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Climate Comfort Analysis of Östersund, Sweden

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Abstract

The required energy for heating and cooling varies due to different climate conditions such as hot and dry, Mediterranean and cold. Olgyay [1] bioclimatic chart helps to define the average amount of temperature and humidity values to provide human comfort in cities. The aim of this study is to examine potentials of human comfort using bioclimatic chart as well as to evaluate weather findings for demanded heating and cooling in Östersund, Sweden. The method of this paper is to analyse human comfort by using Olgyay V [2] bioclimatic chart of 2016. Olgyay [1] bioclimatic chart revealed that heating is needed even in summer period in Östersund. Particularly the months between December and November, additional heating should be more than 490W/m2 to reach the comfort zone. In addition, the comfort zone is achieved with additional heating between June and September as well. The importance of this study is to analyze one of the cold-climate cities in Sweden, Östersund, since there are few studies include climate comfort by using Olgyay [1] bioclimatic chart.

Keywords : Data science; Railroad engineering; Infrastructure intensive industry; Big data

Introduction

In this study, we gave climatic data findings of Östersund, Sweden and analyzed the climate comfort by using Olgyay V [2] bioclimatic chart. The aim of this study is to examine potentials of human comfort using bioclimatic chart as well as evaluate weather findings for demanded heating and cooling for buildings in Östersund, Sweden. The bioclimatic chart was drawn by us receiving the monthly minimum and maximum relative humidity and air temperature values in 2016.

There are research studies, which include climate analysis of several cities to reveal climate comfort, and many of them based on hot and dry climates such as in China [3], tropical climate such as in India [4], as well as sub-tropical Mediterranean climate in Cyprus [5]. There are two research studies based on cold climates, first of which calculate human indoor and outdoor climate comfort such as in Sweden and Hungary [6] when the second one used [1] bioclimatic chart such as in Toronto [7].

The importance of this study is the case area selection, which was based on Östersund Sweden, because there are few articles analyze climate comfort of cities, which have cold climate as explained above. Even though there are studies regarding bioclimatic controls of forests [8] and spatial analysis of historical forest fires [9] due to climate change in Sweden, there is no article based on Östersund city. Therefore, the difference of this study from recent literature is the evaluation of bioclimatic comfort for summer and winter periods in 2016 for Östersund, which has a cold climate conditions.

This first part of this study starts with a literature review of recent studies, which include climate data and an analysis with Olgyay [2] bioclimatic chart. The second part of this study consists of our analysis of climate data of Ostersund to build bridges between the effects of climate components and human comfort. The third part of this study consists of our bioclimatic chart and our explanation of human comfort in Ostersund by the usage of bioclimatic chart.

In addition, the study was prepared by the group four (4) members, who consist of: Suheyla Turk, Adeyemi Kazeem Ajayi, Katayoon Aminmoayed, Luqman Alkhado and Mehmet Sait Cicek. The group members worked together to achieve the result of the project taking up different roles, while each and everyone in the group contributed to ideas, evaluation of graphs, finding figures, usage of the book called sun, wind, light and developing arguments to discuss bioclimatic chart with the findings related to climate conditions of Östersund city.

Method and Data

Climatic parameters have been provided from 5 different web pages, which have been listed in Table 1. In addition, correlation between mean-min temperature and mean-max humidity, mean-max temperature and mean-min humidity for each month of 2016 have led us to plot lines on bio-climatic chart which corresponds to each month of the year. To draw Victor Olgyay [1] bioclimatic chart for each month of 2016, a maximum temperature and a minimum humidity was matched and, then marked on the graph [10]. Then, a minimum temperature, a maximum humidity was matched and pointed on the graph [10]. Afterwards, these two points were connected to create a line for each months of the year [10]. As a result, it has been observed that, the lines, which are in comfort zone do not need any extra heating and cooling, while the lines outside of the comfort zone need either heating or cooling [10].

Table 1: The sources of data.

