THE URBAN IMPACT OF SUSTAINABLE DESIGN INTERVENTIONS IN QUITO

Case study of the implementation of the Eco-Efficient tool in 'La Carolina' neighborhood in Quito

Simbaña, Patricio; Paredes Denisse; Jácome Daniela & Piña, Oscar

Faculty of Architecture and Urbanism, UTE University. Quito, Ecuador
arq.patricio.simbana@gmail.com
denisse.par@gmail.com
danielajacomerivera@gmail.com
arq7oscar@gmail.com

RESUMEN:

Debido al rápido crecimiento de la población y la demanda constante de recursos, varias ciudades buscan implementar estrategias de desarrollo urbano sostenible. Este es el caso de Quito donde, en el año 2016, la municipalidad crea la herramienta de eco-eficiencia (EDT) la cual incentiva un desarrollo inmobiliario más amigable con el ambiente al permitir a promotores construir hasta el doble de los pisos permitidos cuando los proyectos cumplen una serie de parámetros para la reducción del consumo de agua y energía y la mejora ambiental. Esta herramienta puede aplicarse solamente en polígonos definidos por la municipalidad de acuerdo a su accesibilidad a medios de transporte masivos. La herramienta, ya aplicada en varios edificios de la ciudad, ha generado cuestionamientos en cuanto a su impacto al confort de las edificaciones aledañas. Este artículo se enfoca en analizar y comparar el impacto de la aplicación de la herramienta EDT en las edificaciones y zonas aledañas en base a parámetros de acceso solar, radiación solar y ventilación, en tres escenarios distintos.

Palabras clave: diseño sostenible, herramienta de eco-eficiencia, radiación solar, perfil urbano, Quito.
Líneas de investigación: 1. Ciudad y proyecto **Bloque temático:** Planificación, políticas y gobierno de la ciudad.

ABSTRACT:

Cities worldwide look to implement sustainable urban development strategies given the rapid urban growth and the constant demand for land and resources. This is the case of Quito where, in 2016, the Municipality created the Eco-efficient Design Tool (EDT) which encourage sustainable real estate development by allowing developers to double the number of specified stories when the project complies with a series of sustainability

parameters to assure lower water and energy consumption and improvements to the environment and the urban landscape. The tool can only be applied in specific polygons, defined due to its closeness to massive transportation system's stops. The EDT has already been applied to develop several buildings around the city generating questions regarding its impact to comfort in surrounding buildings. This paper will focus on analyzing and comparing the EDT impact on surrounding buildings and public areas based on solar access, thermal radiation and ventilation as parameters to compare and contrast in three different scenarios.

Keywords: sustainable design, eco efficient design tool, radiation analysis, skyline, Quito.
Thematic clusters: 1. City and project **Topic:** Planning, policies and governance.

1. - Introduction.

Global issues such as climate change and sustainable development have never been as relevant and concerning as they are nowadays. In this scenario various international agendas like the Paris Agreement, the New Urban Agenda and the 2030 Agenda for Sustainable Development have urged cities to come together and tackle these issues from the local scale. As cities become relevant actors, multiple local projects have been established in order to achieve objectives such as reducing carbon emissions and the ecological footprint of the city while allowing for a more sustainable and equitable development. Among these efforts, the Municipality of Quito has developed and approved legislation that seeks to promote sustainable real estate development through a set of rules and incentives defined by the Eco-efficient Design Tool (EDT). The EDT regulates and promotes transformation at a plot scale while also impacting the urban scale, allowing greater heights and densification in predefined areas of the city.

In the year 2016, the Municipality of Quito, through the Secretary of Territory, Habitat and Housing, expedited the Resolution No. 13-2016 which allowed real estate developers to increase the number of built stories in defined polygons in the city when complying with set sustainable design strategies. In order to properly manage, guide and control development under this resolution, the EDT was developed as a set of rules and incentives that seek to reduce and score the environmental footprint of new buildings while encouraging densification and migration to sustainable transport modes (Davis, Jacome Polit, & Barros, 2019). Therefore, the EDT can only be applied in predefined areas of the city that are well served by public transportation such as the existing Bus Rapid Transit (BRT) system and the city's first metro line, which is currently under construction. The EDT Resolution No,13-2016 was updated and replaced by Resolution No. STHV-50-2019 in the year 2019, the update revised EDT's technical scoring parameters but maintained the EDT general objectives, strategies and results and therefore changes are not relevant for this study.

To be granted additional stories, projects are scored in a scale from 0 to 100 points, according to its compliance to mandatory and optional parameters established in the EDT, having to reach defined scores based on the number of floors to be increased. The parameters are divided in three main themes: (1) water, (2) energy and (3) landscape, environment and technology contributions. Specific actions include water retention and reutilization, energy efficiency, use of sustainable materials and green infrastructure among others (Municipio del Distrito Metropolitano de Quito, 2019). In addition to the point system, the number of additional floors allowed are determined by lot size, street width and zoning codes. According to the latest update of the resolution[1] projects located within the metro line influence area can be granted up to 100% of the permitted height established in the zoning codes and up to 18 stories within the BRT influence area (Municipio del Distrito Metropolitano de Quito, 2019). Up to date the highest building approved by the EDT within the metro influence area is 32 stories high, enough to become the highest building in the city.

The additional profit that developers can obtain from the sale of extra floor area, along with an increasing general interest on sustainability, has encouraged the application of the EDT in certain zones of the city. Nevertheless, the EDT has also faced some resistance and criticism regarding its impact in the urban skyline and its surroundings. Considering that the strategy is designed for and works at plot scale, there is little or no information about its actual impact at an urban scale, specifically in terms of thermal comfort and sun exposure in surrounding buildings and public spaces such as sidewalks. Therefore this paper seeks to analyze the impact of the EDT application at an urban scale and determine if it could be detrimental for human

activities both in public and private spaces due to a decrease in solar radiation and therefore thermal comfort in surrounding areas. For this purpose La Carolina neighborhood, a highly developed mixed use area within the hyper-center of the city, has been determined as the most appropriate case study. Various projects approved under the EDT are currently being built in La Carolina, one of the most expensive area of the city, highly demanded by developers for both housing and office space. The analysis of current and prospective scenarios in this polygon will allow the visualization of urban implications of the EDT.

2. - Methodology.

