Passive building design strategies for creating a healthy and comfortable indoor environment in garment factories located in Bandung

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1 | ABSTRACT

Since the emergence of garment factories (in the Industrial Revolution) has the level of health and comfort of their indoor environments always been problematic. Also today the indoor quality of many garment factory buildings is very poor. These often simple buildings, mostly located in less-developed countries, have hardly any measures or provisions to adjust the building to the local climate. The high worker density, the noisy and polluting production activities, and the absence of good electrical and mechanical installations have a negative impact on the mental and physical wellbeing of the workers. The goal of this research was to establish suitable passive building design strategies to create healthy and comfortable indoor environments (thermal conditions, lighting, air quality and acoustics) in garment factories located within the tropical climate of Bandung. The required information was gathered through literature research, field research and data analysis.

It can be concluded that passive building design strategies cannot solve all the problems regarding the health and comfort within garment factories, but they can improve the indoor environment substantial with regards to some of the biggest issues. For thermal conditions it is the high indoor air temperatures combined with high humidity levels and low air movement that are problematic. Smart use of passive building design strategies, like the right orientation and well-chosen roof shape, could minimize the heat gain and optimize the airflow through the building. With regards to the lighting conditions can passive strategies solve the problem of the absence / lack of daylight and the absence of view to the outside. Here strategies are mostly focusses on the right implementation of facade- and roof-openings. The indoor air quality can be highly improved by applying strategies that assure good natural ventilation. The acoustic conditions can be improved by splitting the big production spaces into separate smaller (and well-insulated) production spaces and by implementation of more ‘soft’ materials on walls and ceilings. Besides separate passive strategies for each of the indoor environmental factors presents this research paper at the end also two conceptual building designs where the strategies are integrated: a ‘1-floor’ design and a ‘2^{+}-floors’ design. Still more (field) research and experiments are needed to optimize these passive strategies with regards to the most suitable and effective application for garment factory buildings.

2 | INTRODUCTION

The indoor work environment of garment factories is generally considered to be unhealthy and uncomfortable. “Working conditions in the clothing industry and some industry practices can be particularly challenging for female workers” (ILO, 2014). Four different environmental factors play a key role in the (lack of) quality of the indoor environment: thermal comfort, lighting, indoor air quality and acoustic conditions. A bad indoor environment can harm both the physical and mental wellbeing of the occupants, causing different kinds of diseases and disorders (Bluyssen, 2009). These poor working conditions are a serious threat to the 60-75 million people that are worldwide employed in the garment industry. The vast majority of these factories are very simple halls or building blocks, built at the lowest costs possible, located in less-developed Asian countries with (sub) tropical climates. (Stotz & Kane, 2015) These buildings generally become a victim of their local climate: the climate has a negative influence on the indoor conditions (Emmanuel, 2005). Combined with the high occupant density inside the factories (rise of CO_2-level, rise of temperature, etc.) and the impact of the production process on the level of health and comfort of the indoor environment (air pollution, noise, etc.) can indoor conditions become harmful and very unpleasant (Fatemi, 2012). If solutions to improve the indoor conditions are implemented, these are often very basic ‘quick-fixes’ like providing earplugs and mouth-caps or adding electrical or mechanical installations (lighting, fans, etc.). Though these ‘add-on’ solutions could help, they will only work effective when they are used in the right way, properly installed and well maintained (which is often not the case). Furthermore is the extra use of energy not sustainable.

A lot of research has been done to address the problems of indoor factory work environments, but not many solutions have been provided to prevent (most of) these problems by the design and construction of the factory buildings. In ancient Asian civilizations there was a consciousness and know-how on how to design buildings in a way that they use the local climate to create comfortable indoor conditions (Emmanuel, 2005), but this knowledge seems to have been either lost or simply neglected in the practice of today’s factory buildings. (Re-)application of ‘passive building design strategies' assures optimal use of the connection between outdoor climate and design, in order to create a more healthy and comfortable indoor environment. The Pactics Factory in Cambodia is a real life example that shows it is an effective and affordable solution for garment factories. The factory was designed to protect the indoor environment from the negative climatic aspects and make optimum use of the positive climatic aspects to create comfortable indoor conditions. (Bijlstra & Rijnsoever, 2015)

The aim of this paper is to research what passive building design strategies are applicable for garment factories in Bandung. Bandung, Indonesia's textile and fashion hub, has the ambition to become "the most sustainable and competitive urban region for fashion production in the world" (Smit, Loen, Toledo, Yanindraputri, & Ingen-Housz, 2016). To reach this goal it is vital that factory buildings are sustainable and offer good indoor working conditions. Building new factories according to passive building design strategies might be an effective approach.

LIMITATIONS OF THE RESEARCH

The term 'indoor environment' contains the aesthetic quality, spatial quality, ergonomic quality and building physical quality (or environmental parameters) of the indoor space(s) of a building (Bluyssen, 2013). All these aspects are important when it comes to architectural design, however this research only focusses on the building physical aspects of the indoor environment: thermal conditions, lighting, indoor air quality and acoustic conditions.

THE RESEARCH QUESTION

The main purpose of this paper is to understand the problems regarding the indoor conditions of today's garment factories and to research what passive building design strategies could be deployed in the climate of Bandung to create (more) healthy and comfortable indoor conditions. Therefore the following **Research Question** has been formulated:

> *Which passive building design strategies can be established to achieve a healthy and comfortable indoor environment in a garment factory located in the tropical climate of Bandung?*

To be able to answer this research question, several helpful sub-questions are:

1. *What are the main characteristics of the outdoor climate of Bandung, and what passive building design strategies fit with this outdoor climate to create a healthy and comfortable indoor environment?*

2. *Looking at the thermal conditions inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

3. *Looking at the lighting conditions inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

4. *Looking at the air quality inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

5. *Looking at the acoustic conditions inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

6. *How can the suitable passive building design strategies be integrated in a way that a building takes care of all four the indoor environmental factors?*

STRUCTURE OF THIS PAPER

Part I covers the abstract, introduction and applied methodology. In Part II-A is the outdoor climate of Bandung analysed and are potential passive building design strategies explored and discussed. Part II-B covers the research on the indoor environment, both of garment factories in general as well as in two specific garment factories in Bandung. Part III contains a final discussion and conclusion with regards to the main research question. Suitable passive building design strategies are connected to the four indoor environmental factors, and an attempt is made to combine those strategies into two conceptual building designs. Part IV (the Appendices) contains a historical overview of the working conditions in garment factories, an overview of the five different garment factory building types, charts of Bandung's outdoor climate, pictures of the indoor environment of garment factory PT Perdana Firsta, interviews with factory workers and factory managers, and measurement data of the indoor environment of PT Perdana Firsta.

3 | METHODOLOGY

The research for this paper was done both in **Bandung** and in **Delft**. In Bandung the research consisted of interviews and field observations; in Delft the research was conducted on the basis of internet, literature and data analysis.

BANDUNG

Observations
During visits to garment factory PT Perdana Firsta and three 'home factories' in Kampung Cigondewah, the indoor environmental conditions were well observed. The lighting was visible, the thermal conditions could be felt, the odours could be smelled, dust particles in the air were visible, and the noise could be heard. These 'first hand' observations are relevant to understand the current problems and to see what potential passive design solutions have in this context.

Interviews
A Master student from ITB (Institut Teknologi Bandung), named Suhendri, was doing research on Bandung's outdoor climate and suitable passive building design strategies for this climate. An interview with him was focussed on understanding the challenges and opportunities regarding these two topics.

Managers of garment factory PT Perdana Firsta have been interviewed to gain a good general understanding on how the fashion industry works, the way factories operate, the problems that they face within todays fashion business and economic climate. They also provided information about the factory organisation, the production process and the relation between the factory and its workers. This kind of information is very valuable, since it is hard to find this in literature.

Interviewing several workers of garment factory PT Kahatex about how they experience their work environment and their current health status, gave a general impression of the relevant issues and problems within their factory. (We did not get permission to visit this factory for own observations).

DELFT

Internet research
With regards to this research, information was needed on the local outdoor climate of Bandung. There are several meteoric data centres that put their measurements and climate analysis online. By studying these data, the main characteristics of Bandung's outdoor climate could be understand.

Literature research
Literature research (books and scientific papers) provided a lot of relevant information about the relation between the indoor environment and human health and comfort. Also literature was studied on passive building design strategies that are suitable for tropical climates.

Data analysis
When determining the quality of the indoor environmental factors of a certain building, besides observations also measurements are helpful to judge the indoor quality as objective as possible. These measured values are in a way 'facts' that give important information about the indoor conditions. By comparing these measured values to health-standards and comfort-guidelines, some conclusions can be drawn about the level of health and comfort.

4 | BANDUNG'S OUTDOOR CLIMATE CHARACTERISTICS

This chapter regards the marked part of sub-question 1: *What are the main characteristics of the outdoor climate of Bandung, and what passive building design strategies fit with this outdoor climate to create a healthy and comfortable indoor environment?*

The analysis in this chapter is based on data collected from meteorological stations and various literature sources. The climatic variables that directly affect indoor building comfort, and therefore will be discussed in this chapter, are: solar radiation, sun path, air temperature, humidity, precipitation, wind direction and wind velocity. All the figures that are referred to in this chapter can be found in Appendix C.

4.1 The climate of Bandung

Indonesia has a tropical climate: high average temperatures, high humidity levels, little climatic variations between day and night and between seasons, heavy rainfall (especially during the rainy season), and high and relatively diffuse solar radiation. (Coch, 1998) Positive is that in these kind of climates the high annual rainfall results in a significant vegetation cover, which moderates the temperature by providing shade and cooling down the air by water evaporation from the leaves.

Because Bandung is located in a green mountain area, at an altitude of 768 meters above sea level, it has a relatively moderate climate compared to other tropical cities nearby (like Jakarta and Singapore). (Chen B. , 2017) Bandung is surrounded by volcanic highlands (Gumilar, et al., 2015) with lots of vegetation and multiple rivers. Also in the city itself is quite some vegetation, which provides a more comfortable city climate.

