2018 Building Performance Analysis Conference and
SimBuild co-organized by ASHRAE and IBPSA-USA

Chicago, IL

September 26-28, 2018

DEVELOPMENT OF A METHOD FOR SELECTION OF REPRESENTATIVE CITY IN A CLIMATE ZONE

Mayank Bhatnagar[1], Jyotirmay Mathur[1], Vishal Garg[2], and Javed Iqbal[3]
[1]Malaviya National Institute of Technology, Jaipur, India
[2]International Institute of Information Technology, Hyderabad, India
[3]Advanced Building and Urban Design, Hungary

ABSTRACT

A building is a boundary between an outdoor climate and indoor conditions. The building energy consumption, notably the energy used for air-conditioning is closely related to outdoor climate. The Solar Radiation, Dry-bulb Temperature and Relative Humidity are the important climatic parameters which affect building's thermal and visual conditions. The energy codes development analyses and evaluation of new technologies with respect to energy savings and financial viability have been carried out for selected cities that are supposed to represent any particular climate zone. There is a significant change in thermal loads in different cities of a climate zone. Selection of a representative city for a climatic zone is important because it needs to reflect average climatic conditions for a particular climate zone accurately. This study presents a new method that has been developed for the selection of a representative city in any climate zone, using the principle of Euclidean distance approach having a dry-bulb temperature, wet bulb temperature and solar radiation as three axes. The city having minimum Euclidean distance with respect to remaining cities of the same climatic zone is proposed to be taken as a representative city. The proposed method has been applied on each of the five existing climatic zones of India according to National Building Code (NBC) of India and eight climate zones according to ASHRAE Standard 169-2013. The results show representative city according to NBC climate zone classification: Ahmedabad (hot and dry), Lucknow (composite), Kolkata (warm and humid), Bengaluru (temperate) and Srinagar (cold); and according to ASHRAE Standard 169-2013: Ratnagiri (0 A), Ahmedabad (0 B), Kolkata (1 A), Varanasi (1 B), Tezpur (2 A), Amritsar (2 B), Shillong (3C) and Srinagar (4 B).

INTRODUCTION

Weather of an area represents the state of the atmospheric environment over a brief time-period. Integrated weather condition over several years is referred to as *climate* or specifically, as *macro-climate*. For several purposes, it has been an international practice to group similar climatic regions under one climatic zone. This approach helps in handling number of cases of climatic variations while analysing any policy or initiative. The climatic zone-based approach is used in most of the applications ranging from agriculture to building design practices and codes. The analysis of the climate of a particular area or climatic zone can help in assessing the seasons or periods during which a person may experience comfortable or uncomfortable conditions. It further helps in identifying the climatic elements, as well as their severity that causes discomfort. This information helps a designer to build a house that filters out adverse climatic effects while simultaneously allowing those that are favourable (Papakostas and Kyriakis, 2005).

Most widely used climatic classification in India was proposed (Bansal and Minke, 1988) who carried out detailed studies on Indian climate and divided it into six climate zones, namely hot and dry, warm and humid, moderate, cold and cloudy, cold and sunny, and composite.

Table 1: National Building Code 2016 climate zone criteria

Climate Zone Categories	Mean Monthly Maximum Temperature (°C)	Mean Monthly Relative Humidity (%)
Hot & Dry	>30	<55
Warm & Humid	>30 >25	>55 >75
Temperate	25-30	<75
Cold	<25	All values
Composite	When six months or more do not fall within any of the above categories	

India has a National Building Code published by Bureau of Indian Standards in the year 2005 and updated in 2016. In climatic classification used in NBC 2016, the country has been divided into five major climate zones. Table 1 describes the classification criteria. The major variation from the Bansal et.al is that the Cold and Cloudy, Cold and Sunny has been combined into a Cold climate zone. Additionally, the moderate climate zone is referred to as temperate in NBC 2016 (Bureau of India Standards, 2005).

There is an internationally acceptable climate classification reported in American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE) Standard 169-2013. This classification is systematized by numeric numbers from 0 to 8 and letters (A, B, and C) and based on cooling, heating degree-days and precipitation quantity(Crawley et al., 2013).

