

# Thermal Comfort and Occupant Perception in Dwellings for the Low-Income Sector in Hot Climates of Mexico

ROMERO, R.<sup>1</sup>, VAZQUEZ, E.<sup>1</sup>, BOJORQUEZ, G.<sup>1</sup>, VALLADARES, R.<sup>2</sup>, MARINCIC, I.<sup>3</sup>,  
GOMEZ, C.<sup>4</sup>, MACEDO, J.<sup>5</sup>, POIJOL, F.<sup>6</sup>, ESTRADA, J.<sup>7</sup>

<sup>1</sup> Faculty of Architecture and Design, Autonomous University of Baja California, Mexicali, Mexico

<sup>2</sup> Faculty of Architecture and Design, University of Colima, Colima, Mexico

<sup>3</sup> School of Architecture, University of Sonora, Hermosillo, Mexico

<sup>5</sup> University Veracruzana, Veracruz, Mexico

<sup>6</sup> Department of Fishing Engineering, Autonomous University of Baja California Sur, La Paz, Mexico

<sup>7</sup> Faculty of Architecture, Autonomous University of Sinaloa, Culiacan, Mexico

**ABSTRACT:** *These are the results of a field study about the physical characteristics of dwellings for low income people and their perception as residents about the thermal and space conditions reported over the housing operation. The study was made through surveys applied in seven cities with hot-dry and hot-humid climate in Mexico. Results show that the system of dwelling construction is similar, even though weather conditions where they are built may be different. There is overcrowding in these dwellings and in most cases little or no thermal comfort at all during summer or winter is reported.*

**Keywords:** *Low- income dwelling, occupant's perception, thermal comfort, hot climate.*

## INTRODUCTION

In Mexico, during the last decade the economic dwelling construction has been subsidized to help low-income families. This has helped to decrease the existing dwelling deficit. The demand has been met; however, the quality of this kind of dwellings has been affected by the building and urbanization costs. The problematic of the spatial conditions for the user gets worse when it is constructed on warm climate places, because of the humidity and high temperatures that create uncomfortable thermal conditions for the residents.

This research has been trying to identify the way the low-income dwelling works when inhabited. To determine in which way it responds to the needs of the residents in the different zones of the country. The post occupation evaluations allows identifying mistakes and make the most out of the results for future constructions of the same type.

Some studies show investigations that have allowed evaluating the habitability conditions in the dwelling, placed in different climatic conditions [1]. These studies were done through surveys, observations, calculation and simulation. In México there are no studies evaluating the habitability the dwellings for low-income families, particularly located in hot and warm climate.

The study is a part of the project “Thermal Comfort and Energy Saving in the Economic Dwellings in México: Hot-dry and Hot-humid climates” sponsored by the National Council for Housing and the National Council for Science and Technology [2].

## METHOD

The research consisted of a field study, based on surveys applied to the residents of low income dwellings of seven cities located in hot and warm regions of the country (Fig. 1).



Figure 1: Localization of cities, México

The study cities were Mexicali, Hermosillo and La Paz, these cities had hot-dry climate; Culiacan and Colima had warm sub-humid climate; and, Merida y Veracruz had hot-humid climate. The complete data of localization of the seven cities is shown in Table 1 and the climate is shown in Table 2.

Table 1: Localization of cities

City	Latitude	Longitude	Altitude *
Mexicali	32°39'54" N	115°27'21" W	4
Hermosillo	29°04'23" N	110°57'33" W	200
La Paz	24°08'05" N	110°20'10" W	16
Mérida	20°59'00" N	89°38'00" W	22
Veracruz	19°12'00" N	96°08'00" W	16
Colima	19°12'50" N	103°43'21" W	433
Culiacán	24°49'00" N	107°25'00" W	40

\*meters over the sea level

Table 2: Climate of cities, Mexico.