4.2 | Solar Analysis

Located at low latitude and high above sea level, Bandung receives all year round a large amount of solar radiation (Al-Obaidi, Ismail, & Rahman, 2014). The average annual sum of Global Horizontal Irradiation (GHI) of Bandung is around 1800 kWh/m^2 (fig App.C.1) (Solargis, 2014). As a comparison: this is almost twice as high as in Amsterdam (around 1000 kWh/m^2). (Chen B. , 2017)

Bandung is located close to the equator, so the solar radiation comes mostly from above. A Sun Path Diagram (fig App.C.2) shows that the maximum expatriation of the sun from the east-west axis is around 20°. (Suhendri, 2017) A second Sun Path Diagram (fig App.C.3) shows that the solar altitude is all year round higher than 45° from around 10.00 to 16.00 o'clock. (Chen B. , 2017) During these hours the solar radiation intensity is also the strongest, reaching over 400W/m^2 around noon (Chen B. , 2017). Also related to Bandung's location close to the equator is the fact that sunrise and sunset take place at approximately the same time all year round. This means that the hours of daylight are every day from ±05.30 till ±18.00 (fig App.C.4). (timeanddate.com, 2017)

4.3 | Precipitation, Temperature and Humidity

Tropical climates only have two seasons: the rainy season and the dry season. The rainy season in Bandung is from November until April, and dry season is from May until October. (fig App.C.5) (Climate Bandung, 2017)

When looking at the average temperatures in Bandung (fig App.C.6), the warmer months are not extremely hot and cooler months are quite similar to the warmer months. The average daily air temperature ranges between 18°C and 27°C. (Climate Bandung, 2017) This temperature range is small compared to for example Amsterdam, where the average temperature ranges from 1°C to 22°C (Climate Amsterdam, 2017). The rainy months in Bandung have in general a more constant temperature: the difference between the mean daily maximum and minimum is only 3-5°C, while this difference is 6-9°C in the dry months. With 27°C as the highest average daily temperature (in August, September and October), Bandung has a mild climate compared to other Southeast Asian cities. For example, in Jakarta is the highest average daily temperature 33°C (Climate Jakarta, 2017).

Rain means cloudy skies. Combined with high temperatures, this results in high humidity levels all year round in Bandung (fig App.C.7). The (little) variation is quite coherent with the precipitation data: the lowest humidity levels are in the dry season (September and October), and the highest humidity levels are in the rainy season (January and February). (Humidity Bandung, 2016)

4.4 | Wind direction and wind velocity

The average wind speed in Bandung is around 5km/h (1.4m/s). January and February contain days with the highest wind velocity; April and May have on average the lowest wind velocity (fig App.C.8). The wind rose (fig App.C.9) shows that the prevailing wind direction is South-Southeast (SSE), with on the second place (though almost as frequent) East-Northeast (ENE). (Climate Bandung, 2017)

5 | PASSIVE BUILDING DESIGN STRATEGIES FOR BANDUNG

This chapter regards the marked part of sub-question 1: *What are the main characteristics of the outdoor climate of Bandung, and <u>what passive building design strategies fit with this outdoor climate to create a healthy and comfortable indoor environment</u>?*

The indoor climate varies both in space and in time, and is influenced by the (continuously changing) outdoor climatic conditions in the immediate surroundings (Isenberg, 2014). If these outdoor conditions are not taken into account as a design determinant in the design process, they can contribute to an overall poor indoor environmental performance of the building. As a result mechanical help will be needed to make the indoor environment more comfortable. So when trying to create good indoor conditions with minimal use of electrical and mechanical installations, it is necessary that the building design relates appropriately to the local outdoor climate and makes optimal use of the power of nature. The way to do this is by designing the building according to 'passive building design strategies'. (Emmanuel, 2005) When properly applied, these strategies will contribute to an optimal comfortable indoor environment for the local climatic circumstances.

Depending on the local outdoor climatic factors, there are several passive building design strategies that affect the indoor performance of a building. In Bandung's climate, the following strategies need to be taken into account:

1. Building orientation
2. Building configuration (building shape and building volume)
3. Building mass and building materials
4. Building elements (roof and facades, including openings)
5. The use of vegetation

In the following paragraphs, for each of Bandung's climatic characteristics (see chapter 4) will be discussed which of the mentioned strategies are important to apply and how they should be applied.

5.1 | Solar Analysis - Passive building design strategies

The solar radiant intensity in Bandung is all year round high, which results into the heating of the indoor environment. Therefore it is important to prevent the heat gain as much as possible.

1.Building Orientation

"The amount of indirect sun radiation falling on a surface is almost independent of surface orientation whereas direct sun radiation is highly dependent on orientation." (Ahmad, Ossen, & Ling, 2004) Since in Bandung both the morning and the late afternoon sunshine are strong, the East and West facades are heated-up most (fig App.C.10). To minimize the direct sun radiation onto the building, the most optimal orientation of the building volume is by placing the longer axis of the building along an axis that is rotated 10° counter-clock-wise from the East-West axis (see the block in fig App.C.10). This will lead to a minimum solar heat gain by the building envelope. (Chen B. , 2017)

2.Building Configuration

Heat transmitted through the sunlit walls should be kept minimal. Because the sun path follows the East-West axis during the day, the North and South facades receive little radiation compared to the East and West facades. Therefore the ratio of the building shape 'length : width' should be about 3 : 1. This is the most optimal ratio regarding indoor spatial quality (efficient floor area/shape) versus acceptable heat gain. By keeping the facade-areas at both East and West minimal, the exposure to direct sunlight is minimized and the amount of solar radiation is kept minimal. Also the sun shading devices or roof overhang can then be kept minimal, which saves costs. (Suhendri, 2017)

3.Building Mass and Building Materials

A study by Wonorahardjo, Edward, Olivia & Tedja (n.d.) proves that heavyweight materials (bricks, concrete, etc.) have a negative influence on the thermal environment in countries with a high level of solar radiation. “Heavyweight materials have high value of heat capacity, so it absorbs and traps the heat from sun and increase the air temperature at day and night-time.” (Wonorahardjo, Edward, Olivia, & Tedja, n.d.) Lightweight materials (such as wood, bamboo and glass) have a better influence on the thermal environment of their surroundings. To minimize the heat gain of a building it is important to use materials with low heat capacity and high thermal insulation, like for example sandwich wall panels composed of bamboo with coconut fibre thermal insulation (which could even, if a more ‘solid’-look is preferred, be covered by a thin layer of fibre concrete).

4.Building Elements

Due to the strong solar radiation from above the heat gain of the roof constitutes up to 70% of the total heat gain. (Al-Obaidi, Ismail, & Rahman, 2014) Roof insulation is therefore an important measure. When the roof or facade has openings / windows, they should preferably be orientated in such a way that no direct sunlight can enter the building. Otherwise an effective sun shading solution is essential. This means for Bandung that windows and openings should be avoided on the eastern and western facades. Since the sun altitude is all year round high during the hours with the highest solar radiant (10.00 to 16.00 o’clock), the shadow range is in these hours limited to the contour of the building roof. Therefore larger overhanging roofs or overhead shadings are preferable. (Chen B. , 2017)

5.2 | Precipitation, Temperature and Humidity - Passive building design strategies

Bandung’s humidity is very high, in both the rainy season and dry season. A problem for humans is that the high humidity restrains cooling down by the process of evaporation (of sweat), which could lead to overheating of the body (Szokolay, 2010). So for the comfort of occupants, but also to avoid moisture accumulation inside a building, passive strategies are needed to stimulate the airflow through a building. The outdoor air temperature is all year round quite moderate. This makes it possible to use outside air directly for ventilation cooling (the air doesn’t need to be cooled down in advance). Since passive building design strategies with regards to the temperature and humidity strongly relate to the use of wind, they will be discussed in paragraph 5.3.

Precipitation is heavy during rainy season, but also during the dry months there is quite some rainfall. Rainwater could be collected and used for passive cooling strategies. There are various ways how this can be done in the facade or on the roof. All these strategies depend on the evaporation of water. A suitable strategy is for example the application of a blue-green roof. (McGar, 2015)

5.3 | Wind direction and wind velocity - Passive building design strategies

In a tropical climate is a good airflow through the building needed to prevent indoor temperature rise, to help building occupants to cool down, to provide fresh air and to prevent the accumulation of moisture in the indoor environment (Feriadi & Wong, 2014). So passive building design strategies are needed to enable the wind to flow through a building. The wind frequency and wind velocity in Bandung are relatively high compared to other tropical areas, yet so low that it needs to be used optimal to have a positive effect on the indoor environment.

1.Building Orientation

For an optimal natural airflow, the building should ‘catch’ the available wind. In Bandung is the prevailing wind direction SSE, so the longest facade side of the building should face this direction. Though, since the second main wind direction is ENE, it is impossible to catch both winds with the longest facade side (unless the building is designed as a square shape, but that is not desirable with regards to the solar radiation (see par. 5.1). This means that an optimum must be found between the preferred ratio for thermal comfort (3 : 1, see par. 5.1) and the most efficient ratio to catch the two prevailing wind directions on the facades (1 : 1).

2.Building Configuration

The efficiency of a cross-flow of wind through a building depends on the building shape. To prevent obstruction of the airflow inside the building should not be too deep. (Koerniawan, 2016) Regarding the two prevailing wind directions in Bandung this means that the building shape should be kept as small as possible for both the length and the width. Otherwise the cross-flow will be obstructed for one of the two prevailing wind directions. With regards to a large factory this means that the building should preferably consists out of several separated smaller volumes instead of one big volume.

3.Building Mass and Building Materials

As far as the writer knows of, there are no passive building design strategies with regards to building mass and building materials in relation to the precipitation, humidity, air temperature and wind.

