RESEARCH PAPER
ABOUT THE REVALUATION OF PASSIVE CLIMATE SYSTEMS

A study on low-tech climate strategies in colonial buildings in Bandung

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ABSTRACT
This paper aims to demonstrate that instead of newly constructed, expensive and energy-inefficient
buildings, it is possible to fuse cultural heritage and a high quality of comfort by using passive design
strategies in historical architecture. Bandung takes an exemplary position in terms of Indonesian
modernization and adaptation to the climate. However, these techniques seem to have been forgotten.
Therefore lies the focus in this article on the passively designed architecture that was constructed during
the colonization in the interwar period in Bandung. This research assesses arguments facing indoor
thermal conditions and question alternatives for mechanical solutions. A comfort range has been set,
aimed at the desired indoor climate in warm and humid regions. The results proved that passive design
techniques can positively impact the thermal conditions, but that there are no passive solutions yet to
reduce humidity. However, the allowance of fresh airflows through the building by means of natural
ventilation has been proven effective, because it cools perspiration and thus increases acceptance
of high humidity levels. Case studies provided evidence that passive design techniques used to be an
integral part of modern architecture in hot and humid climates. The research confirms the hypothesis,
where proven passive design methods are able to positively impact the level of comfort, and thus also
in Hotel Swarha. However, in order to successfully redesign an existing building, the reinforcement of
mechanical ventilation will be necessary to be consistent with the expectations of the users.

KEYWORDS: Sustainable Architecture, Thermal Comfort, Passive Cooling, Hot-Humid Climate,
Colonial Buildings, Hotel Swarha, Bandung, Indonesia.

1. INTRODUCTION
Indonesian architecture has undergone many
developments in recent decades, in which
colonialism has played a major role. As the cities
were colonized, European architects introduced
new techniques, materials and architectural
forms. Experiments were carried out with the
combination of classical forms and vernacular
building methods from both Europe and Asia.
This eventually developed into an eclectic style
where rational thinking sought solutions for
building in tropical climate conditions, while
aesthetically responding to local and regional
architectural typologies.

Due to its higher altitude and cooler
climate, Bandung was considered more
comfortable to live in than for example Jakarta.
When the capital, formerly known as Batavia,
became too crowded, plans were made to move
the government of the Dutch East Indies to
Bandung. During the colonial era, Europeans
brought modern western architecture to
Indonesia, which is particularly visible in
Bandung. Especially during the inter war
period Bandung expanded rapidly, becoming
representative for the development of modern
architecture in Indonesia. (C.J. van Dullemen,
2010)

Times have changed and the long
struggle for independence has put Indonesia on
its own feet. Cities are growing in population
and economic terms and can afford to invest
in the development of the city. Contemporary
Indonesians tend to be future-oriented rather
than facing the past. Because of a positive
attitude people mainly see opportunities in new
projects with innovating technologies. However,
smart low-tech solutions from the past seem
to be forgotten. Nowadays, the construction
sector focuses primarily on new and high-rise buildings, which are completely independent of its surrounding climate, and consume a great deal of energy. At the same time, many existing, passively designed buildings with a rich history are left vacant. (Wolfgang Lauber, 2005)

The relevance of this paper lies in reminding the reader of a time when climatological conditions in buildings were still solved analogously. With an educational purpose examples of successful passive climate solutions are given. In addition, it provides insight in how the value of a historic building can be determined, thus empowering the building to be reused instead of demolishing it and building something new.

This paper specifically focuses on how Hotel Swarha, an abandoned building in the city center of Bandung, can be altered to meet modern climatological comfort standards. This building has been, despite its historical value and tactical position (religious, social and enterprising) vacant for more than 30 years. The building has been isolated from the street due to many expansions of the mosque and has therefore gradually fallen into disrepair.

To revitalize the building, the program and the climatological concept must be adapted to modern energy needs and comfort standards. The thematic research question in this article therefore reads as follows: What are the characteristic passive climate strategies of the original design of hotel Swarha and how can the building be re-used and adapted to meet modern comfort standards?

2. METHOD
A comprehensive answer to the research question is obtained by dividing the chapter on the results into different focus groups. The aim is to ensure a coherent research procedure, with different perspectives and complementary methods. Therefore, the results of the article are divided into four parts.

The first part is chronologically structured and describes, based on significant historical events, how the urban and architectural developments of Bandung took place. It also explains how European urban planners and architects reacted to the climatic conditions. The approach was to collect the information by means of extensive literature research. The aim of the first part is to give an overview of the lessons learned with regard to climate design in Bandung from the past.

The second part researches the current climate conditions in Bandung. The focus is on researching the orientation, climate characteristics and comfort standards. The approach used was to first collect information from relevant literature and accurate weather websites, then document it using climatic maps and diagrams, and finally process it by comparing and analyzing the obtained data. The aim of this analysis is to learn more about the climate characteristics of the city and the thermal comfort zone in a building.

The third part discusses passive design strategies in hot and humid climates. The focus lies first on the importance of the orientation and surrounding elements of a passively designed building. Then solutions such as sun protection, roof insulation, different ventilation techniques and efficient space planning are discussed. The aim of this research is to provide standard passive design solutions that in the past have been proven to be successful.

In the last part, the obtained theories of passive design strategies tested on different case studies. To provide a comprehensive survey, the chosen buildings are each built in different modernist styles. All examples were constructed in Bandung, in the period of colonization during the interwar period. The analysis is performed at different scales, and focuses on the passive climate techniques. This analysis is also carried out for Hotel Swarha. The goal of this extensive research is to learn about the intended climate control in the Swarha building, what the important design characteristics and values are.

This research approach is beneficial in terms of finding characteristic qualities of an existing building and revaluation of passive climate strategies. The research of this paper questions how an existing building (specifically hotel Swarha) can be reused, responding to the local climate, and thereby reduce unnecessary building waste and excessive energy consumption.

Figure 1 Structure of this paper: knowledge gained from the first three chapters (regarding history, climate and passive design structures) are tested in the case studies in the fourth part and finally tested in the existing Swarha building in the last part of the paper.
3. RESULTS

3.1 BACKGROUND INFORMATION

To understand the climate design of Hotel Swarha, it is essential to have an idea of Bandung’s original urban design and the period in which the building was constructed. This chapter focuses on heritage and the lessons that are learned, regarding climate design of Bandung’s urban context and modern architecture with a shared history. It also addresses problems that modernity caused and new visions on the city. The main question of this chapter therefore is: How did the European urban planners and architects react in their design to the tropical climate? And, what is the contemporary vision of new generation Indonesians on the urban developments of Bandung?

3.1.a URBAN DEVELOPMENTS

This paragraph chronologically describes important historical events in Java and highlights key urban and architectural developments of the city Bandung.