It has been pointed out through several studies that the 20-year-old climatic zones of Indian cities as per NBC classification needs to be revisited (Bhatnagar et al., 2016). To revisit the climate zone classification, the weather data including temperatures, relative humidity, solar radiation, precipitation, and cloud cover are required. The Indian Society of Heating Refrigeration and Air-conditioning Engineers (ISHRAE) published updated weather data in the year 2014. These weather data files include climatic parameters such as global horizontal radiation, dry-bulb temperature, wet-bulb temperature, wind velocity and direction, and cloud cover, etc.

Bhatnagar et al. (2016), presented revised climate zones for 60 Indian cities based on ASHRAE Standard 169-2013 and NBC 2016. The cities are classified into eight climate zones for ASHRAE Standard 169-2013 classification, and five climate zones for NBC 2016. Out of the eight climate zones, it is found that there are three climate zones as per ASHRAE Standard 169-2013 and two climate zones as per NBC have only one city in each climate zone. The three cities are Amritsar (2 B), Shillong (3 C) and Srinagar (4 B) as per ASHRAE Standard 169-2013 and Bengaluru (Temperate) and Srinagar (Cold) are single cities classified in individual climate zones as per NBC 2016.

NEED OF THE STUDY

The research in building science requires selection of cities for testing new technology, to evaluate the effect of changes in different parameters on building energy performance, and to develop existing and new energy codes. For the development of code or to verify the applicability and performance of new technologies, the building energy simulation and analysis is required. However, the analyses in all cities are not justifiable because of increasing cost and time and may be prohibitive to undertake the studies. These researches use *representative cities* as proxies for a target building energy efficiency to get meaningful information.

The conventional method of selecting representative city as proposed by Shehata et al. (1979) is to examine the demographic characteristics such as population, commercialization, metropolitan/ nonmetropolitan cities etc., of different cities and to select the city that most closely resembles the target market. These representative cities may be appropriate where the climate does not affect the analysis.

The United States (US) Department of Energy (DOE) developed commercial reference building models in 16 representative cities of 16 climate zones. It suggests a selection of representative locations based on Pacific North-west National Laboratory (PNNL) study on a set of typical locations. The selected locations were a balance of the representativeness of the climate and the number of buildings in each climate zone (Deru et al., 2011).

Another study of market research includes total index as the parameter for representativeness. The total index is estimated by summing the weight scores of individual demographic variables. The index offers a means for ranking cities or different market areas according to their overall similarities to the target market areas in the total index (Shehata, 1979).

Energy-efficiency standards and green building certification used by the U.S. Department of Defense for Military Construction and Major Renovation, selected representative cities based on the geographic location of the city within the climate zones. Centrally located cities within the climate zones were selected (National Research Council, 2013). It may not be representative with respect to climate.

Briggs et al. (2003) mentioned two criteria for selection of representative cities. First, the representative city needed to be similar to the "average" weather conditions within a zone, not favoring either mild or harsh climate and preferably located centrally within the zone's geographic extent. Second, a representative city should, to the extent possible, favor weather conditions where buildings are predominantly located. However, the detailed method for selection of a representative city has not been presented.

In India, the researchers have used different sets of criteria in the selection of representative city for their studies. These criterions are demographic that is metropolitan cities in some studies; average climate conditions preferably dry-bulb temperature only and sometimes based on literature.

A study of energy use projection and saving potential of residential buildings in India selected representative cities based on literature (Rawal and Shukla, 2014). The determination of an Overall Thermal Transfer Value (OTTV) equation for buildings have been done on three cities representing three climate zones. These three cities are metropolitan cities possibly having a large number of buildings (Devgan et al., 2010). A stringency analysis of Energy Conservation Measures (ECM) has been done in 5 cities of India. The representativeness of cities is determined based on the mean dry-bulb temperature of a city in a climate zone (Somani and Bhatnagar, 2015).

Few studies have been conducted with different cities as representative of climate zones of India. The estimation of the energy savings by cool roof application on buildings in five climate zones of India has been done using Mumbai (warm and humid), Ahmedabad (hot and dry), Bangalore (temperate), and Delhi (composite) and Shillong (cold) as representative cities. The study has not clarified how the representative cities have been selected (Bhatia et al., 2011).