In the construction field, as well as in urbanism and architecture, the interest on sustainability and climate and climate change is growing and has led to the development of specific software in order to understand climate change scenarios and determine actions to both reduce the carbon footprint of the field and adapt to possible changes. However, most of these studies have focused solely on energy efficiency performance of individual buildings whilst ignoring the passive aspect of energy efficiency such as natural illumination and ventilation at an urban scale. This may be the result of the existing inability to determine the exact collective performance of every single building in a block considering that not every building can guarantee the application of sustainable systems. Therefore, it is easier to study and predict the energy efficient behavior of a single building. According to Baker and Steemers (2000), the energy performance of buildings is determined by five factors: climate, urban geometry, buildings design, systems efficiency and occupant behavior. In addition Kanters and Horvat (2012) establish that depending on the correct design and urban planning the use of passive solar systems can produce a 20 to 50% in energy savings. This paper will focus mainly on the passive natural system which is the climate and analyze the urban impact of the EDT in one of the hyper centric polygons of Quito: La Carolina

In order to understand the urban implications of the EDT it is important to establish some comparison parameters that determine the possible impact of this tool on urban blocks. The first part of this paper focuses on analyzing the current situation of two blocks located in La Carolina's neighborhood, the second part analyzes a second scenario that includes existing and approved EDT projects in the area that will be completed in two to three years, finally a third scenario is presented in which existing small buildings are replaced with new high rise construction, generating a projection of a high EDT implementation scenario. As a result a comparison of the actual, projected and possible outcome situations are tabulated in charts which can help us understand the variation on solar access, thermal behavior and ventilation and therefore indicate whether the densification of this area, under the EDT parameters, has a positive or negative effect on urban comfort.

This article contemplates three main parameters to be analyzed in each scenario. The first parameter, shadow projection, enables us to understand the impact of EDT approved projects in the study areas' skyline and surrounding surfaces including buildings and public spaces. In order to achieve this, the climatic information of the Quito is generated in Grasshopper/ladybug uploading the EPW file which contains the city's weather data such as temperature, humidity, wind rose, radiation rose, and precipitation. Once the temperature is determined, the necessity of sun access or control in the area of study is established. The second parameter is radiation, where the sun's availability in buildings as well as at street level is determined. Too much or too little radiation will directly affect the comfort of any space, making it a necessary parameter to consider in order to allow proper sunlight inside and outside. Finally, ventilation is studied in order to determine the flow and velocity of wind, as well as the capacity of the area to allow cross ventilation,

necessary to maintain thermal comfort at street level as well as indoors. An extended description of these parameters is included to fully understand how to calculate, read and use the generated data to compare, contrast and develop appropriate recommendations and conclusions.

Shadow Projection.- The shadow projection graphics are obtained using the daily solar path, where sun rays are projected in the geometries from sunrise to sunset, casting shadows on the surrounding buildings as well as on the street level. With this analysis micro climates at street level are identified in order to understand pedestrian comfort. Additionally, shadow projected from taller buildings to small buildings, generating a lack of sun radiation in interior spaces, can be visualized. The shadow projection graphics for this paper positions the sun on December 21st (winter solstice) at 5:00pm determining the azimuth and angle of the sun at that specific hour, everything colored gray at the street level is the shadow projection, while other surfaces colored gray are shaded areas. Moreover, shadow range analysis map projects the merged shadows of every building from sunrise to sunset on a specific day, areas shaded during the day will be colored gray, determining the areas that have solar access during the day and the ones that do not.
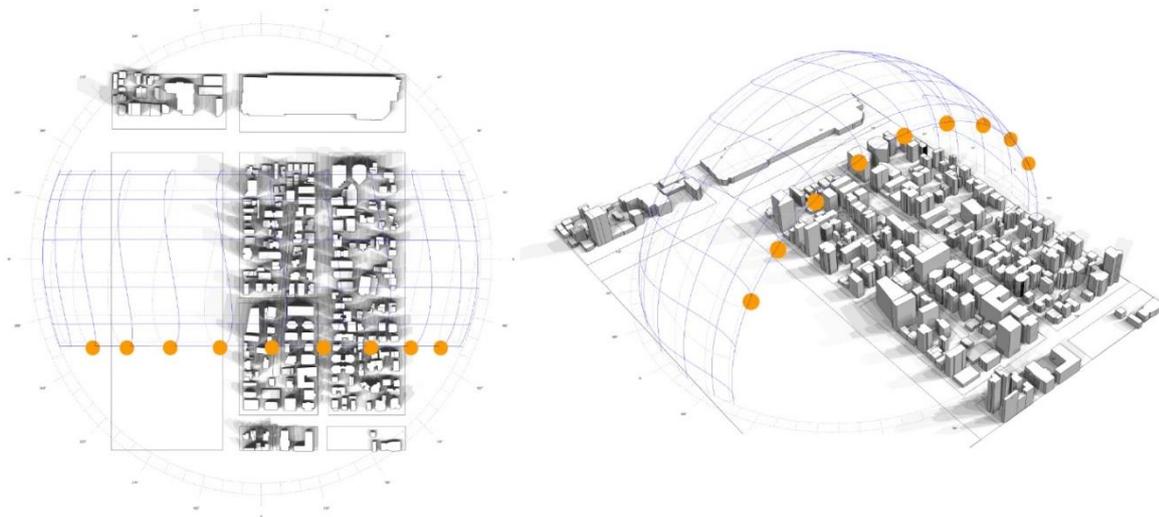
Image 01: Shadow range analysis. 21 Dec. 9:00am to 5:00pm. Diva-Grasshopper-Rhinoceros. Elaborated by authors..

Radiation Analysis.- The radiation analysis graphics represent the amount of sun that a surface is exposed to monthly or annually. To determine this, the utilized software divides each surface of the volume in pixels and then colors them according to the amount of sun that they receive monthly or yearly. The data collected is measured in KiloWatt per square meter (kw/psm). This result is represented graphically using a red-yellow-blue color gradient scale in which the areas with highest kw/psm are colored red and then vary to the lowest kw/psm areas which are colored blue. According to the NEC 2011 (Ecuadorian Construction Regulation), the average solar radiation value per day is 5075 kw/psm for Quito. This value is important to understand the variation of radiation in each scenario and determine whether sun gain strategies are required or not. Therefore,these graphics easily show heat or cold islands at pedestrian levels as well as the surfaces that receive a great amount of sun and the ones that do not, making it possible to understand and improve the

performance of buildings in relation to solar access necessities through the variation of geometry, story height or the use of reduced sun access devices such as cantilevers or other sun protection systems.
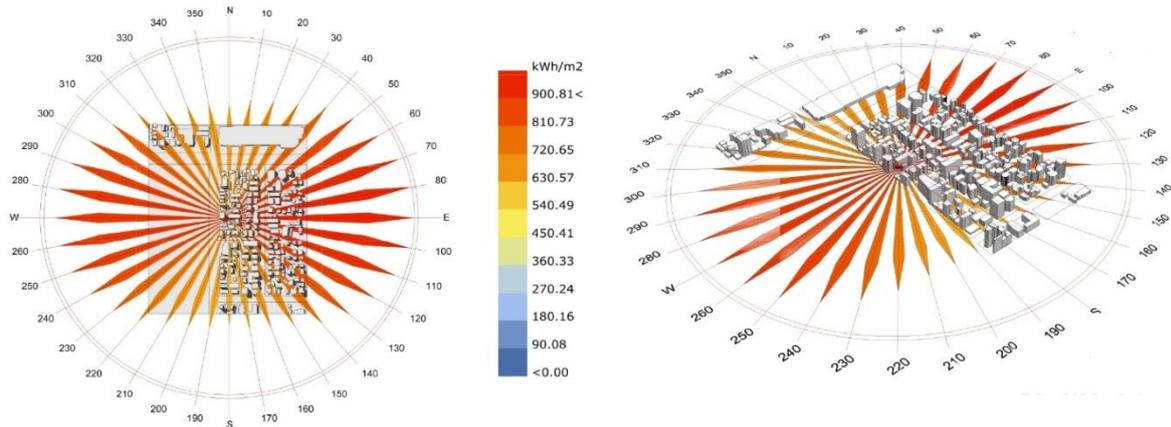

Image 02: Radiation Rose. Annual Radiation. Ladybug-Grasshopper-Rhinoceros.Elaborated by authors.