Data Findings	Name of the Web Page
Temperature	https://www.wunderground.com
Humidity	https://www.wunderground.com
Solar Radiation	https://www.weatherbase.com
Wind	https://www.windfinder.com
Precipitation	www.yr.no

Literature Review

There are three articles [4,5,11] exist that include hot climates were selected for literature review. The first article was written by Singh et al. [4] based on North East region of India Singh et al. [4]. The three bioclimatic regions referred to warm and humid, cool and humid, cold and cloudy considering the variables of monthly mean data for solar radiation, temperature, humidity, precipitation and wind and sky situations over the country [4]. The aim of the study is to analyze different zone conditions of bioclimatic building design charts for 12 months by using bioclimatic building design chart. The data based on the meteorological data collected from various meteorological stations of India. Their findings can be used for design principles of a building in the beginning stage of design, which can be supported by a detailed analysis as a next step [4]. These principles were developed to decide the orientation of building, the ratio of surface to volume, thermal comfort, material selection, the size and shape of windows, fenestration, ventilation type and sun control to design a climate responsive energy efficient residential buildings. Even though Singh et al. [4] study consists of a detailed analysis of bio climate, the used scale is regional, which does not include city specific information.

The second article consists of five climate types, which were developed and referred to severe cold, cold, hot summer and cold winter, mild and hot summer and warm winter [11]. A bioclimate analyses was used for each of 18 cities for twelve months period for a city scale analysis, for which [12] a comfort zone was adapted by using the mean minimum temperature and mean minimum relative humidity, as well as the mean maximum temperature and mean maximum relative humidity of 18 Chinese cities [11]. The aim of the study is to develop passive design principles for summer and winter conditions to be used for solar heating, ventilation, heating and cooling of passive designed building. The study of Yang et al. [11] found the potential usage of solar retrofitting during the year for each climate zones were calculated. Also, passive cooling needs, air conditioning and passive solar heating needs were analyzed to define passive design principles. The outcome of study shows, there were nine different zones of passive design principles should be adapted for energy efficient building design. However, there is no information about how their climate data was gathered.

The article of Katafygiotou & Serghides [5] was useful for this research in terms of their focus on heating and cooling strategies as well as the usage of Olgyay V [1] bioclimatic chart. In the article, there were three climate zones developed by Katafygiotou & Serghides [5], which were referred to coastal, inland and mountainous in Cyprus. Two cities called Limassol and Nicosia as well as one village called Prodromos was selected as examples of three climatic zones [5]. The aim of this study is to develop building design principles for thermal comfort conditions for three climate zones in Cyprus. To provide thermal comfort, the capacity of solar radiation was analyzed, and its potential use of passive heating was calculated. Therefore, a bioclimatic analysis was used to define the comfort zones for each selected climate considering the temperature of air, humidity level, solar radiation, radiant heat and evaporation for cooling. The data, which consists of maximum air temperature and minimum humidity as well as minimum air temperature and maximum humidity of each month, was gathered from Cyrus methodological service for last ten years period starting from 2005 [5].

The study of Katafygiotou & Serghides [5] gave cooling and heating strategies, which were developed by considering the above and below parts of shading line of bioclimate chart. Then, cooling strategies divided into five main types, which were referred to natural ventilation, radiative cooling, thermal mass night ventilation, evaporative cooling and mechanical air conditioning. Katafygiotou & Serghides [5] suggested three different types of mechanical cooling, which consist of humidification, dehumidification and conventional dehumidification with mechanical means. In terms of heating strategies, developed efficient usage of existing temperature by insulation and solar heating.

In addition, a first study that we reviewed from cold climate literature studies [6,7] belongs to Gal & Szalay [6], which gave information about climate characteristics of Sweden and Hungary by using building scale to find out energy needs of two types of houses in these countries. The outcome of their study reveals that, in both countries there was potential to use in buildings for solar retrofitting. However, the usage of solar energy was not economically efficient based on their economic analysis. This is because, they found out that the paybacks of solar investments in building systems did not compensate the solar investment expenses. Gal & Szalay [6] assumed that the future prices would have been reduced to expand the usage of solar energy for building retrofits of Sweden and Hungary.