4.Building Elements

To assure all year round proper cross-ventilation within the building, there should be openings in all facades to catch wind from all directions (Koerniawan, 2016). According to Suhendri (2017) the optimal opening size is derived from the height level of the human body. Taking the human body in both a sitting and a standing position as the reference point, the opening in a facade should start at a level of 0.9m (or below) and reach up to 2.0m (or above) (both measured from the indoor floor level). Furthermore, to prevent obstruction of the airflow through the building, the height of the facade-part above the opening (so between the opening and the roof) should be minimal 0.5 x the height of the opening. Also, the optimal roof shape to guide the wind through and over the building is when the roof plane is placed under an angle of 30-45° with the horizontal. (Suhendri, 2017)

5.4 | Plants as passive building design strategy

A lot of research has been done to understand the influence of plants on the indoor environment. Here a short overview of the various ways in which plants could improve the indoor environment:

Indoor Air Quality

Experiments show that plants have a positive influence on the indoor air quality (AIRY, 2016). Plants use CO_2 and produce O_2 in the process of photosynthesis, and they can absorb and neutralize various types of (toxic) substances out of the air. This absorption mechanism depends on “the physical and chemical properties of the pollutants, the plant species and the environmental conditions.” (Curtis & Stuart, 2010) Gaseous contaminants (like NO_2) can be absorbed by plant leaves and small solid particles (like PM_{10}) can be electrostatically attracted onto the leaves (Luitse, Okkinga, & Voorhorst, 2015).

Acoustics

One of the benefits of greenery systems within buildings is the noise attenuation (Azkorra, et al., 2015). Plants leaves are ‘soft’ material and have in general quite a high absorption coefficient (Horoshenkov, Khan, & Benkreira, 2013). Vertical greenery systems could function perfectly as noise reduction tool inside a noisy space or as a sound insulation tool for better insulation of indoor walls or facades (Azkorra, et al., 2015).

Thermal comfort

Both the indoor air temperature and the indoor relative humidity are influenced by the presence of plants. Research shows that plants reduce the indoor air temperature and increase the relative humidity, which both has to do with the evaporation of water from their leaves. (Daluwatta, 2000) Green roofs can also have a positive influence on the thermal conditions inside a building: implementation of a green roof will lead to “thermal comfort improvement under such roofs” (Köhler, et al., 2002). The heat gain via the roof is lower because the temperature of the rooftop decreases due to the mass increase (dry or wet substrate and plants), due to the shading effect of the plants (the leaves of the plants reflect the sunlight), and because of the evaporation of water from the plants and the substrate (Köhler, et al., 2002). As a result could the temperature inside a building decrease with 2.5-3.5°C (Chowdhury, 2016). Plants can also be used around buildings or integrated in the facade to functioning as natural shading system (Hernández, Brebbia, & De Wilde, 2010).

Psychological effects

Other ways in which plants have a positive influence on the indoor environment have to do with the positive psychological effect on humans. Plants give humans psychological comfort, the feeling of being in touch with nature (Daluwatta, 2000). When humans look at plants it lowers stress and negative feelings, it helps to ease tension, and improves concentration, productivity and performance (Ten Caat, Evertzen, & Kaimenaki, 2016). So the presence of plants improves human wellbeing.

6 | THE COMPLEX RELATION BETWEEN HUMANS AND THE INDOOR ENVIRONMENT

Over the past decades, many researchers have tried to establish the health and comfort effects of the four basic indoor environmental factors (thermal comfort, lighting, indoor air quality and acoustics). Those studies “have shown that the relationships between indoor building conditions and wellbeing (health and comfort) of occupants are complex.” (Bluyssen, Oostra, & Meertins, 2013) For a more successful understanding of these relations it is essential to understand the mechanisms of the human body (Bluyssen, 2014).

The human system contains several response mechanisms: oxidative stress, endocrine disruption, circadian entrainment, inflammation / irritation, anti-stress hormonal responses, cell changes and cell death. “Roughly those mechanisms can be divided into two categories: mechanisms originating with the endocrine system (anti-stress mechanism, disturbance of sleep-awake rhythm and endocrine disruption) and mechanisms originating with the immune system (oxidative stress, inflammation and cell death and changes).” (Bluyssen, 2014) Studies have indicated that indoor building conditions can disturb these mechanisms, which could lead to several diseases and disorders: depression, obesity, diabetes, chronic respiratory diseases, cardiovascular diseases and cancers. (Bluyssen, 2014)

Environmental sub-factors that influence humans are also called external stressors. “A stressor or stress can trigger a mechanism or several mechanisms, and can cause an effect (or multiple effects) immediately (within seconds), or in the medium term (within minutes to hours) or long term (days to years).” (Bluyssen, 2014) There are two kinds of stressors: physical stressors and psychosocial stressors. When the stressor is continuously or repeatedly present, it can imbalance the bodily system and influence one or more of the body’s stress mechanisms. These mechanisms can on their term affect other bodily systems, which could eventually lead to diseases or disorders. (Bluyssen, 2014)

“Comfort as a basis for setting environmental standards has developed out of recognition of people’s need to remain more than simply healthy and safe in the buildings they occupy.” (Fatemi, 2012) Health is often more related to the physical and mental wellbeing of humans, while comfort generally regards more the psychological aspects of the occupants’ environmental satisfaction. According to Hensen (1991) can indoor environmental comfort be described as “a state in which there are no driving impulses to correct the environment by the behaviour.” Bluyssen (2014) describes quality as “a value judgement such as annoyance, discomfort or acceptability.” This judgement depends on how the physical stressor (like a certain sound or an odour) stimulates one of our sensory receptors. The judgement of the indoor environmental quality (IEQ) depends on both the kind and intensity of the sensation. When a stressor stimulates the human senses, this sensation could be pleasant (comfortable), neutral or unpleasant (uncomfortable or annoying). Furthermore, the sensory stimulation can have various degrees of strength or levels of intensity. (Bluyssen, 2014) In their search to find out which of the four indoor environmental factors influences the human experience of comfort most, Frontczak & Wargocki (2011) came to the conclusion that “creating a comfortable thermal environment is often considered to be the most important factor for achieving overall satisfaction with IEQ.” They also state that “providing people with the possibility to control the indoor environment improves thermal and visual comfort and overall satisfaction with IEQ as well as satisfaction with indoor air quality.”

When trying to determine the quality level of indoor environmental factors, there are both the measurable aspects and not-measurable aspects. The measureable aspects can be ‘objectively’ judged, for example the illuminance, the sound pressure level, or the concentrations of air pollutants. The judgement of not-measurable aspects depends partly on a person’s subjective experience with regards to a certain sensation, and is therefore harder to judge objectively (like the quality of a certain smell or a certain piece of music or a certain view, etc.).

Factors like age, gender, ethnicity, genetics and lifestyle can influence the way environmental stressors are handled (Bluyssen, 2014). Up until today mainly the relation between these personal factors and the perception of thermal comfort has been researched. With regards to the other three basic environmental factors, it seems logic that health-standards are quite similar for all human beings (harmful levels of air pollutants for the human body; harmful noise levels that cause hearing loss; etc.). Though, it could be possible that body (stress) mechanisms react different on certain indoor environment aspects according to gender, hormones, culture, lifestyle, etc. Frontczak & Wargocki

(2011) concluded for example that women ranked the levels of comfort for all four basic environmental factors differently than men. They established that the ranking also depended on many other factors, like the country where the survey took place, if the indoor space was a workplace or a home, if the was person a visitor or an occupant, if the building was public or private, etc. But Frontczak & Wargocki (2011) finish their paper with the words that "no general conclusions regarding the influence of the above factors on ranking could […] be formulated because these impacts were not systematic." It seems that more research is needed to draw conclusions on the relation between personal factors and the level of health and comfort of the indoor environment.

7 | THERMAL CONDITIONS & THE PHYSICAL AND MENTAL WELLBEING OF GARMENT WORKERS

This chapter regards the marked part of sub-question 2: *Looking at the thermal conditions inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

7.1 | What is 'thermal comfort' and how to measure it

Talking about thermal comfort is talking about thermoregulation: "the body's ability to physiologically regulate its inner environment to ensure its stability in response to fluctuations in the outside environment and the weather." (Fatemi, 2012) The human body can either loose or produce heat in order to (try to) keep the temperature at a constant level. Thermal comfort can therefore be defined as "that part of total human comfort which can be attributed to the thermal balance of the body." (Fatemi, 2012) In the ASHRAE Standard 55 (2004) is the term 'thermal comfort' determined as a state of mind: "Thermal comfort is that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation". Thermal stress or discomfort occurs "when one is not able to regulate its thermal balance or when one believes or perceives it isn't possible." (Bluyssen, 2014) The psychological effect of 'feeling in control' makes people feel more comfortable. Secondly is also the psychological effect of expectations important.

When trying to determine the level of thermal comfort inside a building, the interaction of the following six variables needs to be taken into account (Fatemi, 2012):

Four environmental variables

1 | t_a = Air temperature (°C)
2 | v_{ar} = Air velocity (m/s)
3 | RH = Relative humidity (%)
4 | t_r = Mean radiant temperature (°C)

Two personal variables

5 | Activity level (W/m^2)
M = Metabolic rate (met; 1 met = 58.2 W/m^2)
6 | I_{cl} = Clothing insulation (clo)

There are two main ways that people can lose their heat: by evaporation and by convection. When the humidity level is above 60% the temperature perception is higher than the actual air temperature, because the heat loss of the human body by sweat evaporation will be reduced. (Fatemi, 2012) According to Nicol (2004) can this effect of humidity on thermal comfort be significant. On the other hand, higher wind velocity decrease the temperature perception, because "air motion significantly affects body heat transfer by convection and evaporation." (Fatemi, 2012) The faster the air movement, the bigger the cooling effect (if the air temperature is lower than the skin temperature). According to Webb (1959) the favourable wind velocity to provide a pleasant thermal sensation for people in hot and humid climates is about 0.2m/s.

