

# Vernacular Havelis of Bikaner: Indigenous Method for Thermal Comfort

Tanaya Verma, Tejwant Singh Brar

**Abstract:** Vernacular architecture based on bioclimatic concepts was developed and used through the centuries by many civilizations across the world. Bikaner is a non-river basin settlement in the hot and dry climatic zone of India and cooling of indoor spaces is the single main agenda for habitation design as the temperature is very harsh throughout the year. The vernacular architecture of the Bikaner Haveli's has provided a comfortable shelter against the harsh climatic conditions of the region and has survived for many decades. Physical analysis of the Haveli's provide with substantial data on their thermally comfortable design. The indigenous approach of its inhabitants for achieving comfort in these harsh climatic conditions is an exciting study area. Acclimatization plays a vital role in the perception of thermal comfort, and the younger generation does not perceive the same situation as comfortable as their parents and the natives of the land due to behavioural change. Bikaner have many Havelis dating over 250 years old, and these are master examples of vernacular architecture built by the indigenous community in response to the geographical location, climatic condition, and emerging from their cultural needs. The objective of the research is to understand indigenous cooling systems employed by the people and how they work. The process of physiological adjustment that takes place when subjected to stressful situations. The results show that the natural and passive design systems provide a comfortable indoor environment irrespective of the outdoor climatic variation. Is it more useful to re-introduces the native ways of lifestyle practices rather than adapting to global ways of living. In the paper, an attempt to bring forth the climate responsiveness, appropriateness and the adaptive lifestyle of the inhabitants of the vernacular Havelis of Bikaner.

**Keywords:** Thermal Comfort, Bioclimatic, Acclimatization, Vernacular.

## I. INTRODUCTION

Vernacular architecture is the architecture of the native community, evolving out of their understanding, assessment and need for shelter in the given geographical constraints. Vernacular Architecture use locally available material for construction, using experience and traditional knowledge systems to tackle the external climate for creating a livable comfortable interior space. The whole aim is to minimize the sensation of discomfort indoors and promote healthy living. The social, economic, cultural and occupational patterns are all manifested in the environmental constraints

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of the geographical location. Shelter design, clothing styles, farming patterns and crop selection are all done with the knowledge and experience gained from hundreds of years and Transferred generation to generation as the best means to adapt the environmental factors. With the traditional knowledge practices on how adaptive ways of lifestyle can mitigate the climate or situations which are uncomfortable are of great importance for the current and future generations. The sensation of comfort is a personal feeling, and one can say if there is no discomfort, then one is in a state of comfort. Many researchers have addressed the quantitative aspect of thermal comfort, but have not considered: cultural, social and economic dimensions in the evaluation of thermal comfort.

The current government initiative for providing housing for all and in that process, building mass housing which is required fast for the growing population poses an immense challenge for the designers. With the new housing trend and globalization, it is turning our towns and cities into a concrete jungle. We observe that the houses constructed in Kerala, Assam, Simla or Bikaner all look the same. They are similar in their choice of construction material and planning style, services or employing mechanical means for achieving thermal comfort be it for heating or cooling of the interior spaces. The new construction shows no empathy to the local environment, climate or the local customs or traditions. With the advent of television and social media, the world has become a smaller palace, and physical barriers have collapsed. The flow of information has never been so fast than now. This has influenced the society in all aspects, be it the food choices, clothing styles, lifestyle, culture and traditions everything is affected by this exchange of cross-cultural communication. Hopes and aspiration of the people for a better lifestyle is leading them to explore and incorporate the new technological advancements, which resulted in putting stress on the climate and energy usage for thermal comfort.

The purpose of this paper is to analyze the physiological and psychological concept of comfort and how cultural adaptation has resulted in achieving thermal comfort levels. Thermal comfort has been a topic of research for many years, and researchers have looked at various components which can affect thermal comfort. Is thermal comfort a physical parameter which is a mathematical component. Are all the parameters of air temperature, relative humidity and wind velocity if achieved to a given equation will result in the perfect level of thermal comfort? Is comfort only dependent on the physical parameters or we need to study anything else also? Thermal comfort is experienced by an individual in a space when he is acted upon by the stress of the climate, the design of the space, the

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clothing he is wearing and the thermoregulatory mechanism of his body all are in equilibrium. Another equally important aspect is the mental makeup and behavioural adaptation undertake in a given space to minimize the sensation of discomfort.

