

PASSIVE DESIGN IMPLICATIONS DERIVED FROM CLIMATE
ANALYSIS FOR VARIOUS LOCATIONS

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1. INTRODUCTION

In earlier work, we have developed methods of describing climate in terms of the interactive effects of insolation, air temperature, wind speed, and relative humidity.¹ By characterizing their effects in terms of the architectural responses required to produce thermal comfort, we have been able to describe a "Modified Comfort Zone," or MCZ, which greatly exceeds, in frequency of occurrence, the "Standard Comfort Zone," or SCZ, as described by Olgyay. We have found that thermal comfort, in the fourteen North American climates analyzed, is achievable without mechanical heating or cooling, from 20-50% of the year, depending on the location. Further analysis of the way these architectural responses form daily and seasonal patterns has enabled us to begin a description of climates in a format directly usable for architects in the design of buildings which are dynamically responsive to climate. This paper investigates ways of simplifying a climate description, to improve its direct usefulness, without dampening the dynamic subtleties.

This paper describes three locations, representing a variety of climate types, and shows the usefulness of climate description in several phases of the design process.

2. DATA CHARACTERISTICS

For a data base, we used computer tapes containing hourly insolation levels in addition to other climate variables. For most locations, only one year's data was processed so we are not certain that it is a true representative of the actual climate. However, we did have nine years of information for one location, and our analysis shows that the same major patterns recur each year.

¹Brown & Novitski, "Architectural Response to Climatic Patterns", Proceedings of the 4th National Passive Solar Conference, Kansas City, Missouri, October 1979.

3. METHODS

Each hour in a year is analyzed by computer and assigned a code according to what architectural response would be required to produce thermal comfort. Hours in the SCZ require some combination of admitting, filtering or blocking of the sun and/or wind; hours outside the MCZ require heating or cooling and/or humidification or dehumidification. These classifications are determined by where the climate variables for each hour fall on the Olgyay comfort chart (see Fig. 1) and, while suggesting architectural response types, do not dictate specific design solutions.

We then look at the progression of response types throughout a day, using smoothing techniques. Each progression, from midnight to midnight, constitutes a diurnal pattern, and the distribution of these patterns throughout the year describes the nature of the climate and provides information, at several levels of generality.

The three locations are: Dodge City, Kansas (temperate); Madison, Wisconsin (cold); and Phoenix, Arizona (hot-arid).

4. CHARACTERIZATION OF CLIMATE

At the first level of generality we describe climates not by specific architectural response, but in terms of the five generalized codes as illustrated in Fig. 1. Each day in a year is labelled according to the sequence of these codes. As an example, a day which starts out cold, becomes comfortable during mid-day, and becomes cold again at night, is labelled C-MCZ-C. A similar day in a warmer part of the year might have the pattern C-MCZ-H-MCZ. Figures 2 through 4 show the distribution of patterns for each location in two formats. In the first part, the annual pattern summary, the patterns are ordered left to right on the basis of their total frequency for the year, and the black bars show their relative frequency for each month. For any given season, then, it is easy to see which patterns need to be simultaneously accommodated and which are the

most important. A climate can thus be described by the particular combination of patterns that occur at any one time.

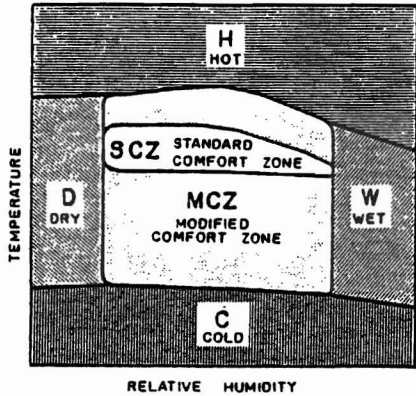


Fig. 1. The Basic Codes

Cross-climate comparisons are also possible from these tables. One of the most universal patterns, C-MCZ-C, is common to all four locations and is clearly a pattern that every structure should be able to accommodate. It characterizes days with cold nights but potentially comfortable daytimes with the appropriate moderation of sun and wind. In hot climates it is a winter pattern; in cold climates it is a summer pattern; in temperate climates it is a spring/fall pattern.