Ventilation analysis. The ventilation graphics take in consideration the direction, speed and frequency of wind which is represented in the wind rose. In the urban scale wind direction is used to design correct cross ventilation among buildings but also to avoid wind tunnels at street level and wind shadows produced by the variation of pressure when the air hits a building facade. In addition, a wind profile graphic is generated, which determines the relationship between the height of the building and air velocity which are symmetrically proportional, meaning that the taller the building the faster the wind blows. This is important in order to determine possible changes to the geometry of a building towards an aerodynamic form or the generation of apertures in specific stories to reduce the wind force on the building and wind shadow effect, which generates turbulences at the back of the building. All of these aspects need to be taken into account in order to generate comfortable, ventilated spaces indoors and outdoors as well as to reduce wind force and its impact on buildings. According to the NEC 2011 (Ecuadorian Construction Regulation), the recommended outdoors air velocity is up to 5m/s and indoors up to 2m/s. These values will be taken in consideration in order to understand the variation in height as well as air intake and determine whether strategies for decreasing air velocity are required or not.
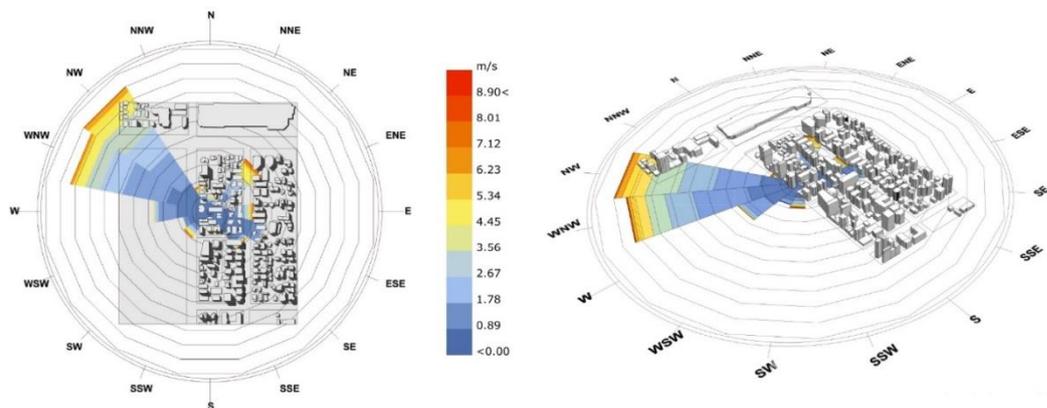
Image 03: Wind Rose. Ladybug-Grasshopper-Rhinoceros. Elaborated by authors.

3.- Analysis and Comparison.

3.1- Scenario 1: Current Situation (up to march 2019)

The first scenario analyzes the study area's current situation. Previously this area was occupied by spacious single family houses which were demolished and replaced by residential and office towers from 10 to 20 stories (30 to 60m height) with the expansion of city to the North and the transformation of this area to a mixed-use, highly valuable zone. The established height responded to the closeness of this area to the city's old airport and the restrictions set accordingly by the General Direction of Civil Aviation (DGAC). When Quito's airport was moved to a suburban area in the year 2013 the DGAC building height restrictions were lifted which in turn allowed the planning and building of higher towers in the study area.. The presence of 'La Carolina Park across the street allows west facing buildings within the study area to have a wide open space across the street guaranteeing city views and plenty solar radiation reception, on the other hand, the presence of tall buildings towards the east complicates solar access for east facing buildings.

The study area focuses on two blocks which will be referred to as Block A (north) and Block B (south). Image 04 shows that not every lot in block A has a high tower real estate development: 48.3% of the lots (29 lots) are empty or built up to 3 stories (3 to 12m height), 20% of the lots have 4 to 9 stories' buildings (12 to 27m height), 28.3% of the lots have buildings between 10 to 14 stories (30 to 45 m height) and just 3.3% (2 lots), have buildings of 15 to 20 stories. Therefore, the tallest buildings in this block are around 60 m height. On the contrary, block B shows a higher density: 48.6% of the lots are occupied by buildings between 10 to 14 stories. Empty lots or buildings up to 3 stories correspond to the 34.3%, buildings between 4 to 9 stories correspond to the 5.7% and finally, 11.4% correspond to the tallest buildings of the area that are between 15 to 20 stories high. The following table shows a summary of this data.

BLOCK A				BLOCK B		
# OF FLOORS	# OF BUILDINGS	% OF THE BLOCK		# OF FLOORS	# OF BUILDINGS	% OF THE BLOCK
0 to 3	29	48.3%		0 to 3	12	34.3%
4 to 9	12	20.0%		4 to 9	2	5.7%
10 to 14	17	28.3%		10 to 14	17	48.6%
15 to 20	2	3.3%		15 to 20	4	11.4%

Image 04: 3d model of current scenario. Sketchup. Elaborated by authors.