However, we have also observed that thermal comfort is a perceived feeling. Two persons in the same thermal area can experience different comfort feelings. Rapoport noted that “vernacular solutions are a response to climate and culture”. The paper explores the lifestyle adaptations and the physical build haveli typology in achieving thermal comfort in the interior space. The study will look into the adaptive techniques, design strategies and the psychological adaptation one has to undergo for experiencing comfort in a space.

### II. STUDY PROBLEM

Energy consumption is an essential factor for today’s living; the dependency on energy is primarily for achieving a comfortable interior spaces. Most of the energy consumed is either for lighting, heating or cooling of the interior spaces. The haveli typology gives us cues for the passive design strategies, use of materials and construction techniques employed in the Havelis within the walled city of Bikaner for reducing the discomfort caused by the harsh solar radiation and subsequent heat gained by the indoor space.

The study is based in the city of Bikaner, which falls in the hot and dry region of India. Residential haveli within the walled city of Bikaner, which are almost 250-year-old and have withstood the test of time and have not undergone any significant modification is selected for conducting the study. Redevelopment in the walled city is slowly resulting in the demolishing the haveli and making way for broader roads and other civic infrastructure. Also in some cases, the owners of the haveli want a new and modern house in place of the old once to get more livable space, modern amenities and also cater to the increase in the number of family members are demolishing the Havelis. Human actions have its bearing in the context, climate, resource availability, religious factors, social set-up and also its architecture. We have observed the indigenous techniques employed by the locals to mitigate climate harshness.

### III. THERMAL COMFORT

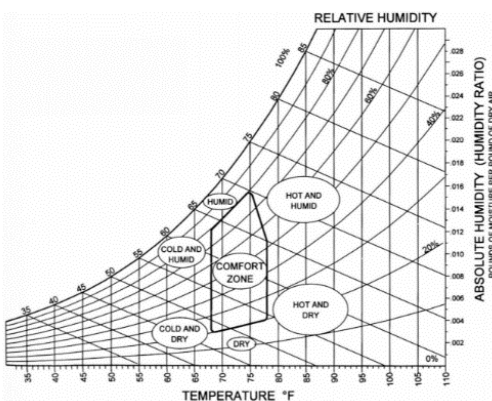


Figure 1: Comfort Zone

The physical condition that determines the feeling of warmth or cold by the human body is a combination of air temperature, mean radiant temperature, relative humidity and air velocity [1]. As shown in Figure 1 a general comfort zone is defined and drawn in a psychrometric chart [2]. As we observe that the comfort zone for different climatic zone lies differently on the psychrometric chart and cannot be a single uniform condition which will fit all. According to the ANSI/ASHRAE Standard 55, thermal comfort defined as “that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation [3]. Comfort is often associated, there was an “absence of discomfort”, “an absence of feelings” Or with “neutrality inside thermal environment” [4].

### IV. INDIGENOUS APPROACH

The indigenous approach observed in every walk of daily life. The people have found ways and means to neutralize the harshness of the climate by way of developing cultural and social practices. Acclimatized by way of adapting their shelter design, occupation, food habits, dressing style, activities of leisure and their technology to the climate and to the available natural resources in the region as described in Figure 2 below. The factors of shelter, occupation, food, clothing, recreation and the construction technology are all developed in close harmony with the climate, and thus they form the social, cultural norm for the place. Any change in these practices impacts the climate and vice-versa our lifestyle also.

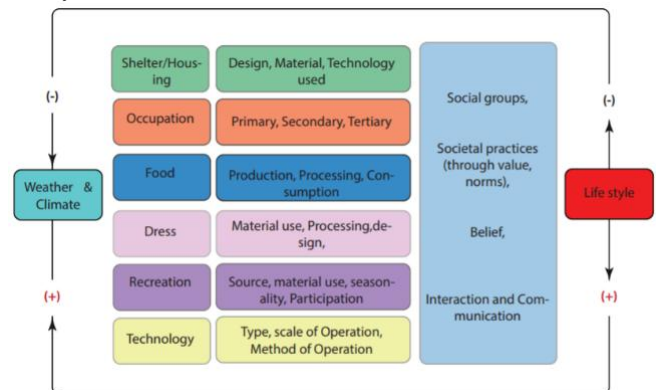


Figure 2

UNFCCC stated that” “Indigenous, local, and traditional knowledge systems and practices, including indigenous peoples’ holistic view of community and environment, are a major resource for adapting to climate change; but these have not been used consistently in existing adaptation efforts. Integrating such forms of knowledge with existing practises increases the effectiveness of adaptation”. [5].