The second part of each figure, the pattern time table, is an annual description for each location, showing an approximate distribution of diurnal pattern types throughout the year. These differ from conventional climatic time tables in that they describe the year's climate in terms of the dynamics of diurnal variation. This is important because the comfort within a space for any particular time of day is often dependent on conditions in that space at other times, i.e., thermal lag design techniques require knowledge of diurnal fluctuations.

Another way these differ from conventional time tables is that they illustrate, not only diurnal patterns, read vertically, but also seasonal patterns, read horizontally. These show the climatic design criteria relevant to a built space which is programmatically intended to be used at particular times of the day or night. For example, a noon activity space in Madison or a night activity space in Phoenix should be able to respond to a C-MCZ-C, again a common pattern; only now the sequence reads from winter to winter rather than from midnight to midnight.

So far we have described climates in the

most generalized form of diurnal patterns, but in order to discern useful criteria we must expand each pattern to the format which gives specific architectural response. We will demonstrate it for Dodge City.

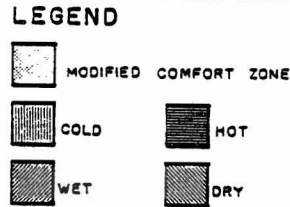
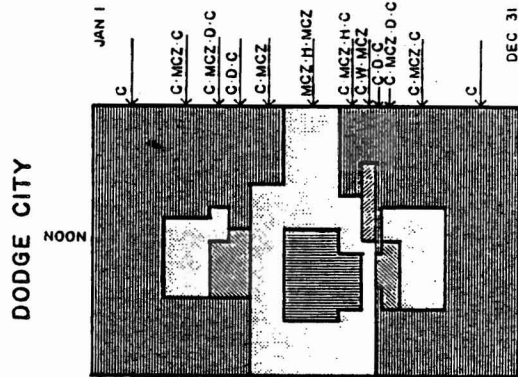
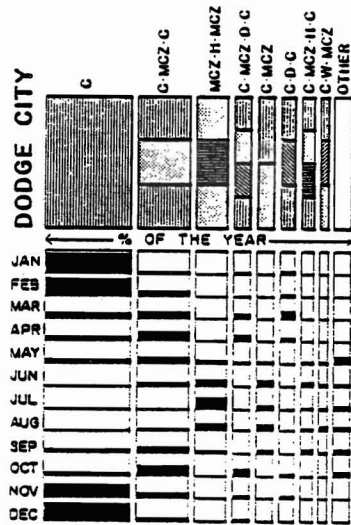


Fig. 2. Annual Pattern Summary and Pattern Time Table for Dodge City.

Each season has a different set of codes which are expanded, depending on which variables are most important. For example, in the winter, when Cold codes predominate, day types are distinguished by amount of maximum insolation. If less efficient indirect gain systems seem appropriate for high insolation and direct gain for low insolation situations, then day types can

be characterized, in effect, by the relative importance of direct solar gain, indirect gain, or heavy insulation. Figure 5 shows the distribution of the various Cold codes throughout the day in the winter (mid-November through February). Since this diagram represents not one day, but 98% of all winter days, it shows, for each hour, the several conditions that are most likely to occur. The overlaps indicate times of day when an architectural design should be capable of responding to more than one condition. In the summer, the critical codes in terms of architectural design elements which need to be expanded are the MCZ codes. These indicate the particular responses required to produce comfort outside the standard comfort zone of 21°-27°C (70°-80°F), including "block sun," "filter wind," etc.² Figures 6 and 7

are diagrams of summer patterns MCZ-H-MCZ and C-MCZ. The first shows times of overheating but also considerable periods when the modified comfort zone appears. The second shows predominantly MCZ periods after dawn. The importance of MCZ periods in these two summer patterns is obvious when it is recognized that without the appropriate architectural responses, most of these times would be overheated.

The last level of generality provides information for the fine-tuning of designs. It involves the exact correlations of sun position and wind direction to those MCZ times of the year when architectural response dictates shading, wind blocking, etc. This information is used at the detailed component level of design.