Several researchers have tried to establish guidelines of thermal comfort for the vast majority of the people. Fanger came up with the 'predicted mean vote' (PMV) and 'predicted percentage of dissatisfied' (PPD) index (Fatemi, 2012). His formulas, which are used by the ISO7730 (the International standard for indoor climate), use the six thermal variables to predict "a numerical value for the mean subjective response to the thermal environment." (Nicol, 2004)

Though it has been proven that people living in tropical climates have a different perception of thermal comfort than people living in not-tropical climates. (Van Hoof, 2004) According to Nicol (2004), who researched thermal comfort in naturally ventilated buildings in tropical climates, "overestimates ISO7730 the occupant response […] at high temperatures and underestimates it at low temperatures. As a result it predicts discomfort at temperatures which subjects in field surveys find comfortable and underestimates the range of temperatures which people find comfortable." This means that the international standards that are "based on theoretical analyses of human heat exchange with the environment calibrated using the results from experiments in special climate-controlled laboratories or climate chambers" (Nicol, 2004) are not suitable to define thermal comfort for people in tropical climates.

Another approach assumes that people are able to adapt to the thermal environment in three ways: 1) adjustments in their behaviour (like changing the insulation value of their clothing); 2) adjustment of their expectations; and 3) acclimatization to the climatic conditions. (De Dear, Brager, & Cooper, 1997) Acclimatization is the best way to become tolerant for warm climatic conditions. (Fatemi, 2012) Thermal acclimatization takes place when an organism is exposed to a stressful climatic condition. With regards to acclimatization to warm conditions it entails physiological and psychological "adaptations that reduce physiologic strain (e.g., heart rate and body temperature), improve physical work capabilities and improve comfort." (Fatemi, 2012) The core temperature can be reduced, sweating can start earlier and be greater, the skin blood flow can start earlier, and the body heat production can be lower. "Acclimatization probably begins to occur within days of exposure to the stimulus, but in general it is a prolonged seasonal process where its full attainment results from everyday thermal experiences. It is speeded up in people whose work is sufficiently vigorous to elevate metabolic heat production, which increases stress, thus accelerates adaptation." (Fatemi, 2012)

7.2 | General thermal conditions within garment factories in tropical climates

In general it can be stated that garment factories in tropical countries "are not well designed in sense of the thermal environment." (Khan, Ahmad, & Khan, 2011) "Many garment workers experience hot, humid conditions, especially those in the ironing section." (Better Factories Cambodia, 2013) The ability of workers to do their job is affected by thermal conditions because "the room temperature and humidity have a strong impact on mental and physical productivity." (Schilperoort & Hermans, 2015)

According to Hossain, Ford & Lau (2014) is there inside garment factories "a significant amount of heat gain […] from the artificial luminaires, workers' body temperature and constantly in-use equipment (e.g. sewing machines, iron machines, etc.). The resultant gained heat is usually trapped at indoor due to lack of air changes." A research by Khan, Ahmad & Khan (2011) to establish the level of thermal comfort in a garment factory in Bangladesh showed that the temperature inside the factory was always 1 to 3 degrees higher than the outside temperature. Chowdhury (2016) observed in his research in Bangladesh that in most of the production spaces of garment factories the indoor thermal conditions were not at all comfortable for the workers. His research concluded that an indoor air temperature of 25-26°C with a relative humidity of 55-65% and a significant air movement (0.25-0.30 m/s) was indicated as 'comfortable' by the vast majority of the garment workers.

Feeling uncomfortable is not the only major problem with regards to working in high temperature and high humidity. In garment factories, the most common health problems related to the thermal conditions are: fatigue and dizziness, heat stress/strain (distress), heat cramps, heat exhaustion/heat stroke, heat rash (prickly heat), lower performance/alertness, fainting (syncope) and increased irritability. (Better Factories Cambodia, 2013) In the (few) cases that measures have been taken to improve the thermal conditions inside the factory, it is often by placing fans to create a higher air velocity. But the problem is that the fans "are often placed in the wrong position so that they compete with the general flow of ventilation air in the factory […]. They also spread dust around the factory." (Better Factories Cambodia, 2013)

7.3 | Analysing the thermal conditions of two garment factories in Bandung

General observation during the research trip to Bandung gave the impression that the factory buildings there have not been designed according to any passive design strategies that could help to create thermally comfortable indoor conditions within this tropical climate. The buildings, made out of the cheapest materials, are built in the most simple shapes: closed boxes. The only measure that has been taken with some of the factories is perforations in the facades for air inlet. (fig App.D.1).

Interviews and observations in Bandung have resulted in the following findings about the thermal conditions within garment factories PT Kahatex and PT Perdana Firsta:

PT KAHATEX

Three factory workers of PT Kahatex were interviewed (see Appendix F for the full interviews):
- Factory Worker A: works in the weaving department since 6 months.
- Factory Worker B: works in the sewing department since 2 years.
- Factory Worker C: works in the socks-knitting department since 1 year.

- During the interviews all three the factory workers stated that it feels warm inside the factory department where they work.
- Factory Worker A said that she gets headaches approximately two days a week. She said that also some of her colleagues have often headaches. It is a possibility that these headaches are caused by the high indoor temperatures, but this cannot be stated with certainty.
- All three the interviewed workers said that there are no fans or airco-units present inside their factory departments.
- Only the department of Factory Worker C has facades with some perforations, but she doesn't notice any airflow inside the factory. The departments of Factory Workers A and B have (according to their observation) no perforated facades and they also don't feel any air movement inside their working area.

PT PERDANA FIRSTA *(collaborates with the Fair Wear Foundation)*

Own observations and gained information

When entering the factory production floor it was clearly notable that the temperature was higher than the outside temperature. It was quite an overwhelming warmth, and due to the high humidity level and absence of any noticeable airflow it was also a bit oppressive and clammy. It felt claustrophobic.

There was no air conditioning system present. There were no fans to provide some airflow for comfort. Having observed the clothes of the garment workers, it can be said that most of them wear flip-flops, long trousers, a blouse (with long or short sleeves), with sometimes underneath the blouse with short sleeves also a t-shirt with long sleeves. Most of the women wear a headscarf for their Muslim religion. On top of that they also have to wear a head-cap for hygiene in the factory. (fig App.D.2 and App.D.3) The clo-values of these clothes are about 0.5 to 0.8.

Measurements

Measurements, taken by the factory's 'Health & Safety Manager' Asni (2017) (see Appendix H), show that the indoor temperature inside PT Perdana Firsta ranges between a minimum of 26.2°C (measured in Building 2, at 13.00 o'clock in January and February 2017) and a maximum of 33.1°C (measured in the finishing ironing room, at 15.00 o'clock in December 2016). Binalab (2016) took also temperature and humidity measurements inside PT Perdana Firsta during the annual air quality check in September (see also Appendix H). These measurements showed temperatures of 31.9°C (in Building 1) and 32.0°C (in Building 2). This is 3°C higher than the average temperatures that were measured by Asni during the month September (which was 29.0°C). Since 32°C is in Indonesia the maximum allowable temperature in garment factories (Asni, 2017), these measured temperatures are (with a few exceptions) considered 'acceptable'. But looking at the comfort range that was established by Chowdhury (2016) (25-26°C), it can be stated that all the measured temperatures are higher than the comfort level.

Measured humidity levels by Binalab (2016) were 56,5% (in Building 1) and 46,5% (in Building 2). With regards to the humidity there are in Indonesia no maximum allowable values for health and comfort in buildings. According to the research of Chowdhury (2016), who gives 55-65% as the comfortable range, can the level of 56,5% be considered as comfortable and the level of 46,5% as a bit too low.

8 | LIGHTING & THE PHYSICAL AND MENTAL WELLBEING OF GARMENT WORKERS

This chapter regards the marked part of sub-question 3: *Looking at the lighting conditions inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

8.1 | What is 'lighting' and how to measure it

According to Frontczak & Wargocki (2011) can visual comfort be defined as "a subjective condition of visual well-being induced by the visual environment." Bluyssen (2014) states that "healthy and comfortable lighting […] depends on the eye task, the time of day, the weather and individual needs. The effect of lighting on performance and wellbeing depends on illuminance, lighting period, timing and spectral distribution. Additionally, psychological effects of light (colour, illuminance) can be different for different people." Parameters that need to be taken into account when determining the lighting quality are (Bluyssen, 2009):

1 | luminance (cd/m^2, with cd = candela)
2 | illuminance (lux = lm/m^2, with lm = lumen)
3 | reflectance(s)
4 | colour temperature (the visual colour of the lighting, measured in Kelvin)
5 | colour rendering index (CIE R_a is about the spectrum of the lighting; daylight gets the optimum value of 100, and artificial lighting sources have (until today) always a value <100)
6 | daylight (includes direct sunlight and diffuse light, often the measurements regarding daylight are about defining the amount of illuminance in lux)
7 | view (if there is view or not)
8 | frequencies (the number of light waves per second, measured in Hz)

When reviewing lighting conditions, both the quantity and quality is important (Hossain & Ahmed, 2013). The quantity entails the luminance and illuminance, the quality includes aspects like the colour temperature or the presence of view. "Comfortable light […] produces good colour impressions, with no reflection and an equal distribution of light. Positioning and intensity of lighting systems, surface area treatment (e.g. mat surface area and colours), solar screens and solar reflecting glazing are means to achieve this." (Bluyssen, 2009) Lighting conditions that lead to visual discomfort are "inadequate illuminance for the task, excessive luminance ratios between different elements of a task, and lamp flicker, even when it is not visible." (Bluyssen, 2014)

Visual discomfort can lead to several health problems including eyestrain. "Symptoms of eyestrain are irritation of the eyes, evident as inflammation of the eyes and lids; breakdown of vision, evident as blurring or double vision; and referred effects, usually in the form of headaches, indigestion, giddiness and so on." (Bluyssen, 2014) Especially (low frequency) fluctuations in light output could cause headaches. Also, "reflection, blinding, too little light, bad colouring of the light can lead to tiredness of the eye or adaptation problems, decreased alertness and concentration problems." (Bluyssen, 2014) Glare occurs in situations that there is a big contrast in brightness within the field of vision. Besides causing discomfort (which leads to eyestrain and headaches) could glare also decrease a person's visual performance when the contrast is really big. Furthermore can excessive lighting / illumination cause discomfort. "There is some evidence for increased discomfort at illuminance above 1000 lux." (Bluyssen, 2014)

Lighting influences the circadian rhythm (day-night rhythm) of the human body. Daylight is fluctuating in colour and intensity during the day, and the human body needs this fluctuating light for stimulation of this mechanism. When indoor environments depend on artificial lighting, the circadian rhythm could be disturbed. This rhythm influences for example the sleep and alertness (by production of the melatonin hormone), but also the core body temperature and other hormone production. A distorted sleep rhythm can lead to "impaired alertness, memory, performance, and disturbed endocrine functions, and upset gastrointestinal function […], but also (winter) depression and even cancer, obesity and diabetes have been related to circadian disruption." (Bluyssen, 2014) Schilperoort & Hermans (2015) talk about how "the lack of daylight leads to complaints of depression, fatigue and sadness." So since lack of daylight has several negative effects on human physical and mental wellbeing, it seems that dynamic artificial lighting (change in colour and illuminance) in the rhythm of daylight will have a positive influence on the wellbeing of people. (Bluyssen, 2014) A good solution is the use of daylight in combination with artificial lighting that is changeable in brightness (automatically or manual) and has the right colour according to the activities that need to take place within the specific space.