3.1.1 Shadow Projection Analysis.

The image 05 shows the shadow projection analysis. In Block A, due to the predominance of smaller buildings, the shadow projection on December at 17:00 does not affect the entire block. In contrast, the shadow projected in Block B, in which small buildings represent just 34.3% of all buildings, covers most of the block during the morning and afternoon. However, both in block A and B, the higher buildings, between 30 to 60 meters, cast shadows that cover surrounding buildings generating shaded areas in the façades. This can create thermal comfort issues in the surrounding buildings, due to the fact that they do not have direct sun access and therefore may require mechanical systems such as radiators to compensate for the lack of solar radiation.
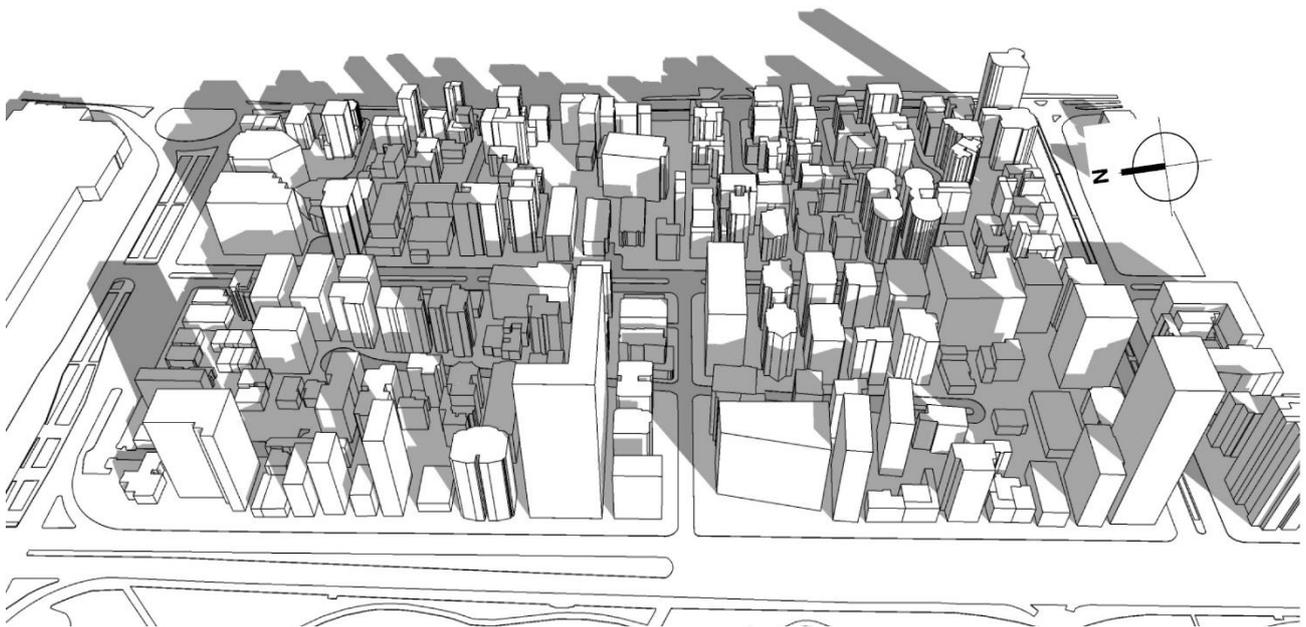

Image 05: 3d model shadow projection analysis December 21, at 5:00pm. CuricSun-Sketchup. Elaborated by authors.

3.1.2. Radiation Analysis.

The radiation analysis shows clearly show that buildings, across the street from the park, have the advantage of great solar access/exposure, especially during the afternoon. Image 06 shows a yearly radiation value of 655.8 kilowatts per square meter   which is considered a medium value according to the Ecuadorian Construction Regulation (NEC) 2011 which stablishes an average of 5075 watt per square metter per day for the city of Quito. This value converting to kilowatts per square metter per year is 1852 kw/sqm. In contrast, on image 07 the surfaces that are colored dark red, close to blue, indicates that the radiation value is low in this case is 360.4kwh/sqm. This low value responds to those areas shaded by the building in front of them. This

simple analysis shows areas/surfaces that require strategies to catch more sunlight inside in order to reduce the use of mechanical systems.
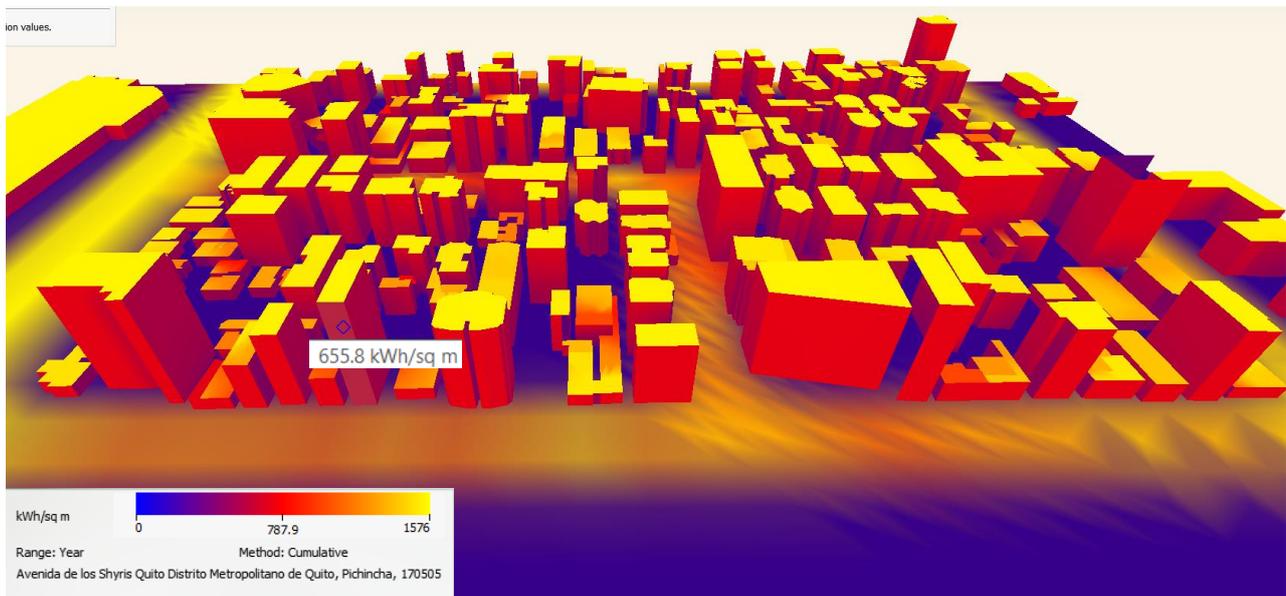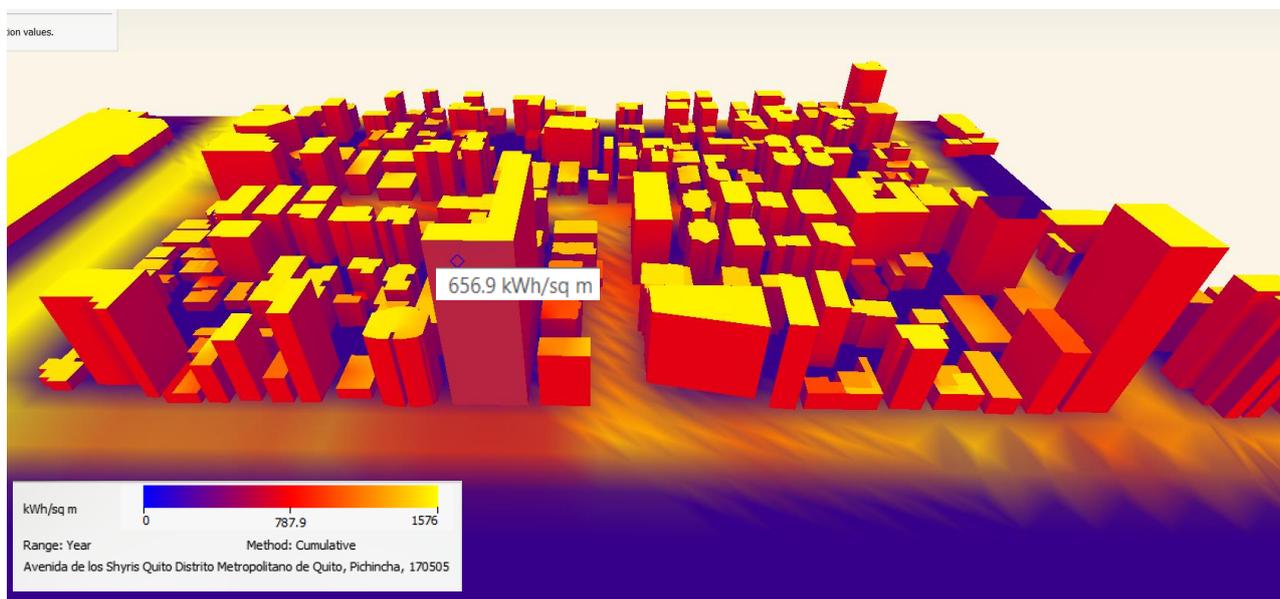