Climate	Cities	Annual temperature <sup>1</sup> (°C)		Relative humidity <sup>1</sup> (%)	Rainfall <sup>1</sup> (mm)
		Max mean	Min mean		
Hot-dry	Mexicali	33.9	13.0	45 <sup>3</sup>	84
	Hermosillo	32.3	16.4	43	320
	La Paz	30.0	16.5	62	183
Hot-humid	Merida	28.0	23.0	72	957
	Veracruz	28.2	21.5	79	1071
Warm sub-humid	Colima	27.3	22.9	67	885
	Culiacan	29.7	19.0	68	615

<sup>1</sup>Servicio Meteorológico Nacional, Normales Climatológicas 1971-2000, México [3]

<sup>2</sup> Dirección General del Servicio Meteorológico Nacional, Normales Climatológicas, Período 1941-1970, México, 1982. [4]

<sup>3</sup> Departamento de Meteorología, UABC, Mexicali, 2006.

In each city, the subjects of study are the housings of the program for low-income dwelling (Fig. 2).



Figure 2: Low-income dwelling, Mexico

This type of dwelling was posted for families whose monthly income was up to 3.9 times the minimum wage and the construction of dwelling should be under a cost of less than 117.0631 times monthly minimum wage \$187,152.99 Mexican pesos on 2008 [5].

The study sample was designed by the amount of housing built in each city. The sample was designed with a confidence level of 95% and a 5% of estimate precision. The survey was applied during 2006. The periods of application and the size of the sample are shown in Table 3. Four handbooks were written: "Directions for Project Managers in Each City", "Directions for Pollsters", "Surveying Directions (field)" and "Directions for Data Recording".

Table 3: Size of the sample and periods of application field study, 2006, Mexico

	Sample (housings)	Period (2006)
		March-April; June-July
Mexicali	372	
Hermosillo	370	March
La Paz	196	March
Merida	406	July-August
Veracruz	389	Julio-August
Culiacan	298	October
Colima	351	July-August
Total	2382	

The application of the survey was handled in each city. Colima, Hermosillo, Veracruz and Mérida hired a survey company while La Paz, Mexicali and Culiacan, trained a group of Architecture students.

The characteristics identified in this study were the typology of construction, as well different actions taken

by the occupants to protect the house from the climate, and modifications made to the building and information about occupants. Also were studied the usage pattern of air conditioning equipment and appliances. The subjective aspects investigated were the perception of thermal comfort, in hot and cold season, the perception regarding the most comfortable and most uncomfortable space, and functionality of the house

The information of the survey was recorded and processed in each city according to the established format. The information was recorded using Excel format and then exported to SPSS. The frequency of each variable was analyzed and a comparative of results was made among the different cities.

All the field study was make to planning, development and feedback of the research that took place in face-to-face workshops and feedback sessions in Mexicali (October 2005), Colima (April 2006) and Veracruz (October 2006).

## RESULTS

**Physical characteristics of the dwellings and air-conditioning equipment [6]** In all the cities, the space of the low-income dwellings is formed by a common area for the living room, dining room and kitchen, and a space for the bedroom and the bathroom. The construction of low-income dwellings shows different architectural plant models used; that more used in each city are shown in Figure 3. Therefore, in facades are similar in all cities, only used decorative element in window or parapets. Low income neighborhoods count with urban utilities (water, sewer, electricity) and paved streets.

In all cities low-income dwelling has only one level, predominantly single family with the exception of the state of Veracruz where it is a duplex. In the cities with warm dry weather dwellings are located on one line of lot but on cities with warm humid weather it extends to both lines of property. In all weathers lots are aligned on North-South direction dominantly. Generally house dwellings are not insulated and do not count with solar protection on windows. The surrounding space is predominantly natural terrain with some sections of concrete for parking. There is little vegetation in housing.

According to the climate, the area and the construction systems of the low-income dwellings are shown in Table 4.