View is also important. “Transparent parts in the enclosure of the space play a pivotal role in the human need […] for visual contact with the outdoors (visual comfort) and daylight entrance." (Bluyssen, 2009) But direct sun radiation from one side could be experienced as uncomfortable and should therefore be prevented (Bluyssen, 2009).

8.2 | General lighting conditions within garment factories in tropical climates

Inside garment factories adequate lighting is essential for the labour intensive precise work of cutting, sewing, checking the quality, etc. Good lighting conditions are necessary to work productive and efficient and to deliver high quality products. (Hossain & Ahmed, 2013) With regards to the wellbeing of the factory workers, both daylight, view and artificial lighting should be analysed.

In general there is lack of daylight and view for the garment workers in factories. The halls are often without any openings in roof or facades to let daylight in or to provide a view. Joarder & Iqbal (2015) talk about “poor natural lighting system and high internal heat gains from artificial lighting, creating an intolerably hot and uncomfortable working environment for the workers.” Since the garment workers spend “more than 90% of their life in an artificial luminous environment” (Joarder & Iqbal, 2015) can the lack or absence of daylight have a serious negative impact on their health. Especially since in countries around the equator the indoor working hours contain the vast majority of the hours with daylight.

Besides the diseases and disorders related to disturbance of the body’s circadian rhythm, another health problem of the indoor lifestyle in factories without daylight (combined with the low dietary intake of calcium, since dairy products are often too expensive for garment workers) is the risk of low vitamin D and decreased bone health (lower bone mineral status). This was found in a research among two hundred randomly selected female garment workers (aged 18-36 years) in Bangladesh. (Islam, et al., 2008)

The artificial lighting in garment production spaces is often “poorly designed and not well maintained […], which results in glare and flicker that may cause vision problems.” (Hossain & Ahmed, 2013) If there is task lighting present in garment factories, this is not dimmable. Within the sewing section of some factories is ‘needle point lighting’ used: LED task lighting that shines directly onto the needle of the sewing machines to achieve the required illumination level at the work plane. “But considering the brightness ratio at the work environment, this solution conflicts with the quality lighting environment and may cause visual problems to the operator.” (Hossain & Ahmed, 2013)

Research has showed that the factory workers that do the sewing, finishing and quality check suffer most from eye problems. (Hossain & Ahmed, 2013) According to Jailer, Lara-Meloy & Robbins (2015) ‘good lighting’ in a factory means that it “helps you see your work without straining your eyes. Not enough light makes you squint or get too close to the work, which weakens the eye muscles and can lead to blurry vision.” Important is to place lights in the right position, so that the workers don’t work in their own shadow and don’t have to adopt poor working postures to do their task. (Better Factories Cambodia, 2013)

Another problem is the dust and dirt that accumulates around the lighting sources and is (often) not cleaned. This leads to poor lighting conditions, with as a result that the workers suffer from eye strain, fatigue, headaches, stress and accidents. (Better Factories Cambodia, 2013) Besides poor lighting a common problem inside the factories is that the lighting is too bright, which causes headaches and stress among the workers. Both too little and too bright lighting “can lead to mistakes at work, poor quality and low productivity. Various studies suggest that good lighting at the workplace pays dividends in terms of improved productivity, and a reduction in errors.” (Better Factories Cambodia, 2013) According to Hossain & Ahmed (2013) should the illumination level at the work-plane of the workers be “within 600-800 lux (average 700 lux) especially for Sewing Operators, Sewing Helpers and Quality Controllers.”

8.3 | Analysing the lighting conditions of two garment factories in Bandung

Interviews and observations in Bandung have resulted in the following findings about the lighting conditions inside garment factories PT Kahatex and PT Perdana Firsta:

PT KAHATEX

During the interviews, garment workers A, B and C told the following:

- All three the workers said there is no daylight inside their factory department at PT Kahatex .
- They all explained that the present artificial lighting is really bright. Workers B and C said it is not comfortable for them, but it is good / necessary for doing their (precise) work-tasks.
- Factory Worker A and Factory Worker C both said there is only general lighting in their department, no specific task-lighting. This general lighting consists out of fluorescent tubes.
- Factory Worker B said that she has, besides the general lighting (fluorescent tubes) also a small extra LED-light that shines on the needle point of the sewing machine.
- Although all three the workers mentioned the bright lighting, they never had any problems with their eyes. No eyestrain, no adaptation problems, etc. Though, Factory Worker A has regularly headaches, which could be caused by the lighting conditions (but this cannot be stated with certainty).
- The three factory workers said all that they don’t have problems with sleeping. No troubles with falling asleep, no problems of waking up during the night, etc.

PT PERDANA FIRSTA *(collaborates with the Fair Wear Foundation)*

Own observations and gained information

There is no daylight at all inside the factory and no view to the outside. Since the garment workers spend a minimum of 8 hours a day in the factory, for 6 days a week (Asni, 2017), the absence of daylight could have a negative influence on their health. Daylight in Bandung is present from approximately 05.30 till 18.00 (timeanddate.com, 2017), which means that the working day of the garment workers (07.00-16.00 or 08.00-17.00) contains the vast majority of these hours.

The general artificial lighting throughout the whole factory consists out of fluorescent tubes, mostly with a cool white colour temperature. At some places inside the factory there is a big contrast between the dark background (where there is no lighting) and the bright artificial lighting hanging just above eye-level. The lamps are mostly placed above the (white) tables to shine directly onto the work planes (fig App.D.5-App.D.7). Depending on the task that needs to be done, at some sections in the factory there are extra (task) lights:

- fabric check: extra fluorescent tubes shine on the fabric (fig App.D.4)
- sewing: a small LED-lamp shines directly upon the needle point (fig App.D.8)
- quality check: fluorescent tubes above the tables are extra bright (fig App.D.7)

Some of the sewing operators are placed on a spot where their own body blocks the general lighting, making them work in their own shadow (fig App.D.8). Though at most of the workspots the fluorescent tubes are placed right above the table, making sure that the workers don’t work in their own shadow. Positive is that the extra LED-lighting of the sewing operators shines directly upon the task, and not into the workers’ eyes.

Measurements

When looking at the measured data of PT Perdana Firsta, the following numbers represent the average lighting levels per activity in the factory (see Appendix H for the total list of measurements):

Fabric Inspection:	1067 lux
Cutting:	395 lux
Sewing:	604 lux (minimum is 330 lux in Line 13, and maximum is 1278 lux in Line 1)
Quality Check:	649 lux (minimum is 516 lux in Line 11, and maximum is 815 lux in Line 7)
Washing:	380 lux
Ironing:	377 lux
Packing:	366 lux

The lighting levels in the cutting, washing, ironing and packing departments seem quite low for to the (precise) tasks that the workers need to do. The lighting levels at the sewing and quality-check departments meet on average the advised levels of Hossain & Ahmed (2013) (600-800 lux), but these measurements show big differences between various areas. In some of these areas are the lighting levels way lower than the minimum advised 600 lux.

9 | INDOOR AIR QUALITY & THE PHYSICAL AND MENTAL WELLBEING OF GARMENT WORKERS

This chapter regards the marked part of sub-question 4: *Looking at the air quality inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

9.1 | What is Indoor Air Quality and how to measure it

When describing indoor air quality, Bluyssen (2009) speaks of “a complex phenomenon comprising odour, indoor air pollution, fresh air supply, etc.”. Frontczak & Wargocki (2011) define ‘acceptable air quality’ as “air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction.” Unlike with thermal comfort or lighting conditions, “the term comfort is not commonly used in relation to indoor air quality and it is mainly linked with the lack of discomfort due to odour and sensory irritation.” (Frontczak & Wargocki, 2011) Though, instead of only having a negative influence (harmful for the body, annoyance, etc.), smells can also have a positive influence on humans: “indoor air pollutants can be odorous and lead to annoyance or pleasure.” (Bluyssen, 2014)

It has been proven that “exposure to odours can alter moods, change attitudes, influence perceptions of health, affect task performance and evoke memories. In general, pleasant smelling odours induce positive moods, attitudes and behavioural changes, and unpleasant odours induce negative moods, attitudes and behaviours.” (Bluyssen, 2014) Even when smells are not consciously observed can they still influence the mood and behaviour of people (Bluyssen, 2014).

When looking at the exposure of a person to pollutants in the indoor environment, it is important to look at the concentrations of the pollutants (expressed in $\mu g/m^3$). There are various parameters that influence these concentrations (Bluyssen, 2009):

1. Pollution sources
    - outdoor sources (traffic, industry, etc.)
    - occupant-related activities and products (cooking, smoking, cleaning, etc.)
    - building materials and furnishing (insulation, paint, fabric, etc.)
    - ventilation system components (filters, ducts, etc.)

2. Concentrations of the pollutants
This is measured in $\mu g/s$ or in $\mu g/s/m^2$ of surface area of the polluting source.

3. Types of pollutants
Indoor air pollutants can be split into chemical and biological pollutants with each various subgroups. For chemical pollutants these subgroups are: gases and vapours, particulate matter and radioactive particles / gases. For biological pollutants the subgroups are: micro-organisms, mould, fungi, mycotoxins, bioaerosols pollens, mites, spores, allergens, bacteria, airborne infections, droplet nuclei and house dust.

