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Multifunctionality of green corridors during pandemic lockdowns: a case study of Riobamba city in Ecuador

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Abstract
The pandemic has demonstrated several weaknesses and inequalities in the way society live and develops within cities, such as economic losses, massive contagions, and above all, the lack of control and people's lack of awareness about the crisis. This study aims to investigate the transformation of cities with a shortage of green spaces into cities with green and sustainable planning, the association between urban greenery and physical activity during the Covid-19, and urban green corridors as a planning tool for urban green areas.

The green corridor was born out of a social need in the face of a health crisis and the improvement of the urban environment. This research employs three methods to study: empirical judgment and experience analysis and network analysis. All those who could not cope with the lockdown exposed green and recreational spaces in Riobamba, since only 7% of those surveyed stayed at home, while 70% left their homes for green or recreational spaces within the urban area and 23% left the city. This shows how the quality of green areas can positively affect people's behaviors during the Covid-19. This effect highlighted the preservation of natural areas, urban reforestation, and re-naturalization of spaces. The urban green corridor is a system that connects several spaces, creating two interactions: the first is how the city can provide the necessary infrastructure during a crisis, and the second is how it energizes and prioritizes the health and supply systems for urban residents, creating safe spaces for each of the city's sectors.

Keywords: COVID-19; pandemic; green corridors; multifunctionality; sustainability; re-space.

Introduction

The Covid-19 pandemic has heightened public awareness about two issues: people's relationships and living places. However, many people have been unable to adapt to a new *"homebound"* lifestyle, and convert their homes to the workplace, school, or university, creating drastic tensions and complexities around (Prime, Wade, &Browne, 2020). The emergency measures have created social and economic gaps in social relations, daily life, and the confidence to return to a place or public space. Although these gaps are unknown and uncertain, they do force us to rethink the structure of cities and their relationships. The people should improve their ability to immediately adapt to the physical and natural environment surrounding them, due to the new and different perspectives and experiences provided during the pandemic about the people's environment (Devine-Wright et al., 2020)

Enhancement and design solutions driven by crisis or risk are not a new topic to address, and they are the same aspects that influenced the design of urban open spaces. Also, these solutions are the most influential driving forces for redesigning the cities and urban regions in general, throughout history (Megahed &Ghoneim, 2020)(Sanchez Herraez, 2020)(Devine-wright et al., 2020). Nevertheless, modern cities have many gaps to encounter the pandemic, including the design, access, and equitable distribution (Scott, 2021)

of green spaces. These gaps raise the question of "*How can we build an urban green corridor based on the lockdowns in the face of a health crisis such as Covid-19?".*

This case study investigates the citizens' behaviors during the Covid-19 pandemic to find solutions to the current environmental crisis in the city of Riobamba with a lacking urban green index (Arroba, Hidalgo, &Granda, 2020) and a low population density. This research considers this premise: *"while it was once thought that low-density settlements with a greater number of green spaces would better address issues of urban health and hygiene"* (Gill et al., 2020). Urban green corridors in the urban environment start from this principle to develop green planning within the city based on the multifunctionality. These spaces, such as urban landscapes, are the main barriers to a low-contagion spatial system, helping communities to access places that counteract the effects of lockdowns or isolation, and stop or slow the spread of disease (Devine-wright et al., 2020).

1.1 Background

1.1.1 Architectures, pandemics, and outdoor spaces

In the 14th century, the bubonic plague motivated the fundamental urban improvements of the Renaissance. In contrast with the dark medieval cities, this period experienced public spaces with wide and open squares (Santillán García & Fernández Canas, 2020), (Martínez Campos, 2006). In this period, the cities cleared out the overcrowded neighborhoods, widened their margins, developed the first quarantine facilities, and opened up large public spaces. These implementations highlighted the first proposals by Leonardo Da Vinci's proposals on the urban remodeling of Milan after the plague (Santillán García &Fernández Canas, 2020). In the 17th century, London replaced the old wood structures with bricks which are more impervious to disease-carrying vermin, to decrease the pestilence threats.

Barcelona is another example that modified the urban manufacturing and industries to improve the health status of the city. Ildefonso Cerdá argued that narrow streets increase the mortality rate during epidemics, and social justice decreases social class differences (Pallares-Barbera, Badia, &Duch, 2011). The development of this city followed an open city pattern by building blocks with a garden inside them, and chamfered intersections between streets to give them greater width, light, and ventilation (Moreno-sánchez, Fernanda, Rovirosa, Teresa, &León, 2018).

In the United States, ***tuberculosis*** prompted the creation of large green spaces in cities such as Boston's Emerald Necklace or New York's Central Park (Klein, 2021). In addition, Napoleon III eradicated the slums, and built wide avenues, green spaces, and sewerage system in Paris in 1854 (Wintle Thomas, 2022). Simultaneously, Baron Haussmann redesigned the city and neighborhoods (e.g., squares, parks, and forests) to combat overcrowding, congestion, overpopulation, and poor hygiene in Paris (Santillán García &Fernández Canas, 2020).

In the 20th century, infectious diseases played a crucial role in urban renewal. Modernist architects considered their own design as a cure for the disease of overcrowded cities, where ***tuberculosis, typhus, polio,*** and outbreaks of ***Spanish flu*** encouraged urban planning, slum clearance, housing reform, and waste management (Allam &Jones, 2020; Chang, 2020; Martínez Campos, 2006; Sanchez Herraez, 2020). On the one hand, Frank Lloyd Wright advocated the integration of technology with nature in his *"Prairie Houses"* and *"Cascade House"*. On the other hand, Le Corbusier built roof gardens to rescue all the roofs of the city into thermoregulating green masses (Moreno-sánchez et al., 2018). His *"Voisin Plan"* for Paris (1925) called for replacing the city center with a large park where large residential towers would emerge (Velasquez, 2016).

The urban planner, Ebenezer Howard, designed garden cities to home 10,000 to 30,000 people, their industries, and rural belt for combining the benefits of city and countryside (Santillán García &Fernández Canas, 2020). This design makes satellite towns that are self-sustaining and resilient to supply chain breaks caused by disease, and enables local agriculture to feed their residents with minimal transport costs, while offering residents a respite from the overcrowding and squalor of the city (Klein, 2021).

This study aims to the quality, quantity, and distribution of green spaces, and how can be assessed and create cities more resilient and better prepared to provide services during natural and health emergencies,

positively improving the well-being and health of all city dwellers in situations of total or semi-lockdown (Belmeziti, Cherqui, &Kaufmann, 2018). And in turn, these spaces such as urban landscapes will be the main barriers, buffers of a low-contagion spatial system that can help communities to access places, counteract the effects of lockdowns or isolation as well as stop or slow the spread of disease (Devine-wright et al., 2020), to establish the question of: *How to design strategies to make spaces within urban green corridors adaptable, transformable and responsive to the needs of all and provide equitable access?* and to be answered during the conduct of the research.

2. Literature Review

2.1 Urban Green Corridors

The ***Greenways*** current, or for us ***Green Corridors***, has been present in urban planning in North American countries, where urban green corridor planning has a long-standing level of leadership since the practice of green park system planning began in the 1960s, and Boston established the Emerald Necklace style park corridor system. This trend becomes more and more popular with the elapse of time, emerging a new global pattern for urban planners to think, design, build, and inhabit a sustainable city by balancing the environment, social, and economic dimensions of the urbanization process.

Widely approving the idea of building outdoor spaces in the 1980s promoted large-scale projects to construct ecological corridors in support of the relevant regulations. These projects develop a set of urban ecological corridor systems with social, cultural, recreational, and biodiversity conservation features. In the 20th century, this pattern transformed into constructing multi-level ecological corridor networks, and formed a system of ecological corridors on national, state, regional, and local scales. Each network and system has different objectives and characteristics (Peng, Zhao, & Liu, 2017), despite their close interconnections from two perspectives: (1) linearity and (2) official designation.

2.1.1 urban scale and functions

Although many researchers consider the ecological corridor as a separate issue, it is dispensable to a complex system that links nature with humans (Benito, 2014). Worth mentioning that constructing ecological corridors has some negative effects, such as providing a fast diffusion channel for harmful substances, intruders, predators, and diseases, and increasing the number of travelers, infrastructure, and land prices due to the green belt construction (Chin &Kupfer, 2020).

Linear spatial configuration is one of the most significant characteristics due to the inherent advantages regarding the movement and transport of materials, species, and nutrients. ***Connectivity*** covers a broad context at various scales, interpreted as a system of nodes with synergistic characteristics linearly integrated for physical planning. ***Multifunctional*** is based on the compatibility (assumed or negotiated) and function of certain applications: ecological, social, cultural, and aesthetic. ***Sustainability-based*** focuses on the complementarity between nature protection and economic development. ***Border effect*** provides a more evident open space per square meter than any other plot or field due to the first-mentioned characteristic. ***Concurrence of resources*** involves many natural and cultural resources of green corridors, due to the ample green spaces.