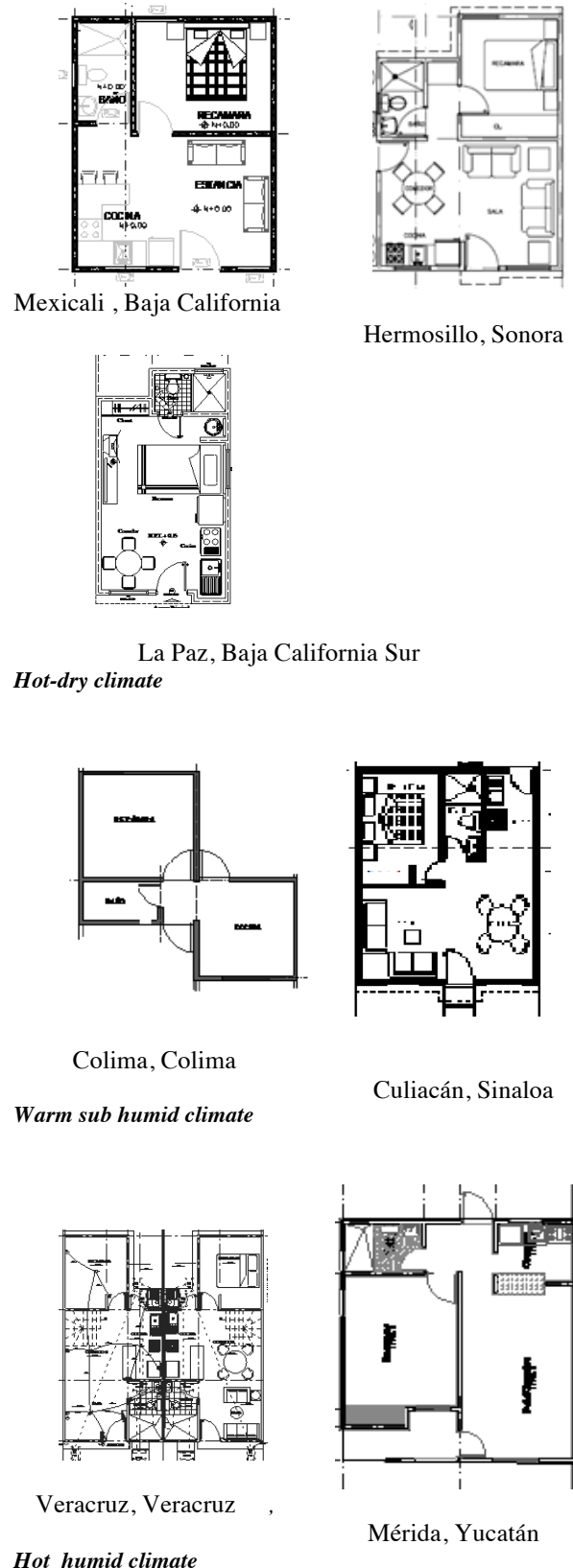


Figure 3: Architectural plans low-income housing, Mexico

Table 4: Areas and constructive systems, Low-income housing, México

CLIMA TE: Cities	Areas		Constructive systems	
	Hou- sing (m <sup>2</sup> )	Lot (m <sup>2</sup> )	Wall	Roofing
<b>HOT-DRY:</b>				
Mexicali	32.3	105	Concrete block 0.12m	Mixed system * 0.15m
Hermosillo	33.5	117	Concrete block 0.12m	Mixed system *0.15m
La Paz	24.0	140	Concrete Block 0.15m	Concrete slab 0.10m
<b>HOT-HUMID:</b>				
Mérida	42.9	160	Concrete block 0.15m	Mixed system * 0.15m
Veracruz	36.4	77	Concrete block 0.12m	Concrete slab 0.15m
<b>WARM SUB-HUMID:</b>				
Colima	30.0	90	Concrete block 0.12m	Concrete slab 0.10m
Culiacán	37.6	96	Concrete block 0.12m	Mixed system * 0.15m

\* Mixed system with concrete joist and light polystyrene square panel.

Table 4 indicates that even this kind of dwell has a limit on cost (117.0631 times monthly minimum wage), because of the cost of urbanization and construction in the case cities of study, they show different surfaces of construction. In the northern and the west of the country dwellings have fewer surfaces but not in the southeast were they count with more area of construction. Dwellings in the city of La Paz are an exception because they are of the kind named progressive dwell and do not count with paved streets.

Predominant building systems on low income houses are common concrete block (0.12m x0.20m x0.40m) and roof made with concrete slab or a mixed system with concrete joist and light polystyrene square panel. The type of windows used is pulled ones with single 3mm glass. There are not specific architectonic considerations for dwells located on hot-dry or hot humid climate.

