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Unplanned Urban Ecosystems Resulting From Building Landmark

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Improvised growth has unleashed imbalances in Latin America. This is why the city of Tunja was analyzed on a spatio-temporal scale between 1970 and 2013 using a qualitative methodological approach that implements the documentary analysis of urban planning and construction licenses, generating historical maps under the Graph Theory, identifying 99 building landmarks to evaluate the dynamics of urban reactivation (DRU) that came to consolidate Tunja as complex urban ecosystem. The study reveals that DRUs are self-organizing and that it is possible to study buildings not only as real estate but also as reactivating elements for urban analysis.

Keywords: urban growth, urban dynamics, buildings, landmarks, urban planning, urban revitalization, urban ecosystem, graph theory.

Resumen

El crecimiento improvisado ha desatado desequilibrios en Latinoamérica. Es por lo que se analizó la ciudad de Tunja en una escala espaciotemporal entre 1970 y 2013 utilizando un enfoque metodológico cualitativo que implementa el análisis documental de licencias de urbanismo y construcción, generando mapas históricos bajo la Teoría de Grafos, identificando 99 hitos edificatorios para evaluar las dinámicas de reactivación urbana (DRU) que llegaron a consolidar a Tunja como un ecosistema urbano complejo. El estudio revela que las DRU se

autoorganizan y que es posible estudiar los edificios no solamente como bienes inmuebles, sino como elementos reactivadores para el análisis urbano.

Palabras clave: crecimiento urbano, dinámicas urbanas, edificios, hitos edificatorios, planificación urbana, reactivación urbana, ecosistema urbano, teoría de los grafos.

Introduction

Worldwide, the study of urban growth and complex systems is profuse to define city growth patterns based on demographics, economics, and other aspects. Some economic theories that have tried to explain the spatial growth of the city stand out, such as the industrial location theory of Webber (2020), the theory of central places of Walter Christaller and redefined by August Losch (Valbuena, 2013; Malczewski, 2009), the location theory of agricultural land uses around the population center (Walker, 2021) and Ackoff's general systems theory, published in 1971 (Bertalanffy, 1989; Johnson, 2001; Wu, 2014), which seeks to explain the relationship between the elements of a specific system.

The city of Tunja, like most Latin American cities, has settled from a center and, to that extent, has had urban growth without a previous conception. However, unplanned growth in several cities has led to an imbalance and chaos in economic, social and environmental factors (Discoli & Martini, 2010).

However, some theories mention that every city is a complex system with structures capable of self-organization due to the effect of emergent phenomena (Turnbull et al., 2018); under this theory, some researchers such as Boeing, (2018) put forward some indicators that allow evaluating the complexity of a built environment in the framework of urban planning. Similarly, Ortman et al. (2020) point out that complex systems differ in social variation and structure and that their properties vary with the size of the system for where and how they are measured.

This is why this research is based on the concept of a system. The ordinances that make up Latin American cities have been defined through land use planning, as is the case of Tunja, whose Land Use Plan (POT) defines the following systems: "road and transportation system, domiciliary public services system, equipment system and recreational areas and public space system (Acuerdo Municipal No 0014, 2001, p. 61), which were later modified and arranged as general systems as follows: "built public space system, mobility system, domiciliary public services system and collective equipment system" (Acuerdo Municipal No 0014, 2001, p. 22) adopting this term is used to regulate some urban structuring systems, from which subsystems are organized generated by the different land uses that are configured by a physical and architectural fact -defined by buildings-, with emerging characteristics that are not predictable in urban planning and that, in turn, promote the growth of the city (Acuerdo Municipal No 0014, 2001).

For Bettencourt, (2013), cities are natural systems that evolve spontaneously at all scales, which is why they should not be seen as controlled or resisted systems since space, time and infrastructure play a fundamental role in the enabling and social interaction that allows for greater connectivity. From another perspective, Permana et al. (2019) indicate that, over the years, the city grows and develops due to population growth, a situation that generates a change in land use in cities, a phenomenon is known as urban morphology.

Understanding that cities founded on a base lacking planning instruments can emerge and self-organize themselves indicates that any city in a basic state of planning can become consolidated as a balanced, complex system. Therefore, this research could demonstrate the implications and factors from the DRU that allowed the consolidation of a complex system in the city of Tunja. In addition, the proposed methodology could contribute to the conventional analysis to study the DRU and behavioral patterns produced by the reactivation of building landmarks throughout history and, in this way, predict some transformations that could revitalize the activities within this complex system called the city.

Under that vision, this article does not assume economic theories to establish a growth pattern since other indicators, such as socioeconomic ones, are needed to analyze a complex system. On the contrary, this research is based on the DRU from the building landmarks to understand the theory of systems, as this allows studying the relationship of the elements, assuming the system of buildings as the main and organizing element. These will be studied as generating elements of emerging properties in the city from the 1970s, a period in which Colombia and cities like Tunja began a stage of consolidation of modernity, bringing with it the development of a new architecture to achieve "the structuring of new urban centralities that act as specialized spaces in the provision of services and commercial activities, in order to lower the pressure on the historical center" (Acuerdo Municipal No 0014, 2001, p. 109), a situation that generated an expansion from new buildings or the change of uses in old buildings of great heritage value for the city.
Therefore, this article aims to identify the growth pattern in this intermediate city from the buildings, understood as useful physical facts that are part of a complex system, from the 1970s to 2013. This will allow evaluation of the DRUs under the panorama of the building landmarks designed according to the graph theory in a given spatial-temporal scale until reaching that point where the city becomes a balanced, complex system. The methodology is a basic qualitative one, with a data population constituted by the urban planning and construction licenses of Tunja and a non-probabilistic sample by convenience processed from documentary systematization cards, which were transformed into maps of the 1970s, 1980s, 1990s and 2000s.

Urban Reactivation Dynamics (DRU)

The DRUs in most Latin American cities happen as a consequent process of some action and allow stimulating other activities around them, not necessarily from a conceived planning. For example, in the research study "Tendencias recientes del crecimiento metropolitano en Santiago de Chile" (Recent trends in metropolitan growth in Santiago de Chile) by De Mattos et al. (2014), who start from an analysis of urban sprawl to define this concept, while for the (Yunda & Montenegro, 2019) dynamics emerge from the patterns in each normative moment of planning in the history of the city. For its part, Jaramillo, (2012) considers that DRU consists of reactivating an object or element that has undergone a spatio-temporal change in order to recover the dynamics of a specific sector. The term economic reactivation is defined by Büchi, (1992) as a process tending to generate greater dynamism in economic activity, since this process generates investment, employment, social welfare, among others. Therefore, the DRUs are also consequent to the economy and development of a city.

Urban systems in a complex environment

Urbanism has attempted to define the functioning and dynamics of the city, in many cases with a complex polysemic perspective planned from segmented heterogeneity (Ayala, 2017) to establish arguments that will allow an approach to its evolution over time. (Sosa, 2020), to be able to study the spatial dynamics of the city and go from predicting future states to being able to anticipate the states inherent to the evolution of the system (Kaufman et al., 2019), for planning purposes.

It is stated that the city is a complex system, which urban planning aims to study, therefore, at first what a system is will be defined. A system is the union of things in an organized way. However, in the general theory of systems, this concept has been used to analyze the interactions of the elements in search of patterns that explain phenomena of the different sciences, so it is "necessary to study not only isolated parts and processes but also to solve the problems found in the organization and order that unify them, resulting from the dynamic interaction of the parts" (Bertalanffy, 1989, p. 31); likewise, they are "groups of interacting and interdependent parts, linked together by exchanges of interdependent and interacting parts that are interdependent and interdependent, linked together by exchanges of interdependent and interacting parts" (Bertalanffy, 1989, p. 31); they are also "groups of interacting and interdependent parts, linked together by exchanges of energy, matter and information" (Costanza, 1993, p. 550).

Likewise, Ackoff, (1971) in his text Towards a system of systems concepts, explains the different concepts to refer to a system, defining it as:

> ...a set of interrelated elements. Thus, the system is an entity that is composed of at least two elements and a relationship it contains between each of its elements. The system's elements are directly or indirectly connected to any other element. Moreover, no subset of elements is unrelated to any other subset (p. 662).