Before a city was built, the area called ‘Bandong’ had been used for coffee and tea plantations, governed by the Dutch East Indian Company (VOC) during the 17th and 18th century. The area is located at a height of 768 meter, in between a ring of higher altitude volcanoes, which makes the area very fertile and interesting for the cultivation of the landscape, see Figure 2. (Tarigan et al., 2016) In order to protect Java from external invasions, a military road was constructed in 1809 under the leadership of governor H.W. Daendels. This road was called the ‘Groote Postweg’ and stretched from West to East Java. Originated from the higher landscape, the ‘Tjikapoendoeng’ river crossed this Postal Road and formed the heart of the city of Bandung, see Figure 3. The city was founded in 1810 and slowly developed as a resort town for European plantation owners. Because of the fertile volcanic soil and the relatively fresh climate, it was a comfortable area to live in. Although the city was founded in the early 19th century, it was not until the beginning of the 20th century before the city began to flourish. (R.P.G.A. Voskuil & C.A. Heshusius, 1996) This makes Bandung a rather young city compared to Jakarta, former ‘Batavia’, allowing relatively new concepts to be applied in urban design.

The expansion of the rail network from Jakarta to Bandung in 1894 was an important development for the city’s growth, since the city became more accessible. Building materials were easier to supply and provided employment opportunities. In 1906 Bandung was established as an independent municipality and the development of the city was to begin. (Cor Passchier, n.d.) North of the railways, luxury residential areas were built according to garden city principles, where the plantation owners and European expats settled. This part of the city was green and spaciously built with villas and public spaces. The area offered beautiful sections; hilly views and automatically drained the water from heavy tropical rains. South of the railway line people from the surrounding villages settled, mainly close to the river. The river was designed as a park landscape and therefore offered plenty of space for informal ‘kampong’ settlements. This area was flat and located lower than the northern part of the city, which caused a clear architectural and residential segregation based on ethnicity, wealth and excising political powers. (R.P.G.A. Voskuil & C.A. Heshusius, 1996)

Figure 2 Location and highland of Bandung, 1931

Figure 3 Map of Bandung with significant colonial buildings, 1937
Bandung was a healthy city because of the relatively fresh climate and resilience to diseases. Therefore, plans were made to move the capital of the Dutch Colonial regency from ‘Batavia’ to Bandung. But due to the war and financial problems that the Netherlands faced at home, the relocation was cancelled. In 1925, however, Bandung did become the capital of western Java and this led to a greater expansion of the city. Especially between the two World Wars a lot was built and most of Bandung’s heritage were realized during this interwar period, see Figure 3. (Cor Passchier, 2016)

The Dutch colony remained in power until the Second World War, until Japan invaded the country in 1942. Indonesia fought back and declared their independence in 1945. (C.J. van Dullemen, 2010) The liberation movement lasted until 1949, when the Netherlands finally accepted Indonesia as independent.

The effect of the independency on the urban development was particularly visible in the suburbs of the city. In the late 1950s the city was expanded again and the new suburbs were divided into a series of rings. Between the rings clusters developed, focusing on fast growing textile industries, and more people moved to the city hoping for a modern future. (Hans-Dieter Evers, 2011) Although the city was sparsely designed, the open areas were increasingly occupied by modern high-rise buildings or informal Kampong settlements, causing more and more pollution of the river and the land.

The country developed enormously and became economically self-sufficient. However, this exponential growth also caused a number of problems. Firstly, it became difficult to keep up with the population’s growth, causing bigger social inequalities. (Tarijan et al., 2016) Secondly, the middle class grew and so did capitalism. This led to an increase in motorized vehicles, an uncontrollable flow of solid waste and the need for the construction of an extensive network of dwellings, offices and infrastructure. Replacing open spaces such as greenery and water with high-rise buildings and pavement solved this need for expansion.

Lastly, as the city densified, historic buildings were left vacant and the natural climate buffer became less effective. The effect of reducing the natural climate buffer is known as the urban-heat island effect, which means that the thermal conditions in the city increase in temperature. (Perini & Magliocco, 2014)

Contemporary urban developments of Bandung focus on smart and sustainable solutions. The current mayor of Bandung aims to make Bandung an example of such a smart city in Indonesia, focusing on the search for innovation through new technical solutions and a bottom-up approach. The plan is to create creative hubs to accommodate specific needs of each sub-district and its inhabitants. Furthermore, the idea is to use social media to involve residents in local urban developments. (World Cities Summit, 2018) While these future plans are mainly focused on social interaction and new technologies, the constant search for modern solutions seems to have neglected lessons learned in the past and urban developments seem to start from scratch.

3.1.b ARCHITECTURAL DEVELOPMENTS
This paragraph discusses the developments of modern architecture in the 20th century with a shared history in the tropical context of Bandung. The focus lies on illustrating common architectural heritage styles and how these designs responded to the climate.

The first two decades of the twentieth century brought forth architects who were born and raised in Bandung and sent to the Netherlands to study. Yet they saw Indonesia as their homeland, had strong desires to come back and were driven by common destiny. During their profession, a relationship was sought between European construction methods and Indigenous Indonesian architecture within a tropical climate. (C.J. van Dullemen, 2010)

The relationship between Indonesian and European architecture has undergone many developments. The book ‘Tropical Modernity’ illustrates the modern tradition of architecture in Indonesia, focusing on modern architecture build, mainly by the Dutch, in the inter war period. Dr. Johannes Widodo, known for his research in heritage conservation and sustainable Asian cities, summarizes the relevance of historical context to architectural design as follows:

“Indonesian architecture is an evolving modernity, from distant past, to recent past, and to the contemporary. The study on ‘colonial architecture’ or ‘shared heritage’ should therefore be seen in the context of modernity and modernization process.”

- Johannes Widodo

Also Dr. Tetsu Kubota, who is known for his research of sustainable building technologies in the tropics, explains that whether in Africa, America or Asia, every European colonial town has specific colonial building typologies, which all play an important role of the modernization process of architecture. These typologies can
roughly be divided into four periods, which are very similar to those from western parts of the world. (Kubota, Rijal, & Takaguchi, 2018)

Most of the buildings constructed before the 19th century, were not yet considered modernistic. Emphasis lay on state buildings. This style is described as the Masonry European Style, which rather directly imitated the style of home; the designs were very static and often designed with a large symmetrically landscaped garden, see Figure 4.

The first modernist period flourished in the 19th century and was called the Indies Empire Style. This style took its inspiration from the Neoclassic Style, using for example, typical ancient Greek pillars at the front. Up to and including this period, the focus in architectural design mainly lied on western aesthetic standards, without considering the tropical climate, Figure 5.

During the second modern period this changed and the design started to take the climate into account. This period developed in the beginning of the 20th century, and was known as the New Indies style. This is an eclectic style that combines European architecture and local Indonesian building techniques. (Kubota et al., 2018) The design of prominent roofs is an exemplary attempt of adapting to the tropical climate of Indonesia, see Figure 6.

The third period evolved in many colonial cities after the First World War, and was known as the Art Deco style. The emphasis lay on curved lines and ornamental details in the facade. Passive climate design is visible in the construction of overhangs and sufficient shaded openings, see Figure 7.

