"THERMAL COMFORT AND URBAN DESIGN AT SEVERAL URBAN CANYONS IN THE CITY CENTER OF CONCEPCION, CHILE"

View from Cerro Caracol toward the center of Concepción. Source: author.

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July 24th, 2015
Toulouse, France

1_INTRODUCTION

This study was developed within the project FONDECYT No. 1130305

"Study and modeling of urban climate on a local scale, as a basis for proposing guidelines for adaptation to climate change in a network of Chilean cities."

by Professor Cristian Henriquez R. Institute of Geography, Pontifícia Universidad Católica de Chile, 2013

1_INTRODUCTION

1.1_Urban problem, morphology and orientation

Chilean cities have a foundational source in the checkboard of conquest.
These cities deny the versatility of each geographical area where are located.

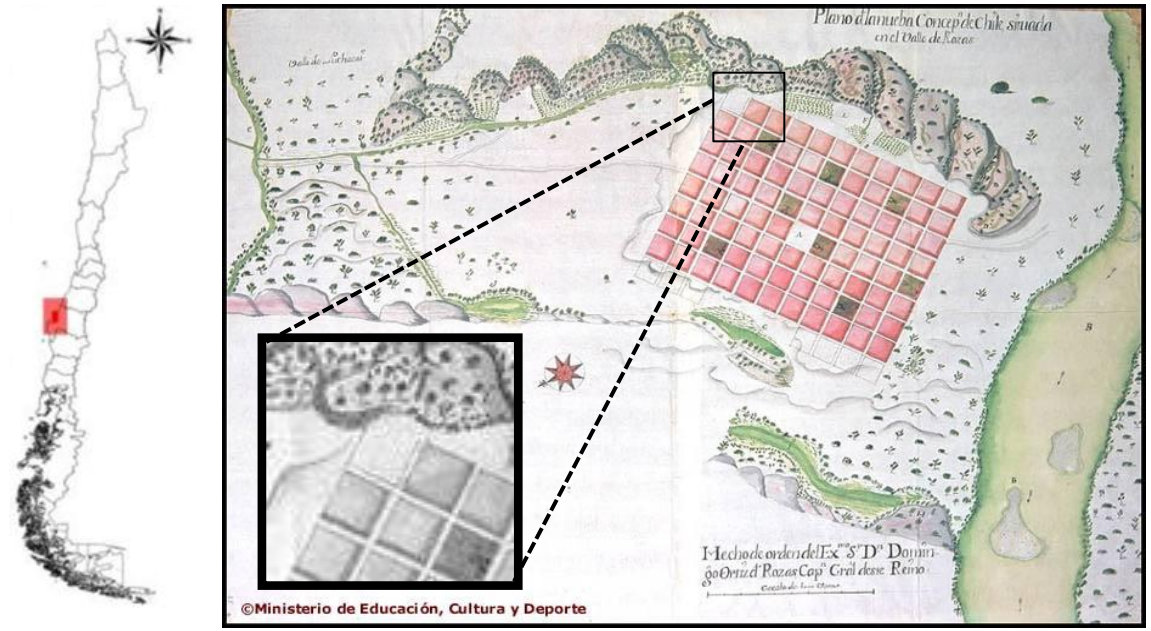

Fig.: checkboard settlement, re-founding map after the earthquake of 1753.
Source: http://www.skyscrapercity.com/showthread.php?t=664738

"Irregular cities appear in places that would have accommodated a checkboard, and there are cases of foundations checkerboard that arise in difficult terrain that would have justified another morphological solution" (Durston, 1994).

1_INTRODUCTION

1.2_Climate problem, physical data and atmospheric measurements.

Investigations of thermal comfort in open spaces based on computational standards, are not the most representative way to obtain values. (Tornero, 2006)

For this reason was decided to use a formula with real atmospheric data collected in field.

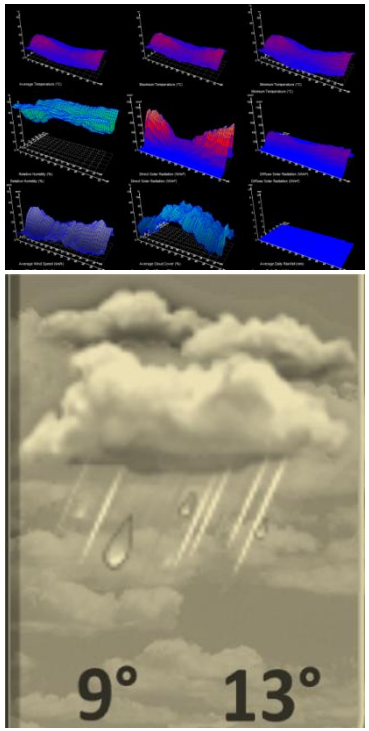

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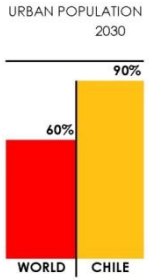
Fig: the standard climate data sometimes gets wrong! Source: author

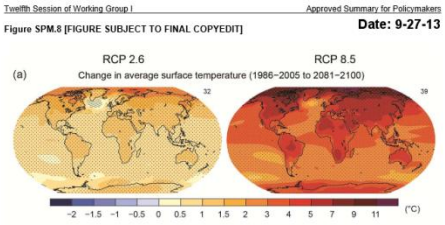
2_THEORETICAL FRAMEWORK_ *THIS STUDY´S THEORETICAL FRAMEWORK*

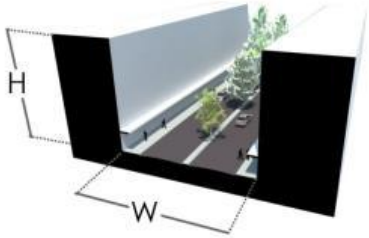


URBAN POPULATION

actual context

CLIMATE CHANGE (IPCC)

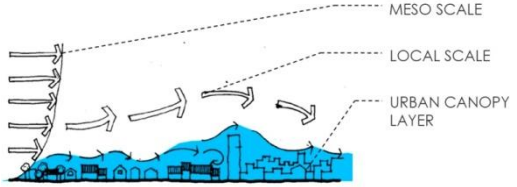




MICRO URBAN SCALE

scale

MICRO CLIMATE SCALE



PERCEPTUAL THERMAL COMFORT (SURVEY)

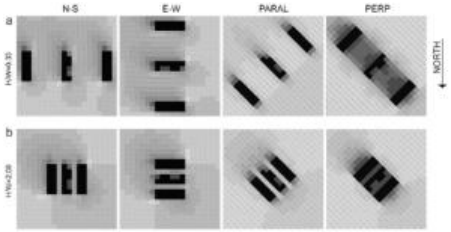
human impact

PHYSICAL THERMAL COMFORT (INSTRUMENT)

URBAN ASSIMMETRY (SVF)

city aspects

URBAN ORIENTATION (SHADOW FACTOR)



“The thermal comfort determines the amount of time spent in outdoor public spaces”

(Setaih *et al*, 2013).

2_THEORETICAL FRAMEWORK

The investigated approach aims to improve understanding of the impact of urbanization, establishing three main actors: man, climate and city.

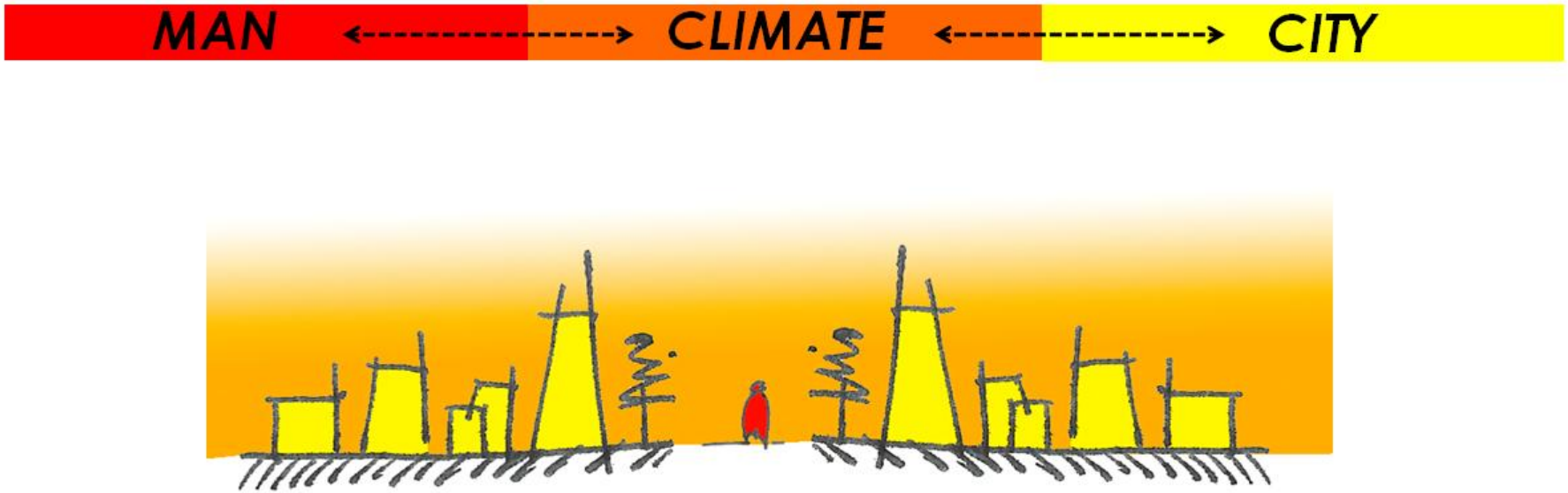


Fig: diagram and sketch concepts synthesized in the theoretical framework.
Source: author

3_PURPOSE

3.1_General purpose

The general purpose of this study is to compare physical and perceptual models to determine the thermal comfort in different urban canyons in the city of Concepción.

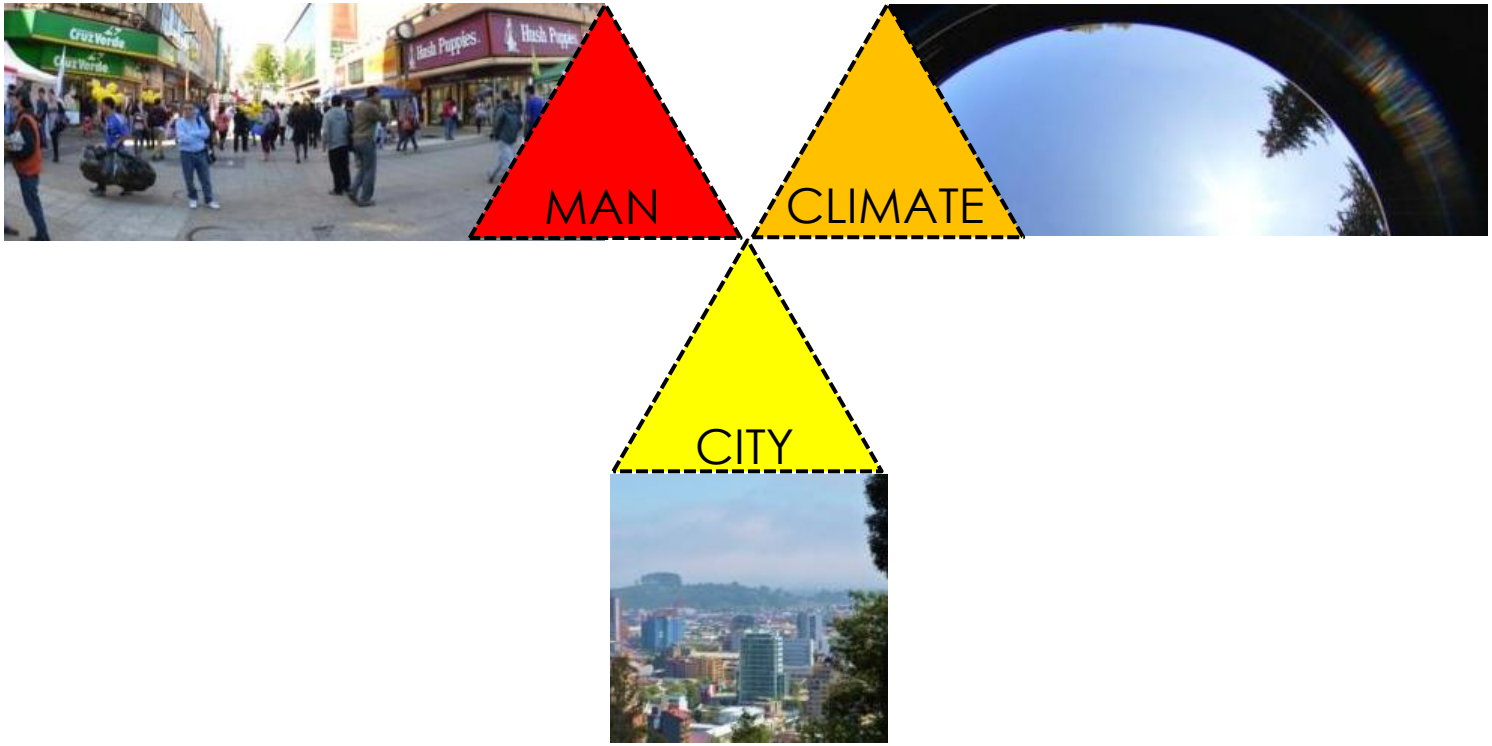
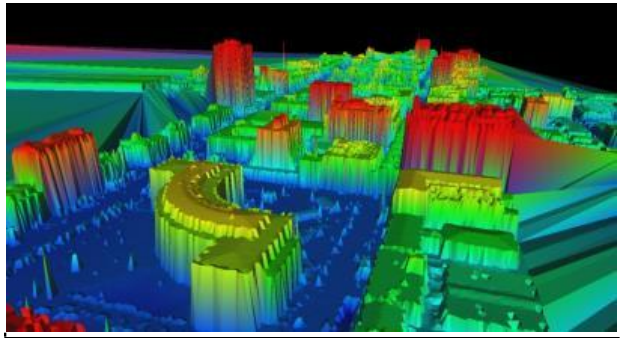