3. Theory

Scientists use various methodologies to investigate urban green corridors, including the qualitative analysis for empirical studies (Wang &Wang, 2021), quantitative estimations for suitability and sensitivity examination (Ahern, 2002), and the spatial analysis with network and minimum cumulative resistance exploration.

a) **Empirical judgment:** Empirical judgment quantitatively identifies the regional or urban corridors in urban planning (Peng et al., 2017). Nonetheless, the validity of the results depends mainly on the researchers' experience and knowledge (Wang &Wang, 2021).
b) **Network analysis:** This method follows the graph theory to measure the landscape metrics (Pouzols &Moilanen, 2014). This method considers that areas with high connectivity play a crucial role in the corridor network. In this method, the Gravity Model toolset(Wanghe et al., 2020) (ArcGIS) (The software is free and open-source on GitHub : http://github.com/wanghekunyuan/Gravity-model-tooxbox) offers a spatially-explicit map of potential corridors to prioritize them according to the opportunity cost

(Zhang, Meerow, Newell, &Lindquist, 2019), (Wanghe et al., 2020), (Kong, Yin, Nakagoshi, &Zong, 2010).

c) Methodological contrast comparing: This analysis combines qualitative and quantitative methodologies with a spatial pattern analysis to improve the methodological effectiveness of urban corridor construction.

4. Methodology

This study concentrates mostly on the evolution of a city with a shortage of green spaces to a city with green and sustainable planning (Weber, Boley, Palardy, &Johnson, 2017), supporting the association between urban greenery and physical activity during the lockdowns by the Covid-19 pandemic in an urban context (Megahed &Ghoneim, 2020). Figure 1 organizes the strategies according to the construction of urban green corridors in the city of Riobamba, as a non-densified city.

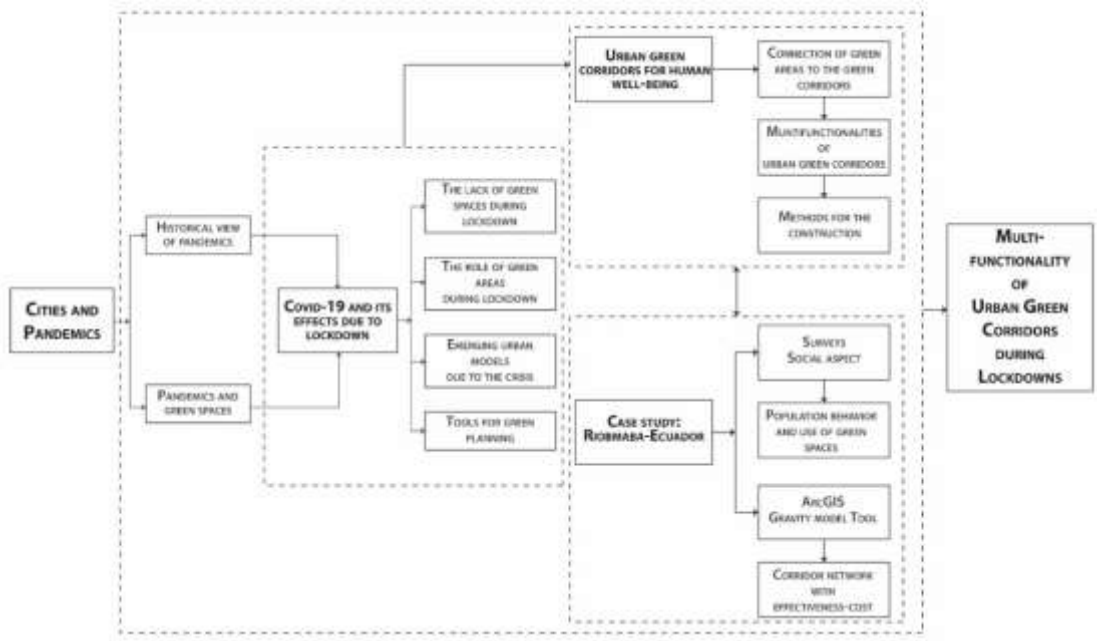

Figure 1- General methodology of the study

(1) A focus is given to the importance between green areas, health, wellbeing, and multifunctional spaces in the territory during a pandemic, to avoid agglomeration spaces or saturated nodes. *(Bibliographic analysis)*

(2) A green diagnosis of the city of Riobamba is carried out and surveys are applied to the city's inhabitants in order to understand their behavior during the lockdown and isolation caused by the pandemic. *(City analysis)*

(3) The construction of the urban green corridor is directed towards the planning and multifunctional role in the city, in order to create a resilient and future-proof city.

(4) The aim of this concept - that of multifunctionality - is the possibility to choose the best combination of green space components in order to provide the maximum number of urban services foreseen.

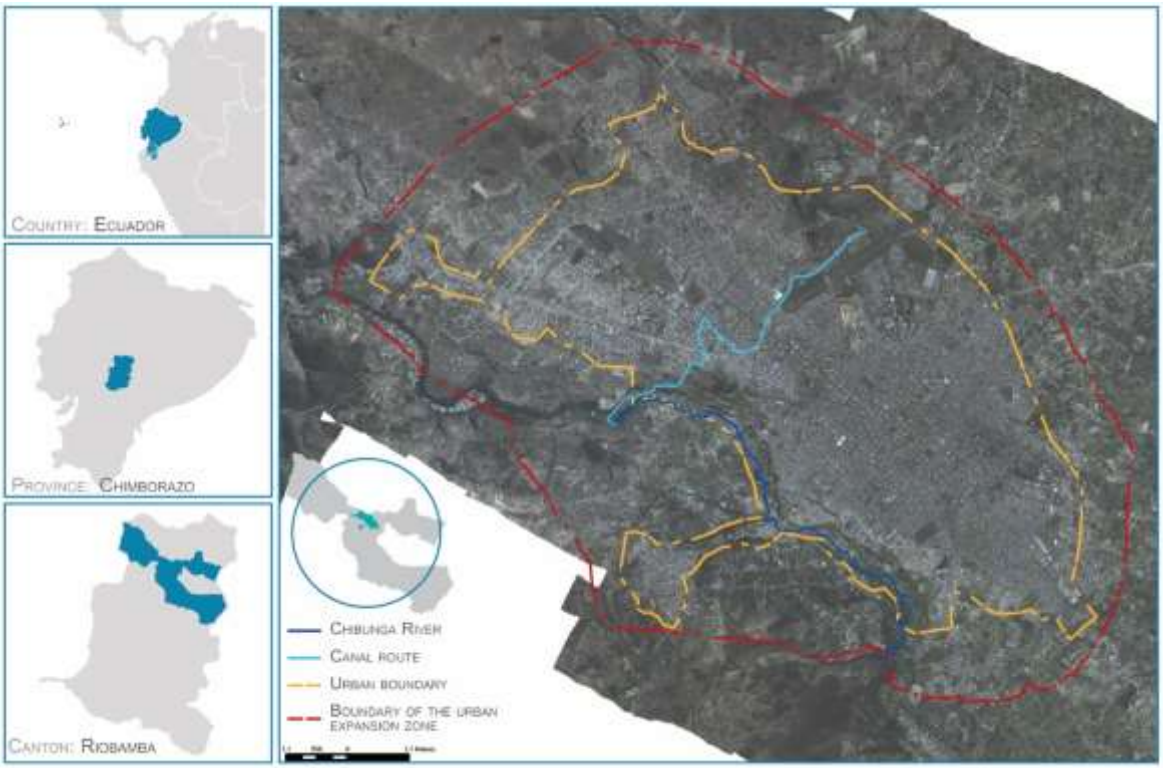

Figure 2- Location of the study zone

4.1 Study site

Riobamba is the largest and most populated city in the Chimborazo Ecuador province, located at the center of the Inter-Andean region (INEC, 2010). In Riobamba, lockdown and isolation became compulsory in March 2020 and lasted two months, boring the people in the city with 225,741 population, including 124.807 and 100,934 inhabitants in urban and rural areas, respectively. As of 7th December 2020, urban and rural areas reported a total of 197,998 confirmed cases and 13,778 deaths (Riobamba, 2020; Zabala Machado, 2019). The quantification of green areas and even taking into account areas that are not related to urban greenery. Riobamba has an index of Urban Green of 2.07 m^2/inhabitant, showing 6.93 m^2/inhabitant deficit in quantity (Arroba et al., 2020; INEC, 2010). According to the Directorate of Territorial Planning of the Municipality, Riobamba has 222 properties registered with 55% corresponding to vacant lots, these were reclassified from the list because some of them are currently with buildings, properties that correspond to communal houses, private parks, or areas outside the perimeter of the urban area or simply could not be considered for the construction of green areas and recreation, removing 47 of them, to obtain more updated information on the green line of the city.