In the low-income dwellings, the use of air-conditioning equipment to maintain thermal comfort conditions in summer is different (Fig. 4). In cities of hot-dry climate is used the air-conditioning equipment (room air-conditioning or minisplit): Mexicali (95.4%), Hermosillo (29.5%) and La Paz (28.2%). Evaporative cooling equipment is used 4.5%, 61.4% and 9.6% respectively; but in hot-humid cities is not used the air-conditioning equipment, except only in Culiacan. That is used wall or ceiling fans.

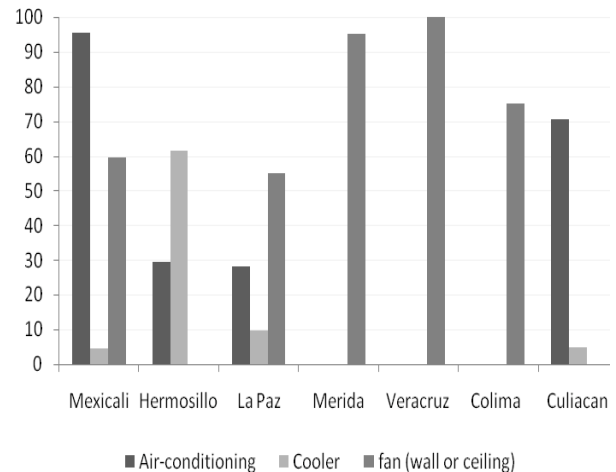


Figure 3: Thermal conditioning equipment in low-income dwellings.

Regarding the capacity of the air-conditioning equipment in the dwellings of Mexicali, 81.5%, use 1½ and 2 nominal tons of refrigeration (tn) equipment, 9% use 1 tn equipment, 7% use more than 3 tn equipment and 3% from 2½ tn.

#### Occupants and their perception of the dwelling

The majority of the dwellings that were studied are occupied by nucleus type families formed by: father, mother and one or two children. In Colima, 59.1% fall under that range, in Culiacán 56.1%, in Hermosillo 58.4%, in La Paz 56.1% in Mérida 73.6%, in Mexicali 56.4% and in Veracruz 64.9%. However, in Mexicali and in Culiacán 20% of the dwellings are occupied by five people. This means that three or four people sleep in a bedroom.

The perception of the occupant's low-income housing compared with their previous dwelling is stated in Table 5.

Table 5: User perception about previous dwelling, México, 2006

	Percent (%)			
	Better	Just right	The same	Worse
Mexicali	37.9	20.9	3.6	34.6
Hermosillo	37.9	20.9	3.6	34.6
La Paz	53.5	14.7	3.1	36.9
Culiacan	10.7	7.6	2.3	6.2
Colima	46.3	16	6.6	7.7

About environmental conditions, the occupants of these low-income dwellings in hot-dry climates as well as in humid climates perceive their dwellings' ventilation conditions as "good" (Table 6).

Table 6: Perception of ventilation, low-income housing; hot-dry, hot humid and warm humid cities, Mexico

CLIMATE-Cities	Percent (%)				
	Very bad	Bad	Good	Very Good	Don't Know
<b>HOT-DRY</b>					
Mexicali	1.5	11.3	85.7	1.5	0.0
Hermosillo	4.7	10.8	80.3	3.5	0.8
La Paz	3.1	9.40	83.2	4.2	0.0
<b>HOT HUMID</b>					
Merida	0.7	3.70	94.6	1.0	0.0
Veracruz	4.5	9.50	77.2	8.4	0.0
<b>WARM SUB HUMID</b>					
Culiacan	4.2	21.8	72.5	1.1	0.4
Colima	3.4	1.40	71.1	10.9	0.3

According to perception, the best conditions of ventilation are in Merida, even if inexpensive dwells do not present a clear design of ventilation. On hot-dry weather, according to perception, there are better conditions of ventilations than on warm humid weather, except on Merida. The ventilation perception is better in Merida.

On the matter of daylighting conditions, in the cities of Colima, Culiacán, Hermosillo, La Paz, Mérida and Veracruz, the daylighting conditions are perceived as "good". However, in Mexicali, 88.1% reported to having "bad" lighting conditions.