On the other hand, Voinov & Smith, (2017) state that analyzing a system is important in order to take a look from three dimensions, namely: time, which allows knowing what has happened in the system over some time; space, which allows understanding the entire context of the system; and structure, which is made up of all the elements and variables, among others. In addition to the above, understanding that one element is related to another and that, in this way, a system is created as a way of approaching the DRU of the city and the configuration of the multiple subsystems created from their interactions. In the same way, understanding how one element directly affects another allows for a critical study of the phenomena; that is, the problems under study can be approached as a whole and not in parts analyzed individually. Now, after clarifying what a system is, it is necessary to characterize it to make the profile corresponding to its type according to its relationships, such as:

Simple systems: They are considered when there is a relationship only between two elements, directly and linearly, without combinations and interactions with others (Ackoff, 1971). **Complex systems:** They "have many components and in turn many relationships" (Terrede, 1995, p. 48), They are also "characterized by strong interactions (usually non-linear) between the parts" (Costanza et al., 1993), which has been an obstacle to facing various research problems, such as "the growth of cities, changes in production systems, which are examples of situations of increasing complexity" (Terrede, 1995, p. 46).

Therefore, complex systems are characterized by non-linearity, and they are dynamic, emergent, and self-organized (Castillo & Velásquez, 2015)**,** where non-linearity implies that there is no beginning and end, but that the system can generate internal adaptation cycles; they are dynamic, which generates an irreversible evolution in the system, that is, it does not remain the same over time; self-organization is the ability of the elements of the system to rearrange themselves without any planning and create subsystems.
For (Johnson, 2001; Carpenter & Grünewald, 2016**;** Patorniti et al., 2018), state that the city is a complex system composed of a series of parts that interact in a non-simple way, where there is disorganization, there are no grouping rules but local rules that lead to a global system structure with polycentric structures around an element that organizes the system and creates patterns from below, i.e., from the people and not from the laws, Rasheed et al., (2024), exposes that from the secondary parts such as buildings, urban spatial fabrics and the kinetic system that unites the parts. This is so that, from planning, a system of understanding the parts of the system can be generated and analyzed over time to determine the ways to approach the planning of a city.
Finally, it can be concluded that self-organization is the capacity of the elements of the system to rearrange themselves without any planning and creating subsystems.

Urban Connections from Graphs

This theory has been implemented in this research as it refers to "a term used to designate a set of points connected by segments, which Leonhard Euler developed in the eighteenth century" (Cardozo et al., 2009, p. 94). Through the graph, different real-life situations can be represented, where one point can be connected to another to determine routes, distance, position in a territory for the previous point, and differentiation of uses between points A and B, among other aspects (Menéndez, 1998; Álvarez & Parra, 2013).
This geometric manifestation is represented by vertices connected by straight lines that can be directed or undirected. This is why the relationships or patterns that determine a graph can be directed, such as arc, path, circuit, Hamiltonian path and Hamiltonian circuit. However, they can also be undirected, such as "a) Edge: It is the union of two vertices omitting the direction; B) Chain: a consecutive path is obtained; c) Cycle: this is obtained by achieving a circuit and closing the graph." (Álvarez & Parra, 2013). In the same way, mixed graphs can be generated in which edges with direction and without direction are combined, such as a) Receiving: It is the number of edges that a point receives; b) Emission degree: It is the multiple numbers of edges that leave a given point of the graph; c) Branching: They are the points whose degree of emission of edges is greater than another; d) Isolated vertex: It is that vertex that is not affected by any edge (Álvarez & Parra, 2013).
Therefore, for this research, this theory has been taken from a set of objects called nodes, which represent each of the selected building landmarks, which have been joined by their vertices, generating a graph with which the DRUs were determined and, therefore, the growth pattern of the city.

Methodology

This basic research was worked with a qualitative methodological approach that implemented the documentary analysis from data of urbanistic characters, whose study population was defined from the urban planning and construction licenses of buildings in the intermediate city. From the population, a non-probabilistic sample was established by convenience since

the buildings were selected according to the current information in the municipal archive of the Administrative Secretariat of Tunja under the following criteria: first, a selection of licenses was made for those buildings with a tectonic characteristic of the architectural period of modernity, new or modifying buildings from the colonial period or the period of the Republic, built from the 1970s; second, those buildings for banking, sanitary, educational, sports, industrial, commercial and residential use were taken into account, in response to the need for these services in places that became poles of the city's growth in the 1970s, 1980s, 1990s and 2000s until 2013.

Thus, with these data determinations, the documentary analysis process began, which consists of three phases shown in Table 1.

Table 1 Methodological phases of the research

Methodological phases of the research		
Phases	**Research technique**	**Results**
Phase 1: Determination of the study population	The primary documents were obtained through digital copies of photographs, according to the criteria of the sample to be chosen.	120 construction and urban planning licenses were selected, of which 99 met the criteria established for analysis.
Phase 2: Delimitation of the study sample	Documentary systematization of the study sample through files based on the city's construction and urban planning licenses.	Data obtained: Date of license, use of the building, project architects, project engineers, use and location in the city.
Phase 3: Analytical process	Spatial location maps and analysis based on graph theory.	Construction of the location mapping of each building for each period studied to determine the growth parameter at a spatial-temporal level with land uses.

Source: Own elaboration.

From the analysis, it was possible to find the "way to reach a result through the decomposition of a phenomenon into its constituent elements," where all licenses were taken and decomposed into elements to be analyzed in the complex city system (Lopera et al., 2010, p. 342), where all licenses were taken and decomposed into elements to be analyzed in the complex city system. For this purpose, each of the selected buildings was located on the map of Tunja to illustrate the connections between the buildings and thus represent the relationships and interconnections between these elements of the city that constitute a dynamic system that evolves over time.

This modeling was carried out by implementing the graph theory on abstract segments that maintain a set of objects called nodes or vertices, which represent each of the buildings selected in the stipulated study decades, to subsequently define the DRUs that determine the growth pattern of the city.

Case study

Tunja is located on the eastern cordillera at 125 km from Bogota, D.C. It is the capital of the department of Boyacá, Colombia (Graph 1), with an altitude of 2810 meters above sea level and the highest capital of this country, which is a determining factor in the climate of this city. Its total area is 121.5 km2, of which 19.8 km2 corresponds to the urban area and 101.8 km2 to the rural area (Alcaldía Mayor de Tunja, 2018). The rural area is divided into ten roads and the urban area into 200 urban developments and eight communes (Secretaría de Protección Social, 2013). The current population is 195,500, of which 187,689 live in the urban area.

Graph 1 Localización de Tunja

Source: Own elaboration.

Results

The city has been studied as an adaptive system where the different elements that make up the general systems and subsystems interact; it is seen as an open system created by man, which is constantly changing as time goes by, through which self-organization, adaptation and emergent order are derived:

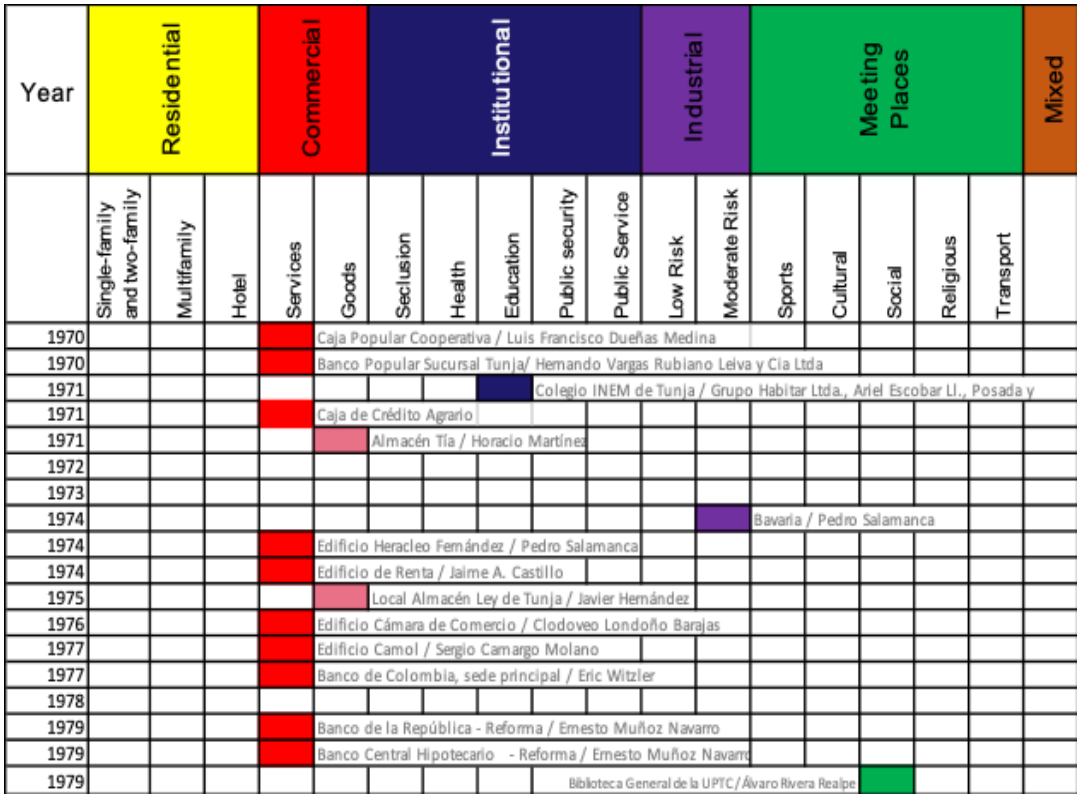
> ... cities do not have central planning committees to solve the problem of buying and distributing goods... how do these cities avoid the devastating alternation between scarcity and abundance, year after year, decade after decade? The mystery becomes more acute when we observe the kaleidoscopic nature of large cities: buyers, sellers, administrators, streets, bridges and buildings that are always changing so that the coherence of a city is imposed on a perpetual flux of individuals and structures. Like the wave rising to a rock in the current, a city is a pattern in time" (John Holand citado por Johnson, 2001, p. 33).

Therefore, the city follows a series of patterns established in a general way by public entities, but these are developed by private entities that give value to the land through buildings.
For the case of this work, the role of the construction of some new buildings and the restoration of other old buildings of great importance for Tunja was analyzed in particular, as DRU elements produced an unplanned growth of the city. This has caused the city to grow largely due to private capital investment and the enhancement of land value through new construction or the change of use of an old building.
Likewise, by constructing a building with use of great value and usefulness for a certain sector, it is defined as an element with high information that dynamizes the system, making it grow concentrically around the nodes, which start from the center of the city and extend to the north and south of it.

The role of landmark buildings in the 1970s

Tunja is a city that, since its foundation, was planned from the concept of a Spanish plot, which indicates that like many others founded by the Spanish, in its beginnings, "they had a model both for its urban design and for the destination of the land" (Instituto Geográfico Agustín Codazzi, 2015, p. 7).
By 1939, Tunja had 86 blocks in the center and 37 to the southeast. In 1957, the city was made up of 149 blocks in the center, 64 to the southeast and the north began to be urbanized with conservative growth. In 1964, out of 235 blocks, 156 were in the central area, 78 in the southeast, and one block in the north. By 1973, Tunja expanded in all directions and began to register an advance in construction, linked to factors related to state policies in which an industrial boom was observed, which generated the growth of the city (Instituto Geográfico Agustín Codazzi, 2015).
Therefore, this research is developed chronologically from the 1970s onwards, a period in which the system is modified, no longer organized and governed by the Spanish fabric, to show dynamics generated by the construction industry from buildings that create a new order within this complex system.
In order to approach the analysis, the information on the construction licenses was extracted from the documentary records to determine the year in which the landmark buildings emerged, taking into account the land use from which they came. As seen in Graph 2, the buildings that stand out in these years are of a commercial nature for the provision of services such as banks and offices, followed by commercial goods such as warehouses, which today are a landmark for the city, generating new growth poles and serving as evidence of the DRUs. Likewise, it can be observed that, unlike the other years, in 1971, this type of building had a greater impact on land uses for commercial in services, commercial in goods and educational institutions.
In the 1970s, technological innovation marked a relationship with structure, form and space in Tunja, changing the construction paradigm for the structural system used, evident through buildings for commercial, institutional, industrial and cultural use, as seen in graph 2.

Graph 2 Selection of buildings from the 1970s



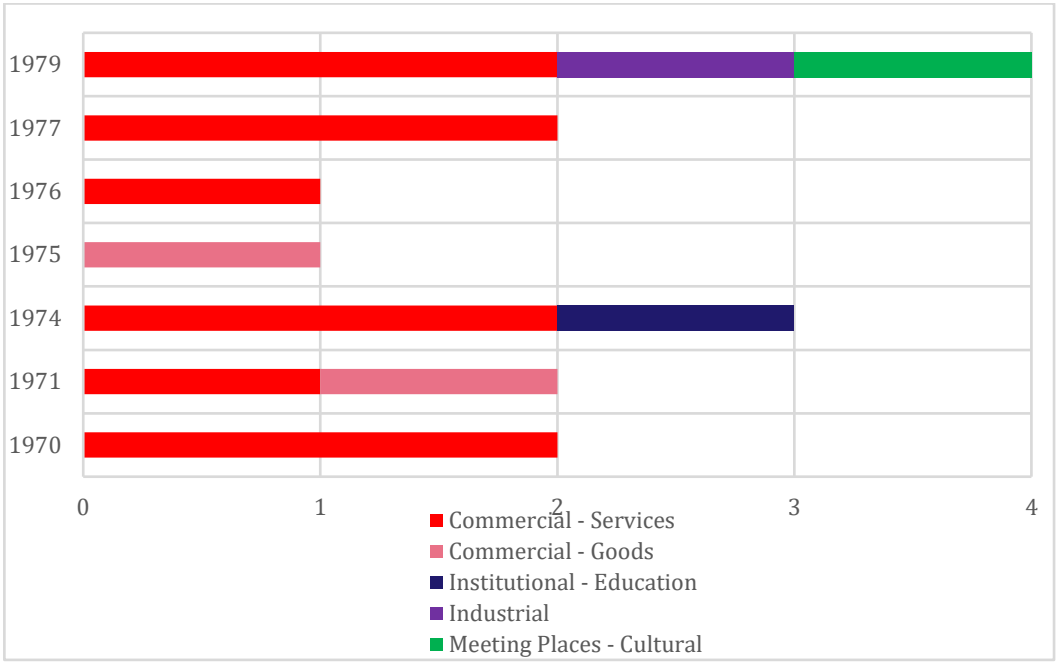
Source: Own elaboration based on information from urban planning and construction licenses from the municipal archive of Tunja

During this period, high-rise buildings impacted the city's growth and new constructions, such as the Caja de Crédito Agrario, the Cámara de Comercio building and the CAMOL Building, which exceeded four stories in height, were built in the historic center of Tunja. This is how modern architecture began to take place previously occupied by heritage buildings.

Thus, buildings were constructed today as a landmark for the city, such as the CAMOL Building. The firm that built it projected a building that, for that time in the history of Tunja, broke with paradigms such as the conservation of the architectural heritage of the Colony, the investment of private capital, the construction of a building whose height exceeded five stories, the execution of a project of such magnitude without having the necessary tools and technological advances to achieve its materialization. This put the city, the planning office, the labor force, as well as the engineers and architects who were to make this work, which is still a landmark in Tunja, a reality.

Finally, the buildings were the elements that gave rise to the new subsystems of the city and thus generated new growth poles, as in the case of the Bavaria brewery industry, built in the north of Tunja in a sector that had not grown in the same way as the urbanization towards the south of the city, due to the connection with Bogota.