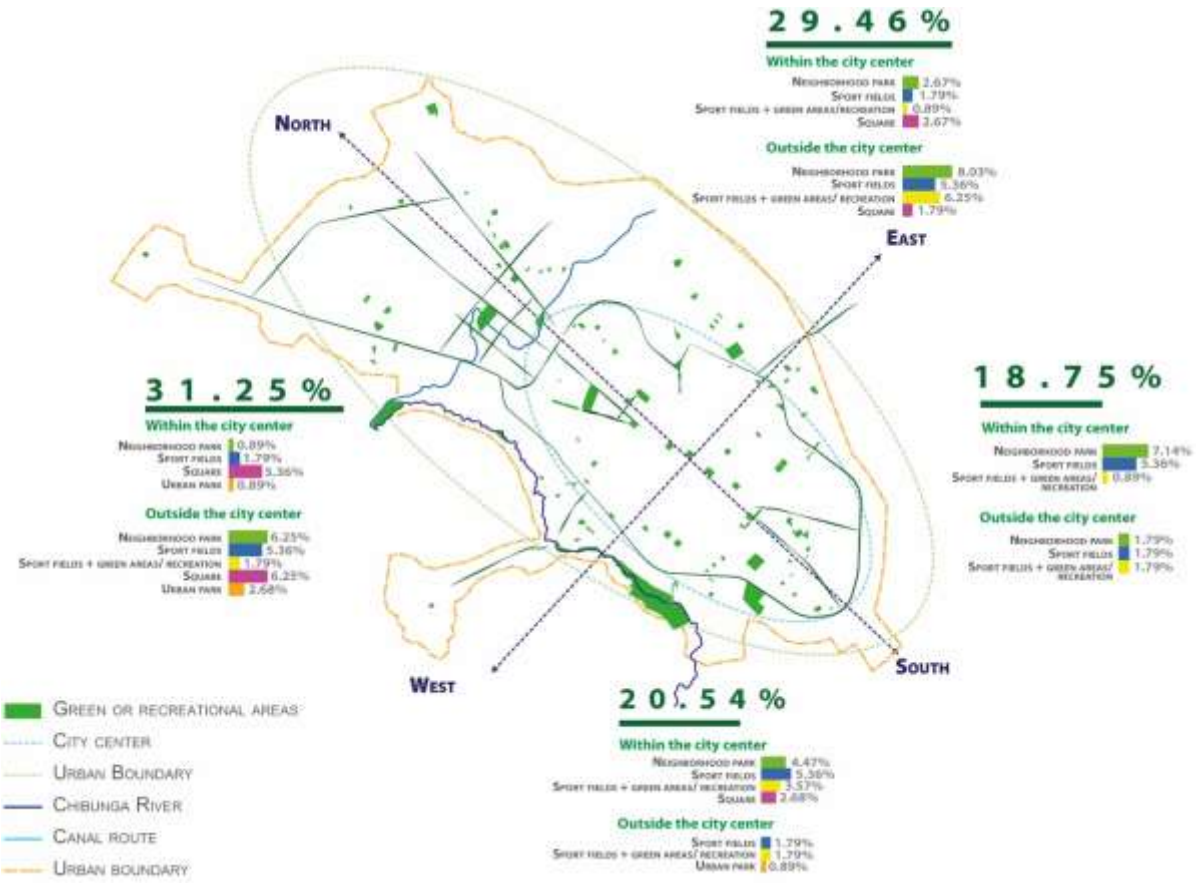

Figure 3- Location of green and recreational areas in the city of Riobamba. They are located based on the inventory that the municipality has according to green and recreational areas and their percentage by zone.

The city has two water resources, including the Chibunga River and the water channel, a great potential for developing the urban green areas. The Chibunga river in the western part of the city has an average flow, and its servitude area is completely green, but its vegetation cover is mostly inadequate for absorbing CO_2 emissions, the topography is irregular, and the valley borders vary from 20 to 30 m on both sides of its channel. The irrigation channel is on vertical concrete walls and has an easement area of 3 to 6 m on each side of the canal. The satellite images show a complete deterioration in these sections. Currently, this area is approximately 3 km in length, and its recovery could provide 30000 m^2 of green areas for the city.

(1) Survey design

Many surveys (in Spanish) analyzed social aspects among 150 citizens in Riobamba using the Microsoft surveys platform (see: https://forms.office.com/Pages/ResponsePage.aspx?id=DQSIkWdsW0yxEjajBLZtrQAAAAAAAAAAANAARYS45VUOUVSUkUySE1GNjJXMkhPT05IQUs1MkcyTi4u)

during March and May 2021. These surveys obtain the citizens' feelings about the lockdown and isolation experience during the Covid-19 pandemic in Ecuador since its beginning in the country, on the 9th March 2020 (ElComercio, 2021). Due to the impossibility of travelling to the Chengdu city in China and carrying out an "in situ" survey, the estimated measures have some errors like the erroneous answers that invalidate the survey, the percentage of confidence at 95%, and the margin of error at ±10 level. To decrease these errors, the research dropped 23 participants from the dataset due to failing in the attention-checks, leaving a total sample of 127 people within a statistical population of 124,807.

(2) Behavior of the population vs. usage of green spaces.

Surveys gathered and analyzed the citizens' feelings in Ecuador between March and May 2021 to compare them with the experience in the pandemic period since the beginning of the pandemic in the country, the 9th March 2020. The Institute of Microbiology of the San Francisco de Quito University represents the results (ElComercio, 2021). This has turned the lockdowns into a routine that is a little annoying for the citizens.

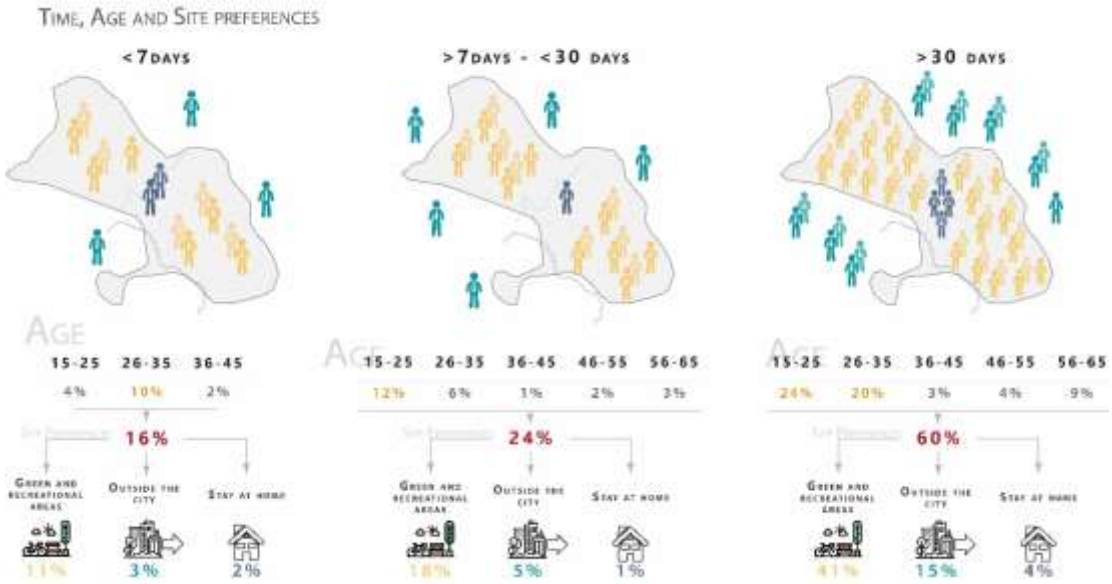

Figure 4- Variable of time of departure from their homes, age, and places, they generally chose to go to

Researchers should combine all these aspects of configuration, distribution, and design with urban landscape ecology to address factors such as structure, processes, and their interactions at a multifunctional level in relation to local and urban people. Each green space should improve the urban environment. These suggestions have two effects: direct and indirect (Azevedo, Luque, Dobbs, Sanesi, &Sunderland, 2020). The direct effect is in relation to human well-being, health, and social factors, and the indirect effects deal with the urban environment. Ignoring each effect causes imbalances such as the various effects of the spread of diseases and crowding-focused places that became evident during and after the encirclement by Covid-19 in 2020 (Belmeziti et al., 2018).

The results show that the people aged 15-25 and 26-35 years show the greatest tendency to leave their homes, equal to 76%, preferring destinations with recreation and relaxation activities. However, adults aged 46-65 years show the lowest percentage with 18% of those who delayed leaving, taking more than 7 days, unrespecting the mandatory lockdown. Those who went to green or urban recreational areas predominated with 70%, while 23% left the city in search of other types of entertainment, and only 7% stayed at home for fear of contagion, respecting the lockdown.