There are few studies on thermal comfort in buildings using some representative cities for a climate zone. An India Model for Adaptive Comfort (IMAC) based on the field surveys administered in 16 buildings in three seasons and five cities are considered as representative of five Indian climate zones. These surveys conducted in five Indian cities selected to represent the five main climate zones i.e. Chennai (warm and humid), Ahmedabad (hot and dry), Delhi (composite), Bangalore (moderate) and Shimla (cold) (Manu et al., 2016). There are other literatures on thermal comfort surveys for composite climate of India using Jaipur city (Dhaka and Mathur, 2017)(Kumar et al., 2016).

A parametric evaluation of the impact of the Energy Conservation Building Code (ECBC) of India on commercial building sector has been done using the following climate zones; Jodhpur (hot and dry), Kolkata (warm and humid), New Delhi (Composite), Bangalore (Moderate) and; Guwahati (Cold) (Manu et al., 2011).

Since researchers used different approaches to select a representative city for a climate zone in India which alter the results and consequently energy policy or possible impact of new technology. In most studies, the metropolitan cities were selected as the representative city. These metropolitan cities may have extreme climatic conditions which affect the analyses and policies. For example, Chennai, Kolkata, and Mumbai are in "warm and humid" climate zone of India. These three cities are all metropolitan with high population and major business centers of India. All three cities have different latitude, longitude, and climatic conditions, and it is difficult to select a city as representative with only demographic criteria. Therefore, there is a requirement of a standardized method for selection of representative city for a climate zone. Additionally, a detailed method for selection of a representative city is required, which includes major climatic parameters.

This paper focuses on a standardized method for selection of a representative city in a climate zone so the future analyses will be based on it to avoid uncertainty in results.

METHODOLOGY

Parameter selection

The building energy consuming components are lighting, receptacle equipment, and heating and cooling equipment. The lighting and receptacle equipment are based on building typology whereas the heating and cooling equipment load are dependent on building typology as well as the climate. The external load (climate), internal load (occupancy, lighting and equipment) and building envelope (wall, roof and fenestration) are the factors for heating and cooling load in a building. If the envelope and internal loads are constant, then the climatic parameters such as solar radiation, dry-bulb temperature, and relative humidity affect the building's heating and cooling load. The following figures are representing climate zone wise variation in solar radiation, dry-bulb temperature, and relative humidity.

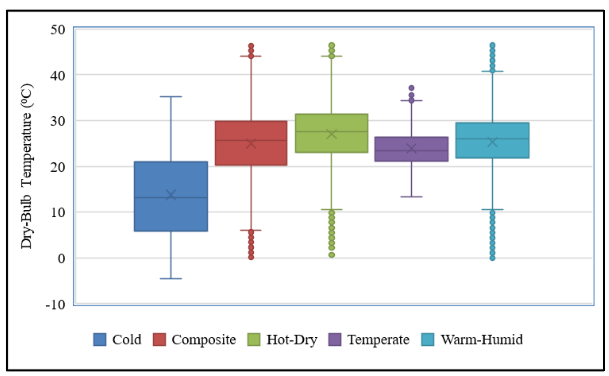


Figure 1: Distribution of dry-bulb temperature in different climate zones

Figure 1 presents the variation in dry-bulb temperature throughout the climate zones. The temperature range varies from 5°C to 35°C in cold climate zone. The temperate climate zone has smallest temperature variation while composite and cold climate has the largest variation. The hot dry and warm-humid climate zones show almost similar temperature range. However, the relative humidity separates them into different climate zones.

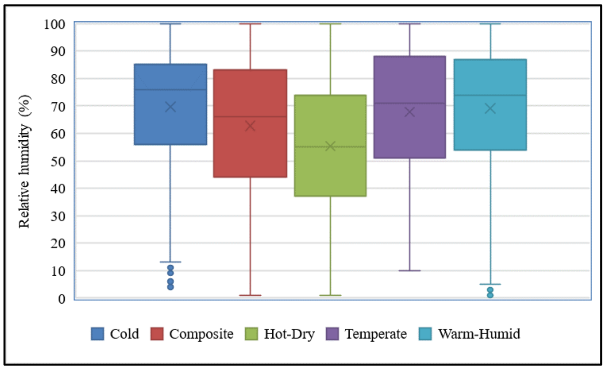


Figure 2: Distribution of relative humidity in different climate zones

Figure 2 presents relative humidity variation in different climate zones. The cold, temperate and warm-humid climate zones have a large number of data in a range of 55% to 85% relative humidity. The hot-dry climate zone majorly varies in the range of 38% to 73% relative humidity.