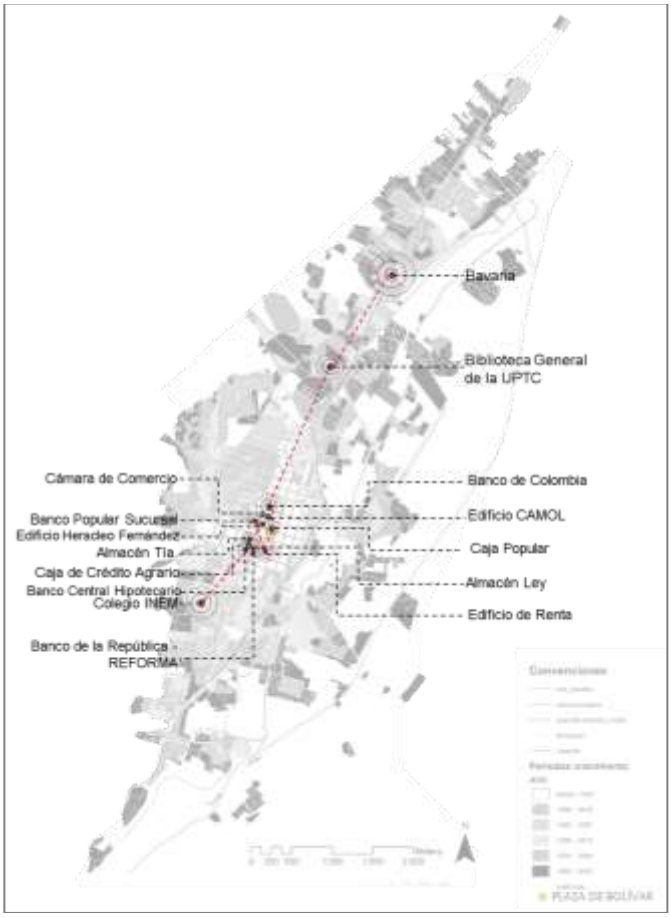
Graph 3 Matrix by years of land use of buildings from the 1970s.



Source: Own elaboration based on the documentary record of the collection of the buildings of the 1970s, obtained from the urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Mayor's Office of Tunja, 2014).

Map 1 shows that the city was not only consolidated with building landmarks in the historic center, like most Latin American cities but also settled in the north of the city without any previously conceived theory of decentralization.
In addition, multiple uses were consolidated around these landmarks in the historic center of the city, contained by residential areas; an effect was also replicated in the north. This chaos of unplanned land uses owed its expansion to a more economic need, defined by the type of land uses described in Graph 3, leaving aside social and environmental aspects.

Map 1 Buildings from the 1970s



Source: Own elaboration with base plan taken from the Plan de Ordenamiento Territorial del Municipio de Tunja. The shaded growth areas were taken from Hidalgo (2010).

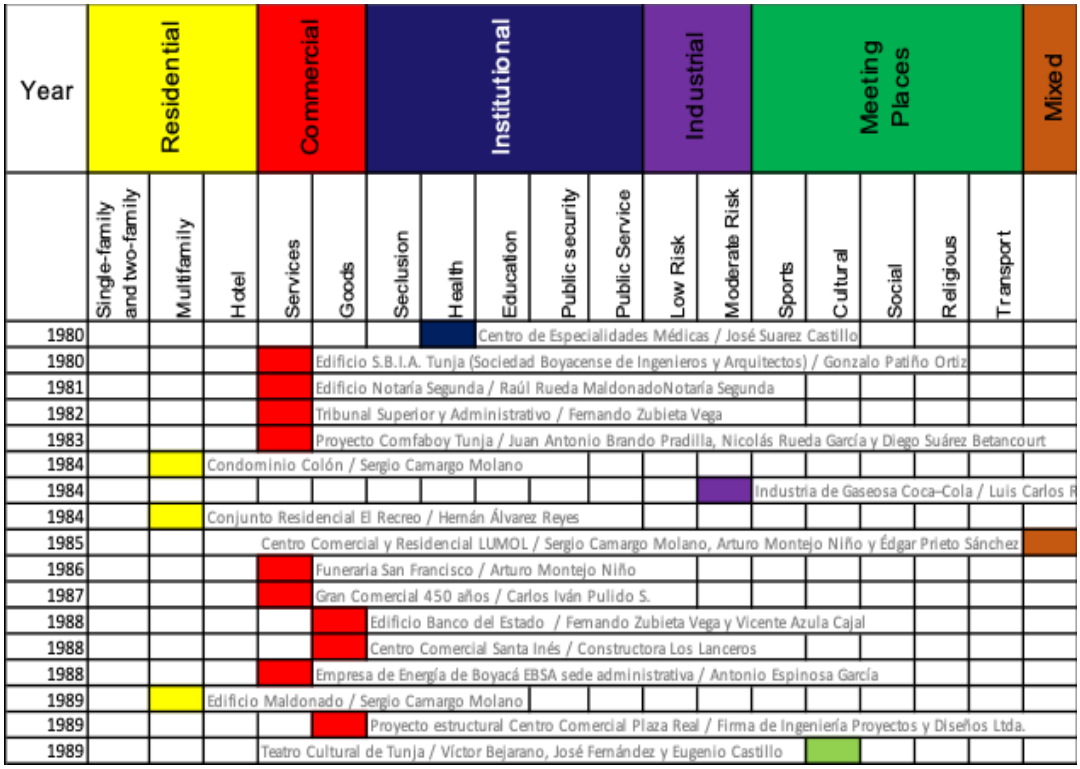
The emergence of urban revitalization in the 1980s

In addition to the growth that had been occurring in Tunja since the previous period, in the 80's, according to Rincón, (2009):

> ... a process of consolidation and population densification, since the expansion areas for this period concentrate 33% of the total population (...). This indicates that there is already a change in the dynamics of population distribution since the city's center begins to lose its residential character and acquire the character of other activities (p. 24).

In the center, a change of uses displaces the population to the peripheries. This brought about many transformations for Tunja, which are reflected in the growth and investment in the city. According to graph 4

Graph 4 Selección de edificaciones de los años 1980s



Source: Own elaboration based on information from urban planning and construction licenses from the municipal archive of Tunja

For example, buildings for institutional and commercial uses were constructed in the center of the city that energized the city's central system, such as: the Medical Specialties Center, the Sociedad Boyacense de Ingenieros y Arquitectos (S.B.I.A.) building, the Second Notary Office building, the Superior and Administrative Court, the Comfaboy project, the Lumol Shopping and Residential Center, the San Francisco Funeral Home, the Gran Comercial 450 Years, the State Bank building, the the Boyacá Energy Company EBSA administrative headquarters and the Cultural Theater.
At that time, banking institutions played a fundamental role in promoting several new projects, among which there was a tendency to build multi-family housing and the beginning of many neighborhoods in this city (Hidalgo, 2010).