Fig: diagram of the general purpose
Source: author

3_PURPOSE

3.2_Specific purposes



· *Specific purpose 1*:
3D Modelling of Urban Canyons

· *Specific purpose 2*:
Quantitative modelling of the thermal comfort ASV

CAÑON N° DIRECCIÓN
9 DIAGONAL PEDRO AGUIRRE CERDA, ENTRE O´HIGGINS Y OROMPELLO

	HORA	T° AMBIENTE			HUMEDAD RELATIVA			VELOCIDAD VIENTO			DIRECCIÓN VIENTO			RADIACION			COEF. SOMBRA			SVF		
		A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
MAÑANA	10:15	27,2	29	27,9	41	35,5	40,5	0,6	0	0,3	NW	-	N	353,09	429,42	528,7	0,3	0,9	0	0,687	0,72	0,746
TARDE	14:12	20	20,6	22,8	64	65	60	3,7	5,1	3,4	SW	NW	N	280,65	292,89	368,21						
NOCHE	22:10	21,2	21,3	21,7	60	58,6	58,6	0	0,4	0,7	-	NW	NW	0	0	0				prom.	0,717	

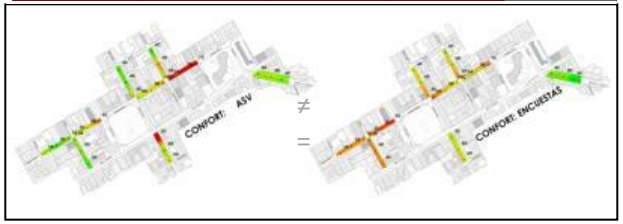
· *Specific purpose 3*:
Qualitative modelling of thermal comfort perception surveys

· *Specific purpose 4*:
Compare results

CORRELATION MATRIX

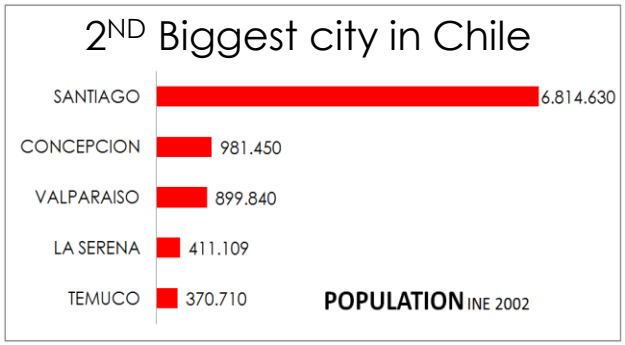
	SVF	SHADOW C.	ASV	SURVEY
SVF	1			
SHADOW C.	-0,907	1		
ASV	-0,815	0,714	1	
SURVEY	-0,129	-0,059	0,072	1

· *Specific purpose 5*:
Interpret and graph the results



4_STUDY AREA

Concepción is the second biggest city in Chile, it has a warm-temperate mediterranean climate.
(Romero, 1985)



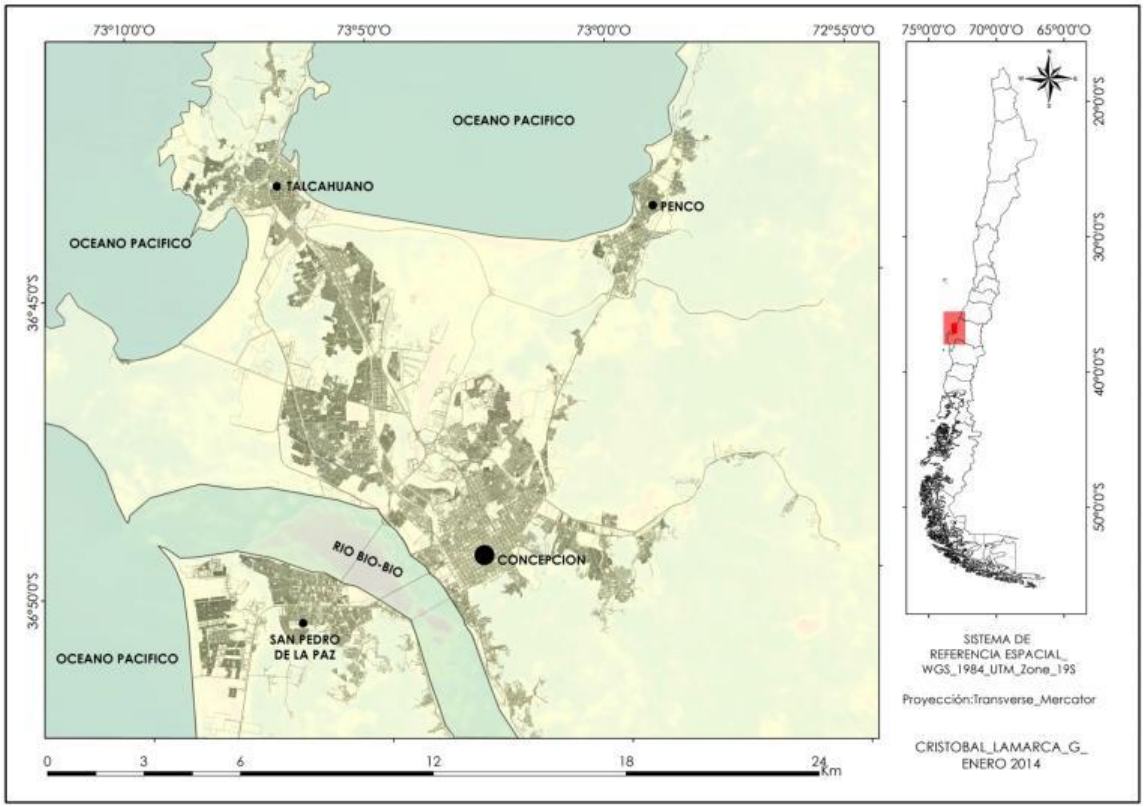
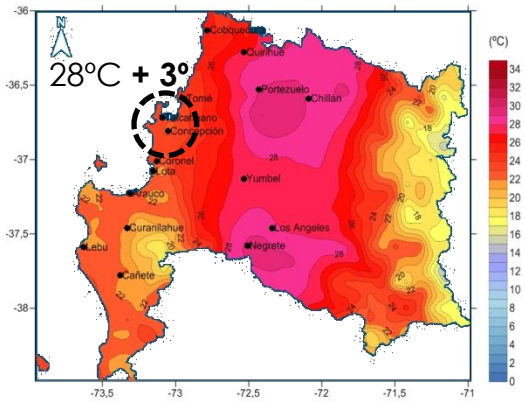


Figure: Mapping of Concepción. Source: author



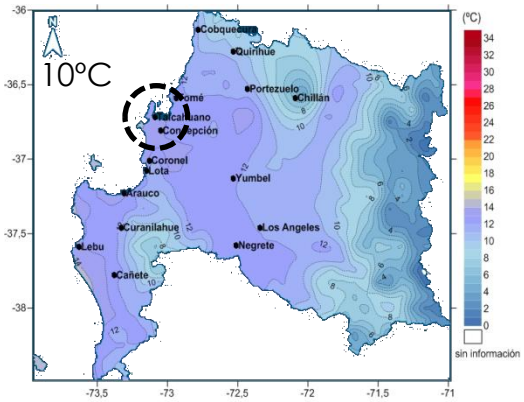


Figure: Max. Tº in summer and winter Source: meteochile

4_STUDY AREA

*4.1*_Determination of the place of study

EDIFICACION PARA LA ZONA C1
(Centro Metropolitano)

CONDICIONES DE EDIFICACION ZONA C1	
SUPERFICIE MÍNIMA	700m²
COEFICIENTE MÁXIMO DE OCUPACIÓN	1
COEFICIENTE MÍNIMO DE AREA LIBRE	No se exige
COEFICIENTE MÁXIMO DE CONSTRUCTIBILIDAD	10
ALTURA MÁXIMA DE EDIFICACIÓN	30,00m + piso de retiro; libre según **Art. 40**

LOCAL CLIMATE ZONE

+

LEGAL LAND USE ZONE

Compact midrise with paved ground.
(Stewart y Oke, 2012)

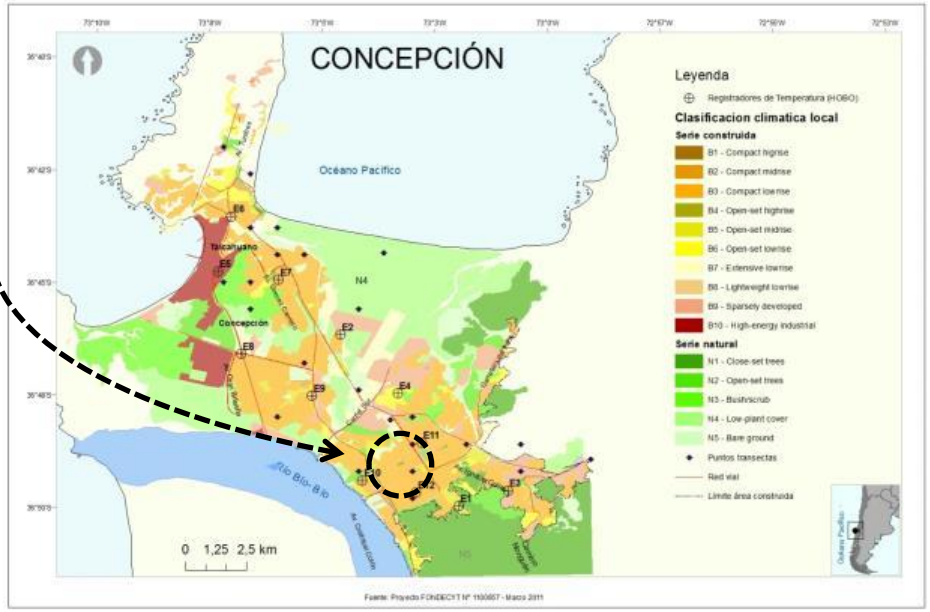


Figure: Oke´s LCZ for Concepción
Source: Previous Fondecyt Nº 1.100.657 (2011)

Metropolitan center of Concepción.
(Municipal Land Use Plan Conception, 2013)

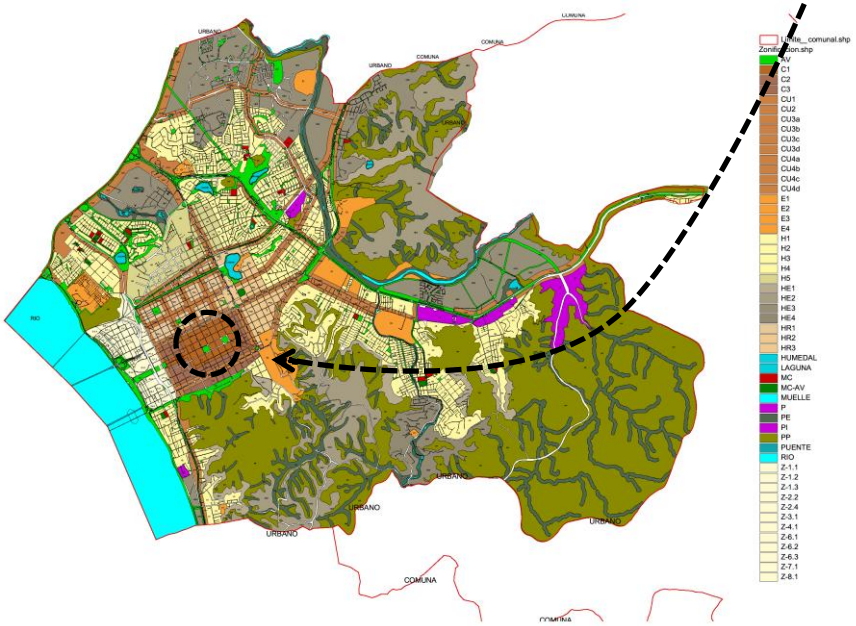


Figure: Municipal Land Use Plan Concepción
Source: PRCC (2013)

4_STUDY AREA

*4.1*_Determination of the place of study

The checkboard in the city center is rotated in 28° to the west, building two axis of urban canyons, NW-SE and SW-NE