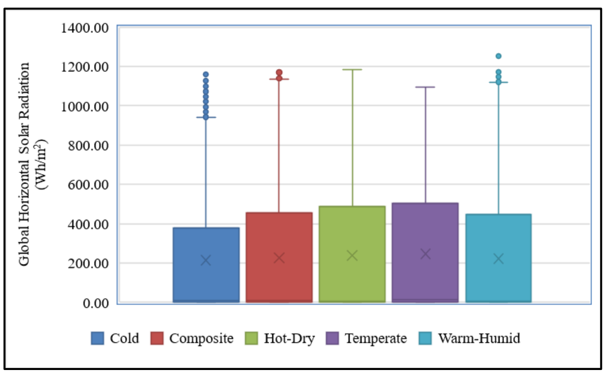


Figure 3: Distribution of global horizontal solar radiation in different climate zones

Figure 3 presents the variation in solar radiation in different climate zones. The temperate climate has maximum solar insolation followed by hot-dry, composite, warm-humid, and cold climate zone.

For the selection of a representative city, a single parameter is not sufficient as they represent distinct characteristics in different climate zones. Therefore, the parameters selected for selection of representative city are dry-bulb temperature, relative humidity, and solar radiation.

Mathematical Approach

Euclidean Distance

The approach used to develop a method for selection of representative city is based on "Euclidean Distance". The Euclidean distance or Euclidean metric is the "ordinary" (i.e. straight-line) distance between two points in Euclidean space [6]. The distance between two points defined as the square root of the sum of the squares of the differences between the corresponding coordinates of the points; e.g. in two-dimensional Euclidean geometry, the Euclidean distance between two points P = (x1, x2) and Q = (y1, y2) is defined as:

$$PQ = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2} \quad \text{.................. (4)}$$

In three-dimensional Euclidean space, the Euclidean distance between points **P (x_1, x_2, x_3)** and **Q (y_1, y_2, y_3)** is:

$$PQ = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + (x_3 - y_3)^2} \quad \text{.. (5)}$$

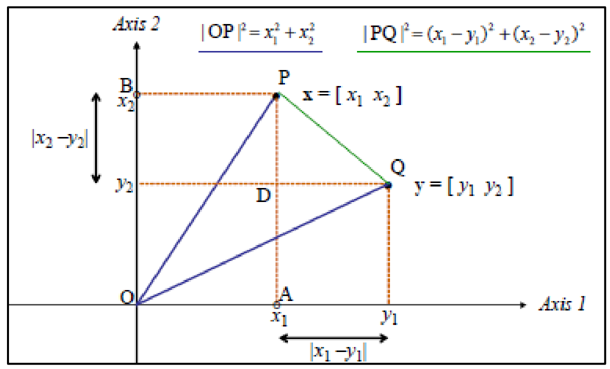


Figure 4: Euclidean Distance in two-dimensional space (Greenacre, 2008)

Data Normalization

The three variables (solar radiation, temperature, and relative humidity) are on different scales of measurement and larger value of the solar radiation will dominate the calculation. Therefore, some form of normalization is necessary. Normalization is the process of reducing measurements to a 'neutral' or 'standard' scale (Shalabi et al., 2006). There are Z-score and Min-Max normalization methods to neutralize the data to make it comparable. Here, the Min-Max normalization method has been used.

PROPOSED METHOD

The major climatic variables which affect building energy performance are solar radiation, temperature, and relative humidity. For applying Euclidean distance method, a city is assumed to be in three-dimensional space. The three axes of three-dimensional spaces are Global Horizontal Radiation (GHR) (X-axis), Dry-Bulb Temperature (DBT) (Y-Axis) and Relative Humidity

(RH) (Z-Axis). The city 'A' defined as 'x' solar radiation, 'y' dry-bulb temperature and 'z' relative humidity i.e. A (x, y, z). The point A (x, y, z) includes hourly values for a weather data year. The proposed method includes following steps:

Normalization

These three parameters have different units and cannot be compared directly. Therefore, the data normalization method is required to transform the data in the same scale for fair comparison. The data has normalized with minimum and maximum values of the particular parameter for all cities in a climate zone. For example, the hourly values of solar radiation have normalized with **a** maximum value over 8,760 hours of solar radiation data. Similarly, the temperature and relative humidity have normalized. There are 8,760 normalized points of solar radiation, dry-bulb temperature and relative humidity for a city.