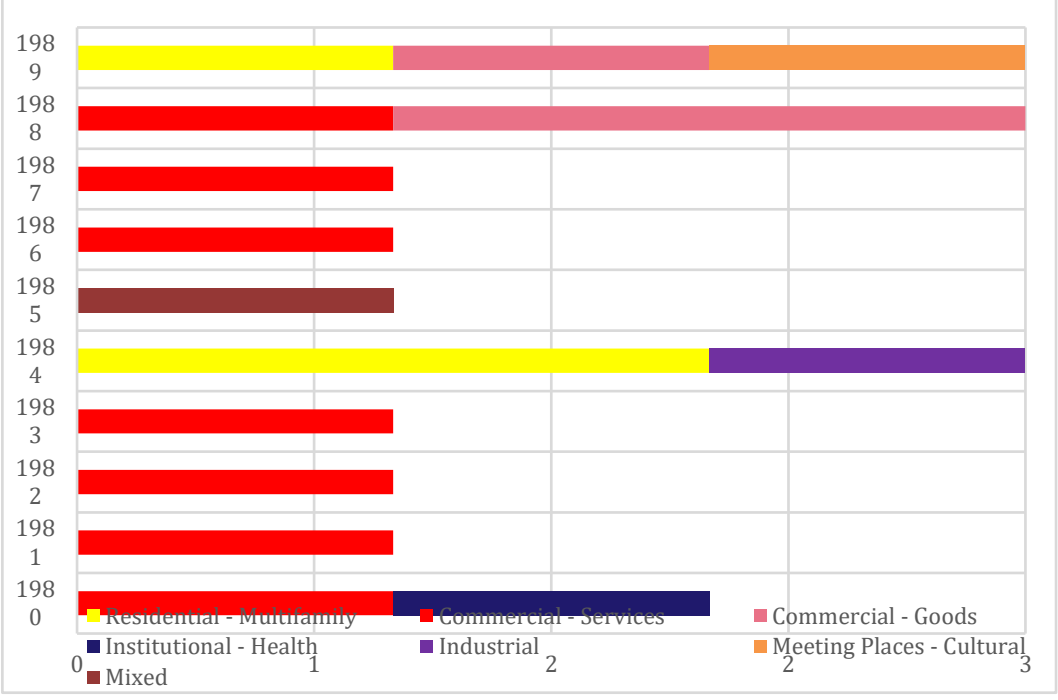
Along with constructive and innovative technological trends, the concept of security for the inhabitants also arose, leading to housing complexes. As part of the city's northward growth, the first residential complexes were the Colón condominium and the El Recreo Residential complex, in the Santa Inés neighborhood and its shopping center.
Also in the 1980s, Tunja was seen as an appropriate place to found some industries as the capital of the department of Boyacá, which were strategically located in different city sectors: to the east, the Coca-Cola soda factory, and to the south, the Gaseosas Postobón factory.

These modern constructions generate "new urban nuclei that have not yet achieved independence from the center, resulting in a dispersed city model" (Rincón, 2009, citado por Instituto Geográfico Agustín Codazzi, 2015); that is to say that at that time, the city becomes a complex system with emerging properties.

Subsequently, in the 1980s, 17 new facilities emerged with land uses different from the previous decade, such as health institutional, mixed use, making up 24% of the different DRUs, where residential use acquired greater importance, which had been visualized in the 1970s (Map 1); in addition, a structurally reinforced facility was found to change from a market place to a new use of commerce and offices, given the commercial dynamics of the environment.

In graph 5 it can be seen that between 1988 and 1989 more landmarks were built with residential, commercial goods, commercial services and meeting places uses. From this point on, it can be clarified that, based on the previous analysis, the appearance of residential areas that emerged from the DRUs from an economic perspective became noticeable, so this analysis could mean the importance of analyzing the dynamics of reactivation to predict future activities.

Graph 5 Matrix by years of land use of buildings from the 1980s

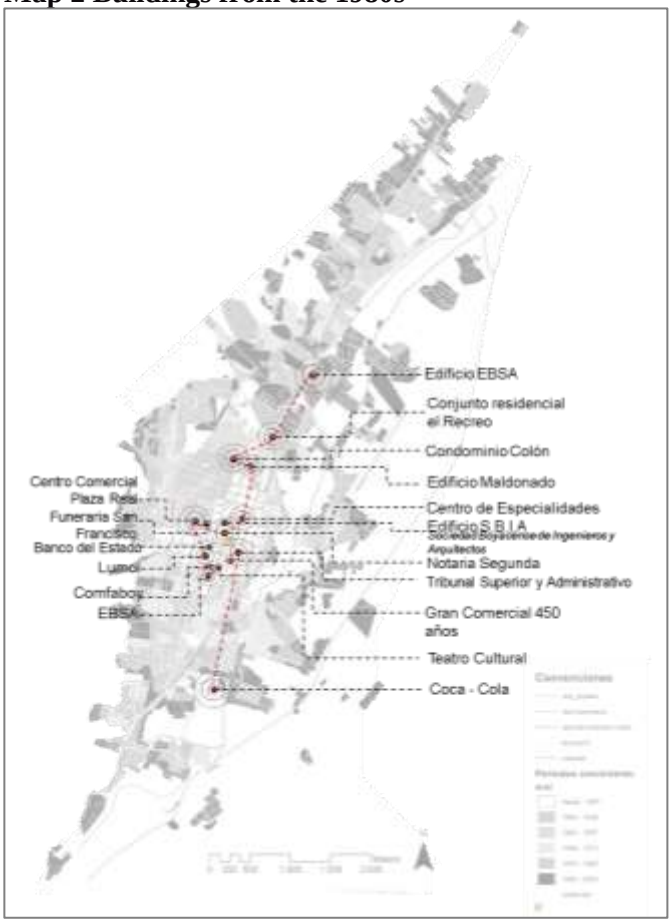


Source: Own elaboration based on the documentary record of the collection of the buildings of the 1980s obtained from the urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Mayor's Office of Tunja, 2014).

As seen in Map 2, there was a process of saturation of activities concentrated in large part of the historic center, which is contained by the surrounding residential zones. The construction of large infrastructures was maximized, promoting different synergies from various activities

that lacked order, where the residential zone coexisted with the industrial zone, zoning with a negative degree of compatibility due to noise pollution factors, among others.

Map 2 Buildings from the 1980s



Source: Own elaboration based on the documentary record of the collection of the buildings of the 1980s based on data obtained from the urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Mayor's Office of Tunja, 2014).

The implementation of a land management instrument in the 1990s

For this decade, the city already has a territorial management tool; in this sense, Law 9 of 1989 mentions urban reform:

> ... which proposes a series of instruments that allow control over the expansion and growth of the city: partial plans, urban renewal plans, the urban file, social housing programs and urban construction licenses (Rincón, 2009, p. 25).

During this period, there was a consolidation of the city's north due to the new buildings constructed in previous periods, which were the cause of recent urban nuclei and constituted elements of the city's densification; in addition, they filled the voids around them. According

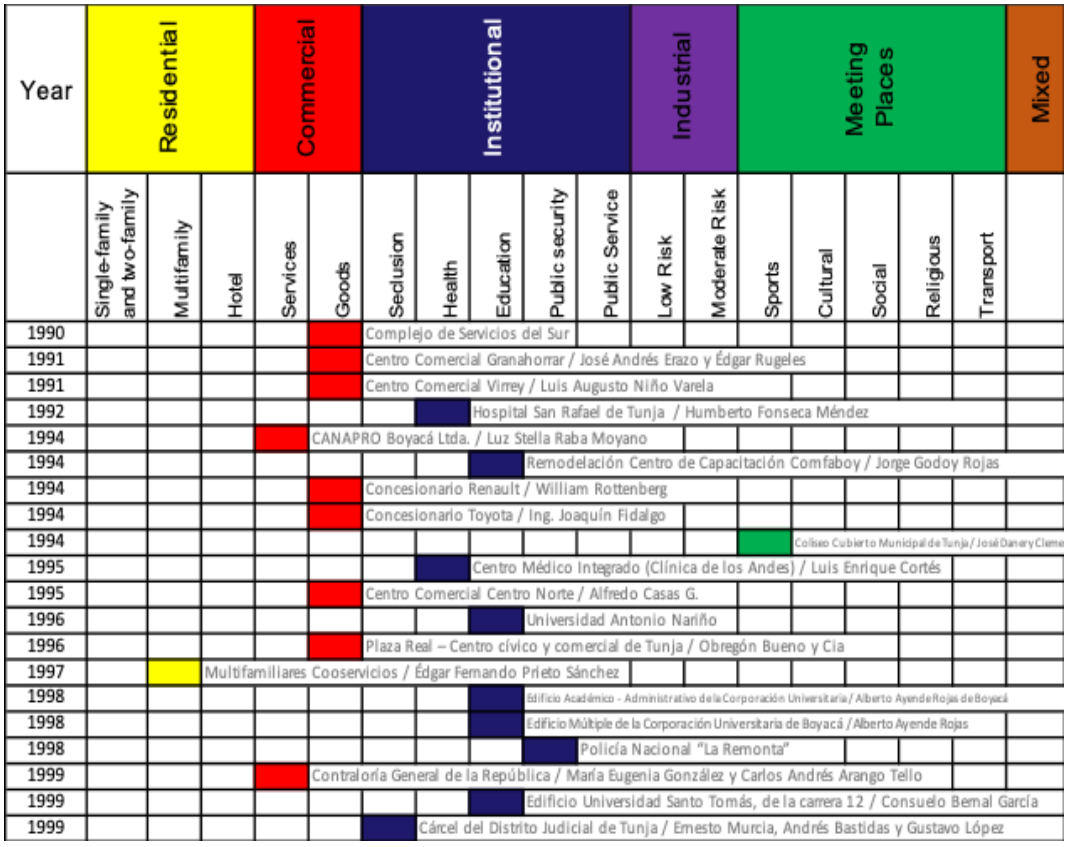
to aerial photographs from 1995, Tunja registered:

> ... a total of 1,044 manzanas [distributed as follows:] 346 Mz. were part of the central zone, 413 Mz. Corresponded to the southeastern zone, while in the northern zone, there is an increase in urbanization with 285 Mz., becoming the sector of preference (Instituto Geográfico Agustín Codazzi, 2015, p. 11).