The latest modernistic style known as ‘Het Nieuwe Bouwen’ or the International Style was introduced in the 1930s. Architects worked according to rationalistic philosophies, which resulted in a streamlined style where unnecessary ornamental details were removed, see Figure 8 (Cor Passchier, n.d.)

Especially in Bandung the rationalistic architectural style became tangible as this new city only developed in the 1920s. As travel became increasingly easy, this style can be found all over the world. The approach employed in the International style is considered the beginning of globalization in architecture. After the declaration of independence, the city grew exponentially and architectural development was focused on internationally used examples. Modern high-rise buildings, dominated by glass and forced air conditioning, were built to replace vernacular architecture and passively designed heritage of the early 20th century and before.

To summarize the chapter, the first part discussed how Bandung’s original urban design was well adapted to its surroundings, making it resistant to extreme weather conditions. However, after the declaration of independence, the city grew rapidly and became denser over time, making the city less resilient. Contemporary developments of Bandung focus on smart and sustainable solutions. The search for new technologies, nevertheless, seems to have neglected lessons learned in the past and urban developments seem to start from scratch.

Regarding the second paragraph, Both Kubota and Widodo stress the importance of colonial building typologies in the process of modernization of Indonesian architecture. Bandung takes an exemplary position in terms of Indonesian modernization, because it is a relatively new city. Most developments originated in the interwar era and can be divided into four periods: the Indies Empire Style, the New Indies style, the Art Deco style and the latest ‘Het Nieuwe Bouwen’ or the International style. As travel became increasingly easy, the International style can be found all over the world. Therefore, the approach used in this style can be considered as the start of globalization in architecture.
3.2 CLIMATE RESEARCH
This chapter discusses today’s climate in Bandung, with the aim to learn about the level of comfort in the city, with respect to climate characteristics and living standards. Subsequently, a set of guidelines is given, describing design strategies to make the thermal condition in a larger scaled, non-residential building more comfortable than neglecting the climate completely. Questions to be answered in this section are as follows: What is the current climate condition in Bandung? What temperatures and humidity levels are tolerable? What non-mechanical, passive design solutions are effective to achieve a more comfortable indoor climate?

3.2.a ORIENTATION
This paragraph discusses the geographical location of Bandung, focusing on external factors that influence the living comfort in the city. The aim is to get an insight of continuous influences from the physical environment, such as the impact of the topography, sun and wind. This will provide the basis for the analysis of passive climate systems in a later chapter.

As for the topographical location, Bandung is very tactically positioned. As described in the previous chapter, the city originated at the intersection of an important road and river. Located at 6°55’ S latitude and 107°36′ E longitude, the city is situated in the basin of an ancient lake, surrounded by high-altitude volcanic landscapes, which results in a very fertile soil and a hot and humid climate, see Figure 9. Because of its average altitude of 768 meters above sea level, the temperature is more moderate than other big cities in Java. Furthermore, as can be seen in Figure 12, the city rises north, which provides beautiful views and ensures that the rainwater is drained naturally via the main river. Lastly, the difference in altitude also ensures fresh breezes blown through the northern part of the city.

The sun is an influential factor in the quality of life in Bandung, because the city is close to the equator and has a high altitude, making the solar radiation extra powerful, see Figure 14. By drawing a solar diagram, it can be calculated whether or not the sun appears on a given façade, and thus heats the indoor temperature. Consulting the solar diagram makes it possible to determine the most ideal orientation of a building and whether sun protection should be applied. The latitude of about 6 degrees southward implies that the sun is at an angle of more than 45 degrees for the majority of the day, see Figure 16. The design of suitable shading techniques will be discussed in the next chapter.

Figure 9 Climate around in equatorial countries
(O.H. Koenigsberger et al., 1973)

Figure 10 Position of Indonesia, relative to the equator. (CartoGIS)
author manually circled Java island

Figure 11 Elevation map of Java, (CartoGIS)
author manually circled the area of Bandung

Figure 12 Elevation map of Bandung region, (Robert Delinom, 2009)
author manually circled Bandung city

Figure 13 Section of Bandung region, (Robert Delinom, 2009)
author manually circled Bandung city
In terms of wind direction and velocity, it is very unpredictable and highly dependent on the specific location. This unpredictability is caused by the altitude and surrounding volcanoes. In the following graphs the average wind speed and direction is measured per hour at 10 meters altitude. Due to the topographical location it is in general fairly calm in the city. When consulting Figure 30 to Figure 32 on the next page, it appears that there is a small peak between December and March the wind comes from the west with an average wind speed between 8.2 and 9.8 km/h, which is about 2 km/h lower than in Jakarta and not even half the average wind speed measured in coastal cities of the Netherlands. Between March and December the average wind speed in Bandung is between 6.5 and 8.2 km/h, during this period the wind direction usually comes from the east or south.

3.2.b CLIMATE CHARACTERISTICS
Temperature is a major contributor to a comfortable climate, both outdoor and indoor. Besides temperature and daylight hours, a number of other variables are analyzed in this paragraph.

The annual average temperature in Bandung has only little variation, because of the location close to the equator. At night there is an average comfortable temperature of 18 degrees and rarely is the temperature experienced cooler than comfortable. During the day there is a warm temperature of 28 degrees on average. These day and night temperature deferrers on average 10 degrees, which results in a very stable thermal condition. Figure 21 and Figure 22 at the next page illustrate the temperature in Bandung.

Another effect of being near the equator is that throughout the year, Bandung has little difference in the length of the days. As can be seen in Figure 23 and Figure 24, the longest day in 2018 was on 22 December and the shortest day on 21 June, where the difference in daylight hours is only 45 minutes. On average, the sunrise is between 5:21 and 6:02 and the sunset takes place between 17:39 and 18:15, which means that generally there is slightly more than 12 hours of sunlight per day.

The influence of solar energy is described in Figure 25. The difference between the incoming short-wave energy is in the light period, between August and October, and the darker period, between November and June, is only 20%. This is very constant in comparison to areas with four seasons.

Cloud coverage appears to be far more seasonal. Generally Bandung is very cloudy, with constant 50% to 70% overcast throughout the day, as is shown in Figure 26. It also shows that the brighter period is from May to October, with coverage 65% of the time. The more covered part of the year is from October to May, with a maximum of 91% cloudiness of the time. This means that in the period from May to October the solar radiation will be higher, and thus needs more attention.
In terms of precipitation, a tropical climate is often characterized by dry and rainy season. In Bandung the period from October to May is the wettest, thus the most chance of precipitation, namely from 44% to 69% chance. The average total accumulation is around 272 millimeters per month. During the drier season from May to October, there is an average change of perception of 14% to 44% and with an average total accumulation of 37 millimeters. A wet day is characterized by a minimum of 1 milliliter of liquid and as is illustrated in Figure 27 and Figure 28, the chance of a wet day all year round is very high.