### V. STUDY AREA BIKANER

Bikaner (28° 1' 22.565" N 73° 18' 42.897" E), established by Rao Bikaji. Bikaner experiences the harshest of the climate. The maximum day temperature experienced in Bikaner is 50.3°C in June. The minimum temperature noted is -2.9°C for January in Bikaner. The extreme climate with a very hot afternoon to cold nights. These significant diurnal temperature variations require sufficient protection by



the inhabitants. The relative humidity is low throughout the year, as there is no primary water source. As observed in Figure 3, Bikaner experiences 79% discomfort hours and only 21% comfort hours in a year.

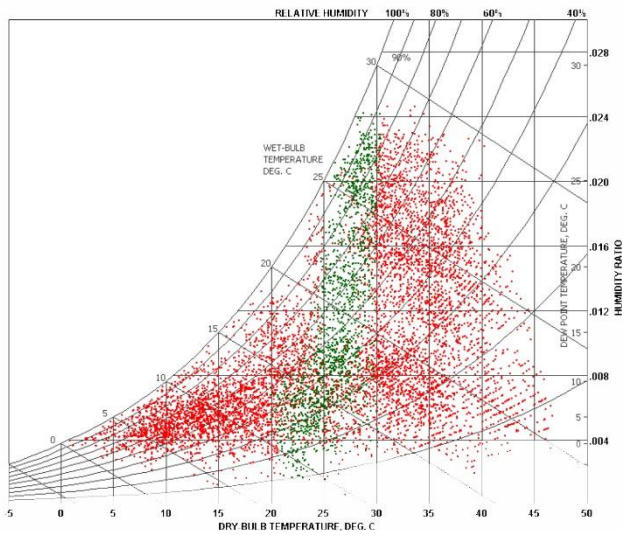


Figure 3: Psychrometric Chart



Figure 4: Haveli Façade and Shadade Street

## VI. THE HAVELI STRUCTURE

The Haveli typology is very common in northern India. The haveli of Rajasthan is especially famous for its scale and intricate ornamentation. The courtyard plays a vital role in the haveli configuration. The courtyard at Bikaner is small as compared to that in Jaisalmer. The smaller size works particularly well as the courtyard is shaded for the most of the day and thus provide an all-day activity zone for its users. The haveli has three to four stories, with one subfloor which is partially underground. The haveli is oriented east-west, and the streets mostly run north-south. Such an orientation results in constant shading of the streets, which are in themselves narrow and have tall haveli abutting the street as seen in Figure 4. The above floors of the haveli have overhanging balconies which also aid in providing shade to the street.

The courtyard is the central core of the haveli, and it is the hub of all activity and the primary source of light and ventilation for the interior rooms of the haveli. To avoid solar heat gain by the walls, they are shaded with projecting balconies and carvings which help by self-shading. The haveli is protected from 3 sides by adjoining Havelis, in case

of corner haveli protected from 2 sides thus considerably reducing solar exposure and subsequent heat gain as we observe in the plan that the street-facing rooms are having access to natural lighting through the narrow windows.

The courtyard is very helpful in providing air circulation in the haveli. The courtyard is the most lively and active space in the haveli and hence the ladies of the house spend most of the day in this space. This differential heating of the courtyard ensures a continuous airflow through the house [8]. The courtyard is surrounded by a veranda and this is the space used for having lunch and relaxing during the day. The access to the haveli interior is always through the courtyard. The rooms are small and dark and are used only for sleeping at night. The front rooms are cross-ventilated from the street on one side and the courtyard on the other. The men occupy the street-facing rooms as office and also for day to day interaction. The spaces in the house are thus divided based on gender and occupational needs. As seen in Figure 5.