But there are also new buildings to the north, such as the San Rafael Hospital, the Renault Dealership, the Toyota Dealership, the Covered Coliseum, the Integrated Medical Center (Los Andes Clinic), the Centro Norte Shopping Center, the Antonio Nariño university, the academic building of the University Corporation of Boyacá, the multiple building of the University Corporation of Boyacá, the National Police building "La Remonta," the Santo Tomás university building on carrera 12, and the Tunja Judicial District Jail. To the west, near the Coca-Cola industry, the construction of Multifamiliares Cooservicios began as an idea of a high-rise complex for social housing, which, along with some neighborhoods in that sector, are pioneers in settlement of western Tunja. Finally, in the south, the Southern Services Complex, was built, which as part of this system, is an element that, due to its dynamic use, creates a central supply of services but does not generate development to be habitable.

The center also restored heritage buildings that acquired a new use, such as the Granahorrar, Virrey, Plaza Real shopping centers, the Tunja branch of the Office of the Comptroller General of the Republic, and some new buildings, such as Canapro Boyacá Ltda, and the Comfaboy Training building; these uses gave the heritage houses the possibility of providing a commercial service that would guarantee their maintenance and operation so that they would not become abandoned buildings, another problem that arises from the colonial system from which the city of Tunja was formed. Graph 6

Graph 6 Selección de edificaciones de los años 90

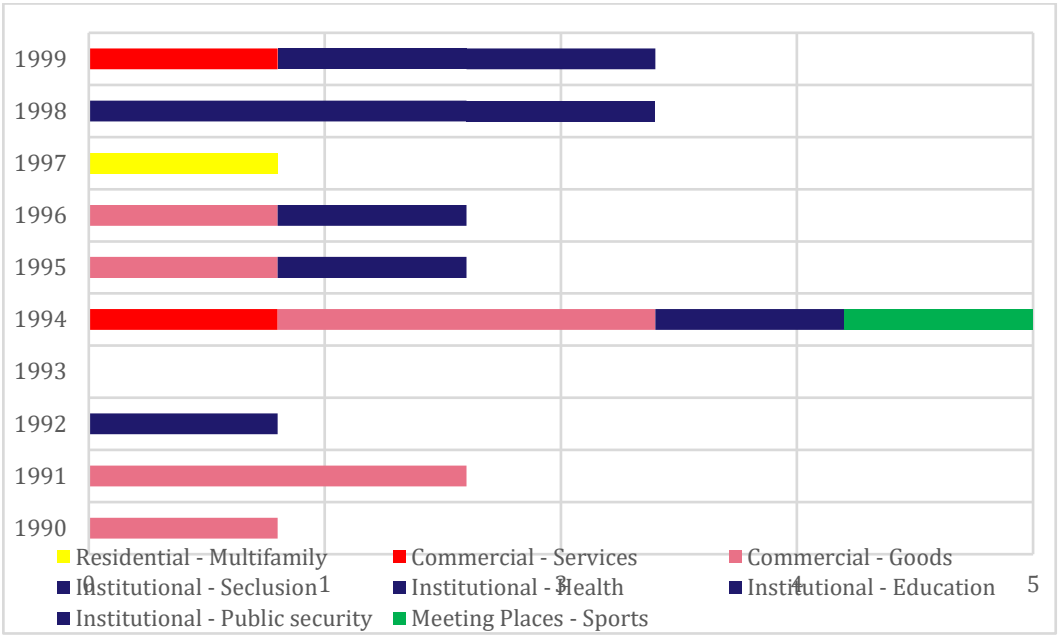


Source: Own elaboration based on information from urban planning and construction licenses from the municipal archive of Tunja

By the 1990s, a land management instrument was already in place to control the city's expansion, disorder and growth. As a result, 20 buildings were constructed, 17 of which were new, considering the DRUs already in place in the 1980s. During this period, the use of commercial land for goods, institutional education and health regained greater importance, generating a 65% different urban dynamic. On the other hand, the phenomenon of restoration began to emerge, implemented in three buildings whose purpose was to house commercial activities different from those previously conceived as residences and marketplace, to ensure their maintenance and operation so that they would not become obsolete buildings.

In 1994, these landmarks' greatest construction was evidenced, destined for commercial, educational institutions and sports meeting places. In addition, as seen in Graph 7, industrial use ceased to be built, giving rise to other uses that are more compatible with residential areas, where this type of decision was probably based on a management planning instrument.

Graph 7 Matrix by years of land use of buildings in the 1990s

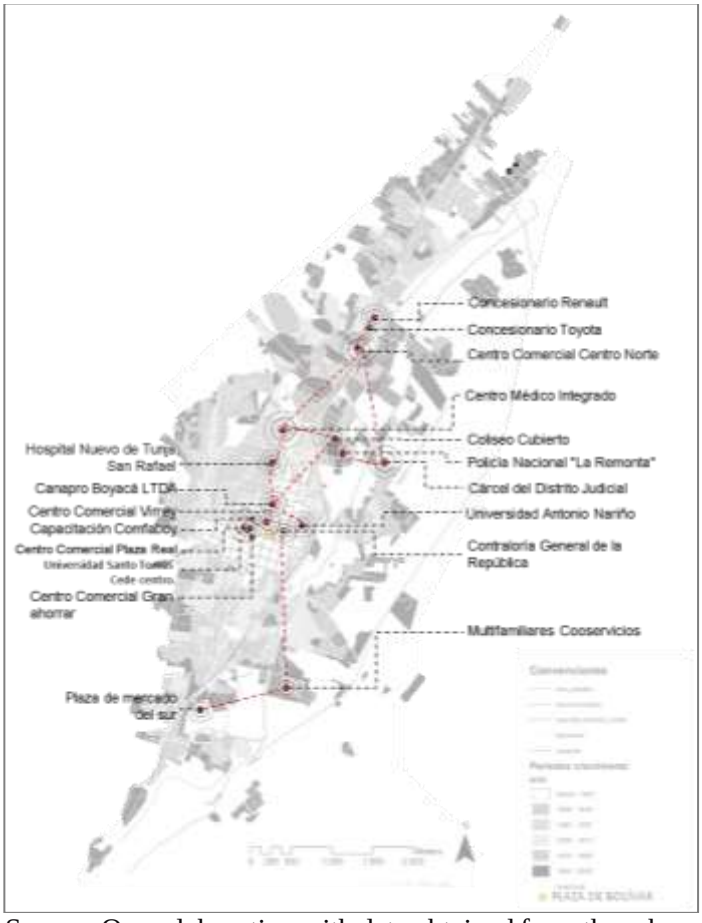


Source: Own elaboration based on the documentary record of the collection of the buildings of the 1990s, from data obtained from the urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Alcaldía de Tunja, 2018).

As can be seen, this new urban planning instrument was born as a response to the disorder and chaos of 1980; to a certain extent, it sought to counteract this effect by generating new polycentric nuclei in the south of Tunja (Map 3). However, the concentration of activities in the historic center did not cease, so this regulatory and management instrument did not manage to put an end to the system generated by the effect of urban reactivation that was being caused by old buildings and others seeking a change of use to continue producing activities as part of a self-organized dynamic system.