The humidity level on is based on the dew point, what indicates whether transpiration evaporates from the skin and thus cools the body. It feels moister when the dew point is higher, and it feels drier when the point is low. The dew point changes more slowly than the temperature, meaning that a humid day is usually followed by a humid night. A relation between the two seasons of Bandung can be seen in Figure 29. Furthermore, the graph makes clear that it is very humid all year round in Bandung.

3.2.c COMFORT STANDARDS
This paragraph discusses the satisfaction of people about the indoor climate, with the focus on air temperature and humidity. The aim is to gain insight into the impact of climatological conditions on the indoor climate and its users. In addition, the research examines how to match the actual to the demanded comfort zone with suitable passive design strategies.

The comfort zone in a building is about the satisfaction of people on the indoor thermal conditions. Thermal comfort is about the state of mind of people towards the indoor climate and is often expressed as ‘too cold’ or ‘too hot’, see Figure 33. (Rosenlund, 2018) Because it is difficult to achieve a desired indoor climate for each and every individual in a building, the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has come up with an American national standard for thermal environmental conditions for human occupancy. This standard outlines a few average parameters that the indoor climate condition must meet to achieve a comfortable...
indoor climate at least 80% of the buildings users. These parameters show acceptable comfort conditions regarding temperature, humidity and wind velocity. (ASHREA, n.d.)

In order to analyze the impact of the climate on the comfort zone in a building, Climate Consult is an effective software tool. (Climate Consultant, 2017) The analysis works as follows: first, given climatic values are translated into various graphs that illustrate annual and daily averages. These outcomes have been described in the previous paragraph. The obtained information is then graphically summarized and compared to the standards of the ASHRAE-55 model. The result is a Psychometric chart.

The Psychometric Chart is a graphic representation of the relationship between air temperature and humidity; showing human thermal comfort conditions, as illustrated in Figure 34. Horizontally the dry bulb temperature is shown, which indicates how hot it is. The vertical lines in the graph represent the absolute humidity and the higher in the chart the more moisture is detected in the air. The curved lines represent the relative humidity, illustrating the percent moisture in the air until saturation is reached and rain or condensation is expected. As the Psychometric chart shows with the saturation line, air can hold more moisture as the temperature increases.

The comfort ranges can be seen through the drawn boxes, as is illustrated in Figure 35. In the psychometric chart of Bandung, the comfort range is colored blue and represent the standard comfort values of the city. In ideal circumstances, all measurements (dots or lines) are within this range. Unfortunately, this is often unfeasible and passive or active design measures are needed to make the indoor climate comfortable.

The psychometric chart of Bandung is shown in Figure 36 and Figure 37, and deals with the ASHRAE-55 Standard. The outcome shows that all data is far above generally accepted comfort standards. The most remarkable fact about the graph is that, even though Bandung might have a more moderate climate than other Indonesian cities, the high humidity is uncomfortable all year round. Although the temperature is averagely comfortable; between 20 and 28 degrees, there is too much moisture in the air to actually stay within the comfort range.

Furthermore, it appears that the mornings are cooler but the temperature quickly increases throughout the day; see Figure 22 and psychometric chart with the daily minimum and maximum values (Figure 36). To create a comfortable indoor climate, ideally the extreme morning values of the graph should be moved down to the right, and the extreme evening values down to the left. These values mean that it is cool and humid at night and warm and humid during the day. Because warm air can hold more moisture, it feels relatively more humid at night than during the day, thus less comfortable and more dehumidification is needed. If the selected hours that the building is in use are changed in the graph to office hours; from 6am to 8pm, the dehumidification requirement is reduced from 73.2% to 62.3%, consult the appendix for the detailed graph.

A shift to the right or left in the comfort graph is related to temperature and can thus be achieved by heating or cooling. There are many successful passive design techniques for this purpose, of which the most relevant will be discussed in the next paragraph. The downward shift relates to the absolute humidity and can be adjusted by removing moist from the air. These movements are illustrated in Figure 38.
Removing moist is harder to accomplish with passive strategies, since the most effective way appears to be the air-conditioning system. The hot and humid climate for people is the most difficult to tolerate and only acceptable if there is sufficient air movement. For this reason, optimal climate conditions can only be guaranteed by using forced air conditioning, i.e. by cooling and dehumidifying the outside air. This is an energy-intensive and expensive option.

An indirect way of dealing with humidity is through the use of natural ventilation, because it cools the perspiration from the skin and gives the impression that the indoor climate is fresher. As a result, the increase in the air movement, if at an appropriate speed, increases people’s satisfaction and allowing higher humidity levels to be tolerated. (Wolfgang Lauber, 2005)

The psychometric table proves that design strategies have a positive influence on the indoor climate. Both active and passive design strategies are given to broaden the comfort reaches. However, when the boxes overlap, the impact percentages does as well and a decision needs to be made to avoid redundant systems.

In addition to design measures, the willingness of users to adapt can also increase the comfort range. This means, for example, that users accept more climate differences when they are willing to change clothes according to ambient temperature. Another option to broaden acceptance is by creating possibilities for the user to influence the indoor climate, for instance by opening a window and directly feeling a fresh breeze. This means that if users can adapt to the climate, both mentally and physically, the comfort zone increases. The willingness to adapt increases the comfort range and thus increases the acceptance. This is very important to take into account when building with passive design strategies.

In retrospect of this chapter, it has become clear that, when appropriate design strategies need to be found, it is essential to first analyze the given local climate. In the first paragraph the orientation Bandung was discussed and it became evident that because of the position at the equator, the sun has a strong radiation level, stands at an angle of more than 45 degrees for most part of the day and consequently the roof absorbs most of the radiation. Furthermore, the wind in Bandung is weak and unpredictable due to the surrounding volcanic landscape. Only 16% of the time the wind speed is more than 3 km/h and averagely the wind comes from the east or the south.

In the second paragraph it became clear that Bandung has a tropical monsoon climate, which is reflected in a stable character with small differences in the dry and wet season. In the third paragraph, these climate conditions are compared with the ASHRAE-55 comfort model and evaluated according to given comfort standards. In addition to design measures, the willingness of users to adapt can also increase the comfort range. It became evident that passive strategies can be effectively applied to the temperature in a building, but that it is difficult to reduce humidity without mechanical support. However, it is effective to allow fresh airflows through the building by means of natural ventilation. This cools perspiration and thus increases acceptance of high humidity levels.
3.3 PASSIVE DESIGN STRATEGIES:
This chapter discusses different passive design strategies to accomplish a climatically appropriate design. The aim of a climatically appropriate design is to create a comfortable, or at least tolerable indoor climate for its users, while using as little energy and technical resources as possible. At the same time, the structure must be able to withstand the extreme external climate and not be damaged by, for example, moisture or high sun radiation. (Wolfgang Lauber, 2005) The relevance of a climatically appropriate design lies in the simple fact that our resources are limited and that we have a moral obligation for the future generation to make sustainable buildings. In addition, it is more economical for current users to be as independent as possible from mechanical solutions and reduce the energy use in buildings. The main question of this chapter therefore is: How can a building be designed to create a comfortable indoor climate without relying on mechanical solutions?