Image 06: 3d model radiation analysis high value current scenario. Form It-Autodesk. Elaborated by authors.
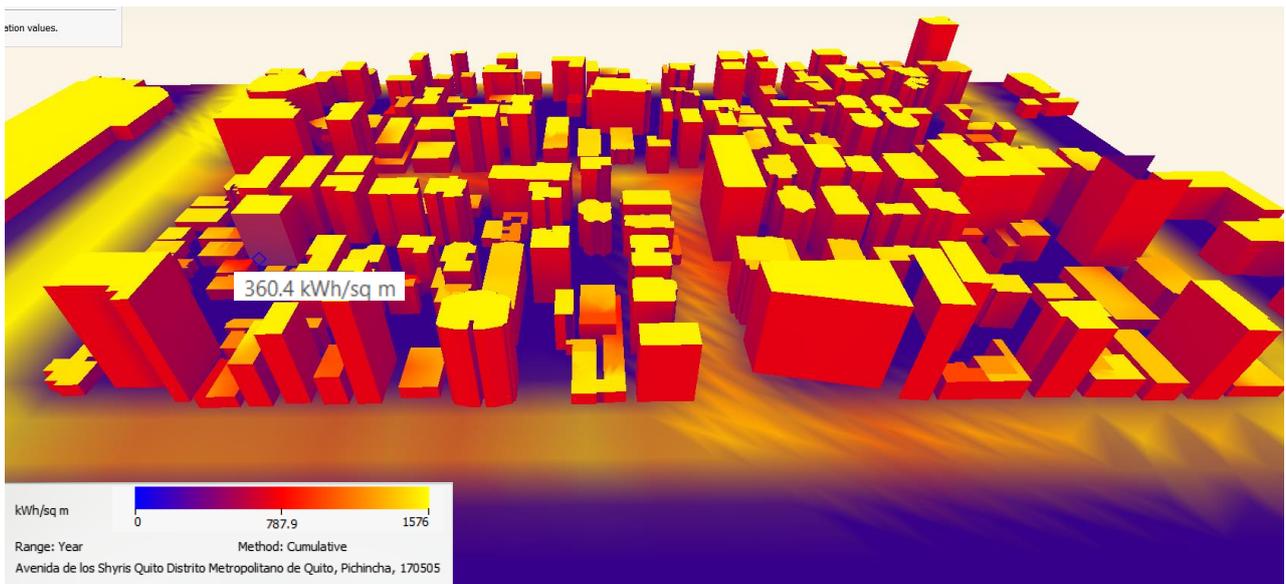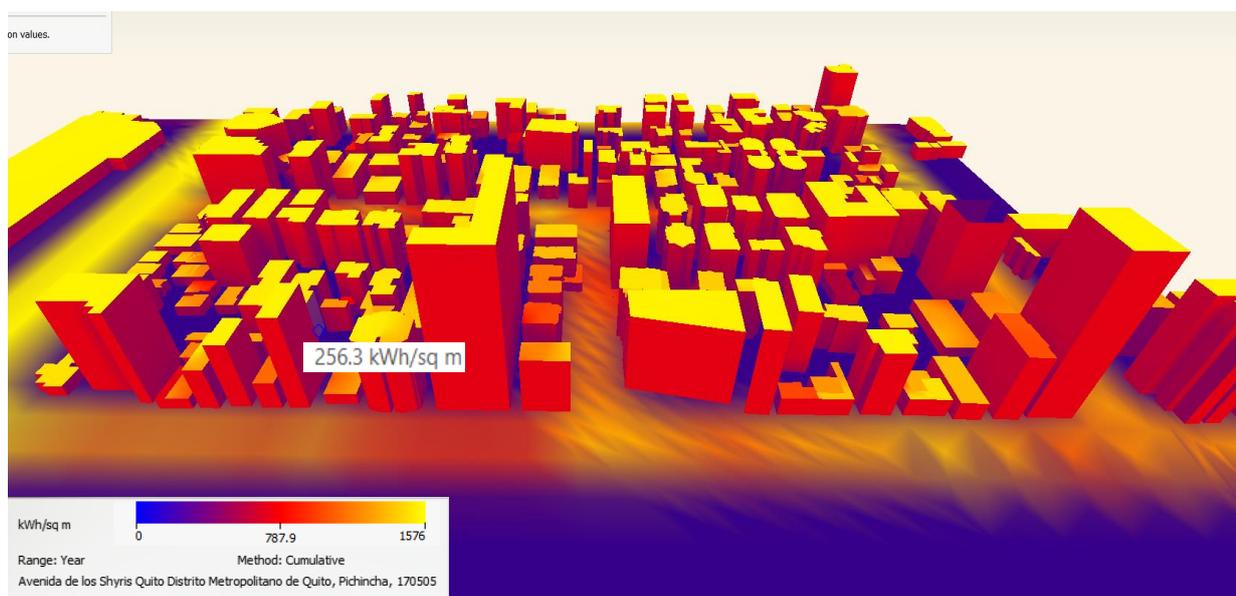

Image 07: 3d model radiation analysis low value current scenario. Form It-Autodesk. Elaborated by authors.