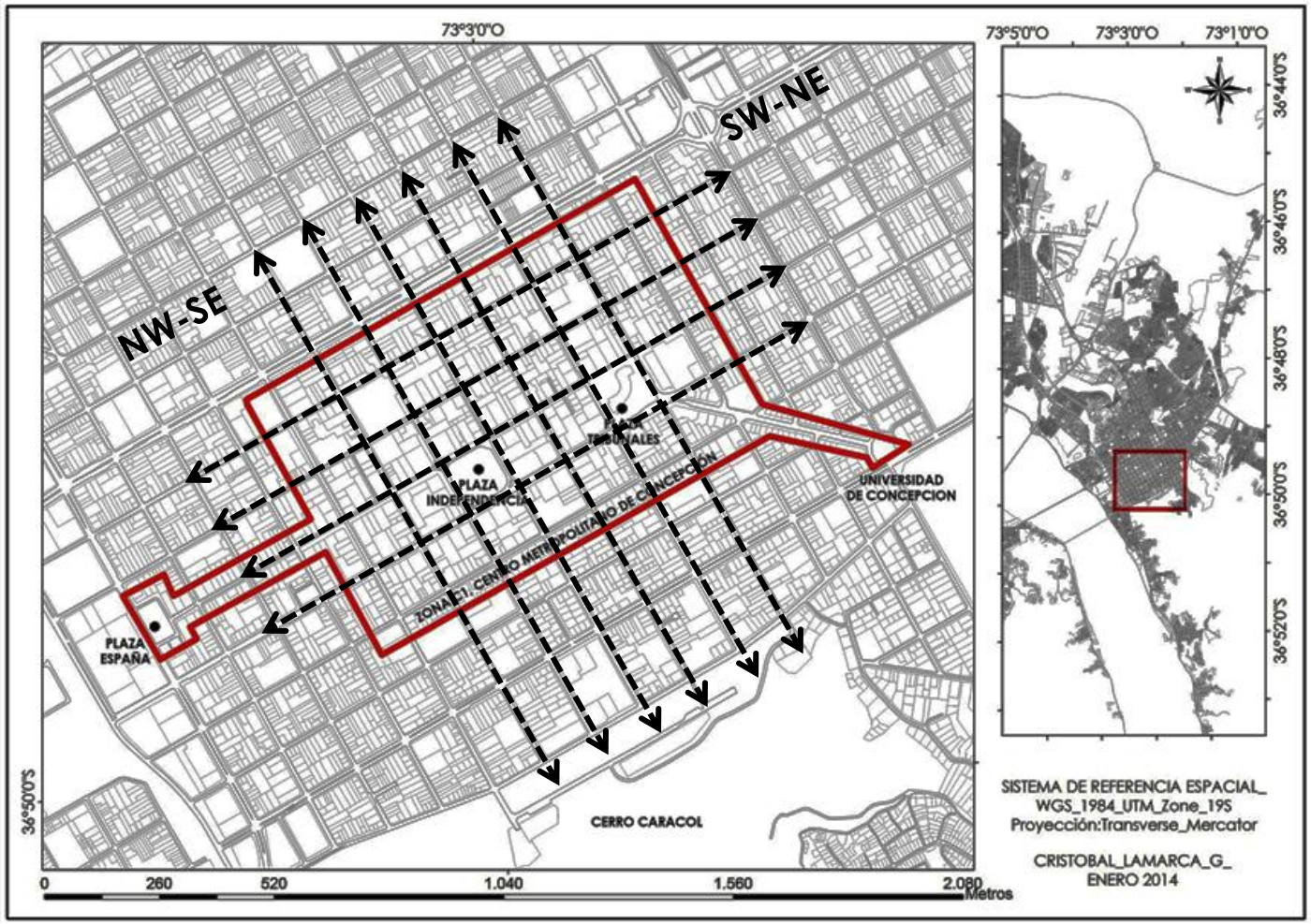


Figure: Metropolitan center of Concepción.
Source: author, based in PRCC (2013)

*4.2_* Selecting urban canyons

The variety of canyons enrich the results studied !

Zutter (1999), Gromke *et al* (2008), Ali-Tourdert (2006) y Dalman (2011) among others.

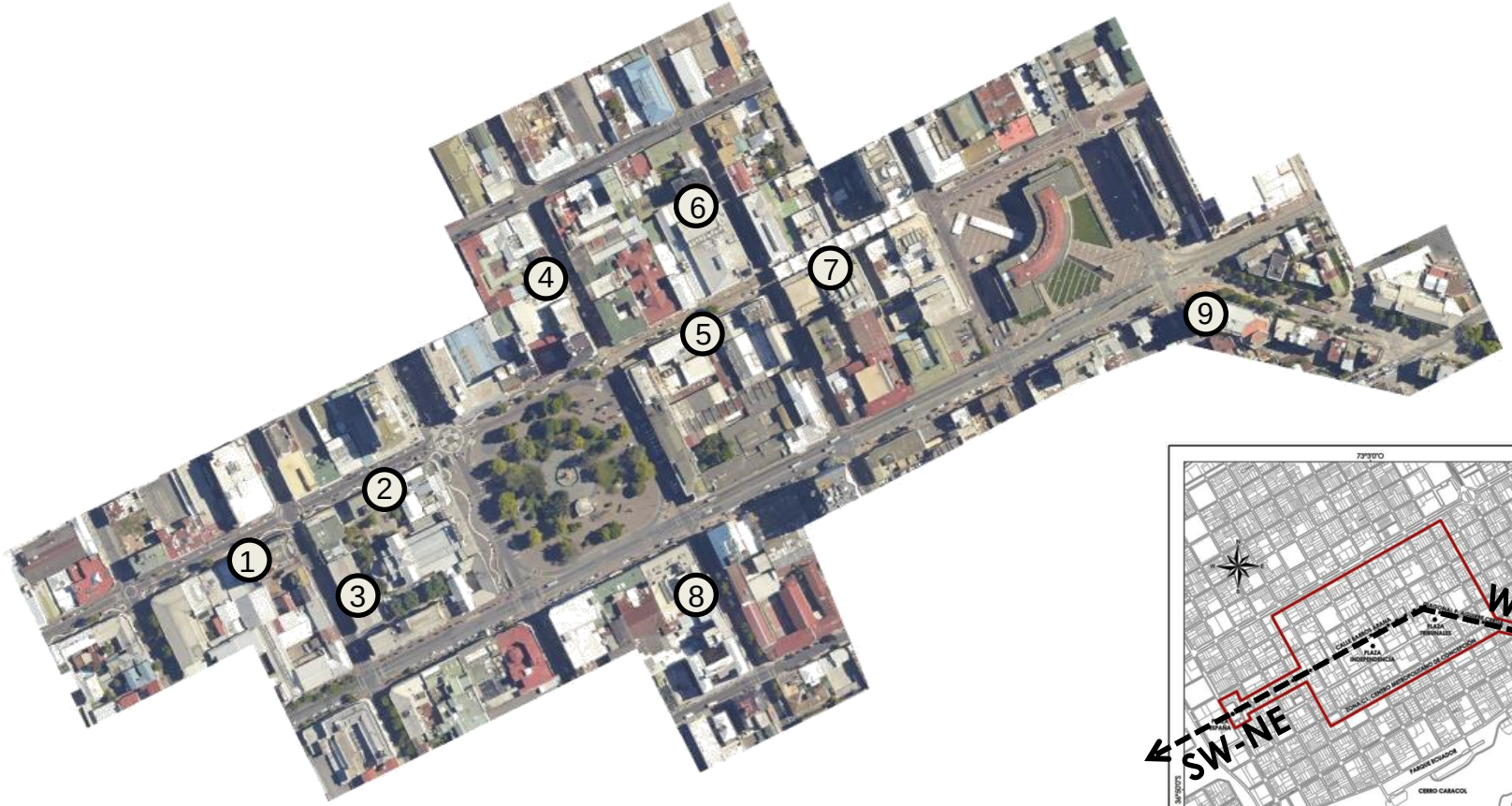
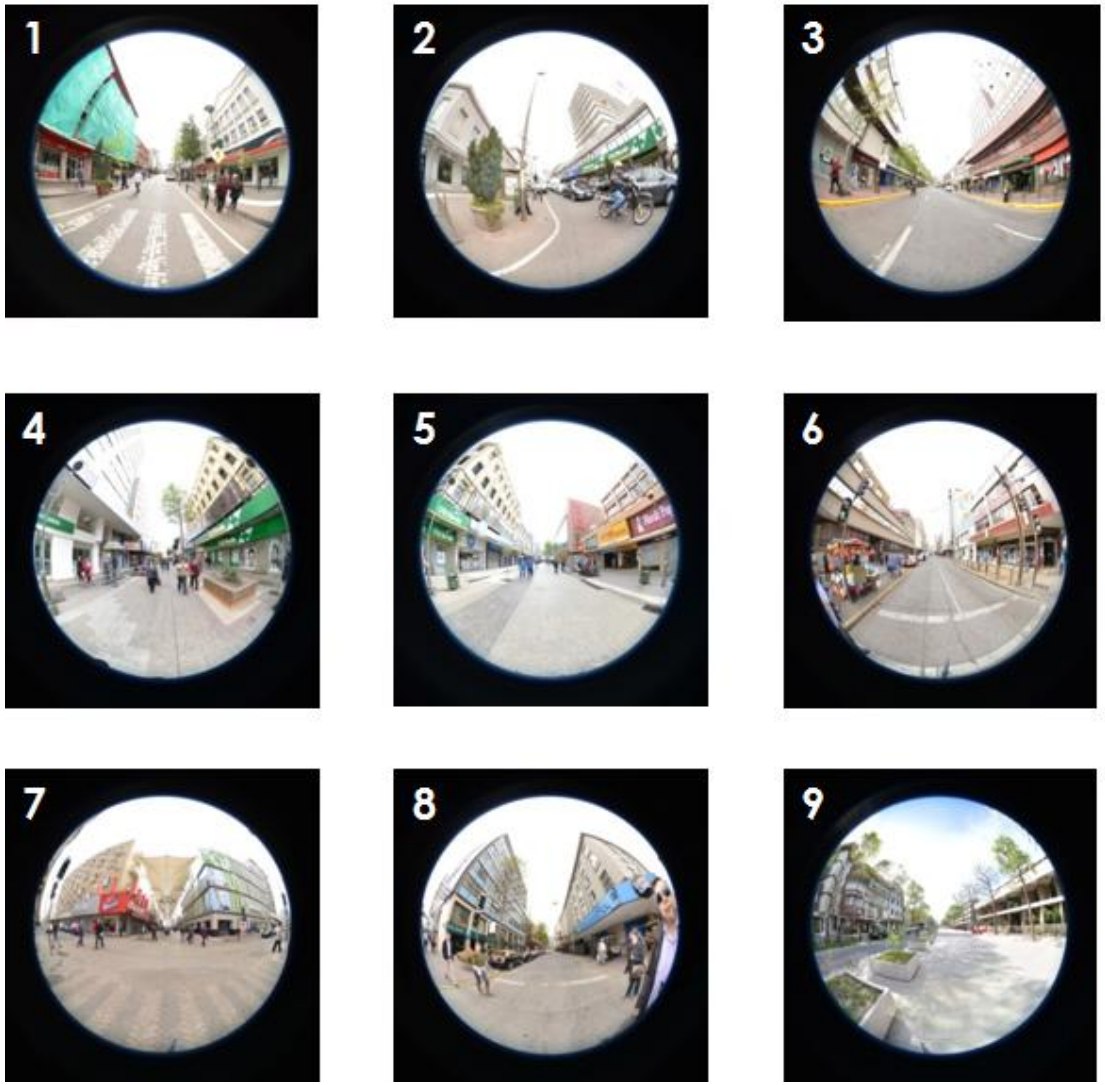
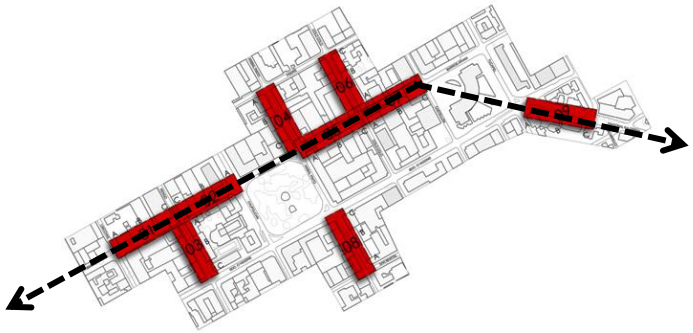


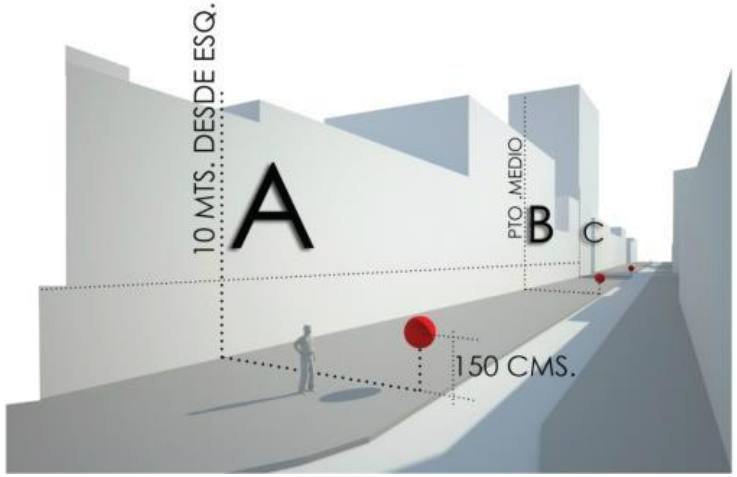
Figure: canyons selected and scheme location of control points per canyon.
Source: author based on Digimapas 2012

Chosen along the future pedestrian Bicentennial axis traced in the metropolitan center of Concepción.