4. Ventilation rate and efficiency
    - the ventilation rate of the concerning space (in l/s or m^3/h)
    - the amount of pollutants present in ventilation air (in ppm or $\mu g/m^3$)

Bluyssen (2009) states that “the detection and interpretation of the thousands of pollutants in the indoor air is difficult and complex: besides the fact that these pollutants interact with each other (indoor chemistry), they also cause interactions with the sensations and perceptions of the human body. Therefore, providing guidelines for levels of permissible concentrations will always be questionable unless a direct relation has been found.” The concentrations of pollutants in an indoor space (and thus the exposure of occupants to these pollutants) vary over time, so it is a dynamic situation. The rates of emission can also be different in different areas of the space. The amounts of emitted pollutants change because of (small) variations in the indoor environment, because of changes in (the level of) activities of the occupants and because of changes in the presence of polluting sources. The indoor air quality is therefore “a function of input from many sources and from ventilation.” (Bluyssen, 2009)

The best way to control the indoor air quality is by minimizing the emissions of pollutants. A second measure is by assuring good ventilation. An air-filtering system can help to actively clean the incoming air from pollutants from outside or (in case of air circulation) from inside. The last measure is activity control, which means that activities that are polluting (like smoking or, in the case of garment factories, the dying of the fabric with chemicals dyes) take place in a separate room from other activities that take place inside the building. Also, attention should be paid that a ventilation system needs good maintenance to not become a polluting source itself (when dust and other pollutants are accumulated inside). (Bluyssen, 2009)

9.2 | General Indoor Air Quality within garment factories in tropical climates

Garment workers are exposed to "high levels of air pollution" (Adhvaryu, Kala, & Nyshadham, 2014). Besides the possibility that air pollution from outside (traffic, etc.) enters the factory, the problem is mainly caused by indoor sources like high densities of people (who produce CO_2), chemicals used for cleaning the factory, building materials and furniture, and last but not least the chemically treated fabrics used to make the clothes.

According to the research of Jailer, Lara-Meloy & Robbins (2015) is fabric "often treated with different chemicals that give the fabric colour, fire resistance, permanent press, or other qualities. Bleach makes the fabric white and easier to dye. Dyes give the fabric specific colours. Mordants improve how colour sticks to the fabric. Sealers and fixers prevent dyes from washing off with water or sweat." When the fabrics are used to make the cloths, some amount of these chemicals will get into the indoor air. Although the garment workers wear often mouth-caps, the ones they wear are 'dust masks' and won't protect against inhaling the chemical airborne particles (for that a respiratory mask is needed, with an air-tight seal and appropriate filtering). The dust masks exist in all types of filter efficiencies, protecting against different sizes of dust particles. Problem is that they don't fit tightly to your face, and therefore will allow the person to inhale a certain amount of unfiltered air. (Jorgustin, 2013) Besides the chemical air pollutants, dust is another problem in the factories. This dust consists mainly out of very small fibres of the fabrics, released into the air during the different production steps (by touching the fabric, cutting it, sewing it, etc.). "Air thick with fabric dust is very common in garment factories and harmful to health." (Jailer, Lara-Meloy, & Robbins, 2015) Inhaling the dust from fabrics can cause several kinds of breathing problems, like a dry or itchy nose, coughing, over-producing of mucus (phlegm) and a general feeling of 'troubled breathing' (chest tightness). Breathing cotton dust day after day can also cause a more serious lung disease called brown lung or byssinosis. (Jailer, Lara-Meloy, & Robbins, 2015)

After the clothes have been made in the sewing department, they go to the finishing department. Some of these finishing tasks are dangerous, like 'acid-washing' of jeans. This means that "workers sponge or spray potassium permanganate bleach, chlorine bleach, or other bleaches on the garment to make it look worn." (Jailer, Lara-Meloy, & Robbins, 2015) These bleaches can burn the skin, and irritate the eyes, nose and throat. "Potassium permanganate bleach can also cause other health problems, including decreased fertility for men and women, and liver and kidney problems." A second way to lighten and soften denim is by 'sandblasting' the jeans, which means spraying the jeans with sand by using a high-pressure machine. This "sandblasting is so dangerous to workers' lungs that it has been banned in many countries. Sometimes brands prefer jeans sanded by hand, but this creates the same health issues and can be worse when workstations do not have strong ventilation to remove the sand. […] When silica dust gets in the lungs, it cannot be breathed out and causes an illness called silicosis. Silicosis makes breathing difficult and can cause auto-immune diseases, lung cancer, and death. There is no cure for silicosis. […] People exposed to silica or who have silicosis are also more likely to get TB (tuberculosis)." (Jailer, Lara-Meloy, & Robbins, 2015)

Most garment factories lack a good natural ventilation flow or a good-functioning mechanical ventilation system. A report by organization Better Factories Cambodia (2013) signals: "What we tend to see inside many garment factories is air circulation, moving air around inside the factory without refreshing it with air from outside." With a limited ventilation flow and several air polluting sources inside can the concentrations of air pollutants get really high.

9.3 | Analysing the Indoor Air Quality of two garment factories in Bandung

Interviews and observations in Bandung have resulted in the following findings about the indoor air quality inside garment factories PT Kahatex and PT Perdana Firsta:

PT KAHATEX

Factory Workers A, B and C provided the following information regarding the indoor air quality:

- Factory Workers A and B said that the air is dusty in their department.
- They all have to wear mouth-caps that the factory provides.
- They also all said that the air smells 'like fabric' (this refers most probably to the smell of chemicals that are used to dye/treat the fabric). Factory Worker A also explained that she get sometimes blisters on her hands. She weaves yarn into fabric, but this yarn gets dyed right before the weaving. The blisters on her hands might be caused by these chemical dyes.
- All three the factory workers said that they don't have any problems with breathing, and they've never had a stuffy, blocked or running nose.
- Factory Worker A said that she and some fellow colleagues get sometimes headaches. It is possible that these headaches are caused by the bad indoor air quality (but this cannot be stated with certainty).
- The factory workers said that there is no mechanical ventilation inside their factory department.
- Factory Workers A and B said that the facades are closed in their departments. Having also no mechanical ventilation, the ventilation flow is most probably quite low. Factory Worker C said that the facades of her department are perforated (they contain probably air bricks for natural ventilation).

PT PERDANA FIRSTA *(collaborates with the Fair Wear Foundation)*

Own observations and gained information

All workers throughout the production sections wear dust mouth-caps. With regards to the air quality I experienced the dustiness and strong smell of 'fabric' (chemical dyes and other fabric treatments). Due to the bright light beams against a dark background, the dust in the air was in some areas even visible. Walking through the different departments, I noticed that the chemical smell was present everywhere. It is quite a strong and (to me) unpleasant smell. It also made my chest feel a bit heavy, as if normal breathing suddenly took more effort.

There is no HVAC-system (or any other air handling unit) present inside the production sections of the factory. This means that the air from outside is not filtered before it enters the building, so pollution from traffic and other outside sources will get inside the building. Asni (2017) said that ventilation takes place through the blue grills in the facade (air inlet) and rooftop fans (air outlet) (fig App.D.9-App.D.12). Since the grills were quite small compared to the volume of the indoor space, it gave the impression that this way of 'natural ventilation' is not sufficient to provide enough fresh air for the workers and to exhaust the air pollutants.

Measurements

During the last annual indoor air quality check by Binalab (2016) the following values were measured for the indoor air quality (see Appendix H for the official document):

Building 1		Building 2	
SO_2	< 6,45 $\mu g/m^3$	SO_2	< 6,45 $\mu g/m^3$
NO_2	7,48 $\mu g/m^3$	NO_2	20,40 $\mu g/m^3$
CO	< 102 $\mu g/m^3$	CO	< 102 $\mu g/m^3$
TSP*	171,95 $\mu g/m^3$	TSP*	171,76 $\mu g/m^3$

*Note: Total Suspended Particles (TSP) is an old regulatory measure of the mass concentration of Particulate Matter (PM) in community air. (Lippmann, 2000)

Except for the TSP-values, these pollutants are usually only measured to determine the outdoor air quality. To determine the indoor air quality inside the factory it is much more relevant and useful if the CO_2-level and the chemical air pollutants are measured. With regards to these measured values can it be concluded that they stay below the allowable values according to the World Health Organization (2005).

10 | ACOUSTICS & THE PHYSICAL AND MENTAL WELLBEING OF GARMENT WORKERS

This chapter regards the marked part of sub-question 5: *Looking at the acoustic conditions inside garment factories, what are the current problems with regards to the health and comfort of the workers and how can passive design strategies improve these conditions?*

10.1 | What is 'acoustic comfort' and how to measure it

It is well known that sounds above certain intensity levels are literally painful for the ears. It can damage peoples hearing immediately or after being exposed to it for a certain period of time. But besides these damaging effects, there is also the more personal perception of acoustic comfort. Navai and Veitch (2003) defined acoustic comfort as "a state of contentment with acoustic conditions". Humans experience sound in different ways. Noise sensitivity differs per human being because the effect that the sounds evoke within the brain can differ from person to person. These effects include "emotions, triggering the release of stress chemicals and impacting the development of new neural pathways in the brain." (Woods, 2015) So it can be stated that "the perception of what is sound or noise is personal. […] Most people define noise as unwanted or unpleasant sound." (Better Factories Cambodia, 2013)

There are several physical parameters that need to be taken into account when determining the quality of the sound environment. These include "both the physical properties of sound itself and the physical properties of a room." (Frontczak & Wargocki, 2011) Sounds are characterized by one or more frequencies (also called 'pitches', measured in Hz) and a certain 'sound pressure level' (also called 'intensity' or 'volume', measured in dB). Research has concluded that it is a combination of volume and pitch that affects humans hearing, not just the sound intensity. Ears are more sensitive for high tones than for low tones. That is why the sound pressure level is usually measured in an A-weighted sound level (dBA), meaning that the perception of loudness by the human ear is taken into account. (Better Factories Cambodia, 2013) The physical properties that determine the acoustic conditions are the presence of sound insulating and absorbing materials. The acoustic quality of a space is often determined by measuring the reverberation time: the time that it takes for a sound to have completely 'died away'. (Frontczak & Wargocki, 2011)

With regards to health, the National Institute for Occupational Safety and Health (NIOSH) sets 85 dBA as the maximum noise level that workers should be exposed to during their eight-hour workday to minimize occupational noise-induced hearing loss. If workers are exposed to higher noise levels is the employer obligated to provide ear protection. NIOSH also "uses a 3 dB time-intensity tradeoff: for every 3 dB increase in noise level, the allowable exposure time is reduced by half. For every 3 dB decrease in noise level, the allowable exposure time is doubled." (Johnson, 2014) Figure App.E.1 (in Appendix E) gives an overview of several noise levels with possible noise sources and the allowable daily doses to minimize hearing loss.