Normalization of all parameters:

$$X_{new} = \frac{X - X_{min}}{X_{max} - X_{min}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

X = value to be normalized

X_{max} = Maximum value in climate zone for each parameter

X_{min} = Minimum value in climate zone for each parameter

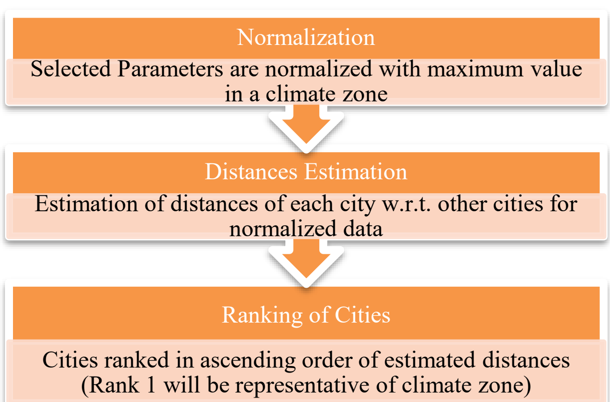


Figure 5: Methodology for selection of representative city

Estimation of distance between two cities:

After normalizing each variable, the climatic distance between two cities (City A and City B) using Euclidean Distance method for three-dimensional space has been calculated. The distance between two cities have been estimated as:

$$d1 = \sum_{i=1}^{8760} \sqrt{(X_{A,i} - X_{B,i})^2 + (Y_{A,i} - Y_{B,i})^2 + (Z_{A,i} - Z_{B,i})^2} \ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

Where

d1 = Euclidean distance between City A and City B

X = hourly normalized value for global horizontal radiation

Y = hourly normalized value for dry-bulb temperature

Z = hourly normalized value for relative humidity

A = subscript for City A

B = subscript for City B

i = hour

Similarly, the distance has been calculated from city A to city C, D, ….. n. The "n" is the last city in a climate zone. The estimated distances named as d2, d3… dn.

After calculation of distances for all cities with city A, the total distance estimated as:

D1= d1+d2+d3+…. dn…………………………….... (8)

Where

n = the total number of cities in a climate zone.

D1 = Total of distance calculated from a city to all other city in a climate zone.