The second article used urban scale and bioclimatic chart for Toronto [7]. Three areas were selected to analyze from a business district, an inner-city housing area with stores and an area consisted of tall office towers between downtown and Lake Ontario. Bosselmann et al. [7] analyzed sun, wind and comfort by using six variables of solar radiation, wind, humidity, ambient air temperature, peoples' activity levels and clothing, which were linked to outdoor thermal comfort. At the end, a street level, urban scale comfort model was developed to be used for other city thermal comfort applications. The model was suggested to be used for experiences of people in different climate zones [7].

Evaluation of Climate Findings of Östersund

Östersund situates in the north - west part of Sweden, which is shown in Figure 1 below and has north temperature climate zone. The city has Arctic winds, which impact the cold climate components similar to other Scandinavian cities. Also, gulfstream cause warmer winter conditions in Östersund city by the effects of warmer Atlantic winds. One of the extreme temperature was 33 degrees in July, while in winter the lowest weather was -38 degrees [13].

In this part, the climate conditions for Östersund city have been analyzed and they grouped with regards to their connections between each other. DeKay & Brown [10] explains that, to find out proposer outside climate conditions to locate a building, an analysis of data of sun and wind is needed. Firstly, sun and wind conditions are evaluated to assess a site microclimate [10].

Secondly, according to DeKay & Brown [10], to find out proper inside conditions of a building, referred to climate comfort, one year long temperature and humidity data of a location should be considered to determine heating and cooling demand in the building. Therefore, solar radiation, sunshine hours and wind data have been provided to evaluate the site microclimate. In addition, temperature and humidity data findings were used to understand climate comfort and then to designate bio climate graph in the following sections of this study.

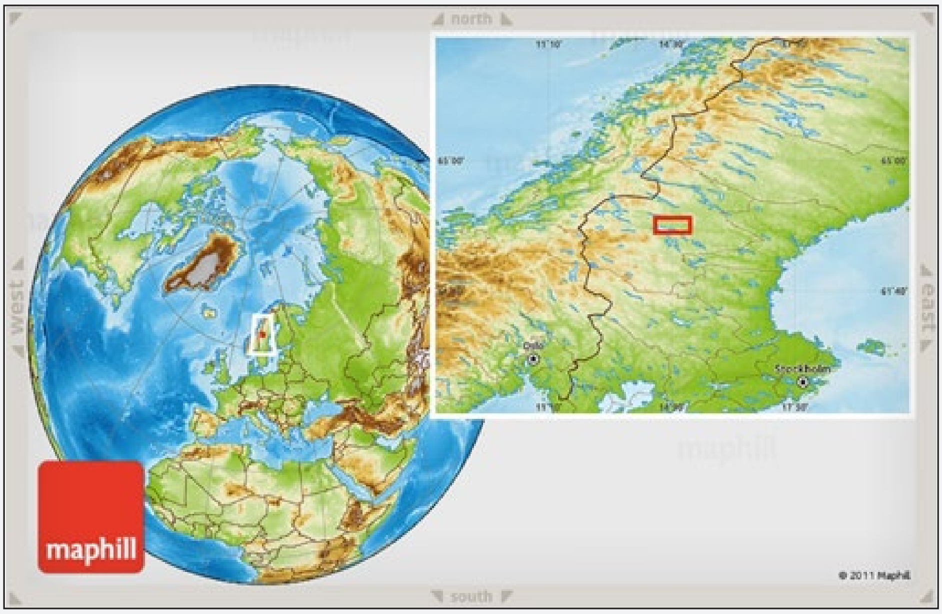

Figure 1: The location of Östersund in Sweden.

Solar radiation

Data obtained from weatherbase.com [14] shows that maximum solar radiation is reached in June as 5.3kWh/m^2 while minimum solar radiation is observed in December as 0.1KWh/m^2. Average solar radiation for a year (2016 in our case) is 2,5kWh/m^2 (Figure 2).

Average Daily Solar Radiation - Global — Years on Record: 22

	ANNUAL	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
kWh/m2	2.5	0.2	0.8	2	3.7	4.9	5.3	5	3.8	2.4	1.1	0.3	0.1

Figure 2 : Global radiation in Östersund in 2016 [19].