*4.2_* Selecting urban canyons





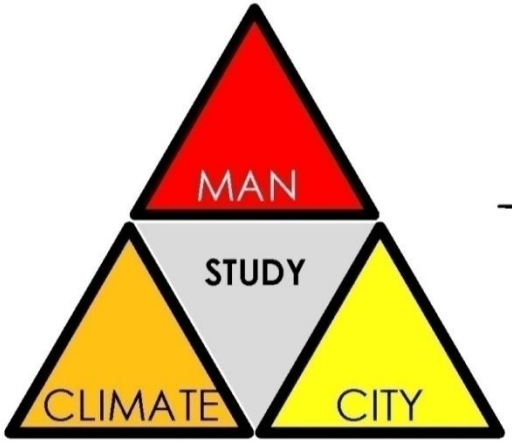


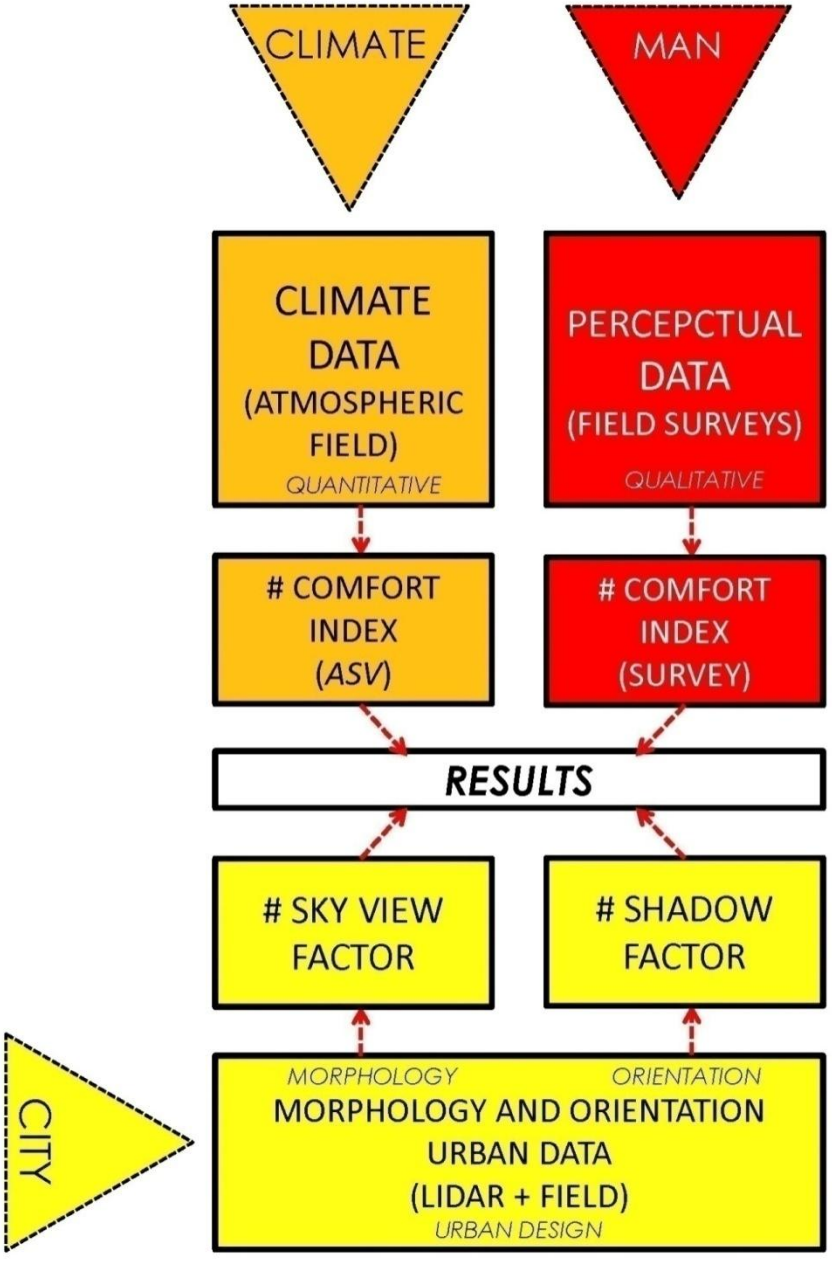
Each canyon will be divided into three control points; A, B, and C. This allows more accurate recording of the roughness and temperature differences of each canyon.

Figure: selected canyons, fish eye image and urban location.
Source: author.

*5.1_* Methodological structure

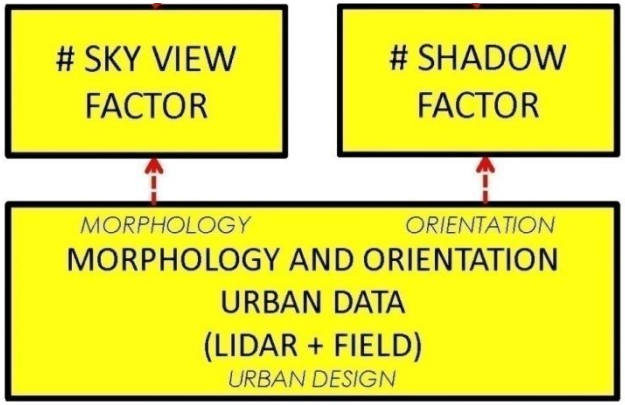
Each unit is coded with an indicator in order to be able to use simple statistical processes, which is the correlation of the variables and the representation of their results in 2D maps.





5_METHODOLOGY

*5.2_* Methodological stages



1_3D Modelling Urban Canyons

This purpose generates two indicators, **the shadow factor** wich is related to the orientation and the **Sky View Factor**, related to the shape and proportion of each canyon.

The use of 2d images is insufficient for classification and study of urban components (Guan *et al,* 2012).

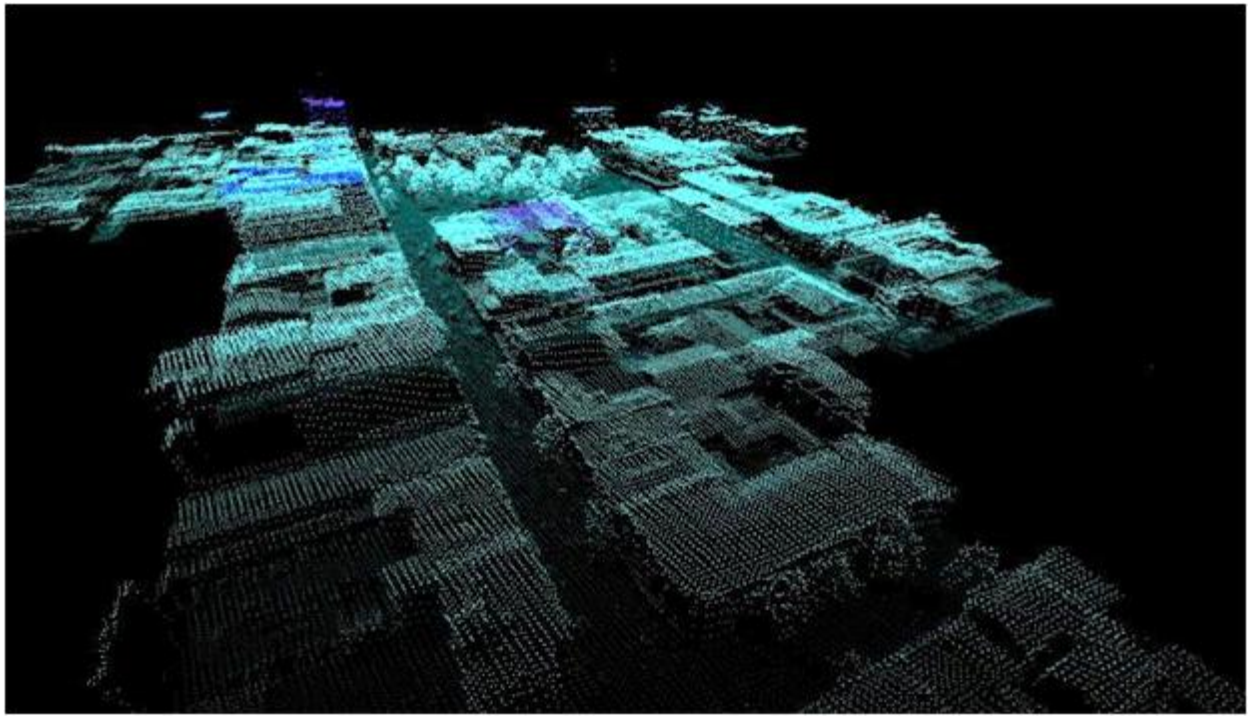
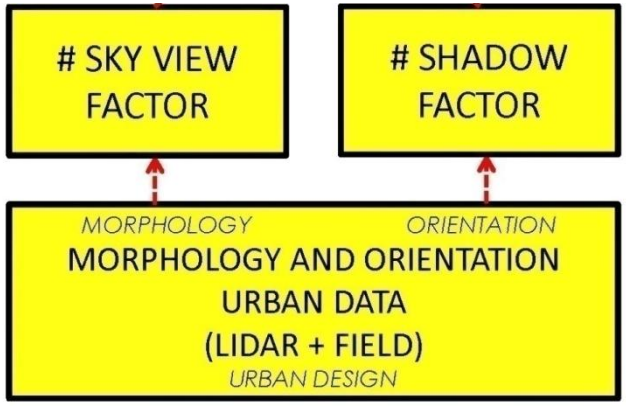


Figure: LIDAR data by Digimapas, 2012.
Density of 1-20 points per m2.
Source: author.

5_METHODOLOGY

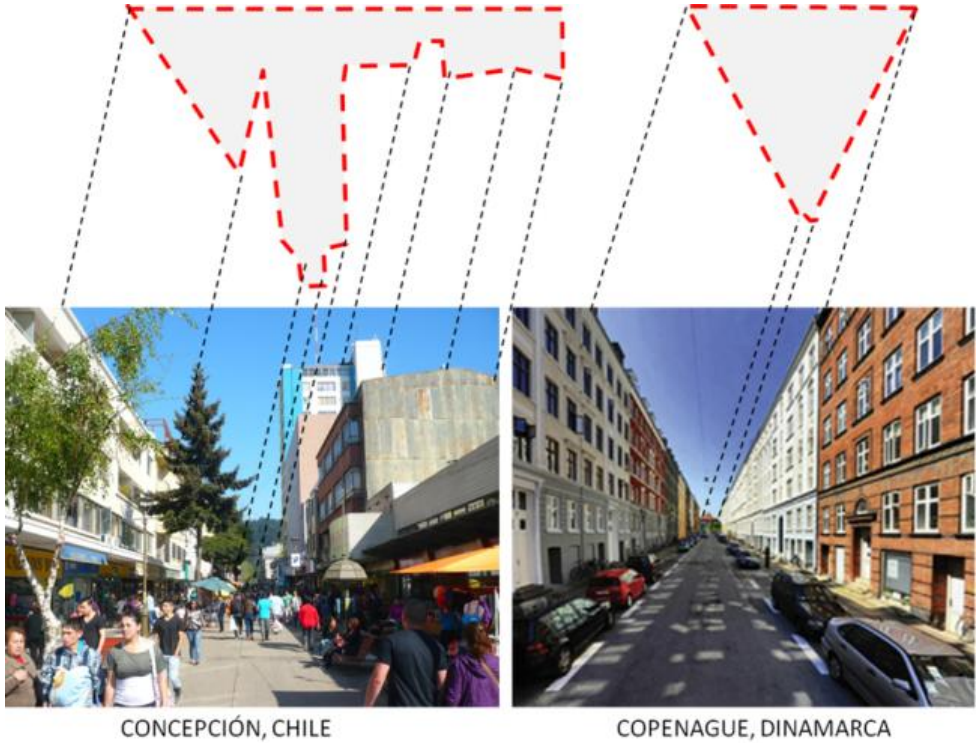
*5.2_* Methodological stages



1_3D Modelling Urban Canyons

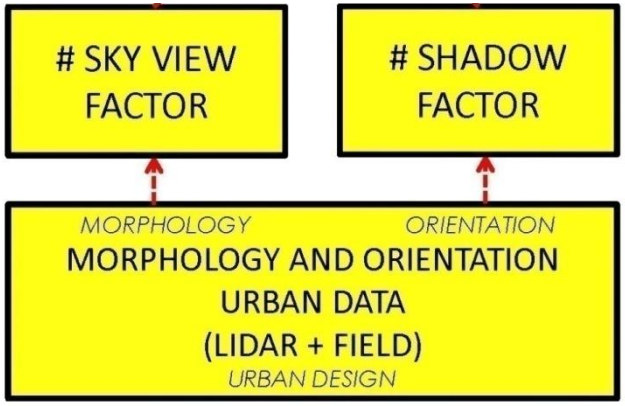
The fish eye photographic technique is particularly suitable for determining in real cases SVF that should consider several sizes and proportion of the constructions.
(Grimmond *et al,* 2001; Gal *et al*, 2007).

Figure: shot fish eye images in terrain.
Source: Henriquez and Lamarca (2013)



5_METHODOLOGY

*5.2_* Methodological stages



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5_METHODOLOGY

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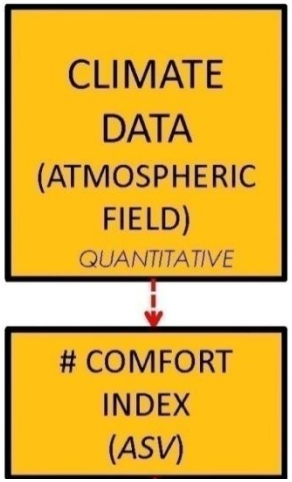


2_Quantitative modelling the thermal comfort (actual sensation vote)

ASV = (0,049 T° air) + (0,001 Rad) – (0,051 Vel v.) + (0,014 HR) – 2,079

(T ° air) = air temperature (in ºC)
(Rad) = solar radiation (in watt per square meter)
(V Vel.) = wind speed (in meters per second)
(HR) = relative humidity (as a percentage)

Nikolopoulou *et al*, (2004)

UNIDADES	T° AMBIENTE	HUMEDAD RELATIVA	VELOCIDAD VIENTO
	° CELSIUS	%	M/S

CAÑON	Nº	DIRECCION
	1	**BARROS ARANA**, ENTRE LINCOYAN Y RENGO

	HORA	T° AMBIENTE			HUMEDAD RELATIVA			VELOCIDAD VIENTO		
		A	B	C	A	B	C	A	B	C
MAÑANA	9:52	23,7	24	25	48,9	46	26,3	1,3	2,1	3
TARDE	14:07	23,3	20,5	20	58,5	66,2	70,9	1,7	4,1	4,9
NOCHE	21:47	21,4	21,5	20,8	59,1	60,8	61,4	0,7	0	0,9

CAÑON	Nº	DIRECCION
	2	**BARROS ARANA**, ENTRE CAUPOLICAN Y RENGO

	HORA	T° AMBIENTE			HUMEDAD RELATIVA			VELOCIDAD VIENTO		
		A	B	C	A	B	C	A	B	C
MAÑANA	9:55	25,5	24,9	24,3	50,2	48,8	52	0	0	2,6
TARDE	14:06	19,9	20,2	20,5	56,5	56,1	56,9	6	3,4	3,2
NOCHE	21:48	20,8	21,4	22,2	60,3	59	54,9	1,5	1,3	0,3

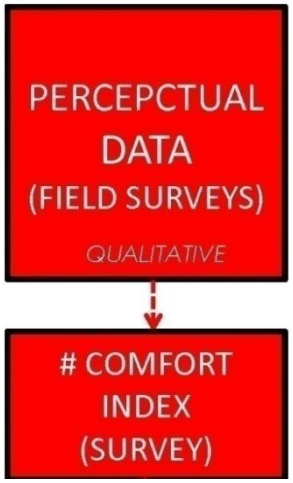
CAÑON	Nº	DIRECCIÓN
	3	**RENGO**, ENTRE BARROS ARANA Y O`HIGGINS

	HORA	T° AMBIENTE			HUMEDAD RELATIVA			VELOCIDAD VIENTO		
		A	B	C	A	B	C	A	B	C
MAÑANA	9:50	24,9	25,3	25,5	47	46,5	40	0,8	1,1	1,3
TARDE	14:00	21,4	21,2	23,3	56,5	56	54	3	3,1	2,6
NOCHE	21:45	22,7	21	21,4	52,6	58	58,9	1,4	1,6	0,8

Figure and Table: Image and table of atmospheric data recorded in the field.
Source: author.