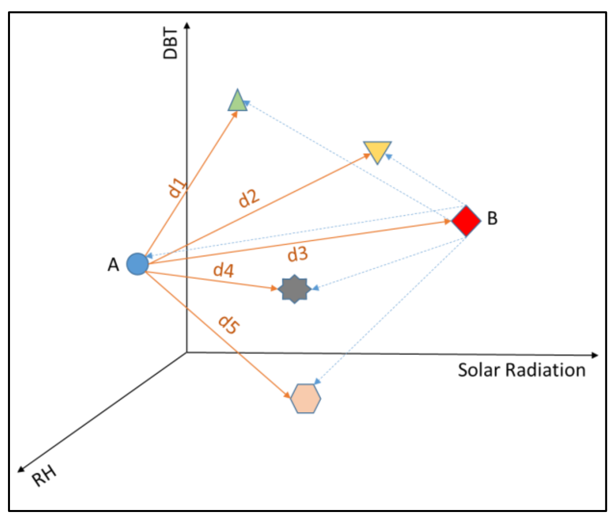
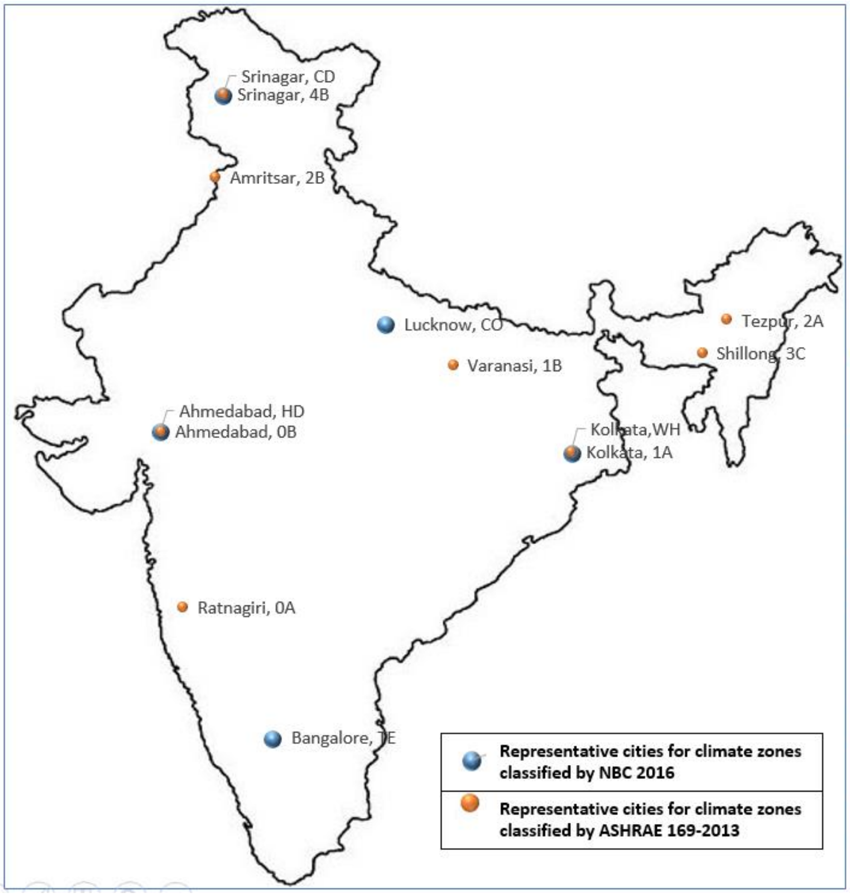


Figure 6: Estimation of Euclidean distance of City A from all other cities in a climate zone

The same procedure has been applied to all cities to determine their corresponding distances from other cities i.e. D2, D3, D4 … Dn. These distances depict variation in climatic conditions with each other.



NBC 2016 climate zones for India		
S. No.	Climate Zone	Abbreviation
1	Cold	CD
2	Composite	CO
3	Hot-dry	HD
4	Temperate	TE
5	Warm-humid	WH

ASHRAE Standard 169-2013 climate zones for India		
S. No.	Climate Zone	Abbreviation
1	Extreme hot humid	0A
2	Extreme hot dry	0B
3	Very hot humid	1A
4	Very hot dry	1B
5	Hot humid	2A
6	Hot dry	2B
7	Warm-marine	3C
8	Mixed-Dry	4B

Figure 7: Geographical locations of representative cities with Rank 1

Representative city selection

Then evaluation of distances among cities provides centroid city in a climate zone. The cities have been ranked based on estimated distances for a climate zone. The smallest distance of a city to all other cities in climatic conditions ranked '1'and is considered as a representative city. It is because the least distance depicts epicenter of cities in a climate zone with respect to climatic parameters. Thus,

Representative City total distance = Min (D1, D2, D3, D4… Dn) ………………………………………..… (9)

RESULTS AND DISCUSSION

The proposed method has been applied to weather data of cities classified in different climate zones as per the classification of ASHRAE standard 169-2013 and NBC 2016. The city with minimum distance from other cities in a climate zone is centrally located with respect to climatic conditions. The cities have been ranked in ascending order of estimated Euclidean Distance and presented top 5 ranks in Table 2, Table 3, and Table 4 for climate zones defined as per ASHRAE standard 169-2013 and; Table 5 and Table 6 for climate zones defined as per NBC 2016. Figure 7 presents the geographical locations of ranked one cities which can be considered as representative cities for respective climate zones.

There are 8 representative cities correspondent to 8 climate zones as per ASHRAE Standard 169-2013, i.e. Ratnagiri (Climate zone 0A), Ahmedabad (Climate zone 0B), Kolkata (Climate zone 1A), Varanasi (Climate zone 1B), Tezpur (Climate zone 2A), Amritsar (Climate zone 2B), Shillong (Climate zone 3C) and Srinagar (Climate zone 4B). As per NBC, the representative cities are Ahmedabad (Hot-Dry), Kolkata (Warm-Humid), Lucknow (Composite), Bengaluru (Temperate) and Srinagar (Cold).