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Sunshine hours

Data obtained from weatherspark.com [15] shows that December 21 is the shortest day with 4 hrs 37 minutes of sunshine while June 21 is the longest day with 20hours 26minutes of sunshine. Yearly average sunshine hours are around 12hours, but we can see that there are changes of almost 2 hours between each month of the year. When it comes to mean monthly sunshine hours during one-year Östersund, the longest hours were observed in June for 2016 according to the data provided from weatherspark.com (Figure 3).

Wind

According to data from windfinder.com [16] prevailing wind directions are northwest and Southeast, which is observed from the (Figure 4). Average wind speed is around 17km/h.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean monthly sunshine hours	32	70	156	199	242	256	259	201	132	87	40	24	1,698

Figure 3 : Sunshine hours in Östersund city [19].

Month of year	Jan 01	Feb 02	Mar 03	Apr 04	May 05	Jun 06	Jul 07	Aug 08	Sep 09	Oct 10	Nov 11	Dec 12	Year 1-12
Dominant wind direction													
Wind probability >= 4 Beaufort (%)	28	33	34	30	29	32	24	18	28	32	32	29	29
Average Wind speed (km/h)	17	17	19	17	17	19	15	15	17	17	17	17	17
Average air temp. (°C)	-6	-5	0	4	10	13	16	15	11	5	0	-4	5

Figure 4 : Wind speed and direction in Östersund [17].

Precipitation

Data from yr.com [17] shows that precipitation is evenly distributed between each month of the year for Östersund but the form of precipitation changes such as rain or snow between the months of the year depending on the season. Maximum precipitation is reached in June as 10 mm as rain while the minimum precipitation is reached in February as 5mm as snow.

Temperature and humidity data

Data obtained from wunderground.com [18] shows that maximum average monthly temperature is reached in July as 18C while lowest mean monthly temperature is reached in January as -14C. Yearly average minimum temperature is 0 degrees Celsius while average maximum yearly temperature is around 7 degrees Celsius.

Humidity

Data obtained from wunderground.com [19] shows that maximum average monthly humidity is reached in November as 92% while lowest mean monthly humidity is reached in May and June as 36%. Yearly average minimum humidity is 55% while average maximum yearly humidity is around 88% and the below Table 2 has been prepared from data obtained from wunderground.com [20].

Different elements of climate have been observed for Östersund as presented above. The main climate elements, which are temperature and humidity, are correlated with each other.

Olgyay (1963)'s bioclimatic chart to evaluate human comfort in Östersund

Table 2 above showed two sets of data, which were mean-min temperature and mean-max humidity, mean-max temperature and mean-min humidity for each month of 2016 for each month of the year. These two sets for each month is marked on Bioclimatic chart as a point and the line connecting these points for each month are regarded the change in each month for 2016 as it was shown in Figure 5.

As it can be seen from Figure 5, which is [21] bioclimatic chart, additional heating is needed all year round for Östersund to reach the comfort zone. For the months; December, January, February, March, November the need for additional heating is so huge that it is even above the 490W/m2 heating is not sufficient to reach the comfort zone. Only in June, July, August, and September with inclusion of additional heating it is possible to reach the comfort zone. This can be regarded as an expected result considering the latitude of the city. As the relative humidity values are so high during whole of the year there is no need for additional moisture inclusion. Also, this is also the case for wind because the heat need is so high that the inclusion of additional ventilation would not needed, because the wind provides enough natural ventilation potential for the inhabitants of the city. Thus, well insulated dwellings are essential in Östersund to achieve human comfort meanwhile, to reduce energy consumption for heating.

Conclusion

This study consisted of an evaluation of human comfort in one of the cold climate cities from Sweden. Olgyay V [1] bioclimatic chart was used to explain the relationship between humidity and temperature, which affects human comfort and reveal needed heating and cooling values. Even though there are studies that used [22] bioclimatic chart, there are few articles to assess the human comfort for cold weather with related different elements of climate such as; temperature, humidity, solar radiation, sunshine hours, wind, precipitation. This study revealed that, heating is needed in Östersund for all months of the year, which is linked to geographical location of the city. In addition, because of the high humidity rate, there is no extra moisture is needed [23]. The wind values provide sufficient natural ventilation opportunity for the citizens to live in human comfort, while insulation system is strongly recommended for buildings.

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