3.3.a SURROUNDINGS & ORIENTATION
The environment in which a building is located has a major influence on the indoor climate. Topography, surrounding buildings, vegetation and water are elements that influence the regional climate of a city. See Figure 39. The regional climate is divided over the area into specific micro climates that affect the indoor climate of the individual building with continuous changes. Allowing certain airflows, creating enough shadows, protecting against high solar energies and heavy rainfall etc., should therefore be considered in each specific case and is the aim of a successful design. (Rosenlund, 2018)

In recent years, the Urban Heat Island effect has been a major problem in the city of Bandung. It relates to the thermal comfort and increases the urban air temperatures by 1-2 C during daytime and 3-5 C during nighttime. This is caused by a reduction in vegetation, increased urban density, heat storage in building masses, increasing building height and heat generating activities, like transportation and industry, see Figure 44. (Perini & Magliocco, 2014)

The heat of the morning sun is less strong than when the sun stands on the zenith. In order to protect the building from the high solar radiation, it is necessary to position a building with the longitudinal axis exactly in an East-West direction, thus the long sides of a building oriented to the south and north. This orientation is the most efficient in both hemispheres. The roof can absorb the hottest rays of sunshine during the day.

Especially in hot and humid tropics the allowance of cooling breezes are important. Providing enough open space, clear water and sufficient greenery have positive influence on the thermal conditions on the urban level and a cooling effect on the smaller micro climates and the indoor climates within. To allow fresh wind passing through the building, a suitable orientation of the building is required. Also, a fresh wind can be integrated into the design by placing trees and a shaded water pond in front of the building.
3.3.b SUN SHADING SOLUTIONS
As indicated in the previous chapter, the indoor climate of a passively designed building is determined by its surroundings. A cleverly designed building slows down the external climate phases making it more comfortable inside when in use. An important external energy flow is the high solar radiation present in hot humid climates. A major challenge is therefore to protect the building and its users from high vertical incoming solar radiation and heavy rain falls, while allowing enough natural incoming light and fresh air ventilating through the building.

Passive solar techniques include the orientation of the building towards the sun and the use of favorable materials to retain or block heat. A widely used solution for passive designs is the integration of large overhangs. Large overhangs provide external shading and protect the interior from sun and rain. In addition, the shade cools the incoming air and creates comfortable outdoor spaces. (Maxwell Fry & Jane Drew, 1982) When the sun gets lower in the afternoon, the radiation power is still high and therefore vertical shading is needed to protect the indoor climate. In the appendix there is explained how to calculate the exposed facades. Figure 15 of the previous chapters shows the radiation angles before 10 a.m. and after 4 p.m., which explains that vertical blinds are required at low solar altitudes.

3.3.c ROOF INSULATION SOLUTIONS
It is noticeable that in equatorial countries, where solar radiation is intense and perpendicular to the earth, the roof plays an essential role in the design. A solution to protect the interior against these high solar energies are to use insulated or double-layer roofs, because the roofs are important insulation elements against high solar radiation from above. Roofs in areas with high solar radiation are therefore usually made of thick materials with low thermal capacity. (DeKay & Brown, 2014) Figure 49 shows a the efficient double layered roof system that successfully have been applied in warm and humid climates.

3.3.d VENTILATION
For people, the warm and humid climate is the most difficult to tolerate and only acceptable if there is sufficient air movement. Optimal climatic conditions can only be guaranteed by forced air conditioning, in other words through cooling and dehumidification of the outside air, which is an energy-intensive and expensive option.
In the previous chapter it has been described that dehumidification is difficult to solve passively. However, it is possible to passively cool a building by means of natural ventilation, as many traditional examples show. The many purposes of ventilation include improving the thermal comfort, structurally heating or cooling the indoor temperature, as well as improving health and removing moisture. There are several ways of making the best use of natural winds to improve the indoor climate, of which cross- and stack ventilation represent the most efficient methods. (Rosenlund, 2018) As a primary design rule regarding ventilation, there should always be sufficient air movement in the living and working areas. During the hottest periods, air velocities between 1 and 1.5 m/s are necessary. (Wolfgang Lauber, 2005) Number B, E and F of Figure 53 shows successful ventilation principles that can be applied in warm and humid climates.

3.3.e SPACE PLAN
In order to withstand the extreme external climate and considering the energy control in building by natural means, the design of the space plan has a major impact.

First of all, the long sides of a building should, in both hemispheres, be orientated north- and southwards in order to capture as little solar radiation as possible. Secondly, it is essential that the geometry of the floor plan and the interior allow cross ventilation, particularly in the living and working spaces. An ideal floor plan has a geometric shape in which living and working rooms are arranged adjacently and are accessible via a shaded veranda or corridor, see Figure 55. Thirdly, it is important that moisture-intensive areas, such as kitchens or bathrooms, are placed separately from work and living areas, preferably on the lee side of the building.

Furthermore, in accordance with K. Petzold, who is an important German thermodynamic engineer, in order to maintain a healthy indoor climate must the airflow rate for housing be between 100 and 200 m³ per m² floor space. To achieve this amount of fresh air by natural ventilation, the opening in opposite external walls must be between 0.1 to 0.2 m² per square meter floor area, see Figure 56, showing the rule of thumb. (Karl Petzold, 1986) Depending on the height in the room, this amount is between 40% and 80% of the total wall surface. In any case this is a very large part of the room and therefore it is desirable to have opening walls. However, it is important that opening walls can be closed in order to be resilient in extreme weather conditions.
Lastly, it is important to keep the depth of a space smaller than five times its height and eliminate partition walls, to avoid exhaust air see Figure 54. (Wolfgang Lauber, 2005)

Summarizing this chapter, passive design strategies in hot humid climates is about considering the energy control in building by natural means. As many traditional examples show, it is possible create a comfortable indoor climate without relying on mechanical solutions. It is therefore essential to include this in the design of a building, in order to save energy and materials.

In the first paragraph it became clear that the regional climate is divided over an area into specific microclimates that affect the indoor climate of the individual building with continuous changes. Due to the densification and reduction of vegetation, the Urban Heat Island effect has increased the temperature by 1-2 degrees during daytime. Therefore the allowance of cooling breezes, creating open spaces and shaded water ponds near a building very important.

The second paragraph sun shading solutions are discussed. It explained that a cleverly designed building slows down the external climate phases, in order to make the indoor climate more comfortable when inside. In hot and humid climates the major challenge is to block the solar radiation and heavy rain falls, while allowing enough natural incoming daylight and fresh air ventilating trough the building. A solution is the use of large overhangs and additional vertical for the afternoon hours.

The third paragraph stated that in countries with intense solar radiation, the roof plays an essential role in a passive design. The use of insulated or double layer roofs is a successful way to reduce high solar radiation and increase indoor comfort.