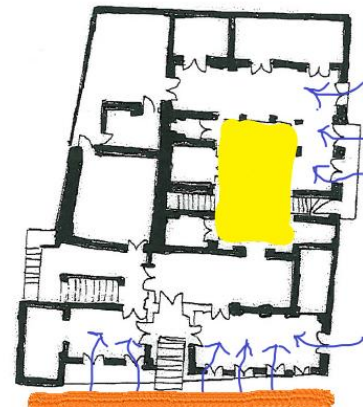


Figure 5: Haveli Plan

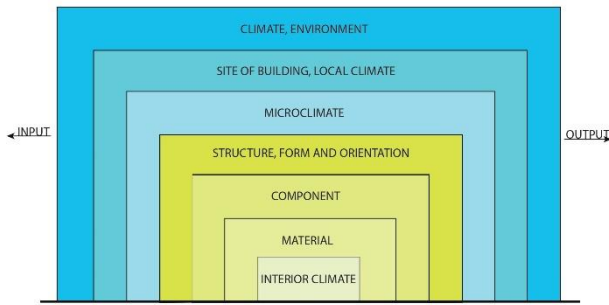
## VII. HAVELI AS A THERMAL BARRIER

The interior space is protected from the extremes of nature by the haveli structure. The thermal resistance provided by the thick walls is an essential aspect for preventing heat penetration indoors. Also, a notable feature for the haveli of Bikaner is the absence of jali's. The external façade has windows which have wooden shutters. The window has one panel of coloured glass, and also louvres. The glass allows light into the interior, and the louvres allow a controlled amount of air into the interior space. The structure has to be designed in such a way that the possibilities of adverse consequences resulting from the climate transformation are minimized [6].

The indoor comfort can be understood in two parts the built mass and the external environment as per Figure 6. The Interior space is acted upon by the thickness of the built envelop, and it is material configuration, the solar orientation of the component, and finally structural form and orientation. The careful selection of the material helps in reducing the thermal ingress into the interior space. The same envelop configuration acts as a thermal barrier as it becomes difficult for the

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interior space heated during the day to lose its stored heat at night when the outside air has cooled down. As observed earlier that the night temperature drops significantly, this thermal insulation provides ambient condition indoor when the outside temperature falls. The second component affecting the interior climate is the external environment.



BUILDING/ ENVIRONMENT SYSTEM APPLIED IN A TRADITIONAL BUILDING PHYSICS ANALYSIS

Figure 6

The microclimate, which is in the immediate vicinity, is impacted due to local features. The site and orientation of the built should incorporate the climatic conditions. The final exposure is of the raw climate. As discussed in Table 1, the factors affecting human thermal comfort in an indoor space is analyzed.

Table 1. Factors Affecting Thermal Comfort.

	Factors	Description	Impacts on Thermal Comfort
Human Factor	Physiology	Metabolic rate	Body thermoregulatory
		Age	Acclimatization
		Gender	Clothing adjustment
	Psychology	Weight	Activity (metabolic) adjustment
		Behaviour	Behavioural adjustment
		Control	Background and experience
Micro Environment	Climatology	Expectation	Acceptability, preference
		perception	Perseverance
	Geographical location	Prevailing wind (Monsoon wind)	
	Climate	Diurnal humidity	
		Outdoor temperature	
Macro Environment	Design		Solar radiation (Sky condition)
			Precipitation
		Building Form	Building Mass (heat transfer)
		Openings	Porosity and shading
		Orientation	Room dimension
	Vegetation	Window wall ratio	
		Building layout	

In the case of a naturally ventilated building, the adaptive model plays an important role. The process of adaptation helps in reaching thermal satisfaction. The architectural design should give enough opportunities to exercise once the choice to control the thermal environment indoors. As shown in Table 1, the three levels segregated from the human factors which are personal and individual-specific, The next influencing factor is the Macro Environment which is specific to a geographical location. Furthermore, the final factor which can play an important role in deciding the comfort level experienced is the Micro Climate; this is specific to the site with its localized site and built features.

**Human Factor:** The human factor also has two components the physiological and the psychological which defers from

person to person to person and play an important role in their expectation of thermal comfort from the interior spaces. In the Haveli, three generations live together, and the observation is that the psychology played a major role as the young members of the family had a very different lifestyle as compared to the older members. The behavioural adjustment that the older generation has incorporated into their lifestyle was completely missing in, the younger members.