5_METHODOLOGY

*5.2_* Methodological stages



3_Qualitative modelling thermal comfort *(perception surveys)*

Authors such as Cheng (2008), Nikolopoulou et al (2004) and Mayer et al (2008) mention **the importance of human thermal comfort in studies** of urban micro climate.

ENCUESTA CONFORT TÉRMICO EN CAÑONES URBANOS (FONDECYT 1130305)			
LUGAR: CONCEPCIÓN, CHILE		**FECHA:** 14 Y 15 ENERO 2014	
CAÑÓN Nº:			
PTO. DE CONTROL:	A	B	C
HORA:	:		
ENCUESTADOR:			
ENCUESTADO			
EDAD:		**SEXO:**	M / F
CONTEXTURA: H: W:	DELGADO.1	NORMAL.2	ROBUSTO.3
VESTIMENTA:	POCA.1	NORMAL.2	MUCHA.3
USUARIO:	TRABAJADOR.1	VISITANTE.2	TURISTA.3

	-2	-1.5	-1	-0.5	0	0.5	1	1,5	2
1- SENSACIÓN TÉRMICA: ¿COMO SE SIENTE USTED RESPECTO DEL CALOR Y EL FRÍO?	MUCHO FRÍO				BIEN				MUCHO CALOR
2- EXPOSICIÓN AL SOL: ¿CÓMO SIENTE LA EXPOSICIÓN AL SOL?	QUIERO MÁS SOL				BIEN				MUCHO SOL
3- VELOCIDAD DEL VIENTO: ¿CÓMO SIENTE LA VELOCIDAD DEL VIENTO?	MUY POCO VIENTO				BIEN				MUCHO VIENTO
4- HUMEDAD DEL AIRE: ¿CÓMO SIENTE LA HUMEDAD EN EL AIRE?	MUY SECO				BIEN				MUY HUMEDO
5- SUDOR DE LA PIEL: ¿CÓMO SIENTE SU PIEL CON RESPECTO AL SUDOR?	MUY SECO				BIEN				MUY SUDADO
6-CONFORT GENERAL: ¿CÓMO SE SIENTE RESPECTO A LA TEMPERATURA?	FRÍO MUY INCONFORTABLE				CONFORTABLE				CALOR MUY INCONFORTABLE
OBSERVACIONES:									

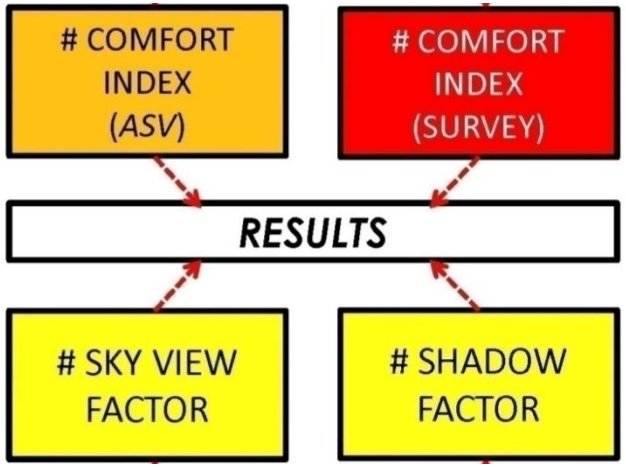
Table: survey of thermal comfort.
Source: modified from Cheng (2008).

Figure: survey of thermal comfort in the field.
Source: author.

*5.2_* Methodological stages

4 - 5_Compare & graph the results

This step was made to simplify the information recorded by the atmospheric and perceptual data, normalizing it to correlate these scales in between 0 to 1.
(Correlation coefficient)

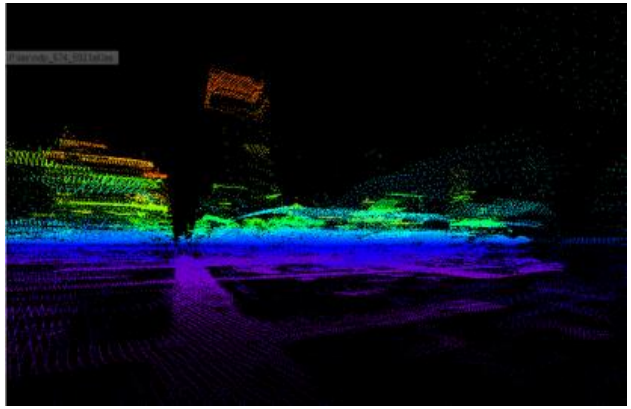


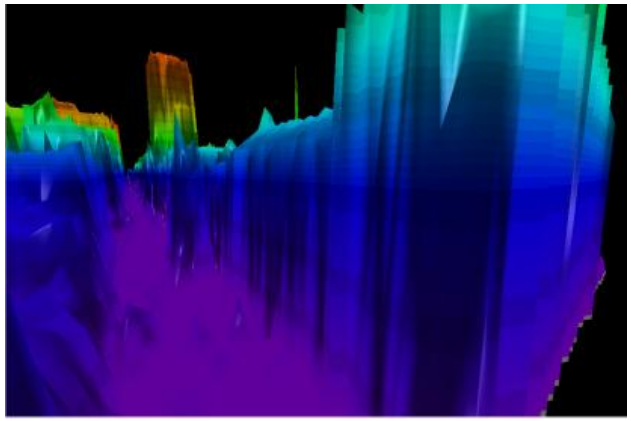
This work was performed with data recorded in field, to which was applied an IDW interpolation (distances) and finally a polygon normalized in values between 0 and 1 for each canyon. **(ASV and Surveys Mapping).**

6_RESULTS

6.1_ **Urban results** (orientation = shadow factor)

From LIDAR data to simple 3ds model for Ecotect.





NO

NO

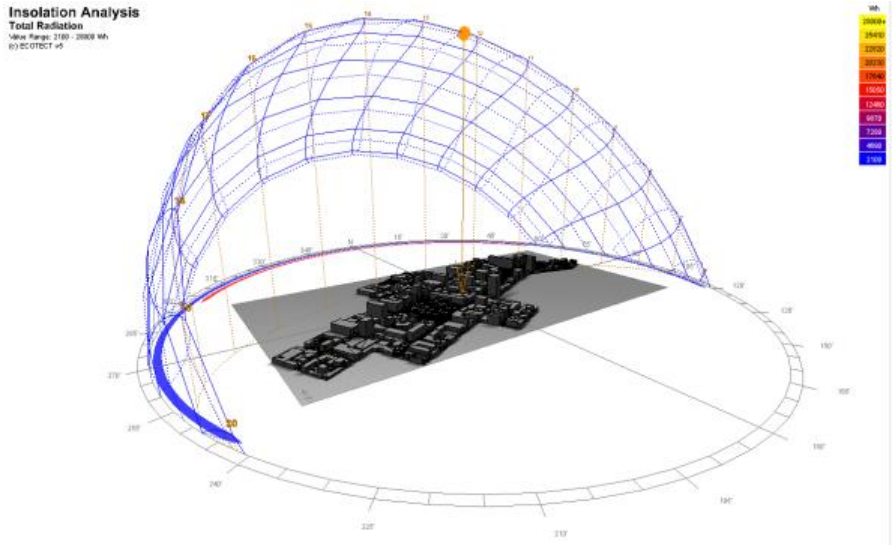
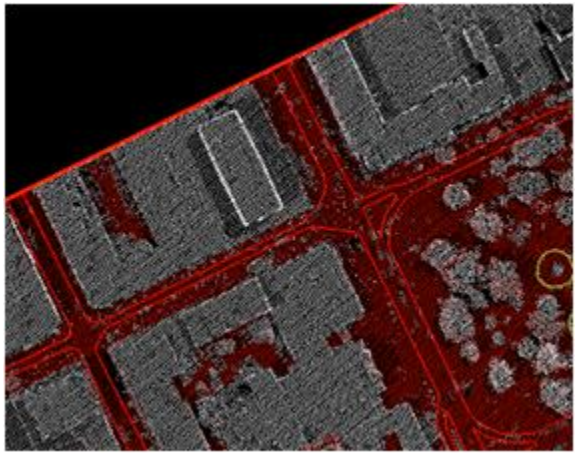


Figure: 3D modeling problems. Source: author.

6_RESULTS

*6.1_* **Urban results** (orientation = shadow factor)

3D modelling sequence…

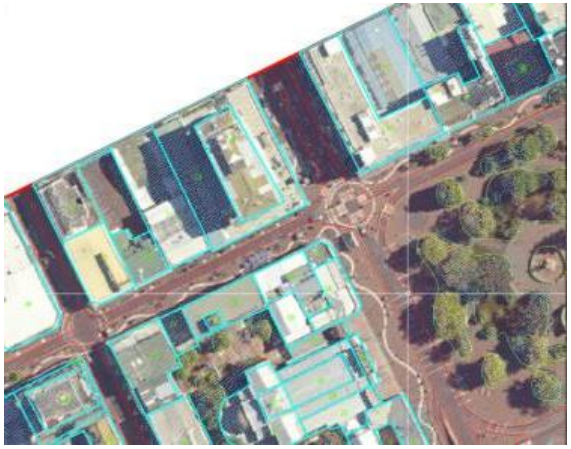


CLOUD POINT(CP) IN AUTOCAD

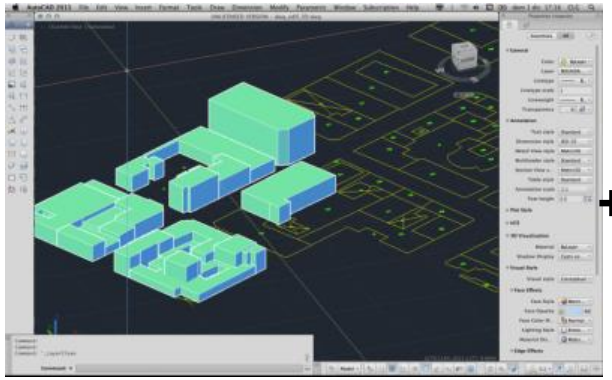
+

CP + RASTER, AUTOCAD

+

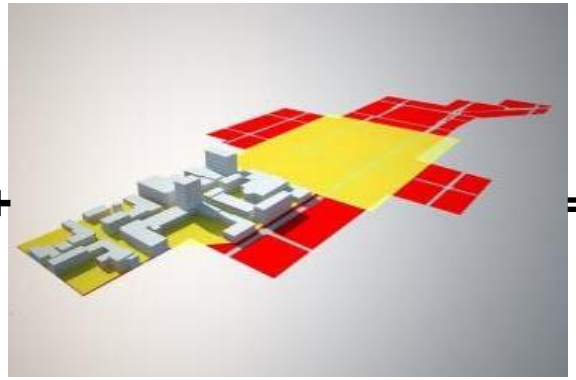


CP + RASTER + 2D POLYGONS, AUTOCAD



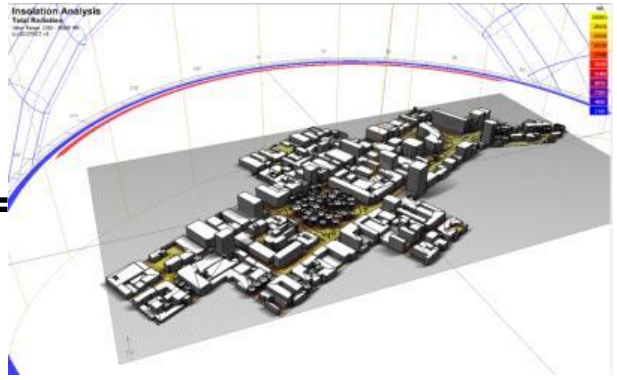
EXTRUSION OF EACH POLYGON WITH Z DATA, AUTOCAD

+



COMPOSITION AND DISPLAY, SKETCHUP PRO

=



ECOTECT ANALYSIS

Figure: 3D modeling sequence. Source: author.