In the fourth paragraph is stated that dehumidification is difficult to solve passively. However, it is possible to passively cool a building by means of natural ventilation, of which cross- and stack ventilation represent the most efficient methods.

Finally, it became clear that the design of the space plan has a major impact on the thermal conditions inside. The focus should therefore be on; orientating the long sides of a building north and southwards, the floor plan has a geometric shape allowing natural ventilation and moisture intensive rooms are placed separately from the working and living areas. In addition, there are desirable dimensions of the occupants’ spaces to avoid exhaust air.
3.4 CASE STUDIES
In this chapter, an analysis is made of several case studies built in different modernist styles, which are originated in Bandung. The aim is to get an overview of the different passive design techniques used over time and provide evidence to match the theory of previous chapters. The focus lies on the findings out about the intended passive climate strategies and reevaluating the historic value. The analysis is done through the scales and discusses the corresponding architect, period, style, orientation, daylight, external sun shading and possible cooling and ventilation techniques. The visual analysis can be found in the appendix. Questions that are asked are: Which European architects were important for the modernization of architecture in Bandung and what where there building philosophies? How did their design react to the climate? Which passive design techniques can be found in Hotel Swarha?

3.4.a NEW INDIES
Bandung takes an exemplary position in terms of Indonesian modernization, because it is a relatively new city. The modernist era in Bandung can be divided into different architecture styles, as was explained in the first chapter of the results.

The first style that adapted to the climate was the New Indies style. This style combines European architecture and local Indonesian building techniques. Henri Meclaine Pont belongs among the first generation of architects who independently worked as an architect in the Dutch East Indies and came to define the appearance of the new architecture. H. Meclaine Pont (1885-1971) took full advantage of the opportunity to combine the rational, technical western solutions with unfamiliar cultures, religions and overwhelming tropical nature. (C.J. van Dullemen, 2010)

A turning point in the history of architecture in the Dutch East Indies is the opening of the East Indian Technical University (ITB). The buildings of the ITB are known and most pronounced in the combination of Western technology and locally oriented design. Typical are the large roof constructions held up by very modern parabolic arches, constructed of laminated wood. The overlapping roofs have provided space for ventilation and the provision of diffuse light.

The building is positioned with the longitudinal axis exactly in an East-West direction, to ensure that the facades are exposed to as little solar radiation as possible. Due to the large overhanging roof, the entire facade is shaded for most of the day. Because the rooms in the buildings have high ceilings and verandas are positioned around the core of the building, naturally cooled ventilation is stimulated. In addition, the emphasis in the original design did not lie on the buildings, but rather on the space in between, which is designed in order to provide space for traffic and to facilitate sufficient entry of daylight and fresh air. (Van Leerdam, 1988)

3.4.b TROPICAL ART DECO
Another great designer is Wolff Schoemaker (1882-1949), whose varied work can be seen throughout Bandung. Schoemaker followed European developments, and his early works were characterized as Tropical Art Deco. Art Deco was a popular European style movement that emphasizing on curved lines and ornamental details. In Bandung this style was adapted to the climate, by designing for example sufficient shading in the façade.

Wolff Schoemaker disagreed with the conviction and working method of H. Maclaine Pont, which led to heated discussions in architecture journals. The two architects were both born in Indonesia, had a Western background and education, but had conflicting views on the Indo European architecture style. H. Maclaine Pont sought architecture rooted in the architectural history of the Indonesian archipelago, while using Western techniques and thus argued in favor of the vernacular group. On the other hand, Wolff Schoemaker profiled himself as a Western-oriented Rationalist and was against ‘superficial knowledge of oriental building techniques’, referring to the work of Maclaine Pont. Although Schoemaker saw no added value in referring to Javanese history, he did see importance in responding to the local climate. Although he used oriental ornaments, he focused exclusively on western building techniques, as he for example introduced reinforced concrete in 1923. (C.J. van Dullemen, 2010)

Schoemaker was able to fully empathize with the Art Deco movement when he was given the opportunity to design Hotel Preanger in 1927, without any financial constraints. Hotel Preanger was an oeuvre to geometrical indigenous ornament and did not lack overhanging eaves, providing shade and controlling the incoming air. The building was set back from the street, in order to distance itself a little from the crowds and noises. The building is made of reinforced concrete and decorated with ceramic tiles, light plaster and lava rocks, resembling the style of Frank Lloyd Wright. Preanger Hotel is orientated in a convenient East-West direction and the large
covered terrace and canopy provide shade and cools incoming breezes, as the façade on the ground floor consists of many largely operable doors. All windows on the upper floors are provided with a thick lintel, which provides sufficient shade in the façade of the guest rooms.

3.4.c INTERNATIONAL STYLE
also known as ‘NIEUWE BOUWEN’
Another, very influential architect in the Dutch East Indies was A.F. Aalbers (1898 – 1961). He was from a later generation than Maclaine Pond and Wolff Schoemaker and introduced the latest modernistic architectural style in the late 1930s. This style was also known as ‘Het Nieuwe Bouwen’ or the International Style. A.F. Aalbers worked according to a pure rationalistic philosophy, which resulted in a streamlined style where unnecessary ornamental details were removed. (Cor Passchier, n.d.) As travel became easier, this architectural style left its mark all over the world. Therefore, this unifying approach can be seen as the beginning of globalization in architecture.

His design for Hotel Savoy Homann is an icon of Modernist architecture in the Dutch East Indies. It is designed as a luxurious hotel, with large rooms, high ceilings; approximately three meters, which is optimal for natural ventilation, wide opening doors and a shaded private balcony. As a result, the incoming air is cooled as much as possible, ensuring a comfortable indoor climate for the guest. In the original design, the façade on the ground floor could be opened completely. But for acoustic reasons and higher climate standards (hence, demand for air conditioning) the façade has been closed with glass.

3.4.d HOTEL SWARHA
Very little is known about the building and the architect. Most likely it was built in the early 50s in the style of ‘Het Nieuwe Bouwen’, inspired by the streamlined architecture of Albert Aalbers. The original function was a hotel with shops at the ground floor. The hotel was designed to accommodate journalists who attended the Asia-Africa conference, held in 1955, with the reason that it is located opposite the post office, making it easier to sent news and statements of the conference all over the world. Today, most of the hotel has been empty for thirty years. There is still a shop on the ground floor, but it has not changed since the 1980s. The building is isolated, in poor condition and no longer meets current climatic requirements.

The design shows many resemblances with the design of Hotel Homann, which is reflected in the streamlined design and materials and colors used in the facade. The building stands on the corner of the former regent road and Groote Postweg and the formed lines stimulate this corner position. In the period in which the building was built, the building with its four floors was considered rather tall and very modernistic. The use of concrete in the construction has most likely made this height possible. Due to the requirements of the plot, the building has an unfortunate North-South direction, whereby the front façade catches a large amount of sun. To counteract these strong radiations, there is a continuous balcony on each floor. The overhang ensures that the large doors of the rooms are predominantly in the shade, thus cooling the incoming air. The space plan is designed in such a way that cross ventilation is stimulated, by means of opposite rooms with a corridor in the middle. The rooms are repetitive and have a spacious height of just over three meters. The floor surface is optimally sized to prevent exhausted air.