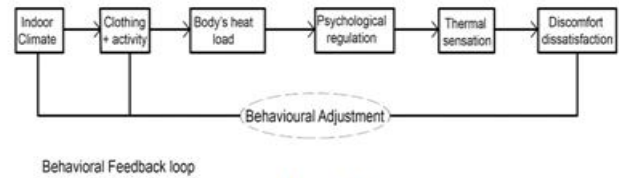


Figure 7



Figure 8

If subjected to constant exposure to conditioned space, then the body adjusts to the new level of thermal comfort. This is one major factor for the young not feel comfortable in the Haveli as these are not fitted with air conditioners. The clothing is another crucial aspect to be looked into. The clothing habits are fast changing for the natives, and the standard global trends are fast replacing local costumes. The most affected with the trend are the youngsters. The choice of fabric, style of clothing and the colours also impact the comfort of the individual. Also, due to education and job requirement, the young population is moving out of Bikaner and experience different locations and climate. The perception of comfort does not match when they return to Bikaner, and this also causes stress and discomfort. The process of physiological feedback is seen in Figure 8.

The behavioural adjustment takes place when the body receives an external stimulus be it from the conditions around in the indoor space or due to physical activity the body is under stress and requires to cool down Figure 7. Any discomfort or dissatisfaction leads to behavioural adjustment. The adjustment that one makes either to their daily routine, clothing choice, food habits and perception is called acclimatization.

**Micro Environment:** The intervention one makes to alter the macro environment to create livable conditions. The micro-environment can be affected by the building form as we have observed in the compact urban composition within the walled city as the Havelis tightly packed and only the front façade exposed to the climate and solar radiation. The haveli's provide mutual shading to one, and another in this process get protection from the harsh solar radiation.



The Havelis are the load-bearing structure, and the building envelops solid with a few narrow windows. The openings provided in the building envelop provides scope for heat ingress and should be treated effectively. The window which opens to the exterior is restricted in number. The built fabric also provides mutual shading and can result in a considerable reduction in heat gain due to it. As the arid region has very dense fabric, this results in compact Havelis with usually only having exposed surfaces on 2 sides namely front and rear, and in many cases, it is only one exposed surface the front side. The compact design dramatically reduces the exposed surface area, which could have resulted in heat gain. The load-bearing construction of the Havelis which have the wall as thick as 600 mm provides sufficient thermal lag. This thermal lag protects the interiors from the harsh temperature of the outside Figure 9.

1. Dense fabric
2. Thermal lag
3. Courtyard
4. Mutual Shading

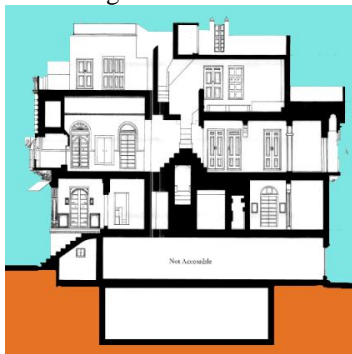


Figure 9: Haveli Section

**Macro-Environment:** The movement of the sun and the variations in solar azimuth and altitude, diurnal and seasonal, are well described in several standard texts [7] and are comprehensively depicted in the form of solar charts specified for each latitude as shown in Figure 10. The macro-environment consists of all the climatological factors, the geographical location, outdoor temperature, solar radiation, sky cover and relative humidity. The temperature 4 meters below the ground level is at an ambient temperature of 25°C to 30°C throughout the year. Almost all the Havelis of Bikaner have a floor which is below the ground. This space is used for resting and spending leisure time in extreme summer or when it is cold in the winters to spend time on the above floors. This is a brilliant adaptive intervention which the indigenous people had developed