3.1.3 Ventilation Analysis.

The wind rose generated in Ladybug with the EPW data sheet corresponding to the closest weather station, Inaquito, indicate that common winds flow with a North West direction with a velocity up to 8.9 meters per second m/s which is considered moderate and therefore strategies to reduce this velocity must be applied. According to Olgyay the wind velocity acceptable to contribute to the comfort zone goes from 0.1 to 2 m/s indoors and up to 5 m/s. outdoors. In addition, in the wind simulation analysis, image 08, the velocity at the top of the buildings that are 10 to 14 stories is between 7 to 11 meters per second which generates a minimal turbulence at the back of the buildings making it necessary to include some aerodynamic or perforation strategies to be applied in the new buildings' geometry.
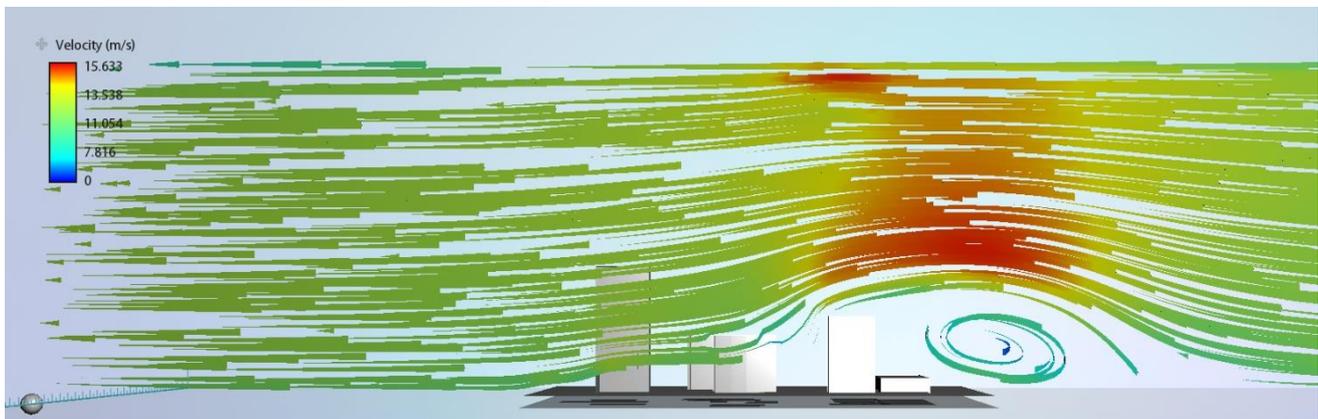
Image 08: Wind simulation current scenario. FlowDesign-Autodesk. Elaborated by authors.

3. 2.- Scenario 2: Projected Scenario (march 2019 to march 2023)

Image 09 visualizes a near future scenario which includes two new buildings that have already been approved utilizing the EDT. These two mixed use towers will have 40 stories each and include commercial, office and housing areas. The total estimated height for each tower is 80 meters, one will be located in Block A and one in Block B becoming the two tallest buildings in the area and in the city.

Image 09: 3d model of projected scenario. CuricSun-Sketchup. Elaborated by authors.

3.2.1 Shadow Projection Analysis.

The second scenario includes two new buildings that were recently approved for construction and certified as green buildings under the EDT. These buildings, currently under construction, will reach a height of 80 meters, therefore doubling the height of most of the surrounding buildings. Each building is located in one of the two blocks in the study area therefore dividing its impact between the two blocks. It is important to mention that in the morning, around 9h00, high profile shadows are projected into La Carolina's Park which does not represent a problem to any building in terms of sun radiation. On the contrary, at 17h00 the sun altitude angle is 20 degrees casting shadow on surrounding buildings and public space. Applying the Pythagorean triangle, the result of the length of these shadows have a value of 217.5 mete

BLOCK A				BLOCK B		
	# OF FLOORS	# OF BUILDINGS	% OF THE BLOCK		# OF FLOORS	# OF BUILDINGS	% OF THE BLOCK
	0 to 3	28	46.7%		0 to 3	11	31.4%
	4 to 9	12	20.0%		4 to 9	2	5.7%
	10 to 14	17	28.3%		10 to 14	17	48.6%
	15 to 20	2	3.3%		15 to 20	4	11.4%
	21 to 40	1	1.7%		21 to 40	1	2.8%

rs meaning that the two new 80 meters towers generate a shadow that covers the whole block plus half the block that is behind. In other words, in Block A the 5 buildings to the east of the new tower, which do not exceed 15 stories height, will be highly shaded during the entire year from 14h00 to 17h00,   when the area is completely shaded. On block B, on the other hand, 7 buildings are partially shaded during the whole year from 14h00 and 4 completely shaded at 17h00.

Image 10: 3d model of projected scenario analysis December 21, at 5:00pm. CuricSun-Sketchup.. Elaborated by authors.

3.2.2. Radiation Analysis.

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The second map is the radiation analysis, as mentioned before, all the buildings in front of the park have the advantage of a great solar access and sun exposure especially during the afternoon. Image 07 shows a radiation value of 656.9 kilowatts per square meters which is considered high, in contrast, Image 08 shows surfaces colored dark red, close to blue, indicating that the radiation value is low in this case is 256.3kwh/sqm. Taking in consideration the preceding scenario, a drop of 110 kwh/sqm is taking place in the surrounding buildings complicating even more the required solar radiation and incrementing even more the necessity of radiators.

Image 11: 3d model radiation analysis high value projected scenario. Form It-Autodesk. Elaborated by authors.

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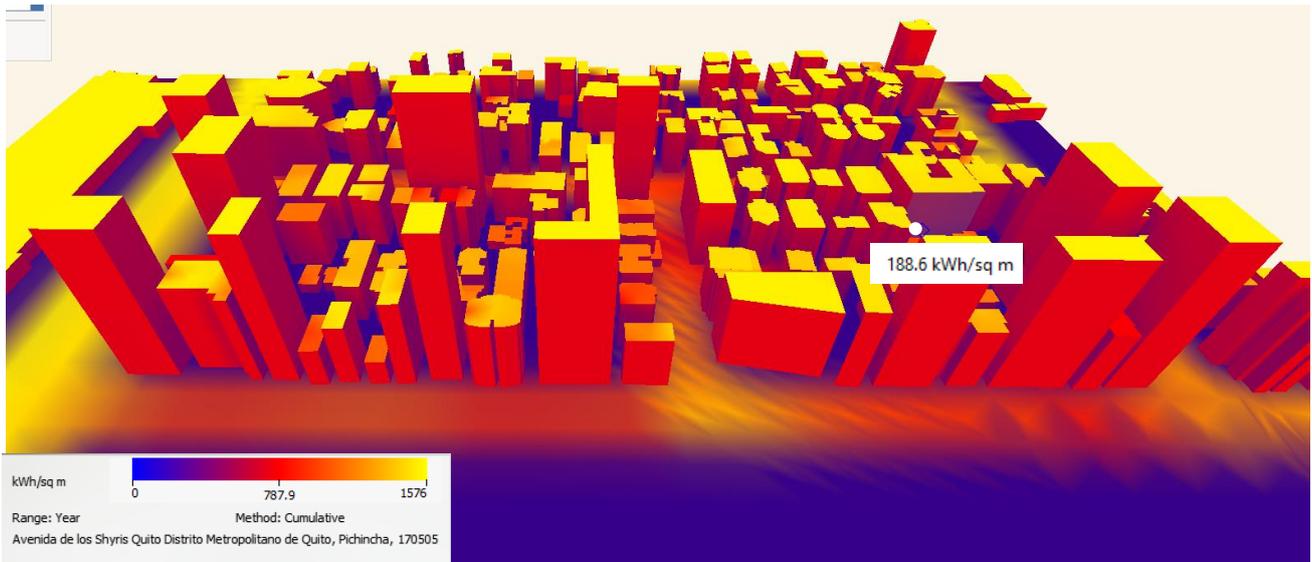
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Image 12: 3d model radiation analysis low value projected scenario. Form It-Autodesk. Elaborated by authors.