From the analysis it appears that in the original modernist and rational design the tropical climate has been well taken into account. However, the current environment has changed a lot. First, the Regency Road was closed by the expansion of the mosque. Second, the Groote Postweg, now known as Asia-Africa road, has become considerably busier than 60 years ago. This is caused by the increase in population, capitalism and the lack of public transport, resulting in a constant traffic jam all over the street. This motorized bustle causes noise and air pollution, and should be taken into account in the new design. Finally, a major factor is the increased comfort standard, which is due to the development of air conditioning. Where in the past the heat and humidity was accepted more easily, nowadays the comfort range has become significantly smaller.

A concise comparison of the four projects can be found on the next page. In addition, the appendixes contain a more detailed analysis of the described examples.
## 3.4.e COMPARISON

<table>
<thead>
<tr>
<th>STYLE</th>
<th>THE NEW INDIES</th>
<th>TROPICAL ART DECO</th>
<th>INTERNATIONAL NIEUWE BOUWEN</th>
<th>(INSPIRED ON) NIEUWE BOUWEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARCHITECT</td>
<td>MECLAINE PONT</td>
<td>WOLFF SCHOEMAKER</td>
<td>A.F. AALBERS</td>
<td>UNKNOWN</td>
</tr>
<tr>
<td>BUILDING</td>
<td>ITB BANDUNG UNIVERSITY</td>
<td>HOTEL PREANGER</td>
<td>SAVOY HOMANN HOTEL</td>
<td>HOTEL SWARHA HOTEL AND SHOPS</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>HOTEL</td>
<td>1927</td>
<td>1939</td>
<td>± 1950</td>
</tr>
<tr>
<td>YEAR</td>
<td>1920</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ORIENTATION**

- **N**
- **N**
- **N**
- **N**

**Non-optimal orientation!**

**SUN SHADING**

- **extreme in June**
  - **6/21 - 10AM**
- **extreme in Dec**
  - **12/21 - 4PM**

**DAYLIGHT**

**VENTILATION TECHNIQUES**

**Optimal floorplan!**
4. CONCLUSION

The purpose of this paper was to find a reason to explain why Hotel Swarha no longer meets contemporary comfort standards and how the building might be reused.

In order to fully understand the problem, it is essential to have an overview of the most critical urban developments in Bandung. This research has shown that Bandung’s original urban design was well adapted to its surroundings, making it resistant to extreme weather conditions. However, after the declaration of independence, the city grew rapidly and became denser over time, making the city less resilient. Due to the Urban Heat Island effect, the average temperature has risen 1 to 2 degrees. In comparison to other cities in Java, the climate is still relatively moderate. Furthermore, it is a problem that the development of the city is focused on modern, climate-independent high-rise buildings, as a result of which historic buildings are abandoned and intelligent passive climate techniques are forgotten.

As for the most prominent characteristics of climate in Bandung are the hot, sticky conditions and the continual presence of humidity. Air temperature remains moderately high, between 21 and 32°C, with little variation between day and night. Humidity is high during all seasons. Heavy clouds act as a filter to direct solar radiation; it is thus reduced and mostly diffused, but the clouds also prevent re-radiation from the earth at night. Vegetation reduces reflected radiation, and lowers ground surface temperatures, thus reducing the impact of Urban Heat islands. The winds are generally of low speed and almost constant in eastern or western direction.

Next, a research was carried out on neglected passive solutions that influence the thermal conditions in a building. Several analyses have been made, starting with a focus on general successful techniques in warm and humid climates. After that, several case studies were discussed, of which the buildings from the time of modernization during the colonial era date from between the wars. The cases studies have confirmed that many options exist to passively cool a building, and that these solutions have positive impact on the indoor thermal condition of a building. However, it is hard to passively solve the humidity problem. The question therefore is whether these measures are sufficient to meet the current standards for indoor climate.

Comparing the outcomes of design strategies to the comfort standards, it has become apparent that, unfortunately, the measures are not always sufficient to meet required standards. The reason for this mismatch is that people have become used to setting higher standards and focused on modern high-rise buildings. However, the reuse of historic buildings with passive climate systems is a way of revaluing and reusing existing buildings. In this way, unnecessary building waste can be prevented. In addition, a building that carefully considers the climate will be more economical, sustainable and energy efficient than a building that runs entirely on forced air conditioning.

If necessary, the gap between the results of the passive design and the high modern requirements can be closed with a psychological approach. This means that if users can adapt to the climate, both mentally and physically, the comfort zone increases. The willingness to adapt increases the comfort range and thus increases the acceptance. This is very important to take into account when building with passive design strategies.

In conclusion, the research confirms the hypothesis, where proven passive design methods are able to positively impact the level of comfort, and thus also in Hotel Swarha. However, in order to successfully redesign an existing building, the reinforcement of mechanical ventilation will be necessary to be consistent with the expectations of the users. Furthermore, the re-use of existing buildings is beneficial in terms of sustainability, energy efficiency and is on top of everything, highly educative.

The question of how exactly Hotel Swarha can be redesigned to fully meet modern standards, that is a suggestions for further research.
5. REFERENCES


6. APPENDIX I

STYLE - THE NEW INDIES
PERIOD - BEGINNING OF 20TH CENTURY
ARCHITECT - HENRY F. MECLAINE PONT
BUILDING - ITB BANDUNG
FUNCTION - TECHNICAL UNIVERSITY
YEAR - 1920

Bandung takes an exemplary position in terms of Indonesian modernization, because it is a relatively new city. The modernist era in Bandung can be divided into four architecture styles, as was explained in the first chapter of the results.

PERIOD
Up to and including 19th century, the focus in architectural design mainly lied on western aesthetic standards, without considering the tropical climate. During the second modernistic period this changed and the design started to take the climate into account. This period developed in the beginning of the 20th century, and was known as the New Indies style. This is an eclectic style that combines European architecture and local Indonesian building techniques. The design of prominent roofs is an exemplary attempt of adapting to the tropical climate of Indonesia.

ARCHITECT
A well know architect who worked according the principles of the reformed, New Indies Style was Henry F. Meclaine Pont, who had a strong belief that the possibilities of new architectural developments in Indonesia should evolve from the vernacular traditions. He is seen as the “father” of modern vernacular architecture of Indonesia.