many years ago and is found in almost all the Havelis of

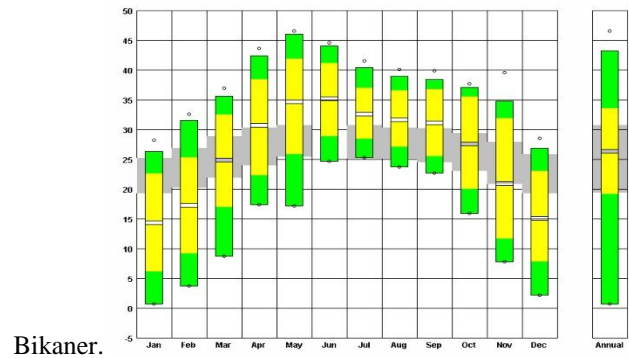


Figure 10 Temperature and Relative Humidity

### VIII. ACCLIMATIZATION

People use cotton clothing, which is of the Kota Doria variety in bright colours by the women. The men usually wear whites with colourful turbans. The complex process of adjusting to the stress situation with behavioural and making climate-responsive choices is the process of acclimatization. Body in its operation of thermoregulation mechanism produced sweat to cool the body temperature, and regulates the rising body temperature and protects the human body against hypothermia or in common words “heat stroke” as if in this extreme temperature the body temperature is not kept in check then life-threatening condition arises. The Kota fabric is one such where the cotton thread woven in a manner that it is very lightweight and allows airflow freely. This helps in evaporation of the sweat, and the body temperature is brought down during extreme heat conditions. The turban acts as a protective covering against the heat and protects the heat from the solar radiation.



Figure 11. Dried Vegetable



Figure 12. Dried Kachri



Figure 13 Local Dress



Figure 14 Local Food

The clothing is light helps in ventilating and drying the sweat produced due to the

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harsh heat. The clothing intervention results in some percentage reduction in the discomfort sensation. The food habits are also very unique and reflect the adaptation to the climate and vegetation of the region Figure 14. The use of spices is very high, and this also helps in the thermos-regulation of body temperature. The region has very scanty rainfall, and no perennial water source is available; this is a significant drawback in terms of agriculture. The food habit has evolved with the natively grown wild and some seasonal vegetables which are dried and stored to consume throughout the year, namely “Kachri, Sangri” and many more as seen in Figure 11. The vegetables cooked in rich spices which are heavily based on chillies and curd. When a person is suitably dressed and follows the local food habits, the body reacts in a manner where the thermal regulation is in place. The process of altering daily activity so that the exposure to solar radiation is controlled. With little modification, the thermal satisfaction level is increased. That is, both satisfaction and opportunity for acquiring and maintaining acclimatization are likely to be enhanced when there is an inducement for exposure to natural variability in atmospheric stimuli, and when people are free to choose between the higher-level strategies of thermoregulatory adaptation. [9]

### IX. COMFORT SYSTEM

Human well being cannot solely be attributed to the thermal environment in isolation from the other determinants of indoor atmospheric quality [10]. These apparent inconsistencies with thermos-physiological predictions led Auliciems (1969) to formulate an adaptive model of thermoregulation within which thermal preference is seen as the result of both physiological responses to immediate indoor parameters (i.e. those measured by the indices) and expectations based on “climate-cultural” determinants, i.e. past experiences [11] as observed in the figure below the whole process in a loop.

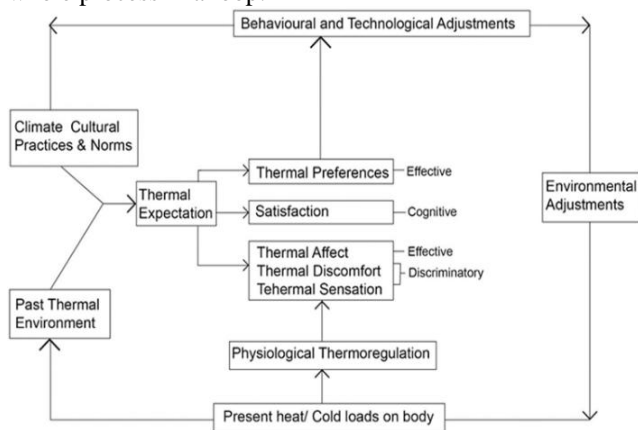


Figure 15

The lifestyle of the occupants as observed in the haveli and has given clues on how they are exercising behavioural, cultural and ritualistic practices to adapt to the thermal conditions. The natives and older generation of Bikaner have a more adjusting thermal limit than the youngster. The difference in thermal acceptance is because of the following reasons:

- Due to education and job opportunities which are outside Bikaner resulting in frequent travel to different climate zone. The process of acclimatization does not happen for a given location and gives rise to the feeling of discomfort.
- Variation of seasonal food and ritual habits have also decreased the process of thermal acceptance.
- Frequent exposure to airconditioned spaces has considerably lowered the thermal expectation of the individual. The process of achieving thermal neutrality is quick in an air-conditioned space, and this makes the body accustomed to the new uniform thermal sensation.