*6.1_* **Urban results** (orientation = shadow factor)

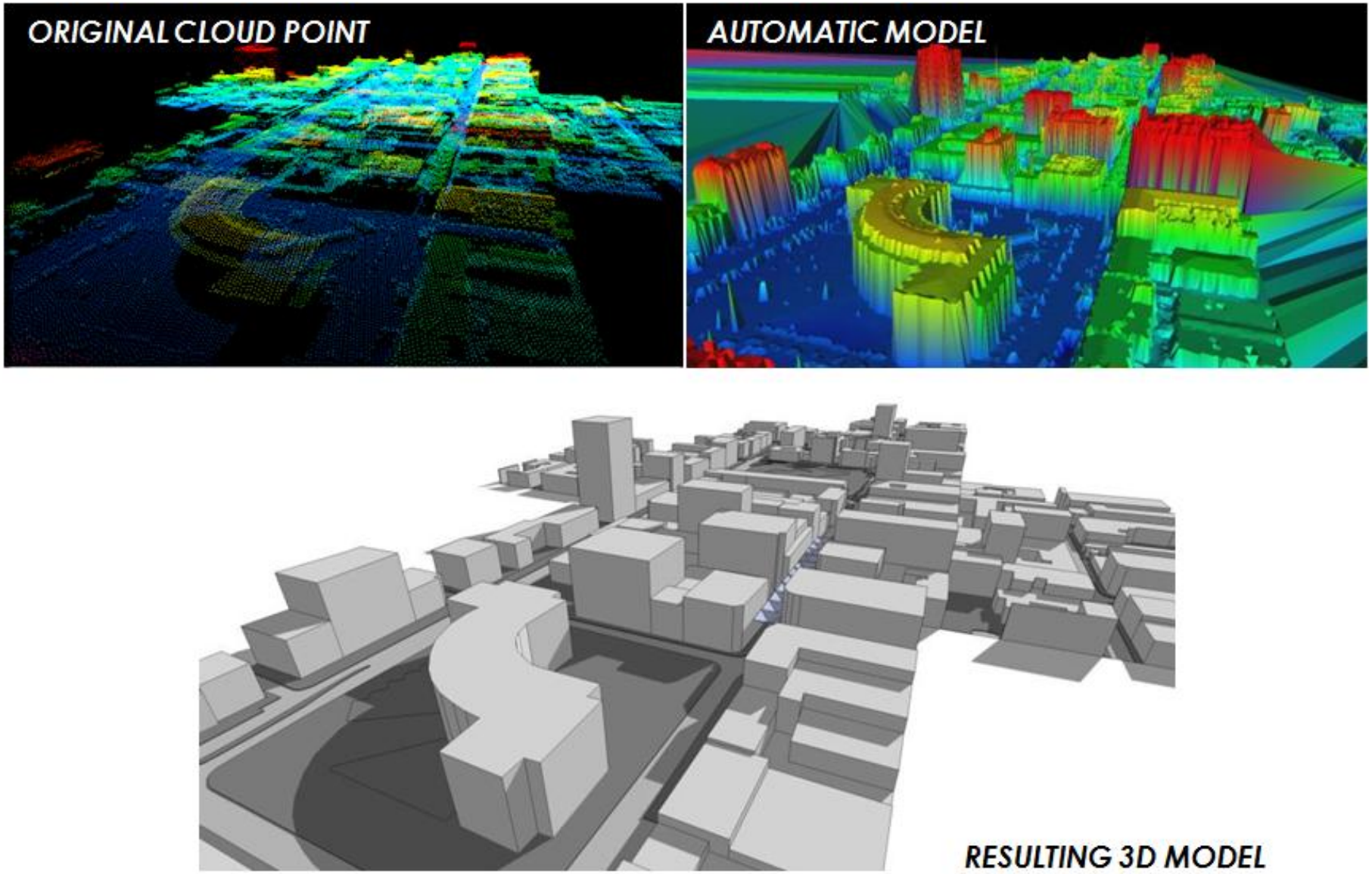


Figure: resulting 3D model from the LIDAR data. Source: Author.

6_RESULTS

*6.1_* **Urban results** (orientation = shadow factor)

The transverse (NW-SE) canyons are more shaded than the longitudinal (SW-NE) canyons.

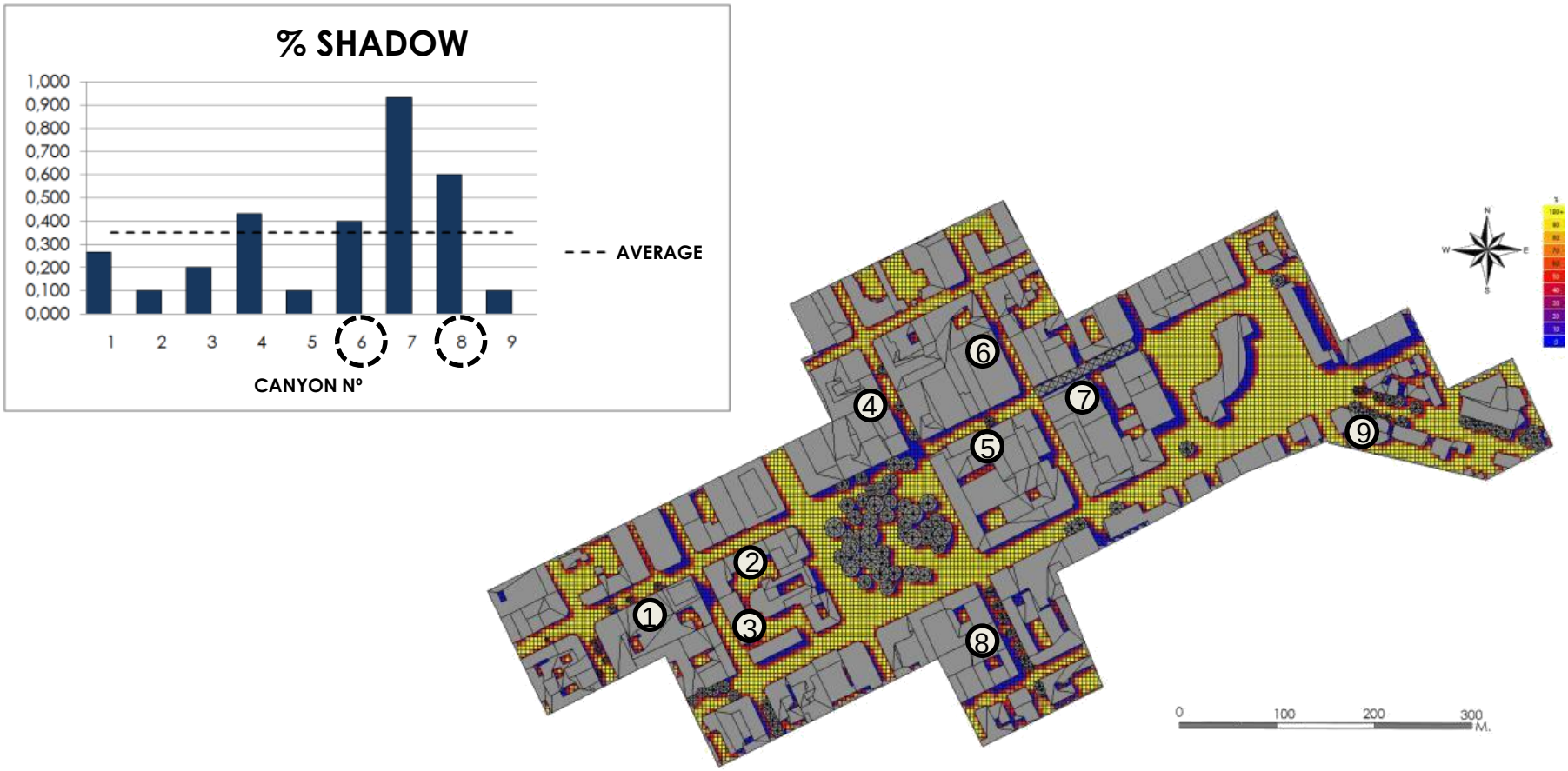


Figure: shadows mapping. Source: authors

6_RESULTS

*6.1_* **Urban results** (orientation = shadow factor)

"Winter street":
Barros Arana 2009 - 2010

"The Tulipas" project was designed with the intention of improving public space in winter, but it had a negative effect on the citizens by not considering all climatic, urban and social conditions.

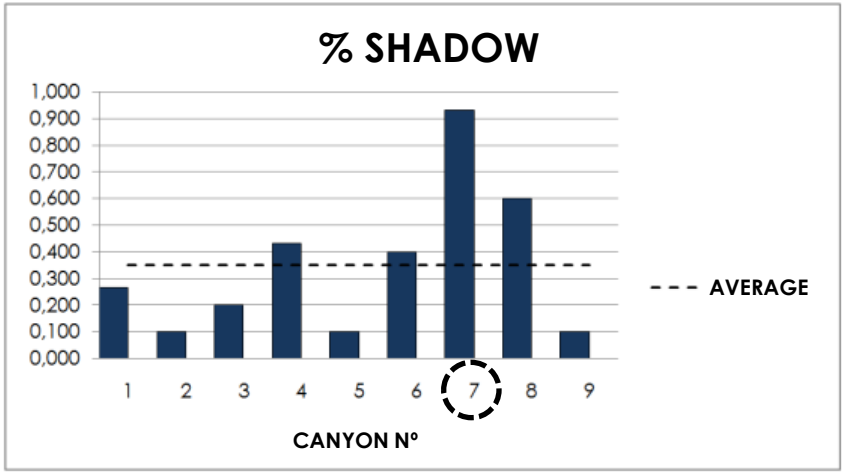


Figure: Intervention "The Tulipas" pedestrian street, canyon N°7.
Source: author.

6_RESULTS

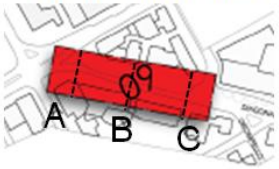
*6.1_* **Urban results** (morphology = sky view factor)

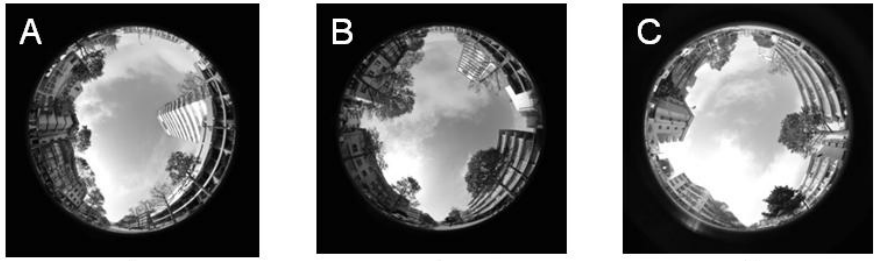
For obtain the SVF was used the method of the fisheye photography.
Grimmond et al (2001); Gal et al (2007), Chen (2013)

CANYON Nº9

CANYON	Nº	ADRESS	SVF		
			A	B	C
	9	DIAGONAL PEDRO AGUIRRE CERDA, ENTRE O`HIGGINS Y OROMPELLO	0,687	0,72	0,746
			prom	0,717	

LOCATION





FRONT VIEW

Factor 1 represents a completely open space

0 factor represents a fully enclosed space

Figure: Table for canyon No.9

Source: author.

6_RESULTS

*6.1_* **Urban results** (morphology = sky view factor)

For obtain the SVF was used the method of the fisheye photography.
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CANYON Nº9

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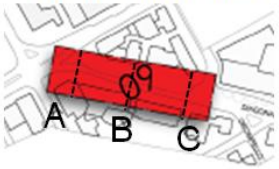
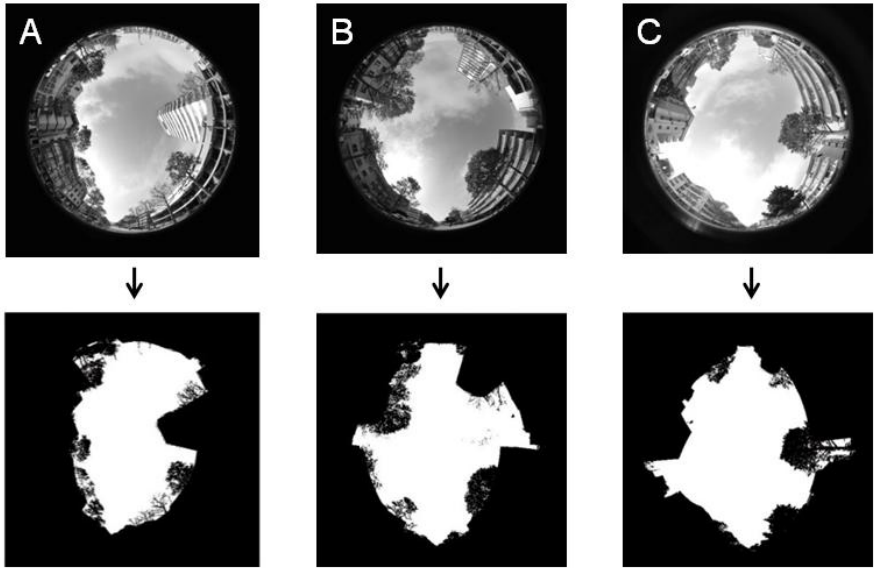




FRONT VIEW

Figure: Table for canyon No.9

Source: author.

Factor 1 represents a completely open space

0 factor represents a fully enclosed space

*6.1_* **Urban results,** technical especification for each canyon (morphology = sky view factor)

Source: author.