The cities with maximum distance in a climate zone indicate extreme climate characteristics compare to other cities. These extremities can be very high or low values of the GHR, DBT, and RH with corresponding hourly values of other cities. These cities represent climatic characteristics which depict boundary condition of respective climate zone.

Table 2: Ranking of cities as per ASHRAE Standard 169-2013 Climate Zones (1)

Climate Zone 0 A		**Climate Zone 0 B**	
Cities	Rank	Cities	Rank
Ratnagiri	1	Ahmedabad	1
Panjim	2	Solapur	2
Mumbai	3	Rajkot	3
Bhubaneshwar	4	Barmer	4
Mangalore	5	Bhuj	5

Table 3: Ranking of cities as per ASHRAE Standard 169-2013 Climate Zones (2)

Climate Zone 1 A		**Climate Zone 1 B**		**Climate Zone 2 A**	
Cities	Rank	Cities	Rank	Cities	Rank
Kolkata	1	Varanasi	1	Tezpur	1
Jagdalpur	2	Lucknow	2	Jorhat	2
Bhagalpur	3	Bhopal	3	Dibrugarh	3
Raxaul	4	Aurangabad	4	Imphal	4
Pune	5	Hyderabad	5	Saharanpur	5

Table 4: Cities with distinct climate zone as per ASHRAE Standard 169-2013

Cities	**ASHRAE Standard 169-2013 Climate zone**	
Amritsar	2B	Hot Dry
Shillong	3C	Warm Marine
Srinagar	4B	Mixed Dry

Table 5: Ranking of cities as per NBC 2016 Climate Zones

Hot Dry		**Composite**		**Warm Humid**	
City	**Rank**	**City**	**Rank**	**City**	**Rank**
Ahmedabad	1	Lucknow	1	Kolkata	1
Aurangabad	2	Jabalpur	2	Bhubaneshwar	2
Solapur	3	Nagpur	3	Mangalore	3
Kota	4	Allahabad	4	Panjim	4
Jodhpur	5	New Delhi	5	Ratnagiri	5

Table 6: Cities with distinct climate zone as per NBC 2016

Cities	**NBC 2016 climate zones**
Temperate	Bengaluru
Cold	Srinagar

Although the presented method aims to combine the strengths of different climatic parameters, which affect building energy performance, there are still some limitations or future work that needs to be implemented to make it better.

The first issue is related to climatic zones of India classified as per method described in NBC 2016. The climate zones and the developed selection method is two-decades-old. This is an essential requirement to revisit the method and criteria to select the climate zones of India. Additionally, the requirement is also because of the climate change and variation in temperatures. If a city is incorrectly constituted into a climate zone, it will affect the consequent representative city based on this method.

Another issue is the weighting of different parameters on building energy. In this method, we are not proposing to add weighing factors of each parameter. This weighing will be accommodated in the method based on their respective weightage based on their application. This will introduce the subjectivity of each parameter in the selection of representative city. Here, the approach is independent of any specific application. In certain cases, there may be unequal importance of climatic parameters. For additional such cases, a modified approach with weighted Euclidean distance would be required.

CONCLUSION

The method has been proposed to select a representative city in a climate zone. The Euclidean Distance method has been used with different climatic parameters which affect building energy performance. The calculated minimum distance of a city from all other cities in a climate zone is the representative city. The maximum distance indicates boundary conditions for the climate zone.

The proposed method can be used for application specific characteristics such as the population existing, and new construction of buildings would be an additional parameter for selection of representative city.

This method provides another way to assist researchers in selecting a representative city to the target market to explore and analyze various technological advancements. If researcher collects the relevant information about the demographic characteristics of various cities and utilizes the appropriate statistical method to find out different weightage, this method can be applied to achieve representative city relevant to the study.

ACKNOWLEDGMENT

This work was carried out as a part of a research work related to building energy performance. Authors would like to thank Centre for Energy & Environment at Malaviya National Institute of Technology, IIIT-Hyderabad for supporting the research.

REFERENCES

Bansal, N.K., Minke, G., 1988. Climate Zones and Rural Housing in India. Kernforschungsanlage Jülich, Zentralbibliothek.