Despite this, during this decade, the city was rethought with a view to recovery, prioritizing important facilities for uses associated with the trade of commercio, health and education; the objective was to achieve a balance between the green and the urban, prioritizing the residential area over the industrial. However, urban reactivation activities were incessant, did not stop and continued with the urban pressure on the historic center.

Map 3 Buildings from the 1990s

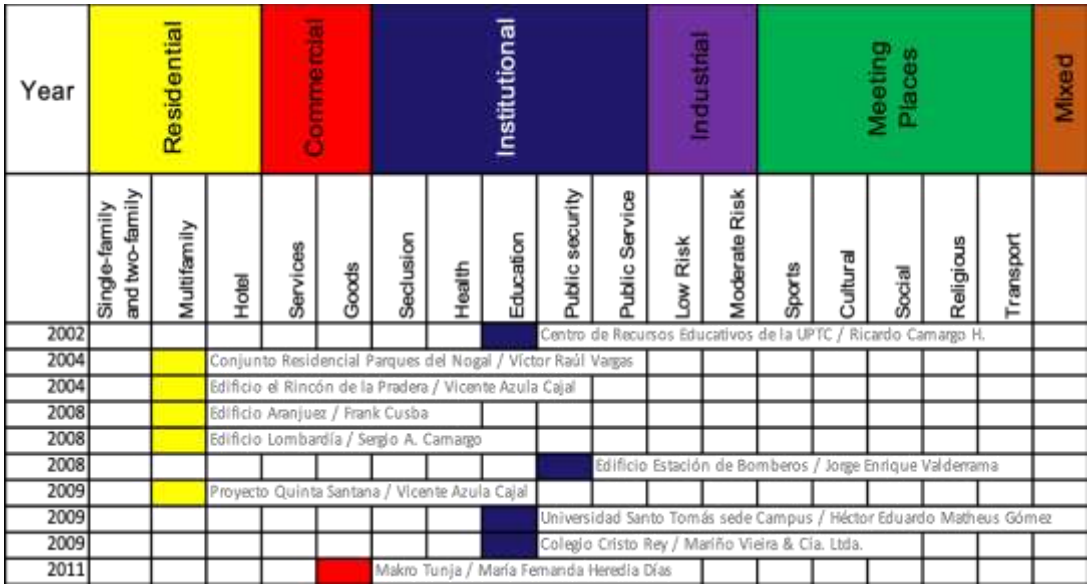


Source: Own elaboration with data obtained from the urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Alcaldía de Tunja, 2018).

Decentralization since 2000

By 2005, Tunja already shows significant growth, with a total of 1,505 blocks, of which 390 belong to the center, 578 correspond to the southeastern area, and 537 to the north of the city. When comparing this information with the growth for the year 2013, it is observed that the city has a total of 2,196 blocks, of which: 621 belong to the center, 1,122 correspond to the southeastern zone and 1,173 to the northern zone norte (Instituto Geográfico Agustín Codazzi, 2015); these data reflect a rapid growth towards the north for the southeast, which had been gradually increasing year after year, while the north grew exponentially due to the construction of new road elements that valorized the sector.

Graph 8 Selection of buildings from the years 2000 to 2011



Source: Own elaboration based on information from urban planning and construction licenses from the municipal archive of Tunja

The opening of main roads brings with it the beginning of the new residential, commercial and institutional such as: the Aranjuez Building, the Lombardía Building, the Fire Station Building, the Santo Tomás university campus, the Cristo Rey School, the Makro store and single center shopping Unicentro, connected to the Olímpica Avenue, which is a transversal road axis on which the construction of multi-family buildings with avant-garde architecture stands out. Olímpica, which is a transversal road axis on which the construction of multi-family buildings with avant-garde architecture stands out, with structural proposals that innovate in form, with volumetric management that responds to the environment and that, to a certain extent, seek to be lungs for the city through their public space projects.

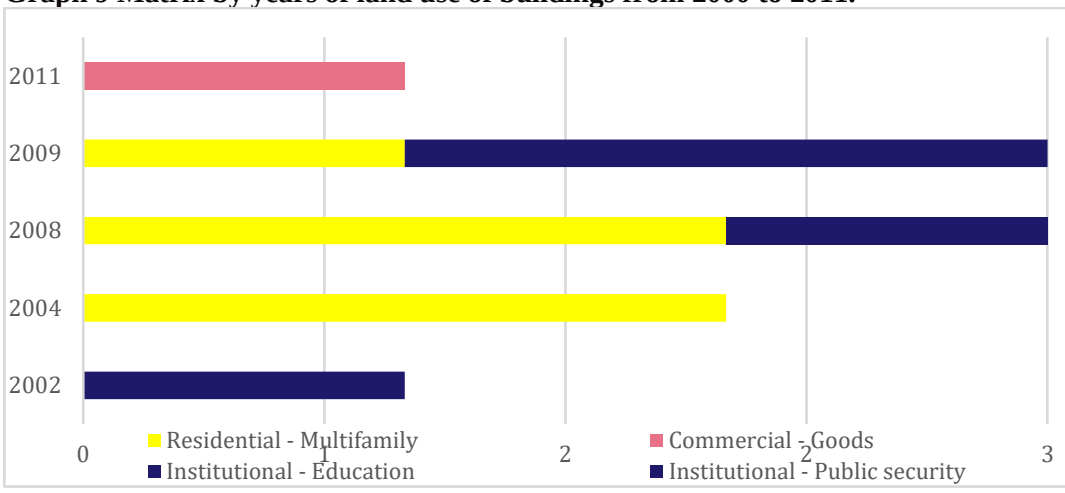
However, in this sector, it is necessary to solve difficulties related to the soil since it was built on land with high water tables, which led to the adoption of new construction systems that allow the modular management of spans and spaces through continuous porches, an example of which is the La Catleya building, located in the Mesopotamia neighborhood, which was a national reference for engineers due to the structural solution given to this problem, without the presence of major settlements.

This new growth came about by implementing a more technical architecture that goes beyond a constructive solution, with buildings that constitute the very skill of the architect, who in his design proposes geometry as a hidden mesh that organizes the structure and gives shape to the project, "architecture is the very skin of the structure (architect José Suárez, from the city of Tunja)." "Architecture drags the technical capacity behind it, empowers it and gives it form" (De Solá-Morales et al., 2000, p. 45).

By 2005, Tunja was already experiencing significant growth due to the construction of new roadways that enhanced the sector's value. The opening of main roads and accessibility to the north brought with it the inauguration of new projects, mostly residential type, which generated a dissimilar urban dynamic of 50% (Graph 9) and were consolidated through new construction systems in the north of the city, breaking up 50% of the commercial activities of

goods, institutional educational and public security, which allowed the decentralization of activities to form a polycentric territory. In this decade, the conformation of building landmarks was lower than in other years; 2008 was the year this type of buildings prioritized residential use were developed to a greater extent.