Figure: Tables for the 9 canyons

6_RESULTS

*6.1_* **Urban results** (morphology = sky view factor)

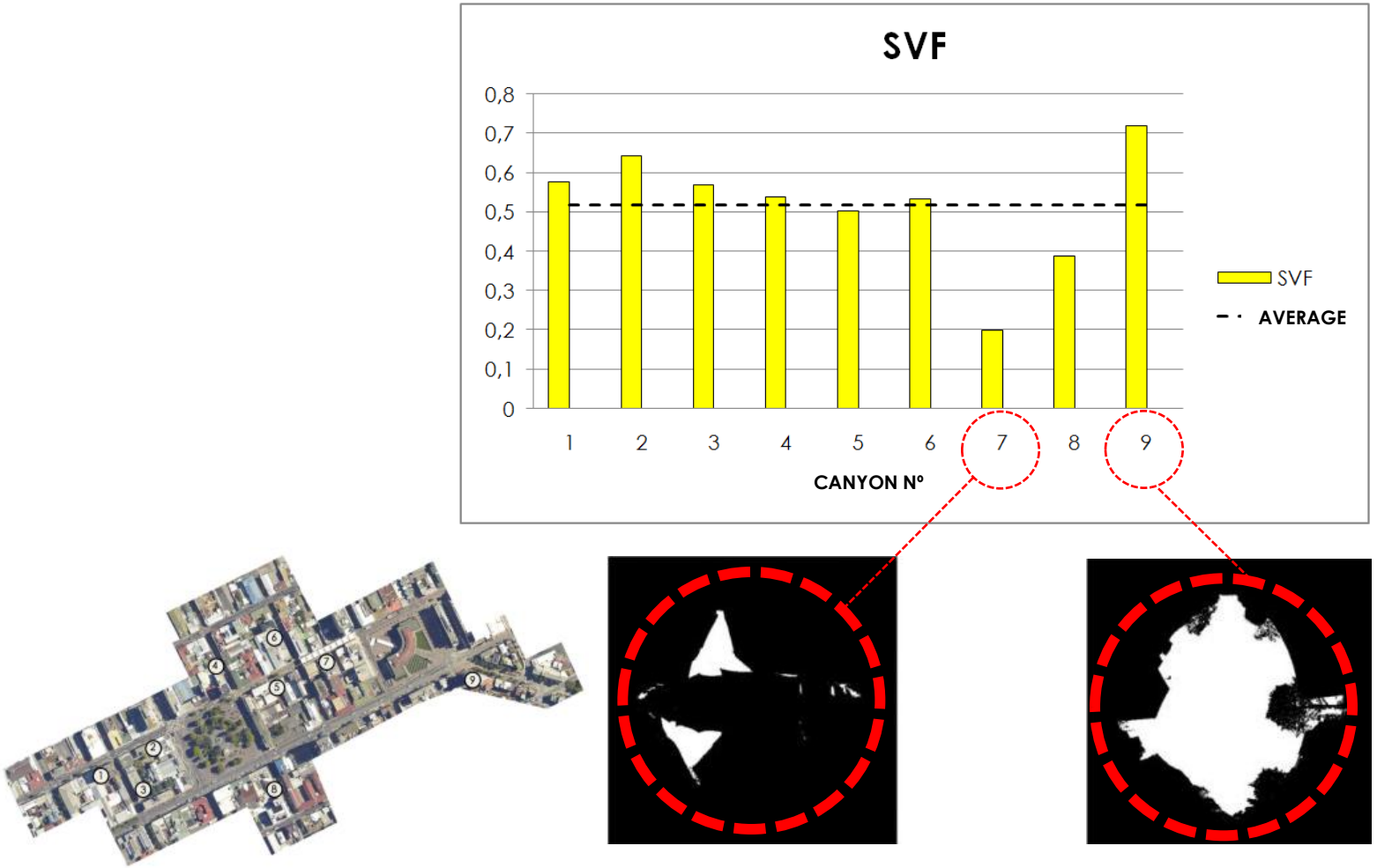


Figure: Results of Sky View Factor, results.
Source: author.

6.2_Physical thermal comfort results (ASV)

	TIME	AIR T° (°C)			RELATIVE HUMIDITY (%)			WIND SPEED (M/S)			RADIATION (Wh/m2)		
		A	B	C	A	B	C	A	B	C	A	B	C
MORNING	10:16	25,8	25,2	25,8	37,7	37	38	1,3	1,8	0,7	286	267,3	377
AFTERNOON	13:40	22,9	22,5	25	58,5	59	49,4	2,5	6,2	2,3	214,8	205,3	299,4
NIGHT	22:07	20,4	20,6	20,7	64,1	68,5	67,9	1	1	1,5	0	0	0

Results obtained for the values of solar radiation, these values are recorded and applied to the ASV formula.

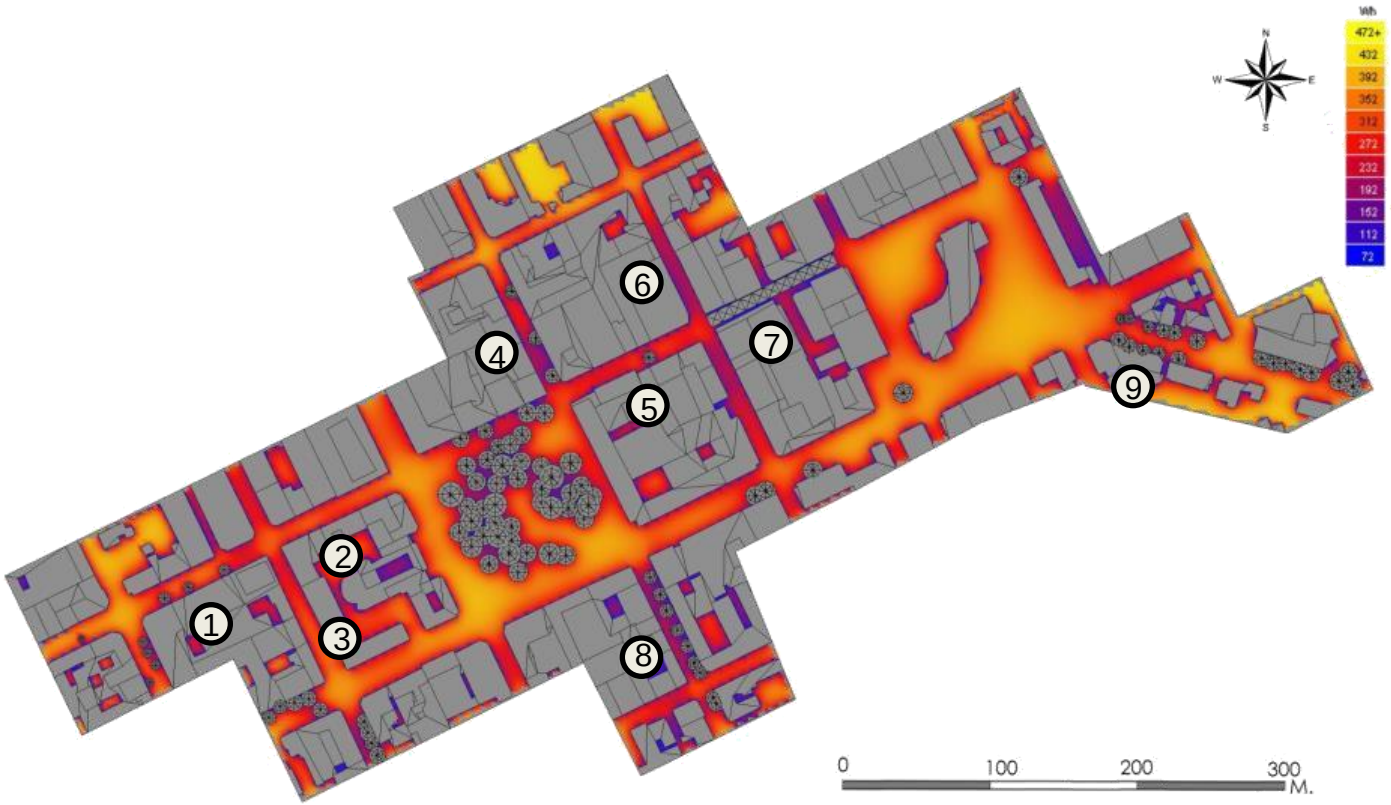


Figure: mapping of solar radiation (direct and diffuse) for January 14 at 14.00hrs.
Source: author.

6.2_Physical thermal comfort results (ASV)

Values of ASV for comfort in each canyon.
This result will be correlated with the perceptual results.

Figure: Mapping of thermal comfort according to the ASV formula Nikolopoulou et al, (2004).
Source: interpolation from John Treimun (2014) Developed by author.

The canyons with longitudinal axis (SW-NE) have more discomfort **(Future Bicentennial axis)**

It is also observed that near the square ends it is less comfortable.

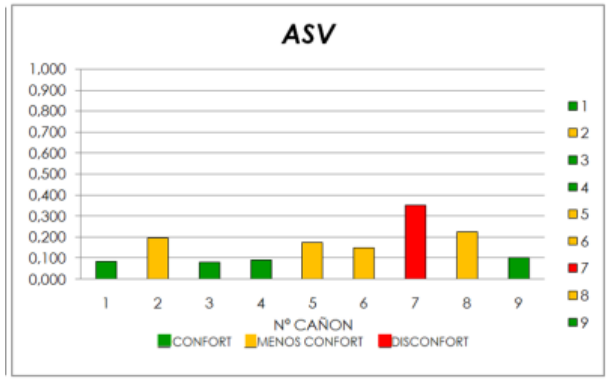


Figure: the values of thermal comfort ASV formula by Nikolopoulou et al (2004).
Source: author.

6.3_Perceptual thermal comfort results (Surveys)

Values of surveys comfort in each canyon.

Figure: mapping of perceptual thermal comfort.
Source: interpolation from John Treimun (2014) developed by author.

Again, the canyons with longitudinal axis (SW-NE) have more discomfort **(Future Bicentennial axis)**

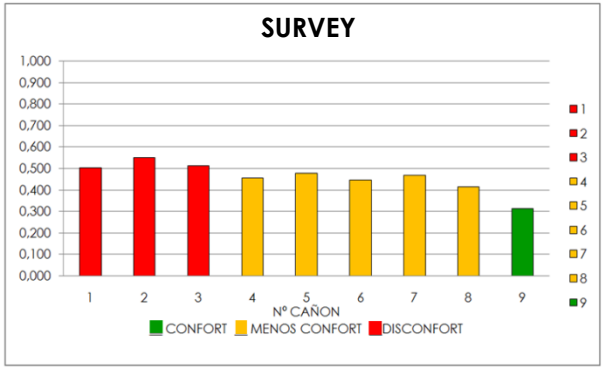


Figure: the values of perceptual thermal comfort.
Source: author.

6.4_Interpretation of correlations between data of urban design, the formula of physical data and the perception of the people.

CITY

CLIMATE

MAN

CORRELATION MATRIX

	SVF	SHADOW C.	ASV	SURVEY
SVF	1			
SHADOW C.	-0,907	1		
ASV	-0,815	0,714	1	
SURVEY	-0,129	-0,059	0,072	1

Table: correlation matrix results.
Source: author.

· The higher SVF represents lower shaded surfaces.

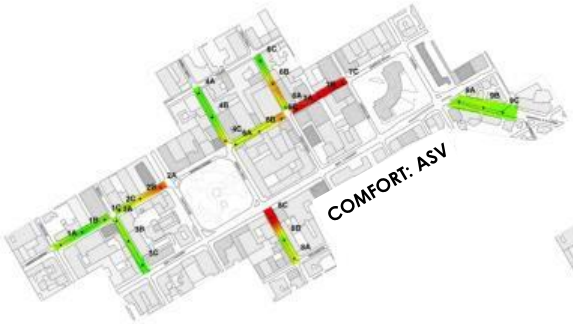
· There is a strong correlation between ASV comfort and City aspects
- more SVF = more comfortable
- more shadow = less comfortable

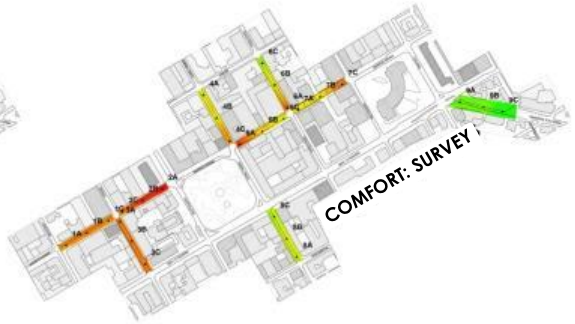
· Comfort models generated only on numerical data do not necessarily represent reality, there is no correlation between ASV and survey.

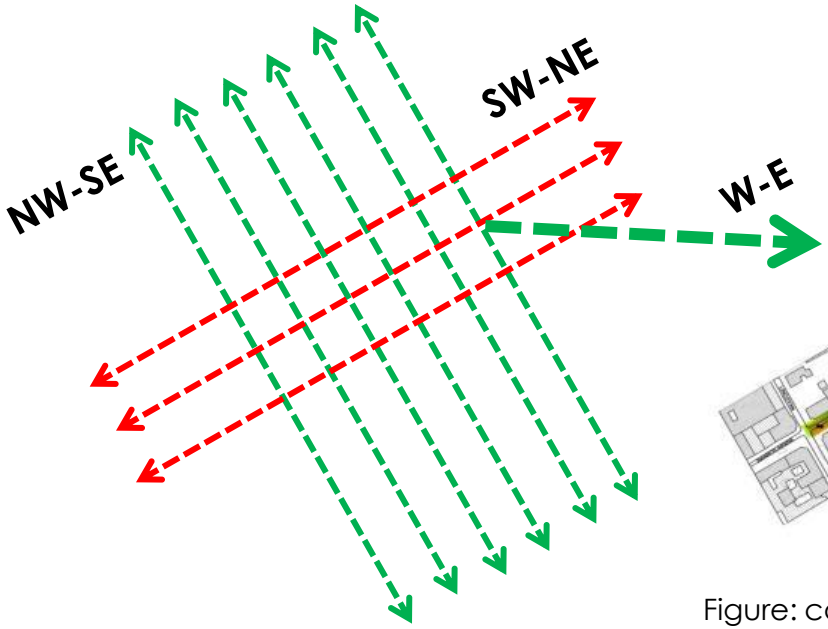
6.4_Interpretation of correlations between data of urban design, the formula of physical data and the perception of the people.

· The two models show a tendency to perceive **better thermal comfort in transverse cannons (NW-SE).**

· the best comfort in both models is represented by the diagonal canyon (W-E).