Bhatia, A., Mathur, J., Garg, V., Bhatia, A., Mathur, J., Garg, V., 2011. Calibrated simulation for estimating energy savings by the use of cool roof in five Indian climatic zones Calibrated simulation for estimating energy savings by the use of cool roof in five Indian climatic zones. J. Renew. Sustain. Energy 23108–1, 15. doi:10.1063/1.3582768

Bhatnagar, M., Mathur, J., Garg, V., 2016. Reclassification of Climate Zones for Indian cities. ISHRAE- Air-conditioning Refrig. J. 19, 34–43.

Bureau of India Standards, 2005. National Building Code of India, 2005th ed. Bureau of India Standards.

Crawley, D.B., Shirey, D.B., Cornick, S.M., Jarrett, P.L., Lott, J.N., Morris, R.J., Walker, I.S., Walter, W.F., Hall, R.L., Anderson, J.R., Barnaby, C.S., Bruning, S.F., Clark, J.A., Dunlap, J.F., Emmerich, S.J., Ferguson, J.M., 2013. Climatic Data for Building Design Standards. ASHRAE, United States of America.

Deru, M., Field, K., Studer, D., Benne, K., Griffith, B., Torcellini, P., Liu, B., Halverson, M., Winiarski, D., Rosenberg, M., Deru, M., Field, K., Studer, D., 2011. U . S . Department of Energy Commercial Reference Building Models of the National Building Stock U . S . Department of Energy Commercial Reference Building Models of the National Building Stock.

Devgan, S., Jain, A.K., Bhattacharjee, B., 2010. Predetermined overall thermal transfer value coefficients for Composite, Hot-Dry and Warm-Humid climates. Energy Build. 42, 1841–1861. doi:10.1016/j.enbuild.2010.05.021

Dhaka, S., Mathur, J., 2017. Quantification of thermal adaptation in air-conditioned buildings of composite climate , India. Build. Environ. 112, 296–307. doi:10.1016/j.buildenv.2016.11.035

Greenacre, M., 2008. Chapter 4 Measures of distance between samples: Euclidean [WWW Document]. Dep. Stat. Stanford Univ. URL http://84.89.132.1/~michael/stanford/maeb4.pdf (accessed 12.14.16).

Kumar, S., Kumar, M., Loftness, V., Mathur, J., Mathur, S., 2016. Energy for Sustainable Development Thermal comfort assessment and characteristics of occupant â€™ s behaviour in naturally ventilated buildings in composite climate of India. Energy Sustain. Dev. 33, 108–121. doi:10.1016/j.esd.2016.06.002

Manu, S., Shukla, Y., Rawal, R., Thomas, L.E., de Dear, R., 2016. Field studies of thermal comfort across multiple climate zones for the subcontinent: India Model for Adaptive Comfort (IMAC). Build. Environ. 98, 55–70. doi:10.1016/j.buildenv.2015.12.019

Manu, S., Wong, J., Rawal, R., Thomas, P.C., Kumar, S., 2011. An Initial Parametric Evaluation of The Impact Of The Energy Conservation Building Code Of India On Commercial Building Sector, in: 12th Conference of International Building Performance Simulation Association. pp. 14–16.

National Research Council, 2013. Energy-Efficiency Standards and Green Building Certification Systems Used by the Department of Defense for Military Construction and Major Renovations. The National Academics Press, Washington, DC.

Papakostas, K., Kyriakis, N., 2005. Heating and cooling degree-hours for Athens and Thessaloniki, Greece. Renew. Energy 30, 1873–1880. doi:10.1016/j.renene.2004.12.002

Rawal, R., Shukla, Y., 2014. Residential Buildings in India : Energy Use Projections and Saving Potentials, Global Buildings Performance Network.

Shalabi, L. Al, Shaaban, Z., Kasasbeh, B., 2006. Data Mining : A Preprocessing Engine. J. Comput. Sci. 2, 735–739. doi:10.1.1.121.2072

Shehata, S.A., 1979. An Index Method for Selecting Representative Cities of a Target Market. West. J. Agric. Econ. 111–118.

Somani, G., Bhatnagar, M., 2015. Stringency analysis of building envelope energy conservation measures in 5 climatic zones of India, in: Building Simulation 2015. pp. 751–758.