3.2.3 Ventilation Analysis.

In this scenario, with the new addition of these new towers with a height of 120m the air velocity at that point increments up to 26 meters per second which demands more complex strategies to slow down the wind velocity. In addition, the wind shadow generated at the back of these towers produces turbulence at the spaces in between the block damaging the public space quality at street level. This because, the turbulence produced by the wind shadow runs at an average of 7m/s which is already 2 m/s faster that the maximum wind value consider to be tolerated for outdoors which is up to 5 m/s according to Olgyay.
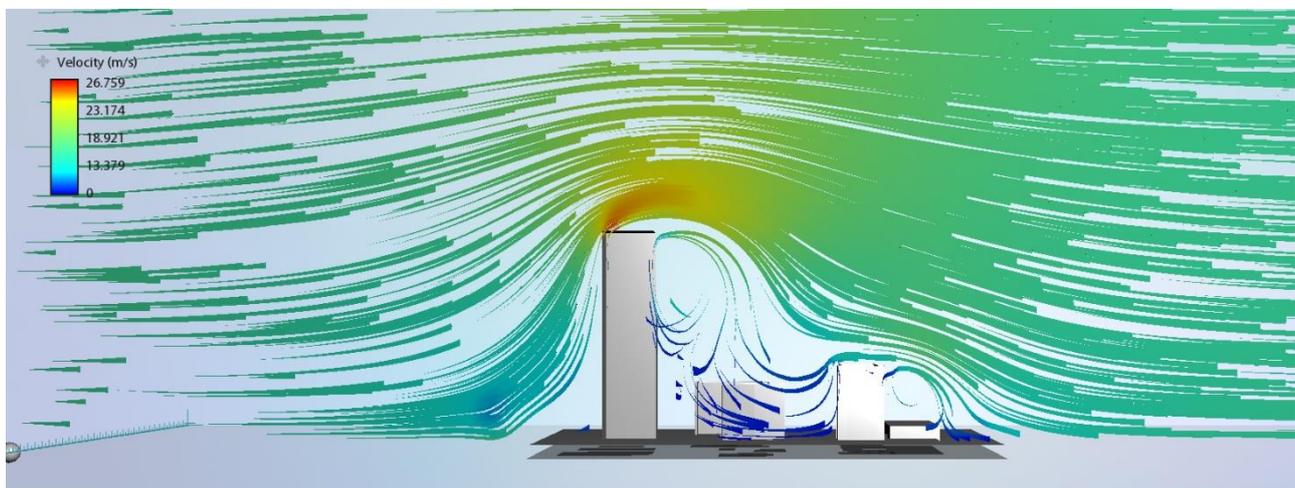
Image 13: Wind simulation projected scenario. FlowDesign-Autodesk Elaborated by authors.

3.- Scenario 3: Plausible Scenario (march 2023 to march 2033)

This scenario, unlike the two previous ones, contemplates an outcome in which most of the empty lots as well as plots with edifications less than 10 m height will be demolished and replaced by new high rises 40 stories high. This scenario is likely to happen in the long term, considering the high interest and land value of the area, that will also benefit from the construction of the high rise buildings already approved and infrastructure such as the metro's first line. Even though the implementation of mechanisms needed to reduce water usage, energy consumption, rainwater recycling, etc. require a higher investment, doubling the number of stories and therefore floor area available to sell make EDT projects extremely profitable for developers. Therefore it is safe to predict a high interest to fully develop available or low used land in the area applying the EDT. In addition, in the long run, these low energy consumption strategies will make the maintenance of the building less expensive, compensating the extra cost of applying the EDT at the construction phase. Nevertheless, it is important to understand the impact of these new buildings on the existing ones and on the urban space especially the lack of sun access as well as the amount of shading they receive.

BLOCK A		
# OF FLOORS	# OF BUILDINGS	% OF THE BLOCK
0 to 3	21	35.0%
4 to 9	12	20.0%
10 to 14	17	28.3%
15 to 20	2	3.3%
21 to 40	8	13.3%

BLOCK B		
# OF FLOORS	# OF BUILDINGS	% OF THE BLOCK
0 to 3	8	22.8%
4 to 9	2	5.7%
10 to 14	17	48.6%
15 to 20	4	11.4%
21 to 40	4	11.4%
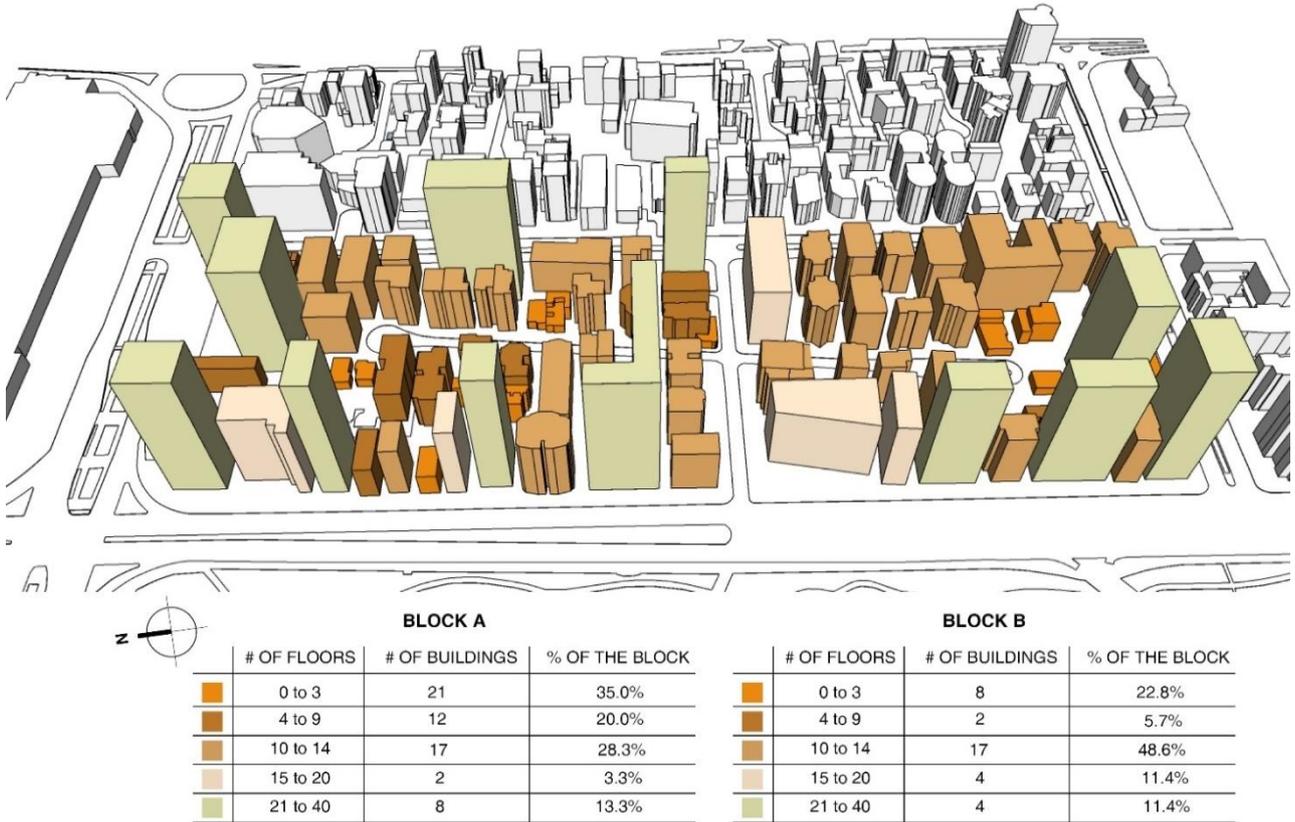
Image 14: 3d model of plausible scenario. CuricSun-Sketchup. Elaborated by authors.