A good acoustic environment entails more than only the prevention of hearing loss. There are other ways that sounds can harm people. "It seems that noise effects do not only occur at high sound levels, but also at relatively low environmental sound levels, when certain activities such as concentration, relaxation or sleep are disturbed." (Bluyssen, 2013) Noise could cause annoyance, which affects the ability to work in concentration, decreases the productivity and could lead to mistakes and accidents. Noise can influence the body in the same way as psychological stress does (Bluyssen, 2014). So like stress, can noise lead to serious health problems, for example with the blood vessels or the heart. According to Maxwell (n.d.) the physical and mental wellbeing of people could be negatively influenced by noise in the following ways: increased illness, increased hormone levels, stress (with all its negative consequences), lower job satisfaction, lower morale, feeling fatigue, loss of inside peace, sleeplessness and tinnitus. Schilperoort & Hermans (2015) write also about aggression and hypertension caused by noise.

The reason why humans react strong to noise has to do with our survival mechanism. Woods (2015) explains this reaction: "Loud noises evoke an instinctive fight or flight reaction in the brain […]. The fight or flight reaction is a release of chemicals that stimulates immediate action. This reaction has been crucial to ensure human survival in the wilderness, and remains important in the modern world. If you hear a loud honk from a car horn, your brain and body respond quickly to move you out of harm's way. Once danger has passed, the brain releases tranquilizing chemicals that counteract the stimulating chemicals. Exposure to too many loud noises can overload your brain with stimulating chemicals. Without the balancing effect of the brain's tranquilizing chemicals, the stimulating chemicals can damage brain cells." Over the long term, the continuous stress-feeling caused by noise can lead to heart, stomach and nervous disorders.

Sounds can also have positive effects on the human body and mind. For example the sound of ocean waves, with a frequency of roughly 12 cycles per minute, is found by most people very pleasant. Interesting is that this is roughly the same rhythm as the breathing of a sleeping human, which makes humans unconsciously associate the wave-sound with being stress-free. (Treasure, 2009) Furthermore is music a form of sound that impacts the brain to link it to memories and emotions. "Music is the most powerful form of sound that affects our emotional state." (Treasure, 2009) Research has proven that "people who listen to music experience less pain and lower levels of depression and disability related to pain than those who don't listen to music. This indicates that music can affect the brain by lifting the mood and alleviating the perception of pain." (Woods, 2015) But also natural sounds can affect our emotions in a positive way. For example, "bird song is a sound that most people find re-assuring, because [through evolution we've learned that] when the birds are singing, things are safe." (Treasure, 2009) This means, when listing to bird song, the level of stress decreases and both blood pressure and heartbeat lower.

10.2 | General acoustic conditions within garment factories in tropical climates

Although the noise level in the garment industry stays relatively 'low' compared to other industries (see fig App.E.2), the noise levels can still be high enough to cause hearing loss or annoyance (with all its negative consequences for body and mind). "Noise is probably one of the most widespread and underestimated of industrial hazards. High noise levels are experienced in many parts of the garment industry, especially in those factories that have weaving machines." (Better Factories Cambodia, 2013)

The various machines are the main noise-producing sources. According to Jailer, Lara-Meloy & Robbins (2015) are especially the sewing machines and the riveting machines very loud. So when many of those are running at the same time in the same space without good acoustic measures, the noise level can be high. Since most garment workers don't wear ear-protection, this could lead to both annoyance and hearing loss.

As mentioned in chapter 9, most garment factories don't have air handling units on the production floor. An HVAC-system can be a major indoor source of noise (Bluyssen, 2014), but it can be assumed that this does not apply for garment factories. Sometimes big rooftop fans or facade fans are used to stimulate the ventilation flow through the building, or smaller fans are placed inside the factory (close to the workers) for more thermal comfort. These fans could produce some noise, though this is quite low compared to the level of noise that all the machines produce.

Research in Cambodia proved that garment workers who are exposed to high levels of noise during the day, often have difficulty with sleeping when they come home after work. The result is that they "are constantly fatigued with that feeling of being tired all the time. Some workers take pain-killers on a regular basis to get rid of headaches induced by the noise." Logically, their job performance will then reduce. "High noise levels in the workplace are thought to be a contributory factor to increased absenteeism. […] Workers exposed to medium to high noise levels for a longer period of time per day suffer from what is known as 'noise induced hearing loss' (NIHL)." (Better Factories Cambodia, 2013)

There are three ways to deal with noise in factories: 1) control the noise at the source; 2) control the noise along the path between the source and the workers; and 3) control the noise at the workers. "In common with all control strategies for health and safety problems, the most effective method is to control the hazard at source. However, this often requires considerable expense and, with profitability being cut to a minimum in the global market, owners and managers are often loathe to spend money in this area." (Better Factories Cambodia, 2013) Controlling the noise at the source means buying quieter machines and assure good maintenance of the machines. Measures to control the noise along the path between the source and the workers means splitting noisy activities from less-/not-noisy activities, placing acoustic panels around the noisy machines or at the walls or ceiling, etc. Finally, the "most common and cheapest method of control, is to put the emphasis on workers wearing some form of personal protective equipment (PPE)." (Better Factories Cambodia, 2013)

10.3 | Analysing the acoustic conditions of two garment factories in Bandung

Interviews and observations in Bandung have resulted in the following findings about the acoustic conditions inside garment factories PT Kahatex and PT Perdana Firsta:

PT KAHATEX

During the interviews, garment workers A, B and C said:

- They don't wear any ear-protection during their work in the factory.
- They have no pain in their ears during or after work.
- They also said they have no difficulties sleeping at night.
- They all confirmed that there is quite some noise inside the factory, caused by the machines. But they all stated that they don't feel annoyed or disturbed by the level of noise.

I was not allowed to go inside this factory and observe and measure the noise myself. So to obtain the most 'objective' judgement about the acoustical conditions in PT Kahatex, the following possible interpretations of the given answers must be taken into account: 1) the actual level of noise is lower than the level that would cause annoyance or pain in the ears; or 2) the workers don't notice the noise because they already suffer from some hearing loss; or 3) they 'accept' the noise, but unconsciously their body still feels annoyed / stressed and their ears get damaged; or 4) they don't want to complain about it.

PT PERDANA FIRSTA *(collaborates with the Fair Wear Foundation)*

Own observations and gained information

My first impression with regards to the acoustical conditions was that the noise was loud, continuous and invasive. It felt unpleasant and I felt annoyed by it. Especially the idea that it wouldn't stop made me feel irritated. The noise disturbed my thoughts and it seemed that I couldn't think clearly because I was distracted. I had to raise my voice to be able to have a conversation with someone. (According to the organisation Better Factories Cambodia (2013) is the noise level in a factory too high - and will cause annoyance and hearing loss during an eight-hour workday - if you are unable to hold a conversation in normal tones / volume when you stand one arm length away from another person).

There was noise everywhere, though depending on the kind of machines that were used the noise was in some areas louder than in others. The garment works don't wear ear-protection (ear-plugs or ear-mugs). This was also confirmed by Asni (2017) during the interview.

The factory consists out of three large spaces (halls) with some smaller rooms attached. Many of the production steps take place within the large halls, and therefore the noise of the different machines is amplified together. Also, within these larger spaces some activities don't use machines (like the quality check and the packing), but these activities are unnecessarily bothered by the noise of other activities that take place within this same space (like the sewing).

As already mentioned in chapter 9, PT Perdana Firsta has no air handling units in the production departments. There were also no fans present in the production sections. So both these aspects don't contribute to the noise inside the factory.

Measurements

Although the amount of dBA's can be measured, it is difficult to find out if the noise in (a certain part of) a factory is too high. "A straight forward method is to take measurements, and compare these with recommended 'dB-safety-levels' of national regulations. Though this gives insight in the hearing loss damage, other symptoms (annoyance, etc.) are still difficult to establish." (Better Factories Cambodia, 2013)

The highest sound levels in the different production sections inside PT Perdana Firsta (see Appendix H), are measured in the cutting department (75 dBA), in the compressor area of Building PFG 1 (74,3 dBA) and in the finishing department (72 dBA). Experiments have proven that noise levels above 60 dBA can cause annoyance, stress and cardiovascular problems. (Tinnitus Treatment Blog, 2017) A part of the measured noise levels is below 60 dBA's, but the majority is above 60 dBA's. Since the workers in PT Perdana Firsta are exposed to these noise levels for eight hours per day, it seems very well possible that some of the workers will feel annoyed or suffer from health problems (hearing loss, headaches, etc.).

11 | DISCUSSION & CONCLUSION - 'connecting the dots'

The state of the indoor environment of garment factories regarding health and comfort related to the thermal conditions, lighting, air quality and acoustics has always been and still is problematic. Although most of the problems have been researched and pointed out, not many improvements are made within the industry. Current garment factories are mostly located in less-developed countries with warm climates. The factory buildings, one- or two-storey halls or multiple storey blocks, are generally of poor quality. These simple 'boxes' contain hardly any measures to make the building fit for the local climate. This leads to buildings that, influenced by the outdoor climate, contain uncomfortable and unhealthy indoor conditions. Combined with the high worker density, the noisy and polluting production activities, and the absence of good electrical and mechanical installations (for ventilation, lighting, air-filtering, etc.), the result is that the indoor conditions of the majority of the garment factories have a serious negative impact on the mental and physical wellbeing of the workers.