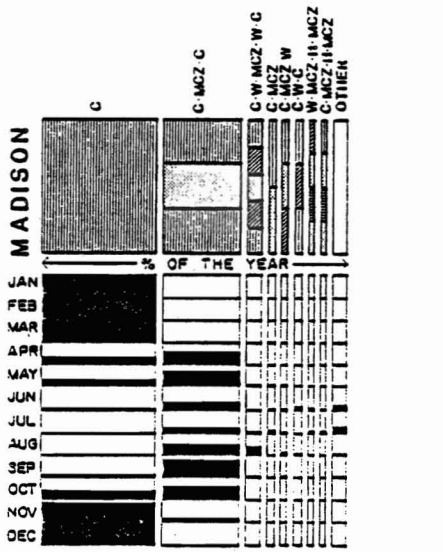


Fig. 3. Annual Pattern Summary and Pattern Time Table for Madison.

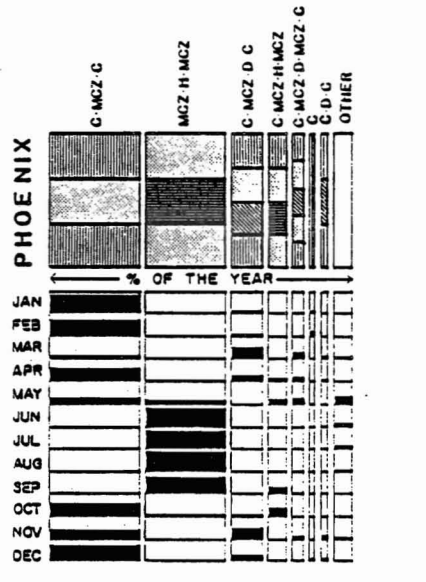


Fig. 4. Annual Pattern Summary and Pattern Time Table for Phoenix.

²Olgay, V., *Design with Climate*, Princeton University Press, Princeton, NJ, 1963.

5. DESIGN PROCESS

From the annual pattern summary for Dodge City, we can see that the three major patterns are C, C-MCZ-C, and MCZ-H-MCZ. For purposes of this discussion we will be looking only at these three, which account for 64% of Dodge City's day types.

A space designed for daytime use should, then, be able to respond to C, MCZ, and H. One approach is to design an insulated shell that functions both in extreme cold and extreme heat, but that is adaptable during periods of MCZ. Another approach is seasonal migration in which two spaces are designed: one enclosed for C and H periods, the other of minimal non-enclosed for MCZ periods. The design strategy outlined below combines these two approaches. We suggest a two-part design: a south-facing open structure backed on its north side by an insulated shell.

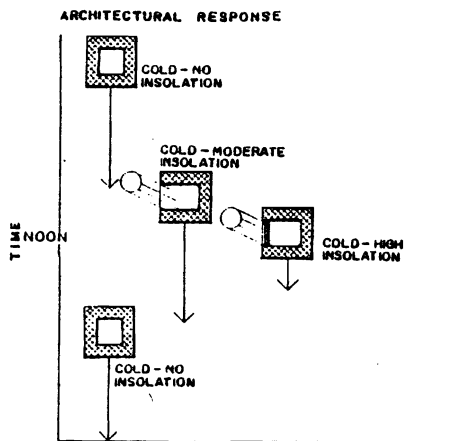


Fig. 5. Expansion of C Codes; Dodge City.

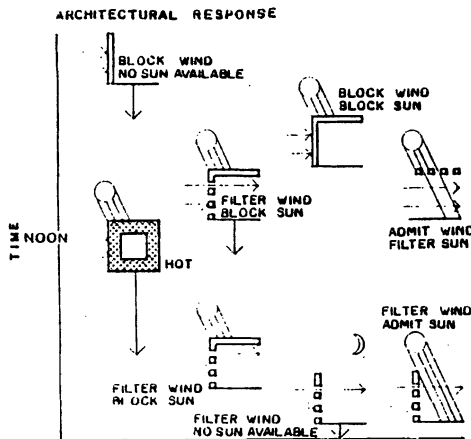


Fig. 6. Expansion of MCZ-H-MCZ Codes, Dodge City.