Table 2: Adaptation Strategies

S. No	Human Adaptation Strategies	Observation
1	Behavioural & occupational adaptation	Physical activity is in relation to the climate.
2	Getting the body and mind adjusted to the outside climate. Pre-conditioning.	Gradual exposure to harsh sunlight. Managing time of exposure by transiting from indoor closed space to semi-open space like the courtyard and veranda and then to the outside. The streets are also so arranged that they are shaded most part of the daytime.
3	Food energy intake and dietary alterations	Use of spices and chilly as this increases the blood flow and subsequent sweating. Food rich in fat and sugar as the body goes under tremendous stress.
4	Clothing choices and material choice.	Lightweight cotton clothes are used, mostly Kota “Doria”, which are light and airy. Men also wear white and have a protective headgear the “Pagri”.
5	Building design	Thick walls provide thermal lag, compact street layout benefits by mutual shading. Incorporating passive design strategies.

### X. CONCLUSION

The study has revealed that thermal comfort is a holistic experience; its bearing is in the physical parameters as much as it has in the psychological factors. The indigenous community has developed a mechanism to sustain a healthy and fulfilling lifestyle in the given adverse climatic condition. The traditional built form of the haveli should not be looked at in isolation as a solution for achieving thermal comfort by intelligent use of design. The whole conventional indigenous ecosystem of Bikaner should be understood in totality.

Individual occupants of the house can have their perception of thermal comfort. The physical derivation of comfort as derived by the established stands may also not be able to define an individual's thermal comfort satisfaction level. The inconsistencies of the thermophysiological calculations can make it difficult to fix an exact thermal comfort measurement as a finite parameter of comfort. The research establishes the link between the outside thermal condition and its impact on the thermal sensation of the individual. The process involves a complex process



which is interlinked between the key components Adjustment, Habitation, and Acclimatization. As observed in Figure 16.

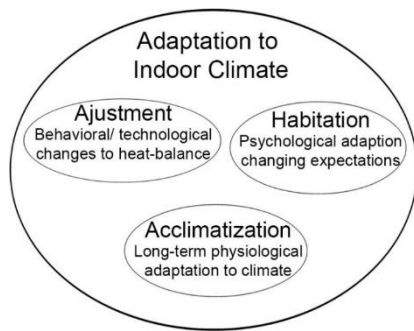


Figure 16: Adaptation

The hot and dry climate of Bikaner is very successfully adapted by the inhabitant. The critical points observed for achieving comfort are as follows.

1. Activity selection based on the climatic condition and the stress the activity produces result of the behavioural and occupational adaptation.
2. Psychological adjustment, this helps to precondition the body and the mind to the reasonable climatic condition and the subsequent stress to be experienced. This precondition will significantly help in reducing the feeling of dissatisfaction. Scheduling of activity based on the heat stress experienced by the body.
3. Based on local produce availability food habits are to be modified to suit the energy requirement and heat stress experienced.
4. Clothing and building skin construction and material choice are significant because they act as a buffer between heat stress and occupant.
5. Thermal Lag for reducing heat penetration into the interior space. The building acts as the first layer of protection, and hence its design should provide protection against the stress from the climate. Significant reduction in heat stress is achieved by careful planning of the built envelop.
6. The house plan should be rectangular with the narrow face exposed to the street. To reduce heat gain from solar exposure.
7. The courtyard helps by way of light and ventilation it release the hot air trapped inside the house by way of stack ventilation.
8. Good natural ventilation can reduce the need for active cooling devices in hot weather if windows are well shaded and oriented to prevailing breezes.
9. Earth sheltering, occupied basements reduce heat loads in very hot dry climates because the earth stays near average annual temperature.
10. Flat roofs work well in hot dry climates, the roof should be sufficiently insulated to prevent any heat gain into the interior space.
11. The size and orientation of the openings need to be controlled. The openings should be minimum and should have high-performance glass for restricting the heat ingress. Or the windows should have adaptive shutters which can be controlled by the users depending on the need.

When the need for effective methods for achieving comfort is reduced, the dependency on energy will also decrease. And less reliance on active energy utilization would promote a more harmonious synchronization between the psycho-physiological functions of people and the natural environment.

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