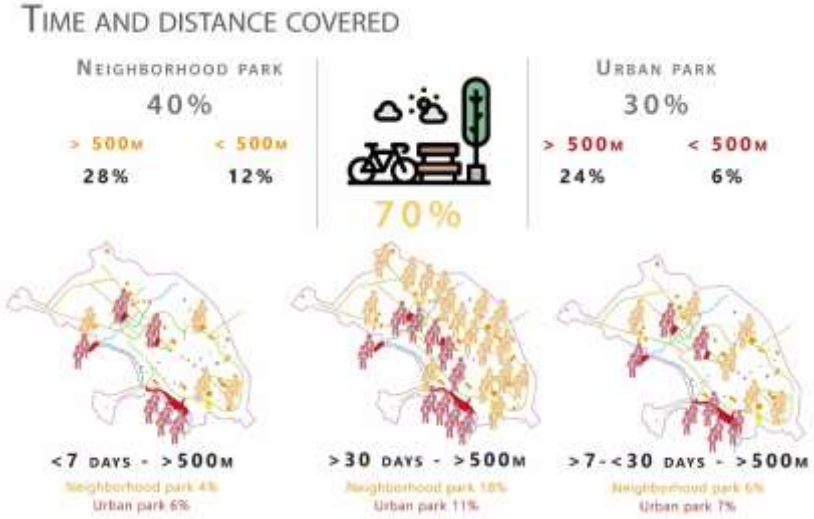

Figure 5- Variables of time spent going out to the urban green and recreational spaces and distance to these spaces

Regarding the distance of the green or recreational areas from their homes, 28% and 24% of the people prefer to move more than 500 m to neighborhood parks and urban parks, respectively. After more than one

month, people were more confident to go out. In less than a week, only 10% left their homes more than 500 m away, while after more than one month, 29% left their homes and put their health at risk without completing the two months of lockdown. In other words, of the 30% of people who visited urban parks, from that percentage 6% of them had accessibility to the urban parks, and of the 40% of people who went to neighborhood parks, only 12% had accessibility to them or the park near of them had a good design and equipment.

The surveyed citizens consider the potential spaces for the green expansion in Riobamba even if they are far from their homes. For example, 21% recognized the Chibunga linear park, and 28% acknowledged certain neighborhood parks as a great ecological potential, whereas 27% admitted no projects with ecological characteristics in the city due to the lack of urban fauna.

The users' preferences highlight the value of urban green spaces when moving outside the city because they mostly (equal to 58%) chose national parks or natural reserves with a greater extension of nature near or far from the urban area, and only 42% chose other urban areas or shopping centers inside or outside the city.

Figure 6- Preference of people who chose to leave the city during and after the Covid-19 lockdown

The last variable is public supply area and their congestion level, where respondents showed discomfort. 45% of people said that the downtown area, places like markets or supermarkets, were full of people, and 29% experienced the same in the southern area, within the main market of the city, where the inhabitants disrespected the sanitary norms imposed by Covid-19. 45% of the people attached great importance to the central and southern areas of the city, and went to markets at the center of the city. 29% said that they were not respected.

Figure 9 displays the main activities carried out by residents within the city, and how, when, and where they moved. This map illustrates the main agglomerations in parks, green places, recreational areas, and main supply areas, where we can see how the central and southern areas are mostly affected by these activities and by the unbalanced distribution of services and parks in Riobamba. Since less than a week after lockdown, 4% and 7% of the people left their homes in search of urban and neighborhood parks in the city, respectively, and 26% and 14% use these spaces a month after lockdown due to the importance of these places.

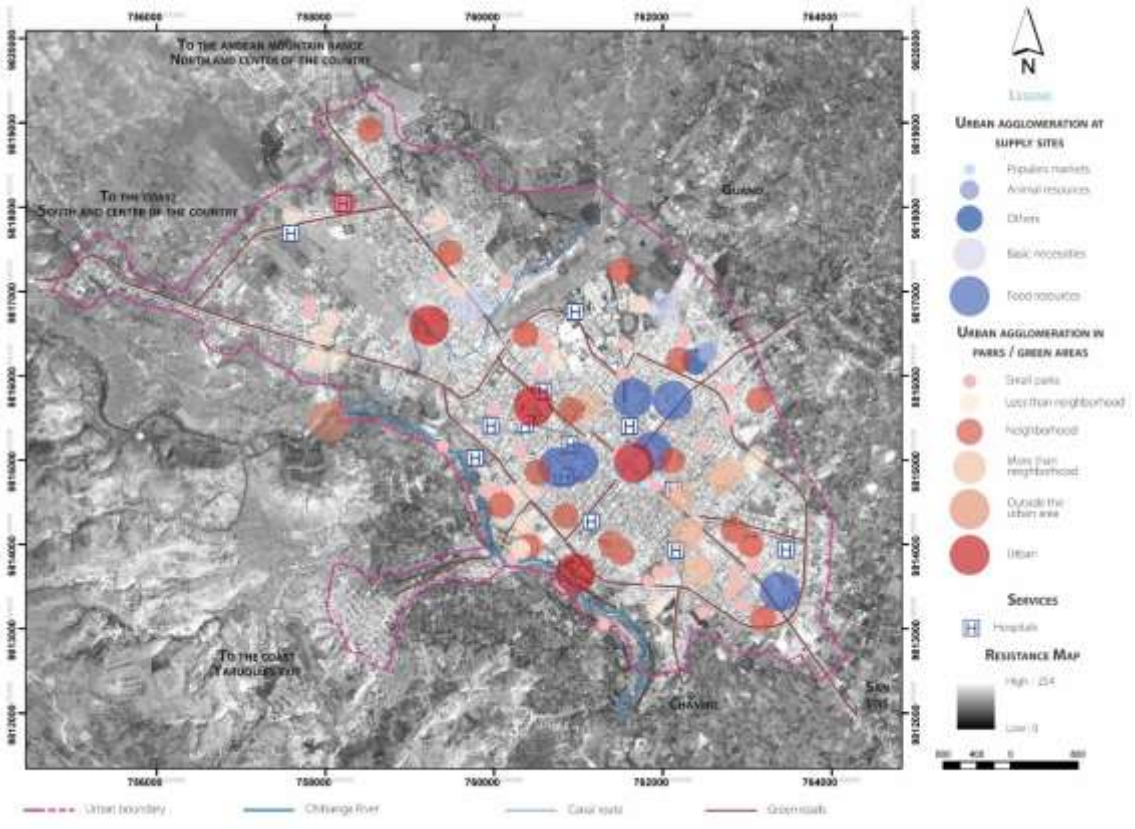

Figure 7- Green or recreational agglomeration areas: supply agglomeration areas

4.1.2 Construction of green corridors in Riobamba

This research covers 28,13 km^2 of the urban area, including residual or active agricultural zones and existing open public spaces, to study how people interact with them before and after the pandemic. Preserving these areas from urban development improves the urban green index and imposes a new order for the territory as a safe or buffer zone and food distribution zone, which avoids agglomerations in the markets or city center.

According to Figure 10, this evaluation improves the connections needed to build a corridor for the city's benefits. This connection involves two valuable factors: the urban residents' opinions based on their experience and the technological tools. The former expresses the needs of people, and the latter describes the needs of the urban environment. In this way, the urban green corridor connects with the highest gravity values and essential routes that connect with the city and allow different types of flows within them, in order to serve society.

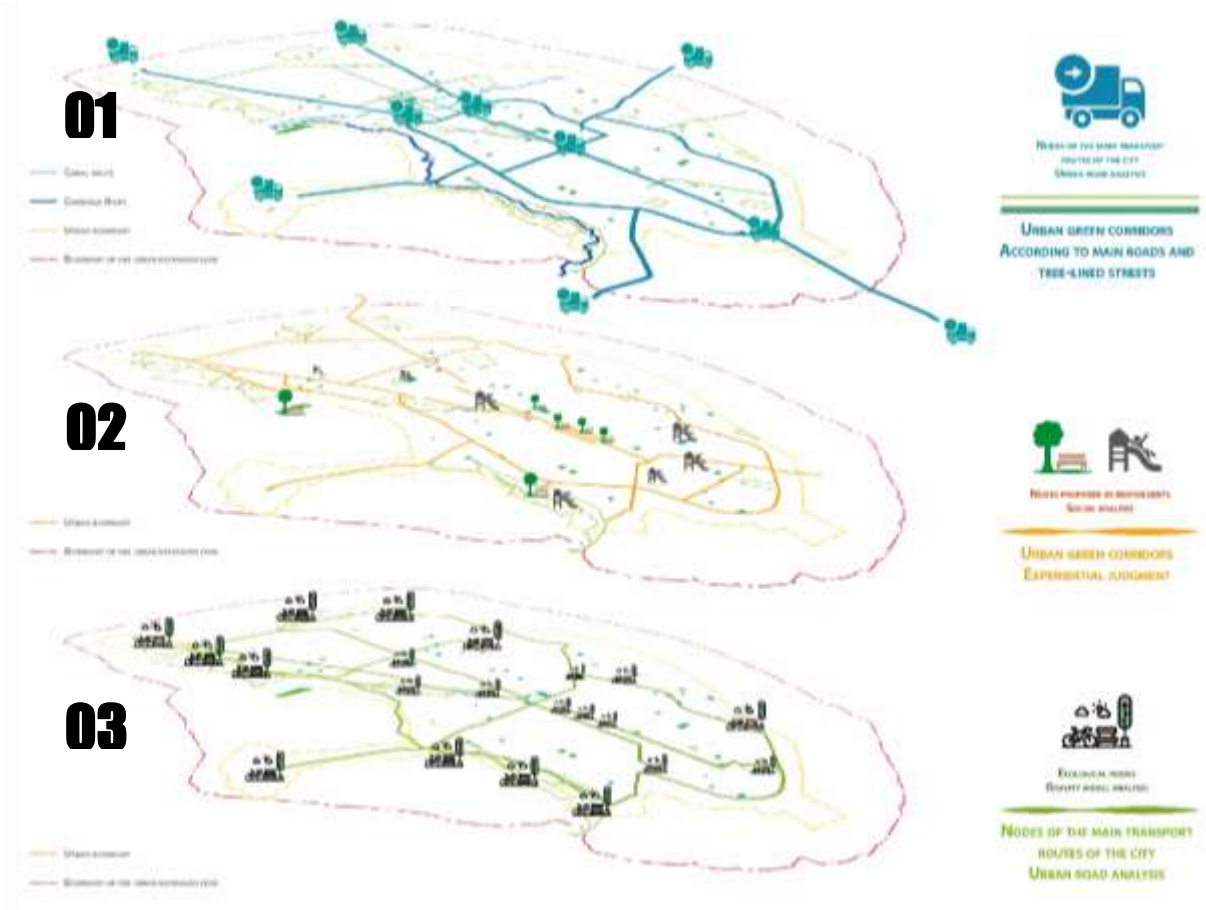

Figure 8- construction of corridors according to (01) main connection routes and tree planting, (02) empirical-social judgment, and (03) the gravity model