Table 7 shows the perception of the occupants on the thermal comfort conditions in hot and cold seasons.

Table 7: Occupant perception of thermal comfort in low-income housing, hot dry and warm humid cities, Mexico

	Summer			Winter		
	Little comfortable	Comfortable	Very comfortable	Little comfortable	Comfortable	Very comfortable
<b>HOT DRY</b>						
Mexicali	81.2	17.6	1.2	43.6	51.0	2.4
Hermosillo	58.4	39.2	2.4	34.3	55.4	6.2
La Paz	60.7	35.6	3.7	19.2	75.4	5.4
<b>HOT HUMID</b>						
Merida	63.7	35.3	1.0	58.8	38.5	1.2
Veracruz	49.3	47.4	2.2	23.2	68.2	8.6
<b>WARM SUB HUMID</b>						
Culiacan	82.8	16.8	0.4	27.1	69.5	3.4
Colima	63.7	24.0	12.3	23.4	67.4	7.4

Low income dwell it is perceived as a "few comfortable" in summer, even in dry or humid weathers, this situations increases in Mexicali (81.2%) and Culiacan (82.8%). On warm dry weather Hermosillo is the city which is perceived as "best comfortable" (39.2%) and for humid weather Veracruz is perceived also as "best comfortable".

According to perception in warm dry climates dwell it is perceived as "comfortable" in winter, the situations increases in Mexicali (51%), Hermosillo (55.4%) and in La Paz (75.4%). In hot humid and warm sub humid climates, the situations increases in Merida (38.5%), Veracruz (68.2%), Culiacan (69.5%) and in Colima (67.4%) according to the people perception the conditions of the dwell are "comfortable"

## CONCLUSION

The results of this work show that the low-income dwellings programs do not take the weather; the construction systems are similar even when the climate conditions are different. The designs of the dwellings do not show significant characteristics that indicate the type of climate for which they are built.

The climate conditions have a stronger impact in Mexicali and Culiacan, but not as much in the rest of the

cities. In Mexicali, the occupants of the low-income dwellings have the possibility of acquiring air-conditioning equipment but not in the other cities.

There is no indication of a significant difference in perception of the degree of ventilation of the dwelling due to dry or humid climate, except in the city of Mérida where the use of ventilation is decisive.

In all the cities, the occupants perceived their dwelling as “not too comfortable” in summer, and the situation worsens in the cities of Mexicali and Culiacan; and where less comfort problems are reported is in Veracruz. Generally, in any of the cities, the dwellings are more comfortable in winter than in summer.

**ACKNOWLEDGEMENTS.** The authors wish to acknowledge the National Council for the Housing (CONAVI), the National Council for Science and Technology (CONACYT) for funding the project “Thermal Comfort and Energy Saving in Low-income Dwellings in Hot Regions of Mexico” and special thanks to Dr. Eduardo González Cruz (Universidad del Zulia, Venezuela) for advice and support to research project.

## REFERENCES

1. Universidad de Chile, Facultad de Arquitectura y Urbanismo, Instituto de Vivienda, Universidad Técnica Federico Santa María, Fundación Chile, (2004). Bienestar Habitacional: Guía de Diseño para un Hábitat Residencial Sustentable, Chile, p.27-45.
2. CONAFOVI-CONACYT, 2005. Convenio de Asignación de Recursos, México.
3. Servicio Meteorológico Nacional, (2007). Normales Climatológicas 1971-2000, México.
4. Dirección General del Servicio Meteorológico Nacional, (1982). Normales Climatológicas, Período 1941-1970, México.
5. Instituto del Fondo Nacional de la Vivienda para los Trabajadores INFONAVIT, 2002, Programa Nacional de Vivienda Económica, available : <http://infonavit.gob.mx>.
6. Universidad Autónoma de Baja California, Universidad Autónoma de Baja California Sur, Universidad Autónoma de Sinaloa, Universidad Autónoma de Yucatán, Universidad de Colima, Universidad de Sonora and Universidad Veracruzana, (2007). “Thermal Comfort and Energy Saving in the Economic Dwellings in México: Hot-dry and Hot-humid climates”, Technical Report CONAFOVI 2004-01-20, México.