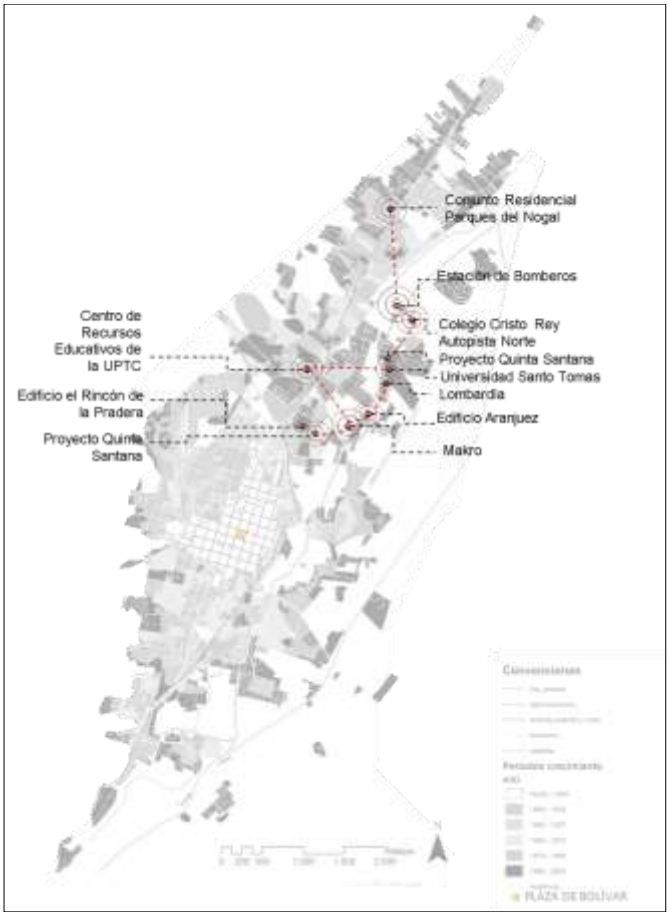
Graph 9 Matrix by years of land use of buildings from 2000 to 2011.



Source: Own elaboration based on the documentary record of collection of buildings from the years 2000 to 2013, with data obtained from the urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Alcaldía de Tunja, 2018).

Finally, it can be deduced that Tunja had an intelligent growth for decades, not developing gradually in both poles, but rather it had a forced development towards the south in the 1990s and during the 2000s, its intuitive development was towards the north. Therefore, as seen in Map 4, this system was formed in parts for a while, but later it was given independently to an urban development plan, completing that missing part and thus evolving into a whole from the DRUs.

Map 4 Buildings from 2000 to 2011.

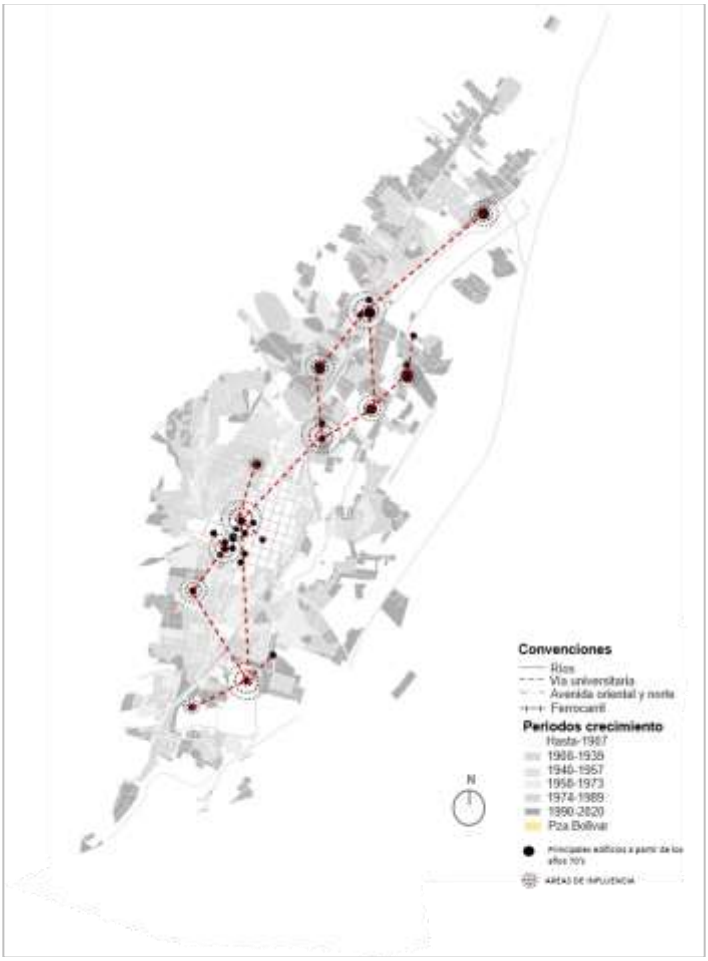


Source: Own elaboration based on data obtained from urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Alcaldía de Tunja, 2018).

Balanced Complex System

The evolutionary superimposition by years shown in Map 5 shows a result of 6 polycentric nuclei that allow the liberation of activities in the historic center; Similarly, the proximity to these service facilities, both in the north and south of Tunja, proves that the DRUs of the building landmarks are nothing more than the response to a complex system that can self-organize, reacting in a non-predictable way to each building that is constructed in the city, which are not independent units and do not function as a whole, since, despite not being planned, they self-organized in such a way that the system was functional.

Map 5 Dynamics of urban reactivation based on building landmarks



Source: Authors' elaboration based on data obtained from urban planning and construction licenses that rest in the municipal archive of the Administrative Secretariat of Tunja (Mayor's Office of Tunja, 2018).

Discussions

The research used a historical documentary analysis processed under graph theory to determine DRUs and reactivation points generated by decades, as opposed to Liu et al.(2010), De Mattos et al. (2014), Yunda & Montenegro, (2019), they used landscape expansion metrics to determine the process of urban growth and transformation as future simulation models.

In that sense, Peña, (2021) proposes a K-Means algorithm that could be complemented with these results for future research, considering that these DRUs can be found outside the urban boundaries, taking into account that analyzing a complex, balanced system does not only start from building landmarks (Steurer & Bayr, 2020), Therefore, this research could complement these results for future research, considering that analyzing a complex, balanced system does not only start from building landmarks. To that extent, this research could be further complemented with other indicators.

The balanced, complex urban ecosystem developed in Tunja underwent a disorderly and chaotic process during the 1980s, which led to an oversaturation of activities that, from the perspective of Graells-Garrido et al., (2021). The study reveals, however, that the city's urban development is not yet in a position to be accessible. In addition, the study reveals that the implementation of management instruments did not have a substantial influence in decentralizing these activities, but rather the system acted by itself, seeking spatiotemporal self-organization based on the DRUs.

Conclusions

The research shows that despite the imbalances caused by the lack of preliminary planning in the city's growth, the ecosystem has managed to self-organize over the years from the DRU produced by the building landmarks, thus consolidating itself as a complex urban ecosystem. The identification of these milestones allowed, based on graph theory, to generate a complete analysis of the DRUs in the period between 1990 and 2013, which took as a starting point classification of historical documents that allowed to identify how the city of Tunja was gradually transformed into a balanced, complex urban ecosystem.

It can be said that the city is a complex urban ecosystem with emergent properties that can organize itself and create new dynamics, even though its beginning was planned under the rule of the Spanish grid; with time, this system has changed and will continue to transform, but without a doubt, capital and the construction of new buildings play a fundamental role in generating uses that satisfy the needs of human beings.

Throughout the investigative journey of this document, it is evident the evolution and modernization of the infrastructures that are part of the complex urban ecosystem, so that in the '70s a giant step was taken in the architectural updating, thanks to the construction of high-rise buildings, a situation that allowed the first evolution with the heritage buildings of the time.

On the other hand, in the 1980s, population growth was already noticeable: commercial buildings of goods began to settle in the center of the city and residential areas around it. This development generated chaos in the concentration of activities incompatible with industry, which responded to economic needs.

The decade of the 1990s was framed in legal guidelines, with the enactment of Law 9 of 1989, which regulated the control of the city's expansion, as growth was remarkable. This law defined the parameters for renovation plans and the creation of social interest programs.

Since 2000, the city's architectural growth has been accompanied by an expansion of commercial areas and cultural and educational buildings, as well as the construction of multi-family buildings with avant-garde architecture, which included environmental and public space commitments.

In conclusion, it is observed that unplanned cities can self-organize in a time when their functional elements respond to a growth that orbits around the land uses that make up the territorial planning, generating a graphically linear growth pattern, according to the resulting graphs in each of the cartographic maps. However, the above does not represent a pattern that follows the shape of the colonial city that manages a plot structure; instead, it is a functional pattern around the building landmarks that allows DRU to be generated.

In this way, it can be seen that various aspects come together for the development of the city, thus creating a complex urban ecosystem where the building is not only spoken of as a

particular asset but also as an element that generates emergent properties that make the city grow, change, evolve and adapt.

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