This evaluation achieves one of the most important objectives of the research, which is to create a system of connections in multifunctional green areas that have the capacity to become health, dispersion, and food distribution points. Achieving this objective helps people in each of the five sectors to overcome future lockdowns, and to distribute the green areas in an equitable manner. This study analyzes the urban green corridor and its construction from the following two perspectives.

a) The first perspective investigates the urban green places and their effects during the Covid-19 pandemic.
a. The urban green areas had some effects on people who spent a long time indoors, serving a two-month lockdown.
b. The first places where the urban residents firstly seek after the lockdown and with even mobility restrictions.
c. The urban residents seek urban spaces with sufficient and necessary equipment.
b) The second perspective explores the urban areas which have no intervention, active, and abandoned cultivation zones. The scarcity of services made such areas which have a high possibility for planning, connection, and densification of green areas to improve the sustainable development of the city. For this reason, the selected study areas are as follows:
a. Building private residential areas during a sub-urbanization process fragments the land to provide the upper-class economic sectors with certain services.
b. The vacant lands can be developed and distributed equally to benefit all the people irrespective of their socioeconomic levels.

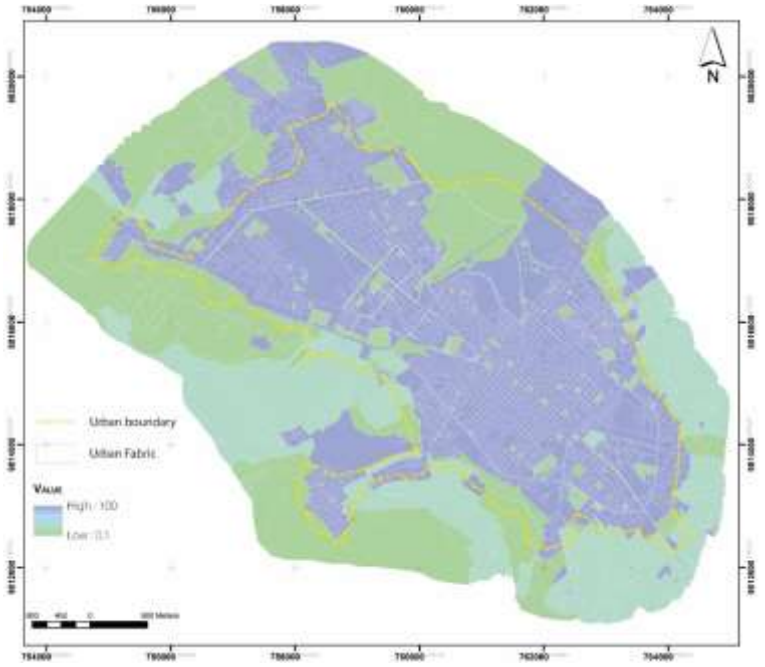

Figure 9- Representation of urban land use: the dark green color represents the green or recreational areas within the city and the potential green expansion areas, the light green color represents the rupture nodes by some farming zones, and the blue color is the current urban settlement.

(3) Node selection

The gravity model applied for the construction of green corridors within the city points out that the growing and rapid urban development has fragmented certain habitats in the city. Selected nodes use peripheral areas (partially or never urbanized) and vacant lands for renaturation, the extensive street system, and the existing public green spaces, represented by the dark green color. However, the city also has places where land exploitation has worn out the land by intensive use for agriculture, livestock, and mining. The intervention in these areas would be a problem both for the re-naturalization of the land and the economy. The light green color shows the same. Also, the blue color represents the urban settlement areas with low value. In these urban areas, intervention and connecting certain nodes are complex and have more weight in empirical judgment than the technological one.

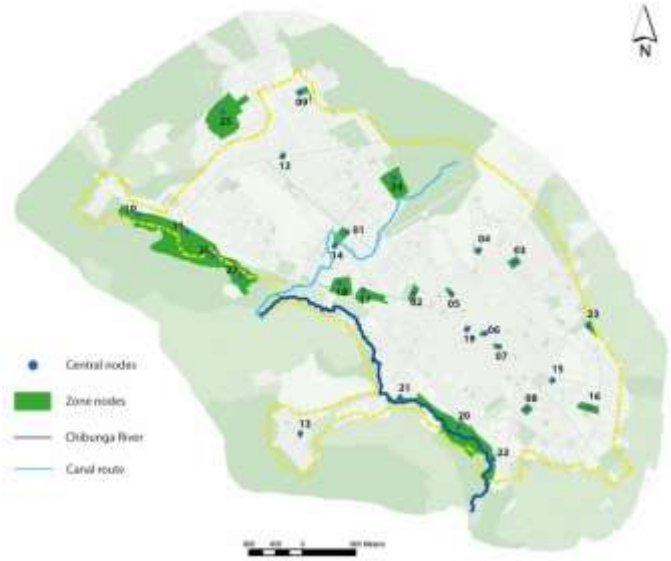

Figure 10- Nodes selected for the study

The location and identification of the ecological nodes arise from the need for spaces expressed by the inhabitants of the city in the surveys, which coincided with the development of this research. The proposed ecological nodes will serve as source or destination points. Figure 13 selects 27 nodes both inside and outside the urban zone based on the following parameters. The patch area varies according to its location.

For example, the nodes within the city were selected for their functionality and proximity to other green spaces such as parks or squares. The areas outside the city were selected for their ability to extend since they have the potential for a large and persistent population and wildlife. Another parameter is their location, allowing connectivity among all of them inside and outside the city and balancing the green areas for the consumption of all residents (Kong et al., 2010).

Table 1: Area of the nodes selected for the study

N°	Node	Area (m^2)
1	"Sesquicentenario" urban park	24.421,53
2	"Guayaquil" urban park	30.078,06
3	"La Panadería" neighborhood park	27.656,08
4	Green Area	6.833,88
5	"Loma de Quito" park	12.552,31
6	"Maldonado" square	5.802,55
7	"La Libertad" square	7.514,05
8	"Politecnica" neighborhood park	23.145,55
9	"Las acacias" neighborhood park	27906,82
10	Urban expansion zone	180.283,39
11	Urban expansion zone	395.454,54
12	Green Area	4.906.47
13	"Yaruquies" square	2.605,7
14	"Sesquicentenario" urban park	18.661,32
15	Neighborhood park	4.179,06
16	Abandoned area	43.978,53
17	Train workshops	86.434,74
18	Abandoned area	97.584,10
19	"Sucre" square	5.375,93
20	Ecological park	303.651,01
21	"Los Shyris" neighborhood park	32.343,08
22	Natural Area	126.105,15
23	Urban expansion zone	26.006,20
2	Green Area	152.318,

4		4
25	Urban expansion zone	3.196.331,57
26	Urban expansion zone	137.739,8
27	Urban expansion zone	1.871.315,50

(4) Construction of urban green corridors

According to Table 1, this step calculates the least cost path and identifies 27 nodes. In theory, the dispersion efficiency of the corridors depends on the source habitats and the impedance created by the mosaic of land use between sources and destinations. The gravity analysis provides 10 potential corridors that run largely through the main tree-lined streets of the city, the "Chibunga" river, and unused railroad workshops to promote connections for the different sectors in the research. This model selects, simplifies, and synthesizes the corridors based on two aspects. The ***first aspect*** is the gravity value (G). The higher the G value, the higher the corridor hierarchy. The ***second aspect*** of selection is those corridors whose link is redundant due to the convergence on another similar node located on the same route. This aspect prioritizes the natural and urban-natural landscape for the benefit of its ecosystemic and socio-cultural services. In addition, this aspect introduces a new order for the urban development of the city through the inclusion of isolated or developing areas that lack green spaces.