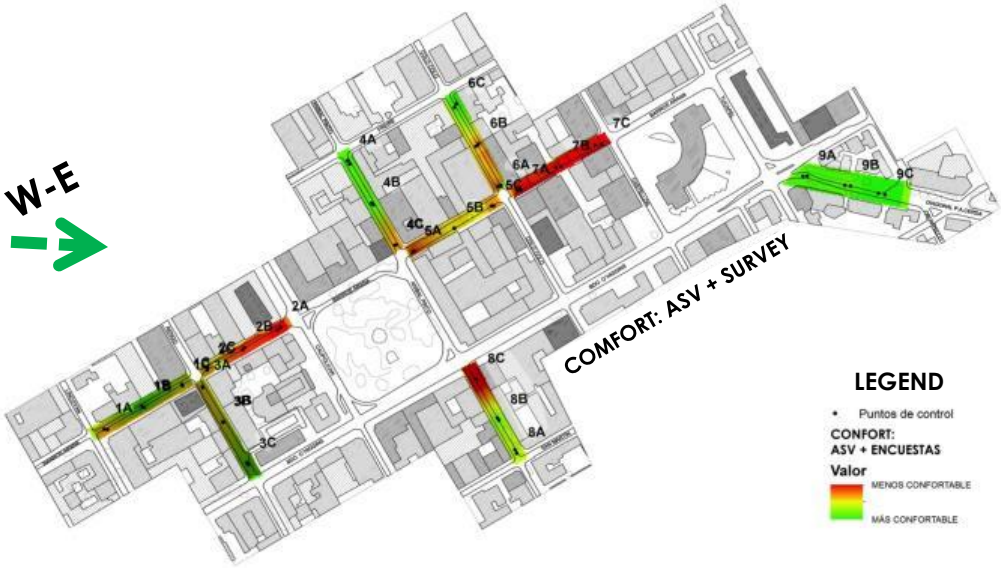


Figure: comparison of physical and perceptual model.
Source: author.

6_*RESULTS*

summary sheet

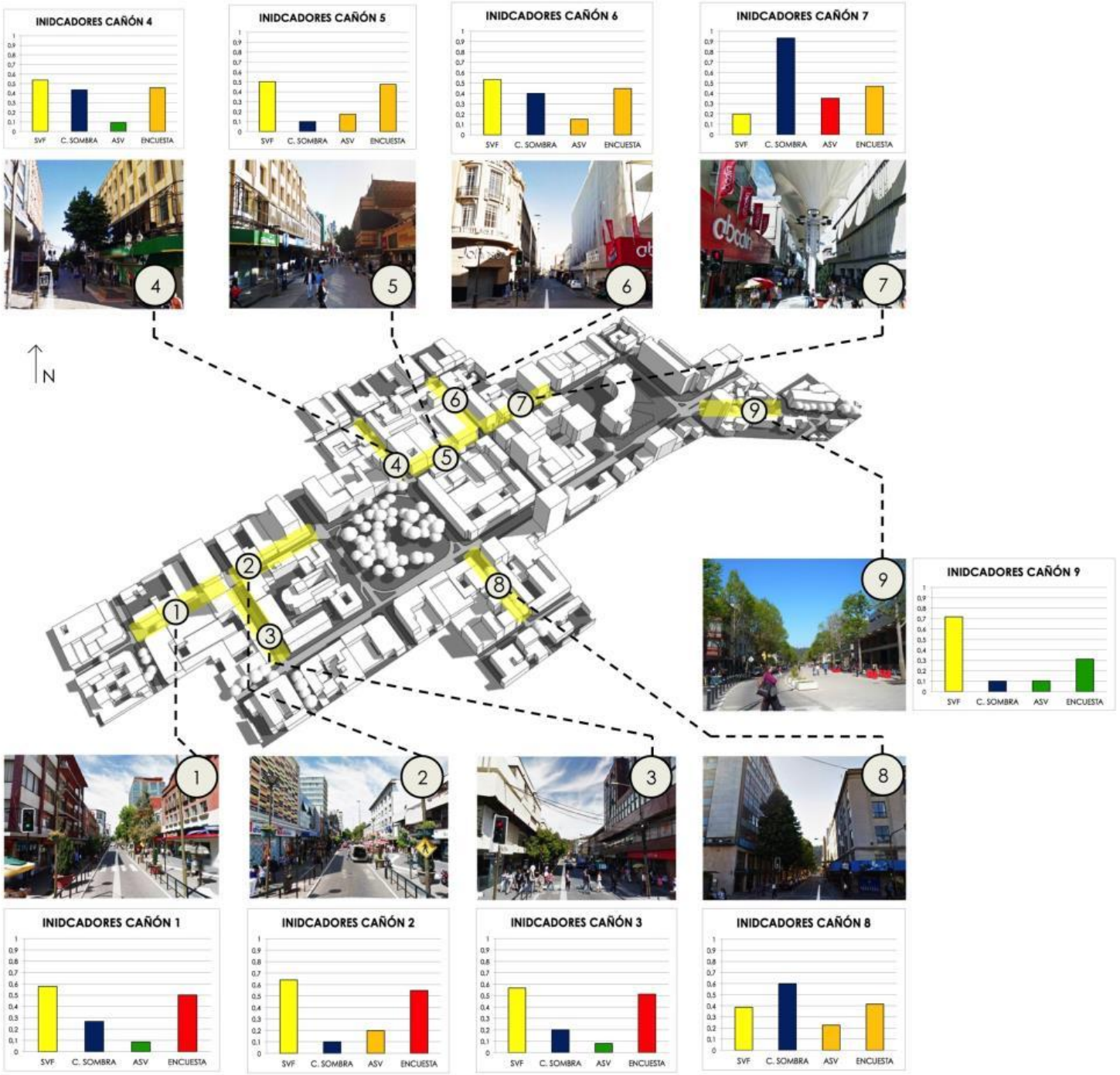


Figure: mixed results, urban, physical and perceptual indicators.
Source: author.

7_FINAL CONSIDERATIONS

· This type of result is useful for urban designers because the proper planning and careful design in urban areas can provide protection against the negative aspects and exposure to positive aspects of climate, therefore, increase the use of outdoor space all year (Nikolopoulou *et al*, 2004).

· **It is recommended to replicate the work during the winter**

7_FINAL CONSIDERATIONS

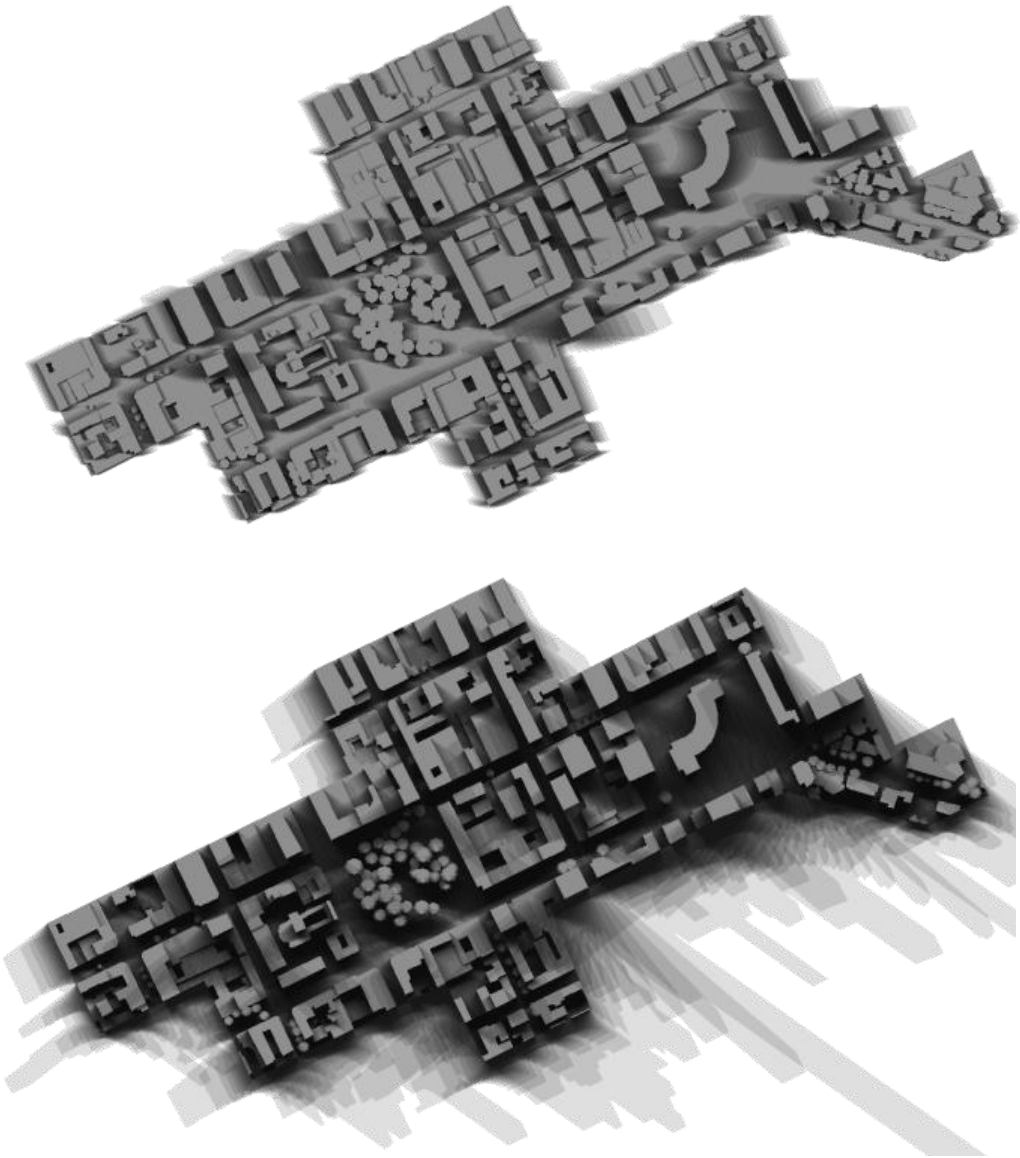


Figure: projection of shadows into the metropolitan center of Concepcion on a summer day and a winter day.
Source: author.

· To be able to deliver some of the possible results in winter, the 3D model was used to draw the shadow cones generated during a day in summer (January 14) and a day in winter (July 8).

· As stated before, the canyons in transverse direction (NW-SE) have better thermal comfort in summer and are also more exposed to sunlight during the winter, due to the blockage of sun exposure by the buildings for the canyons in SW-NE direction.

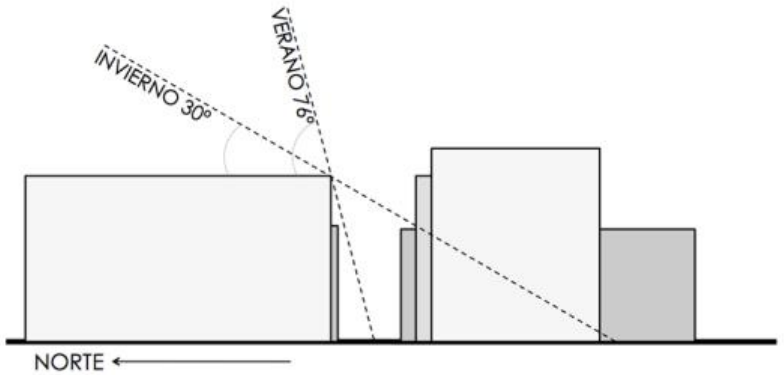


Figure: cross cutting Barros Arana street (SW-NE direction).
Source: author.

7_FINAL CONSIDERATIONS

Finally it is recommended to generate more canyons with the features of canyon No. 9; Orientation W – E; streets proportions where the street width is twice the height of buildings and in each sidewalk have a lateral row of deciduous trees.

Figure: picture of canyon N.9 Diagonal Pedro Aguirre Cerda
Source: author.

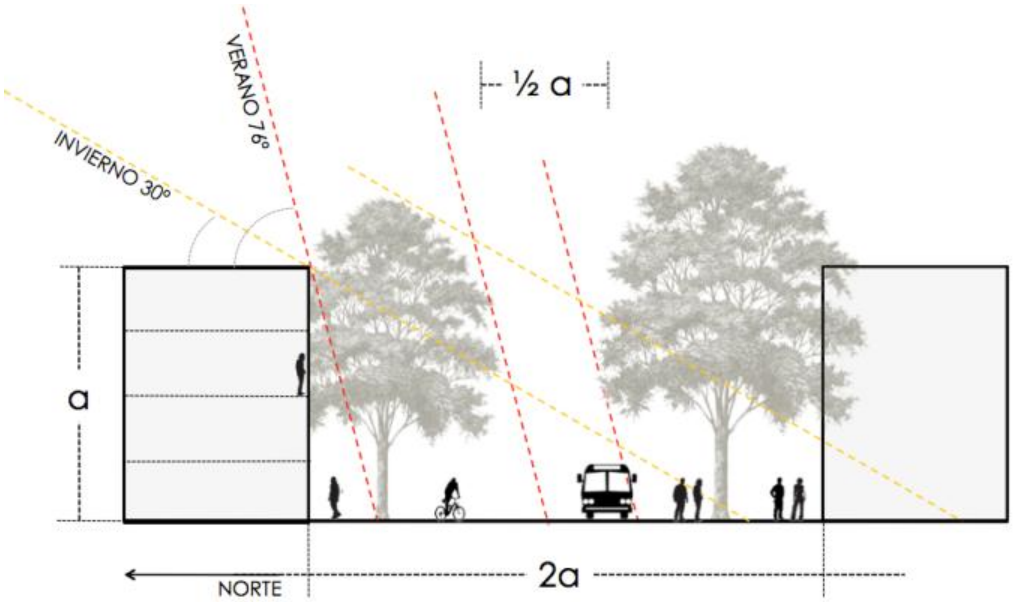


Figure: cross cutting of the canyon No. 9 , the most comfortable in the two models analyzed.
Source: author.

END

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_ ACKNOWLEDGMENTS

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