiânia: Vieira, 2007. 202 p.

AMORIM FILHO, O. B.; RIGOTTI, J. I. R.; CAMPOS, J. **Os níveis hierárquicos das cidades médias de Minas Gerais**. Programa de Pós-graduação em Geografia - Tratamento da Informação Espacial, PUC Minas, Belo Horizonte, 2007. 167 p.

ARCHELA, R. S. Imagem e representação gráfica. **Revista Geografia**, Londrina, v.8, n.1, p.5-11, 1999.

CONTI, A. **O espaço perimetropolitano de Belo Horizonte - Uma análise exploratória.** Tese de Doutorado, Programa de Pós-graduação em Geografia - Tratamento da Informação Espacial, PUCMINAS, Belo Horizonte, 2009. 625 p.

CONTI, A. New urban formats – The challenge of urban and regional planning in the east southeast part of Belo Horizonte´s perimetropolitana area. **15th International Planning History Society Conference**, São Paulo, p. 1-12, 2012.

CONTI, A. **A zona perimetropolitana de Belo Horizonte - Uma análise exploratória**. Editora Livre Expressão, Rio de Janeiro, p.1-14, 2013.

CONTI, A.; PEREIRA, A. L. D. S. Espaço periurbano e novas urbanizações - A análise preliminar do caso de Conselheiro Lafaiete, Congonhas e Ouro Branco. **XV ENANPUR**, Recife, p. 1-11, 2013.

CONTI, A.; VIEIRA, A. A. Elementos do espaço periurbano – análise preliminar das urbanizações ao longo do vetor sul de expansão da Região Metropolitana de Belo Horizonte, considerando os eixos da BR040 e da BR356, até o aglomerado urbano de Conselheiro Lafaiete, Congonhas e Ouro Branco. **III CIMDEPE**, Rio de Janeiro, p. 1-24, 2015.

CONTI, A.; VIEIRA, A. A. As cidades centrais e os aglomerados urbanos da região Leste Sudeste da zona perimetropolitana de Belo Horizonte. **XVI ENANPUR**, Belo Horizonte, p. 1-24, 2015.

MONTE-MÓR, R. L. Outras fronteiras: novas especialidades na urbanização brasileira. In: CASTRIOTA, L. B. (Org.). **Urbanização brasileira: redescobertas**. Belo Horizonte: C/ Arte, p. 260-271, 2003.

FUNDAÇÃO JOÃO PINHEIRO. Estrutura espacial de Minas Gerais. Belo Horizonte: Centro de Estudos Regionais,1988. 165 p.

INSTITUTO DE GEOCIÊNCIAS APLICADAS - IGA. **A hierarquia urbana de Minas Gerais analisada através da circulação de ônibus intermunicipais.** (Coordenação de Amorim Filho, O. B.). Belo Horizonte, IGA/SECT, 1980. 60 p.

INSTITUTO BRASILEIRO D GEOGRAFIA E ESTATISTICA – IBGE. **Contagem de população 2016**. Brasília, 2016.

LELOUP, Y., **Les villes du Minas Gerais**. 1970. 301 p. (Thése de Doctorát) – Institut des Hautes Etudes de L`Amérique Latine, Paris, 1970. 301 p.

MORAES, Fernanda Borges de. **A rede urbana das Minas coloniais: na urdidura do tempo e do espaço.** Tese, Doutorado em Arquitetura e Urbanismo, Universidade de São Paulo. São Paulo, 2006. 3v.

PEREIRA, S. R. M. **Visualização cartográfica e morfométrica da bacia do Córrego da Mutuca – Município de Nova Lima/MG**. Tese, Mestrado em Geografia – Tratamento da Informação Espacial. Pontifícia Universidade Católica de Minas Gerais. Belo Horizonte. 2007. 94 p.

SÁ, P. R. C. **Os centros urbanos emergentes de Minas Gerais**. Dissertação de Mestrado, Programa de Pós-graduação em Geografia - Tratamento da Informação Espacial - PUCMINAS, Belo Horizonte, 2001. 172 p.

SILVA, R. C. **Visualização Cartográfica e Cartografia Multimídia - Conceitos e metodologias**. Editora UNESP, São Paulo, 2005. 184 p.

THEOBALD, D. M. Topology revisited: representing spatial relations. **International Journal of Geographical Information Science**.