Figure 14 represents 7 corridors with the highest severity index. The corridor with the highest score is the one that connects:

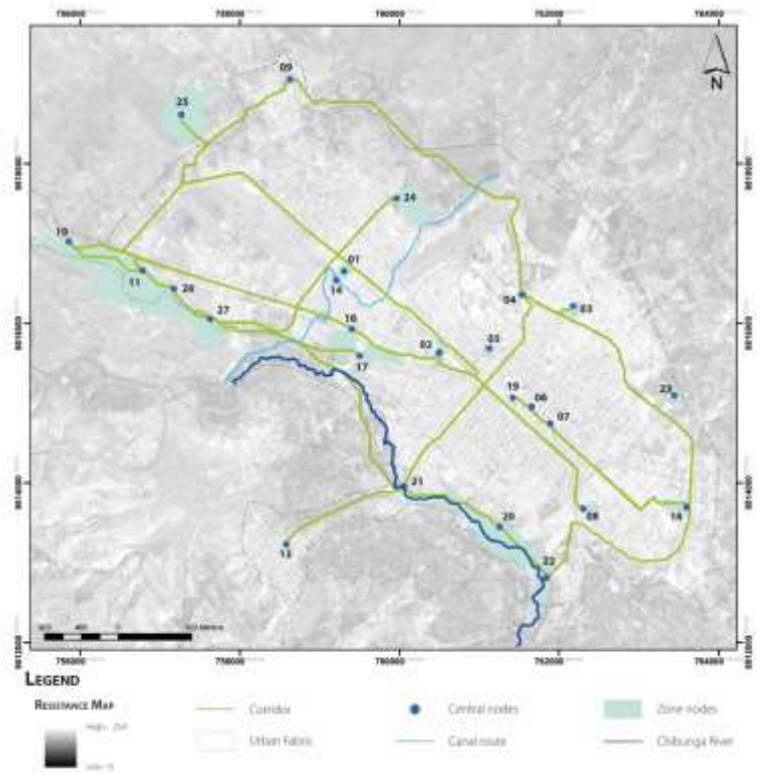

Figure 11- Top 7 corridors with high gravity scores: priority corridors area shown in green along with the core habitat patches on a green and natural areas image of the city Riobamba

The tool in turn provides the prioritization of the most potent green spaces based on the gravity model. In this way, this tool identifies corridors and patches with the best opportunities to create a network that conserves biodiversity in the long term, allows a more sustainable urban development, and with-it green spaces that allow the recreation of its residents. Figure 13 illustrates the corresponding G-index interactions of the nodes in the selection of scenarios.

The corridors identified through the model should provide important social benefits when prioritizing vacant parcels, urban voids, and some streets or alleys. As stronger community connections can be fostered, linking together with the corridor residential neighborhoods can increase access to green spaces and recreational facilities in underserved areas and thus influence people's perceptions of the new landscape. The design of these corridors balances the needs of urban residents who were present in the lockdown period without any opportunity for safe and healthy recreation. These corridors reinforce the concept of *"social confidence"* through a green network that allows such activities in daily life and even more in times of emergency - the activities and services that should be provided by the nodes that structure the corridors - as well as the existence of urban gardens that prevent the city center from collapsing.

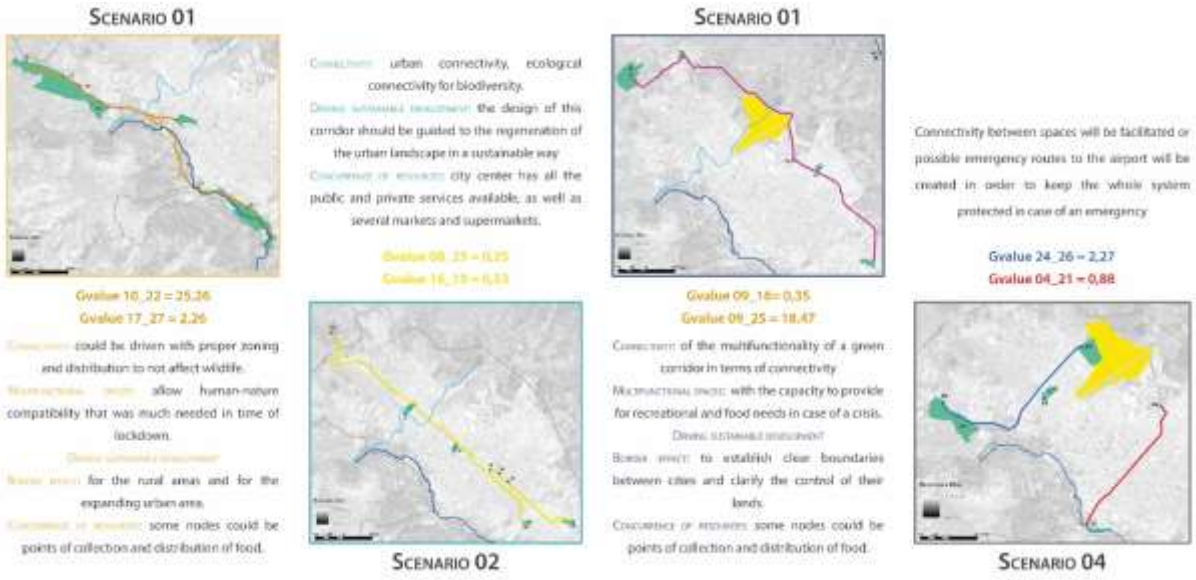

Figure 12- Development of scenarios and description of main features

5. Result

This context introduces the nodes as a buffer space for urban growth, while maintaining elements of the traditional rural landscape in some peripheral areas of the city, such as the east and west zone from north to south of the city- in the face of the territorial homogenization associated with the proliferation of single-family housing developments. The network of paths and roads is a fundamental element in connecting various green and natural spaces in the urban areas due to their extension, distribution, diversity, and public character. For this reason, the urban green corridor occupies these four types of roads. The most important roads are the potential not only as a connecting element but also as a public space.

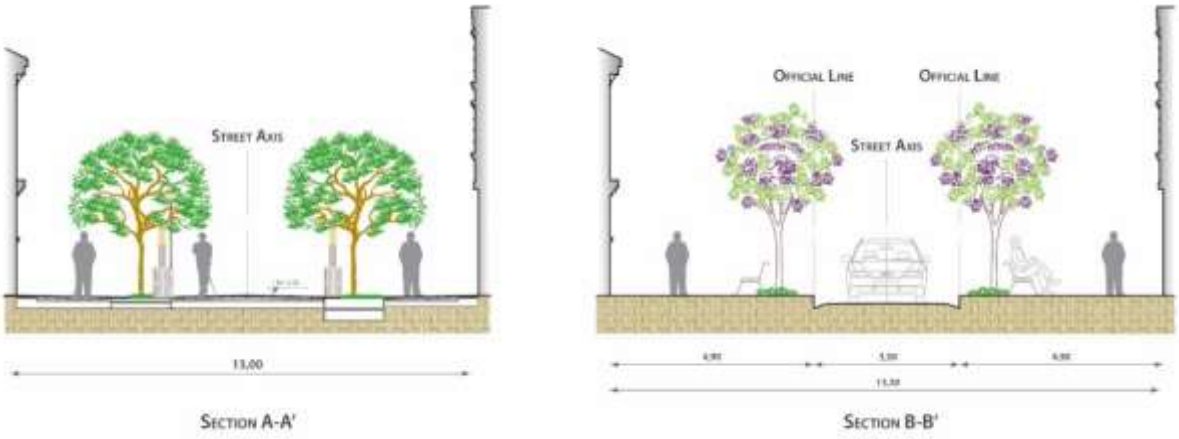

Figure 13- Sections corresponding to the streets that run through the first scenario: the image on the right connects the streets of nodes 19-07; the image on the left connects the streets of nodes 02-08 and 07-16.

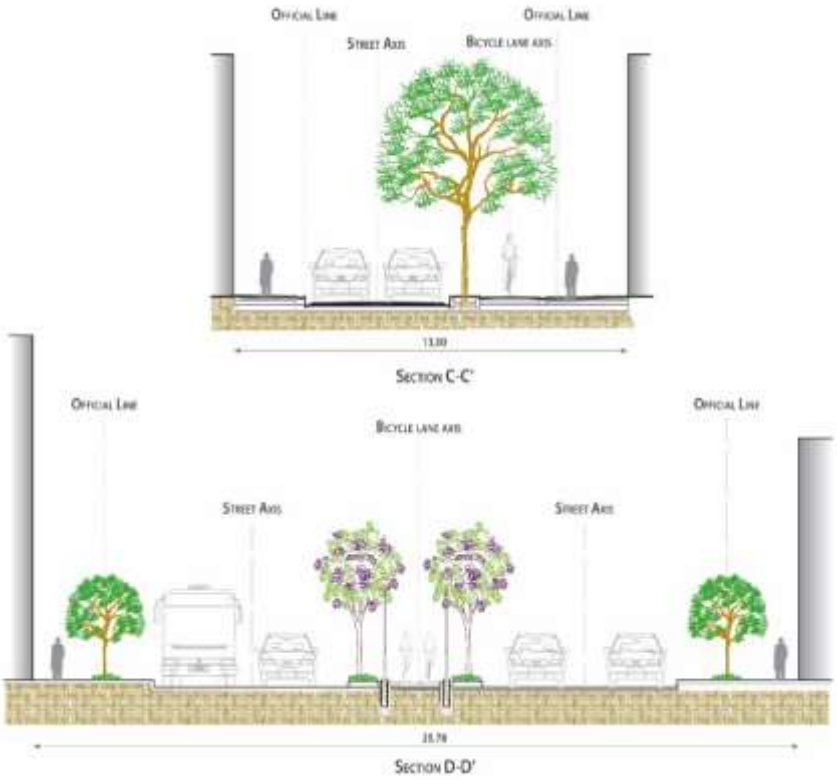

Figure 14- Sections corresponding to scenarios three and two: the upper image is an example of the tracks connecting nodes 21-04, and the lower image is an example of the tracks connecting nodes 16-25 and 24-27.