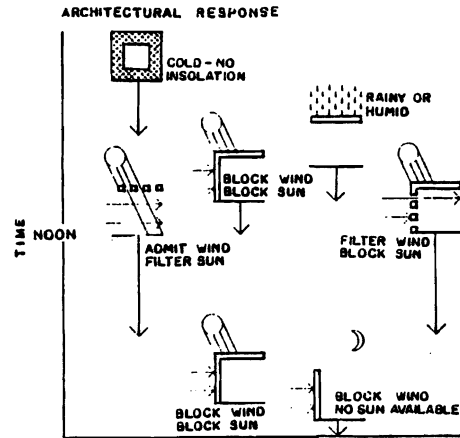


Fig. 7. Expansion of C-MCZ Codes, Dodge City.

As Figure 5 shows, in the winter, a difficult design problem is to accommodate periods of both high and moderate levels of insolation. Periods of no insolation (night times and overcast days) are the most frequent, but the solution is straightforward: heavy insulation. The next most typical condition is when radiation is present but moderate. The problem is to design a space which will take maximum advantage of any available insolation but which has the capacity of "increasing" thermal mass to decrease the potential of large temperature swings during the occasional periods when the radiation level is high.

Figures 6 and 7 show that in the summer a conflict arises from the fact that some days have overheated periods when a cooling mass is desirable, and other days have cold nights, when a heating mass is called for. This conflict can be resolved by having masses of two temperatures, at different locations; for example, a major roof mass for heating each of which would be insulated when the other was "working".

A conflict between summer and winter is resolved by designing a single major mass that can operate in both of the heating and cooling modes. In addition, both conditions of extreme temperature, when infiltration control is required, can be satisfied by the same space configuration.

The north space is habitable at all times. The south space is habitable, under the principles of migration and seasonal expansion during all MCZ conditions. In addition, its roof could serve as a reflective surface to enhance solar gain into the north space,

The roof of the north space should have three principal elements: movable insulation

on the exterior that opens to provide summer night sky radiation; a major thermal mass for both heating and cooling; and movable blinds on the interior. When open, these blinds expose the mass to the space, and the mass to radiation in the winter. When closed, they retain the mass's warmth or coolness during MCZ periods when it is not required.

Clerestory glazing of the north space provides direct solar gain in the winter. The glazing should have reflective blinds that, when closed, block summer insolation or, when open, can direct winter gain to the roof mass.

The roof of the south space is made up of adjustable reflective louvers which enhance radiation through the clerestory in the winter, or when open, admit varying amounts of insolation to the south space during MCZ periods when the response is to admit or filter sun.

The south wall of the south space has adjustable apertures to admit, block, or filter wind in MCZ periods, depending on which is appropriate. The wall between spaces and the north wall of the larger are insulating barriers that control infiltration in the larger space during periods of Hot or Cold, but open during MCZ periods to provide natural ventilation of both spaces, when required.

Most elements described in this design strategy have more than a single function and operate in different ways at different times of the day or year. Thus a single system can function in response to many different conditions. The design of such a system would be unlikely without detailed information about or direct experience with the dynamics of a climate.

6. CONCLUSION

We have found that a climate cannot be described in a single format, if it is to be useful in the design process. Without abandoning our objective to be inclusive and dynamic, we are adopting graphic and analytic means to describe different parts of the year in different ways, for different purposes. Our ongoing work is focused on improving climate description as a design tool. The graphical display of diurnal patterns at several levels of generality is one step in this direction.

7. NOMENCLATURE

MCZ - Modified Comfort Zone
SCZ - Standard Comfort Zone

8. REFERENCES

Brown, G. Z. and Novitski, B. J. "Architectural Response to Climatic Patterns", Proceedings of the 4th National Passive Solar Conference, Kansas City, Missouri, October, 1979.

Olgay, Victor. Design with Climate, Princeton, New Jersey, Princeton University Press, 1963.

9. ACKNOWLEDGEMENTS

Funded in part by the School of Architecture and Allied Arts and the Graduate School, University of Oregon.