BUILDING
The building is positioned with the longitudinal axis exactly in an East-West direction, to ensure that the facades are exposed to as little solar radiation as possible. Due to the large overhanging roof, the entire facade is shaded for most of the day. Because the rooms in the buildings have high ceilings and verandas are positioned around the core of the building, naturally cooled ventilation is stimulated. In addition, the emphasis in the original design did not lie on the buildings, but rather on the space in between, which is designed in order to provide space for traffic and to facilitate sufficient entry of daylight and fresh air. (Van Leerdam, 1988)
6. APPENDIX II

<table>
<thead>
<tr>
<th>STYLE</th>
<th>TROPICAL ART DECO</th>
</tr>
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<tbody>
<tr>
<td>PERIOD</td>
<td>BETWEEN WW1 AND WW2</td>
</tr>
<tr>
<td>ARCHITECT</td>
<td>WOLFF SCHOEMAKER</td>
</tr>
<tr>
<td>BUILDING</td>
<td>HOTEL PREANGER</td>
</tr>
<tr>
<td>FUNCTION</td>
<td>HOTEL</td>
</tr>
<tr>
<td>YEAR</td>
<td>1927</td>
</tr>
</tbody>
</table>

Bandung takes an exemplary position in terms of Indonesian modernization, because it is a relatively new city. The modernist era in Bandung can be divided into four architecture styles, as was explained in the first chapter of the results.

PERIOD
The third modernistic period that interacted with the environment evolved in many colonial cities after the First World War, and was known as the Art Deco style. It was a popular European style movement that emphasized on curved lines and ornamental details. In Bandung this style was adapted to the climate, by designing for example sufficient shading in the façade and many grand overhanging eaves.

ARCHITECT
Wolff Schoemaker (1882-1949), is known for his varied work that can be seen throughout Bandung. Schoemaker followed European developments, and his early works were characterized as tropical Art Deco.

BUILDING
Hotel Preanger was an oeuvre to geometrical indigenous ornament and did not lack overhanging eaves, providing shade and controlling the incoming air. The building was set back from the street, in order to distance itself a little from the crowds and noises. The building is made of reinforced concrete and decorated with ceramic tiles, light plaster and lava rocks, resembling the style of Frank Lloyd Wright. Preanger Hotel is orientated in a convenient East-West direction and the large covered terrace and canopy provide shade and cools incoming breezes, as the façade on the ground floor consists of many largely operable doors. All windows on the upper floors are provided with a thick lintel, which provides sufficient shade in the facade of the guest rooms.
Bandung takes an exemplary position in terms of Indonesian modernization, because it is a relatively new city. The modernist era in Bandung can be divided into four architecture styles, as was explained in the first chapter of the results.

PERIOD
The latest modernistic style known as ‘Het Nieuwe Bouwen’ or the International Style was introduced in the 1930s. Architects worked according to rationalistic philosophies, which resulted in a streamlined style where unnecessary ornamental details were removed. (Cor Passchier, n.d.) As travel became easier, this architectural style left its mark all over the world. Therefore, this unifying approach can be seen as the beginning of globalization in architecture.

ARCHITECT
A.F. Aalbers was from a later generation than Maclaine Pond and Wolff Schoemaker and introduced the International style in Bandung. Aalbers worked according a pure rationalistic philosophy, which resulted in a streamlined style where unnecessary ornamental details were removed.

BUILDING
His design for Hotel Savoy Homann is an icon of Modernist architecture in the Dutch East Indies. It is designed as a luxurious hotel, with large rooms, high ceilings; approximately three meters, which is optimal for natural ventilation, wide opening doors and a shaded private balcony. As a result, the incoming air is cooled as much as possible, ensuring a comfortable indoor climate for the guest. In the original design, the facade on the ground floor could be opened completely. But for acoustic reasons and higher climate standards (hence, demand for air conditioning) the façade has been closed with glass.
Bandung takes an exemplary position in terms of Indonesian modernization, because it is a relatively new city. The modernist era in Bandung can be divided into four architecture styles, as was explained in the first chapter of the results.

PERIOD AND ARCHITECT
Very little is known about the building and the architect. Most likely it was built in the early 50s in the style of ‘Het Nieuwe Bouwen’, inspired by the streamlined architecture of Albert Aalbers.

BUILDING
The design shows many resemblances with the design of Hotel Homann, which is reflected in the streamlined design and materials and colors used in the facade. The building stands on the corner of the former regent road and Groote Postweg and this corner position is stimulated by the formed lines. In the period in which the building was built, the building with its four floors was considered rather tall and very modernistic. The use of concrete in the construction has most likely made this height possible. Due to the requirements of the plot, the building has an unfortunate North-South direction, whereby the front façade catches a large amount of sun. To counteract these strong radiations, there is a continuous balcony on each floor. The overhang ensures that the large doors of the rooms are predominantly in the shade, thus cooling the incoming air. The space plan is designed in such a way that cross ventilation is stimulated, by means of opposite rooms with a corridor in the middle. The rooms are repetitive and have a spacious height of just over three meters. The floor surface is optimally sized to prevent exhausted air.
6. APPENDIX V

To create a comfortable indoor climate, ideally the extreme morning values of the graph should be moved down to the right, and the extreme evening values down to the left. These values mean that it is cool and humid at night and warm and humid during the day. Because warm air can hold more moisture, it feels relatively more humid at night than during the day, thus less comfortable and more dehumidification is needed. If the selected hours that the building is in use are changed in the graph to office hours; from 6am to 6pm, the dehumidification requirement is reduced from 73.2% to 62.3%, see graphs.

The shift to the right or left in the Psychometric chart relates to temperature and can thus be achieved by heating or cooling. The downward shift relates to the absolute humidity and can be adjusted by removing moist from the air.

Weather data summery of Bandung city (climate consult, 2017)
6. APPENDIX VI

A cleverly designed building slows down the external climate phases making it more comfortable inside when in use. An important external energy flow is the high solar radiation present in hot humid climates. A major challenge is therefore to protect the building and its users from high vertical incoming solar radiation and heavy rain falls, while allowing enough natural incoming light and fresh air ventilating through the building.

As a first step, it must be decided when shading is necessary, at what times of the year and between what hours of the day. The best guide to this is the definition of the overheated period. (O.H. Koenigsberger et al., 1973) This can be done with the information retrieved from climate consult.

O.H. Koenigsberger explains the shadow calculation as follows:

“Vertical devices consist of louvre blades or projecting fins in a vertical position. The horizontal shadow angle (δ) measures their performance. Narrow blades with close spacing may give the same shadow angle as broader blades with wider spacing. Using the shadow angle protractor, the ‘shading mask’ of a given device can be established. For vertical devices this is the characteristic sector shape. If this is done on the same scale as the protractor, on tracing paper, it can be laid over the appropriate solar chart and the ‘shading times’ for the particular device (dates and hours) can be read off directly. This is a very quick short-cut, obviating the need to establish solar position angles.

Horizontal devices may be canopies, horizontal louvre blades or externally applied Venetian blinds. Their performance will be measured by a vertical shadow angle (ε). The shading mask is of a segmental shape. These will be most effective when the sun is opposite to the building face considered and at a high angle, such as for north and south facing walls. To exclude a low angle sun, this type of device would have to cover the window completely, permitting a view downwards only.”

(O.H. Koenigsberger et al., 1973)