In the city center, redesigning the roads proposes some strategies for pedestrianization and road narrowing to limit access to the city center, leading to a reduction in carbon pollution. In addition, implementing a development plan can improve and densify the historical places in the city center, which have been abandoned over the years due to the process of suburbanization and the high concentration of services. The corridor aims to improve the environmental services of the central urban area so that those who live near it can enjoy the physical and psychological benefits of urban vegetation as well as the services available.

Redesign of the roads on the east and west side of the city longitudinal and transversal, proposes a more mobilized corridor where priority is given to the use of bicycles and public transportation. The delineation of vegetation that contrasts these roads indicate that it is not only an emergency road but also a road that will join a green area with more services. For example, people who take the route that connects nodes 17-18 have the possibility of finding and reaching these green areas for recreation, supplies, or medical assistance.

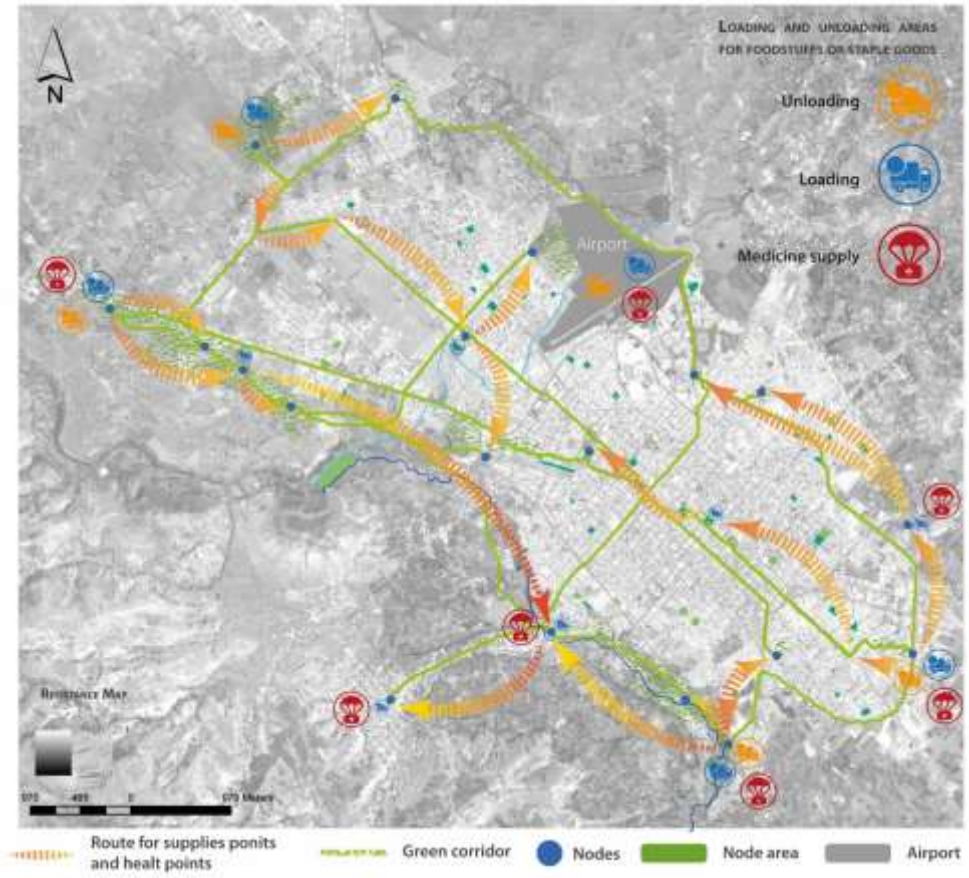

Figure 15- Supply routes and loading and unloading points for foodstuffs and staple products

Furthermore, the green corridor gives hierarchy to the means of transport both on normal days and in crises since people must conform to a temporary lockdown. The means of emergency transport, loading and unloading, must have a priority to use the road for reaching the nodal destinations assigned for delivery or immediate assistance, while people have not to leave their neighborhoods or sectors to perform daily activities without putting their health at risk. Figure 18 displays the necessary supply routes to avoid the concentration of people in popular markets or shopping malls. In a good logistics of movement and flows, these nodes help people to cope with the lockdown and keep them away from dense areas. This effect is economically beneficial for the local retailers and wholesalers since they can distribute their products throughout the city without being isolated in one place.

Based on Figure 19, the "Chibunga" River is in one of the largest parks *(Chibunga linear park)* in the city, which is valuable in the green system due to its connection with the green corridors. This place has two roles in the system; a) it connects the green system of the central city with the western urban sector, and b) it is a delimiter of the urban and rural areas. However, this place lost its traditional functions like recreation and leisure due to the lack of maintenance and insecurity of the area and the degradation of the river. The riverbed are interesting spaces of rural character, with residual formations of riparian vegetation, whose potential to be used as public space has been recognized and claimed repeatedly without having materialized. This space is also an area dominated by respondents as an ecological urban project and one of the most visited and crowded areas.

Figure 16- Sections corresponding to the irrigation canal and the Chibunga river

5.1 Multifunctionality and system design during and after lockdowns.

The proper planning of these areas and linearly forming the corridors practically connect the city in such a way that the 20 main nodes, together with the corridor function as recreation and dispersion centers for the entire city without any exception, irrespective of how vulnerable or peripheral it is. All the nodes join the green line in one way or another once they begin to interact with the green areas. Some simulations should outline emergency scenarios in pandemics to move flows of people depending on the severity of the emergency. These nodes might have different characteristics. The following paragraphs express each simulation.

a) ***The first interaction*** refers to two moments after the lockdown (see Figure 20). This concept considers people who experience a continuous lockdown and feel the need to leave their home and go to a natural space without having to leave the city or even their sector. These people like to have their daily activities on normal days or during a break from the restrictions of crisis, when residents can utilize the space for their activities like cycling, walking along, and exercise. Secondly, this step creates sub-networks and separates the population from possible risks of contagion, i.e., in this mid-crisis phase, where people need supply points or even health care due to movement restrictions. These actions protect the health of residents or their families. Figure 9 shows that agglomeration in the city center threatens the health of the majority of the population. Therefore, these restrictions limit the entry of people in an emergency, giving priority to the supply for loading and unloading food, health tests, and even shelter.

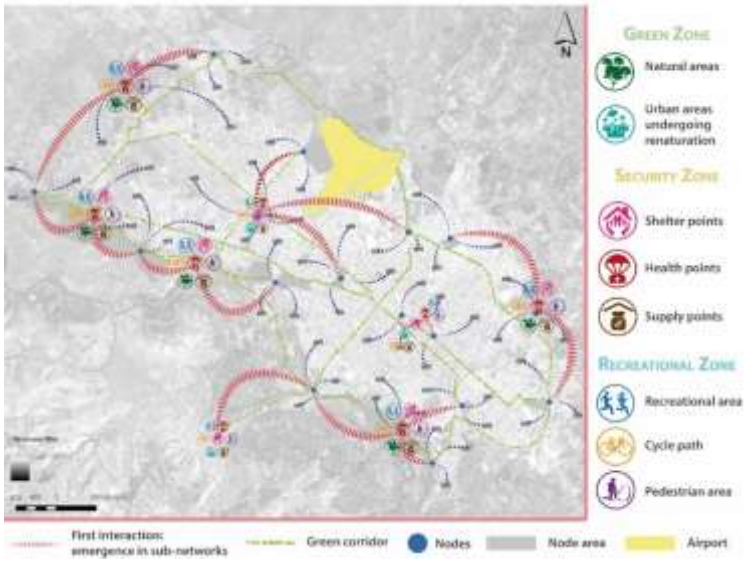

Figure 17- Endowing the city with medium emergency areas

b) The second interaction: Figure 21 shows the second interaction phase. This area has a health crisis, and people have access to a green emergency area (such as the airport) capable of providing help from the outside in case of a massive lockdown. This access point is the first and critical point for emergency routes to the nodes or designated points of the second interaction for any type of distribution of health, food, and shelter. These points can be the greatest defense, isolating and protecting people and even being a point of evacuation. This area develops purely emergency activities such as food supply and necessities, temporary shelters, and health centers since the airport is a massive emergency point with spaces for landing helicopters or emergency aircraft.