Image 15: 3d model of plausible scenario analysis December 21, at 5:00pm. CuricSun-Sketchup.. Elaborated by aut

3.2.1 Shadow Projection Analysis.

The third scenario, 6 new 40 stories buildings in block A and 3 in block B are placed, which modified considerably the shadow projection in the area. As noticed in the previous scenarios, each of these new high rises will project a shadow of 217.5 m at 20 degrees sun altitude at 5pm covering completely the whole block. This, is just an estimation that takes in account all of the possible lots and small buildings to be replaced by 40 stories buildings, the outcome could be less impacting with smaller buildings, however the shade produced by any new construction will definitely generate an impact and diminished the solar access of its surroundings.

3.1.2. Radiation Analysis.

Image 16 shows that the new 40 stories buildings still have great solar access even if they are located in the rear area of the block with an average value of 646.9 kwh/sqm, however the great impact occurs in the existing buildings that do not have sun access and just adquire a value of 188.6 kwh/sqm which results in a very low value.
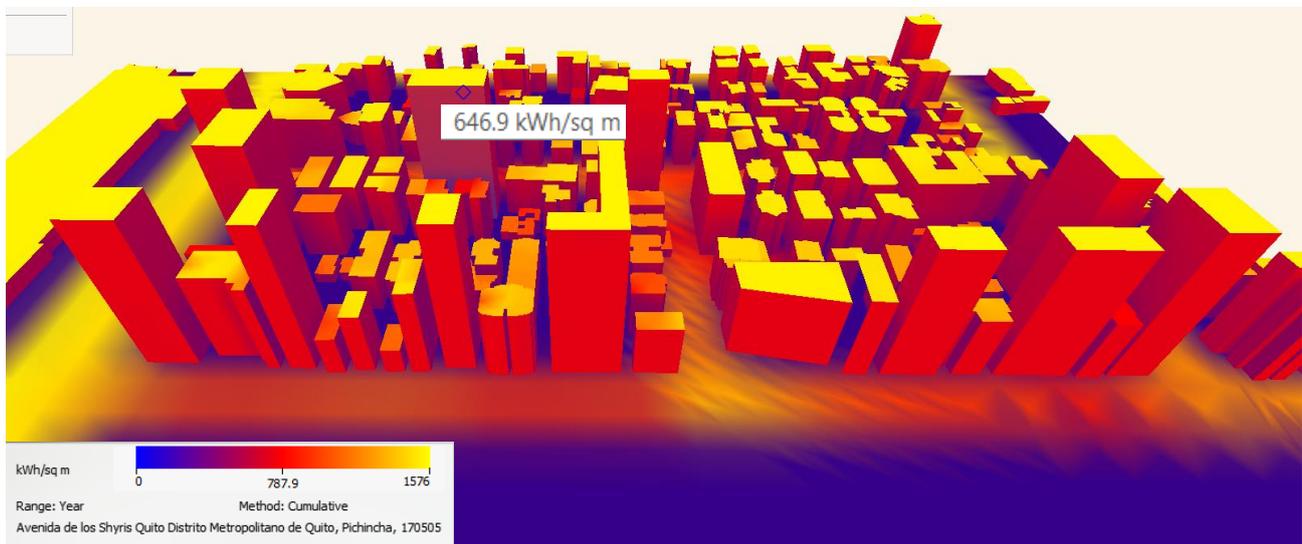
Image 16. 3d model radiation analysis high value plausible scenario. Form It-Autodesk. Elaborated by authors

Image 17: 3d model radiation analysis low value plausible scenario. Form It-Autodesk. Elaborated by authors

3.3.3 Ventilation Analysis.

In this scenario, with the new addition of these new towers with a height of 120m the air velocity at that point increments up to 26 meters per second which demands more complex strategies to slow down the wind velocity. In addition, there are two shadow profiles generated at the back of each tall tower creating a lot of turbulence in between and at the pedestrian level.

Image 18: Wind simulation plausible scenario. FlowDesign-Autodesk Elaborated by authors.

4.- Conclusion and Recommendations.

Currently the EDT does not specify values related to the solar radiation and ventilation within the project nor in the surrounding buildings and public spaces. When considered by developers, this parameters responds directly to the guidelines established by Ecuadorian Construction Norm (NEC) in its Energetic Efficiency in Residential Buildings chapter which recommend values and strategies according to the different zone, including the specific solar heat gain coefficient (SHGC) value. The SHGC value corresponds to the incident solar radiation admitted through a window but is not directly related to the comfort zone base on solar radiation. This shows that currently there is little or no consideration about the impacts of the EDT application at the urban scale.

The EDT has proven to be highly attractive to developers focused in expensive, already built-up, dense areas of the city such as the La Carolina neighborhood. This augmented mixed-use densification in areas well served by massive transportation can be positive at an urban scale to promote less motorized trips and avoid urban expansion nevertheless the study proves that the application of EDT can have an impact on the urban thermal comfort levels of the area, both outdoors affecting the sidewalk and public space experience and indoors in surrounding buildings. This impact can lead to unplanned side effects such as an increase of energy consumption in surrounding buildings due to a created need for heating devices and a lack of public space occupation in this area, undermining the efforts of an active, mixed use sidewalk experience. These side effects contradict the purposes of the EDT, and if not monitored and managed could lead to an overall negative impact for the city.

The analysis of the results have led to the following recommendations:

The inclusion of parameters such as shadow projection, radiation and wind in the EDT allows the evaluation of the impact of the project at urban and surrounding thermal confort level. The use of design and/or other passive strategies to reduce possible negative effects should be included as one of the EDT score parameters to encourage developers to contribute to this effort.

The application of the EDT in already highly dense areas should be more strictly analyzed before approval, with the application of tools such as the ones utilized in this paper for each case to ensure there is no major detriment to urban or private thermal comfort levels in the surrounding areas.

The EDT parameters can be flexible, setting higher standards in certain areas of the city to ensure the maintenance or improvement of thermal comfort in high density areas. Additionally, the Municipality can consider setting limits to the number of projects that can apply EDT in areas that present urban thermal comfort issues.

4. 1 – Comparison Chart

Table 01: Scenario Comparison summarizes solar, radiation and wind analysis. Elaborated by authors.

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