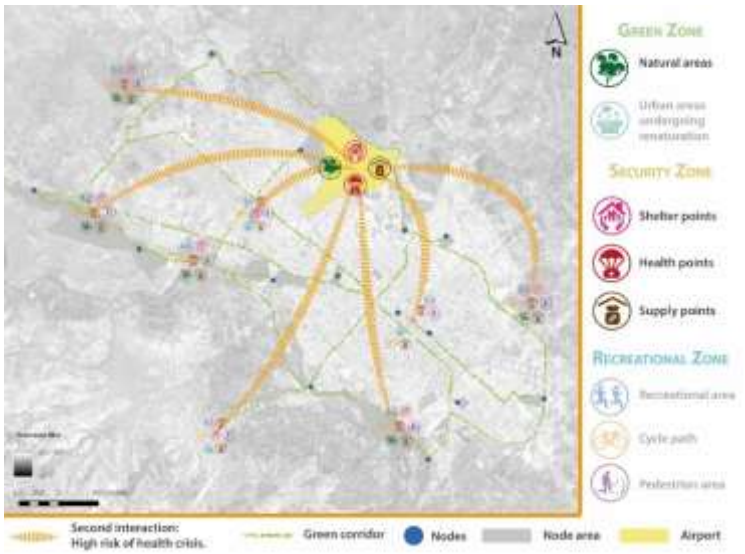

Figure 18- Critical emergency area, possible evacuation

These two interactions are proposed in correlation with the needs that arose among the respondents in the different phases they lived during the lockdown by covid-19. In this period, 7% of people complied with the governmental restrictions on mobility, fear of infection, or lack of free time. However, 93% of the people left home during or after the lockdown, but they found no green spaces with good facilities. Hence, they move further and further away to find these areas unavailable in the city, i.e., these scenarios interact with people from the first to the last phase of a crisis.

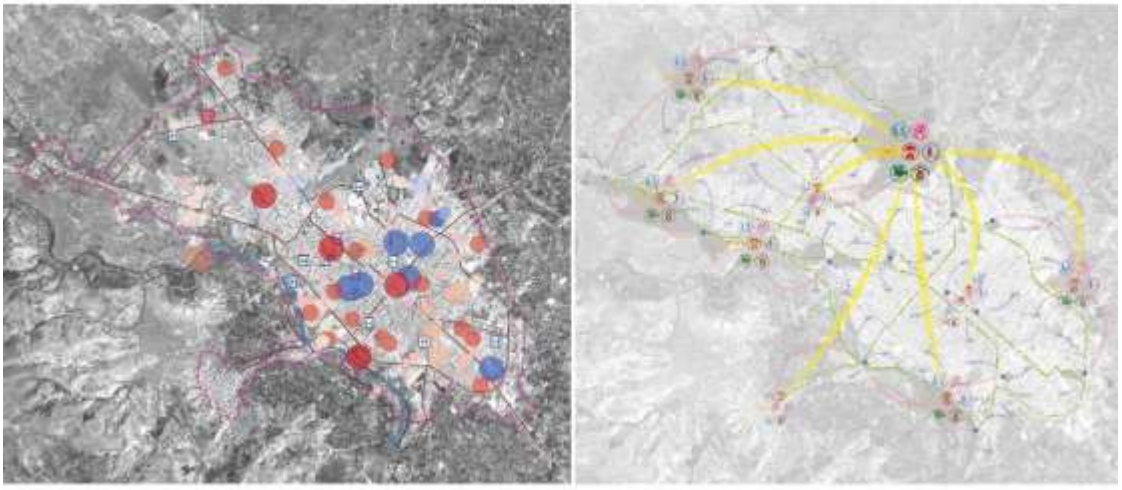

Figure 19- In the left image is the urban agglomeration map in terms of recreational and supply areas, and the right map shows the three scenarios together and where obviously agglomerated centers are avoided, and sub-networks are developed.

Figure 22 represents the differences among the survey results and how the lockdown affected the city, specifically its center and center-south area. The connectivity of the city suggests an improvement in both the environmental and ecological urban parts, and provides people with physical, social, and psychological benefits. Furthermore, this type of planning could be applied in similar approaches wherever planners seek to combat fragmentation and develop multifunctional networks of green spaces as part of smart growth or sustainable development efforts. Applying these networks attracts people to return back to certain urban cores -in the case of the historic city center- reducing the pace of suburbanization and thus habitat fragmentation in the urban peripheries.

The lockdown by Covid-19 in 2020 is the origin of the green areas in Riobamba. This analysis aims to redesign the city regarding not only this affectation, but also the possible outbreaks of other viruses or diseases that could spread more rapidly. In this way, these events have not a shocking effect on the city since it has an efficient system to respond to the challenges. This analysis suggests imposing some plans for urban growth based on the protection of the green circuits, appropriate for the people. In this sense, the green spaces are developed in two ways in form and function of adaptation. In a pandemic, a space for leisure and recreation can function as a point of health or food distribution. The temporary transformations that occur in these green spaces can become permanent as urban gardens in the case of green areas scarcity; and the promotion of private green areas as a response to the lack of public green areas.

6. Discussion

The system for creating green cities considers not only the recreation of people but also their use in developing the local economy, isolating contagious infections, and separating population from the risks of the health crisis. This research explains the intentions for developing the project of urban green corridors as follows.

a) Addressing the ***externalities of urban agglomerations***, such as traffic congestion and air pollution, within this corridor connectivity proposes the creation and use of non-motorized transport modes, as well as walking.
b) Leveraging ***density and urban form*** advantages through ***spatial and land use planning*** to prioritize corridor infrastructure that is climate-resilient and low carbon.
c) A ***more efficient use of resources***, while corridors provide multiple ecological services, in this case, we also talk about the urban benefits that the corridor can provide, for example, food distribution, urban gardens, loading and unloading points, among others, i.e., a more sustainable consumption and production patterns, avoiding waste generation, reusing and transforming waste into resources.
d) ***Benefiting the most disadvantaged social groups*** through the influence of the corridors, not only giving them a better quality of life but also being the most active group in the labor market, providing them with safe routes to their jobs, decongesting public transportation and bicycle lanes.

e) Consequently, with intention c, they also stimulate the ***local economy*** - local food production - while reconsidering short-distance logistics.

Researchers and policymakers should rethink an urban development model, food production, and distribution systems as well as urban planning, mobility systems, transportation, and areas available for leisure and recreation of people. In these areas, they project functional and adaptable spaces for the benefit of society, as a priority in the context of sustainability and epidemics (Azevedo et al., 2020). The evaluation of these aspects constitutes green sub-networks accessible to the whole city. This study focuses on three different types of interactions as follows.

a) For the physical and psychological benefit of people, creating a greener and friendlier city, where people, after a long period of lockdown, can interact with nature in safe spaces without fear of contagion. *(first interaction)*

b) Regarding health and supply points, cities need spaces where people can access in an orderly manner of the food distribution. This case does not mean that they are rationed what they should buy since this point supports the local economy of certain retailers who produce food or distribute them, and decongests the large markets. In terms of health, provisional centers can be set up in case of contagion in a specific sector, avoiding that the infected have to cross the city to access a public health service since they can be transported from this point. *(first interaction)*

c) Sanitary emergency involves a part of the second scenario in a major city, where people need to be isolated from each other, but in a different category and, at the same time, it allows easy mobility of first aid and evacuation services. *(second interaction).*

The transformation of urban space to deal with this type of emergency must be part of a plan that develops along with the urban sprawl, and the denser cities rely on green spaces to respond feasibly to a crisis. Therefore, working on a multi-scale study, involving case-by-case analysis of soils that are influenced by the corridors. Now, we know their nature and give greater prominence to trees and plant composition. Then, we can build a post-pandemic scenario in which the city and its residents are prepared for future crises with the opportunity to enjoy these improvements more respectful of the environment. In some way reduced infection rates, especially during the exponential phase of transmission that was the first outbreak, when the encirclement was decreed.

7. Conclusion

Cities have insufficient equipment to face various health crises like different mutations of Covid-19, while the layout of urban green corridors provides multifunctional services to address these problems. Strategies concentrate on the equitable distribution of green areas and the construction of the corridor to combat the lockdown by providing the people with urban green areas that represent recreational and leisure quality. This strategy interconnects humans with nature, as people can access these spaces when they need *"a break"*. Its linear form connects most of the urban areas with these features, allowing the exchange of ecological and environmental resources (i.e., urban gardens) for food products, or rural crops for urban products.

The patches from which the corridors originated came from different perspectives, from the basic considerations of the lack of green areas, segregated, fragmented sectors, and dense zones during the lockdown to the qualities of the urban landscape. Creating corridor connectivity has several advantages for preserving natural areas, urban reforestation, re-naturalization of spaces, or urban voids in favor of health and recreation, and prioritizing outdoor activities. The corridor connectivity raises emergency sub-networks that maintain the stability of cities and their residents. Providing these spaces connects the local economy, decentralizes certain nodes with collapsed services, and promotes a more resilient and healthy city giving value to each space. In addition, these corridors have other benefits; for example they allow the implementation of other projects such as wastewater treatment, urban wetlands, and rainwater harvesting.

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