With regards to the thermal conditions, the biggest issue for the health and comfort of the garment workers is the high indoor air temperatures. The buildings are often designed in such a way that the heat gains (of the sun and the indoor heat production) are bigger than the heat losses. As a result the indoor air temperatures are often higher than the (already high) outdoor air temperatures. Air movement helps the human body to cool down, and is therefore (especially in very humid climates like Bandung) contributing to the thermal comfort. But in the vast majority of the garment factories there is no (noticeable) air movement. To establish the comfortable temperatures for the factory workers it must be taken into account that the human body is (to a certain extend) able to acclimatize to the temperature of its surrounding. So people living in Bandung are comfortable with higher temperatures than for example people living in The Netherlands. In a climate like Bandung is an indoor air temperature of 25-26°C with a relative humidity of 55-65% and an air movement of 0.25-0.30m/s considered to be comfortable for garment workers.

When looking at the lighting conditions inside garment factories, an important issue is the absence or lack of daylight. Besides the fact that diffuse daylight (not direct sunlight) is in the indoor environment generally experienced as comfortable, it is also important for the health since it influences the circadian rhythm of the body (this has to do with the fact that daylight changes in colour and illuminance during the day). Because there is in Bandung all year round daylight from ±05.30 till ±18.00, this could be used optimal during the working hours. Furthermore is there at the moment in factories no or hardly view (to the outside), but this is also an important aspect for comfort and mental health of the garment workers. The artificial lighting in garment factories is often not comfortable: lack of lighting, too bright, unpleasant colour temperatures, unpleasant fluctuations, etc. The ideal situation for the health and comfort of the factory workers would be to use maximum daylight in combination with dynamic artificial lighting (automatically or manually dimmable).

The biggest problem regarding the indoor air quality is the fact that the chemically treated fabrics, used to make the clothes, bring a lot of dust and chemical pollutants into the air. Most factories don't have good natural or mechanical ventilation. This means that the concentrations of pollutants in the indoor air can get really high. Garment workers often wear dust mouth-caps, which prevent the inhalation of (most of the) dust but don't offer protection against inhaling the chemical air pollutants.

With regards to the acoustics, the biggest issue is the fact that the machines inside the factories make a lot of noise. Since the factories often consist out of one big space, with mostly hard floor-, wall- and ceiling-surfaces, the noise produced by the machines is not muted. This leads to noise levels that are uncomfortable and can have several negative effects on the health, like damaging the ears and causing annoyance (which is also damaging for the human body in various ways). The vast majority of the garment workers don't wear ear-protection.

Looking at Bandung's outdoor climate, it can be stated that it is a tropical climate (warm and humid). One of the most important characteristics is the high solar radiation, which comes mostly from above since Bandung is located close to the equator. There is a rainy season (November-April) and a dry season (May-October). The average air temperature range during the year is quite small: 18-27°C. Bandung has all year round high humidity levels. The wind velocities are on average around 1.4m/s, and the prevailing wind directions are South-Southeast and East-Northeast.

Existing garment factory building types are not suitable for creating an optimal indoor environment within the outdoor climate of Bandung. A new building type, shaped according to well-chosen passive building design strategies, should be considered, built and tested. Though passive strategies cannot solve all problems regarding health and comfort of the indoor environment in garment factories, it is expected that they contribute to great extent. But more (field) research and experiments are needed to optimize these passive strategies with regards to the most suitable and effective application for factories.

The following passive building design strategies are considered to be effective measures to achieve a healthy and comfortable indoor environment in a garment factory in Bandung:

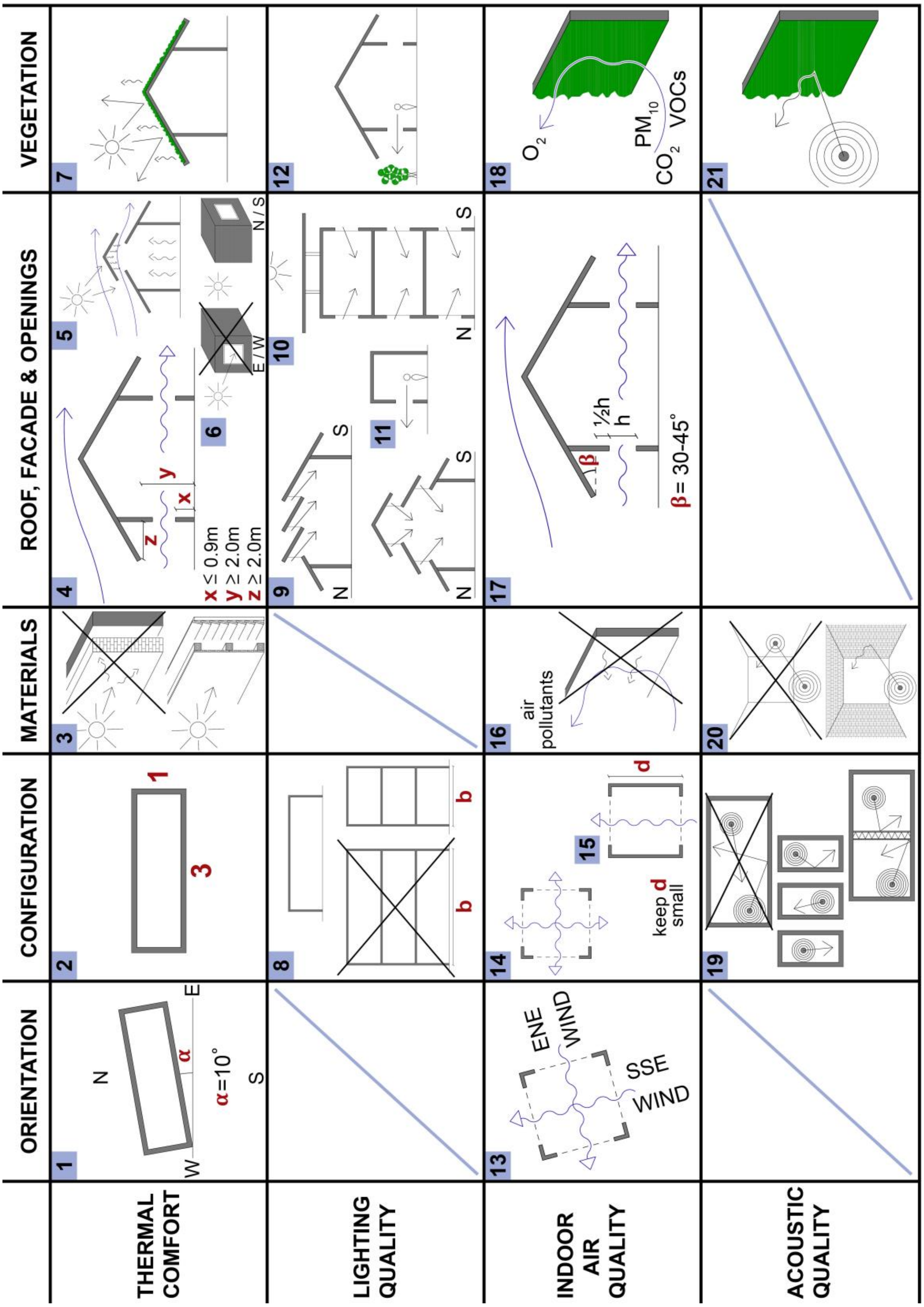


fig 1 | suitable passive building design strategies to optimize the four indoor environmental factors with regards to health and comfort in garment factories in Bandung (own image)

Thermal Comfort design

1) To minimize the amount of solar radiation on the facades, the optimal orientation of the building is when the longest facade is parallel to the axis turned 10° CCW from the East-West axis. 2) The optimal building shape ratio ‘length : width’ is 3 : 1. 3) Materials with a low thermal mass are preferable to minimize the accumulation of sun heat. 4) To provide a comfortable air movement for the workers, openings in the facades should start at 0.9m (or below) and reach up to 2.0m (or above). A roof overhang of minimal 2.0m will provide shade for the facades during the hours with the highest solar radiation. 5) Also effective is to enable a good airflow underneath the roof, to let the warm air (that rises up from inside the room and is obtained via the sun-heated roof) escape. 6) Direct sunlight through transparent parts / openings should be avoided, so in Bandung windows are preferably placed at the North or South facades. When placing windows at the East or West facade a good sun-shading solution is needed. 7) Since most heat from the sun catches the roof, green roofs are a good measure to minimize the heat gain.

Lighting quality design

8) To assure good daylight inside a larger building it is important that the building volume is either wide but just one floor (so light can enter via the roof) or narrow but with multiple floors (so enough daylight can enter each floor via the facades). Wide buildings with multiple floors are not preferable. 9) Roof lights should be placed under the right angle and orientation to provide diffuse daylight and avoid direct sunlight. 10) With a multiple-storey building should windows ideally be placed on the North and South facades to prevent exposure to direct sunlight. A roof overhang could assure that the windows and facades are shaded during the hours with the highest solar radiation. 11) Providing a view to the outside will have a positive influence on the comfort and mental health of the workers. 12) Most preferable is a view with vegetation.

Indoor air quality design

13) For an optimal cross-ventilation flow should the building be orientated in such a way that it catches the prevailing wind (from SSE and ENE). 14) Ideally the building should allow cross-ventilation from all directions, since this will assure an effective ventilation all year round (for all winddirections). 15) Also important is the fact that cross-ventilation only works when the building is not too wide in the direction of the flow. 16) Important is also to choose building materials that contribute minimal to the indoor air pollution. For example, wood and bamboo are good options (unless they are treated with chemicals), while asbestos and concrete give off pollutants. 17) Roof angles between 30-45° stimulate the cross-ventilation because of the way they guide the wind flow through and around the building. Also important for an optimal airflow is that the facade height above the opening is around 0,5 x [the opening height]. 18) A vertical green wall inside the factory can filter part of the pollutants out of the air.

Acoustic quality design

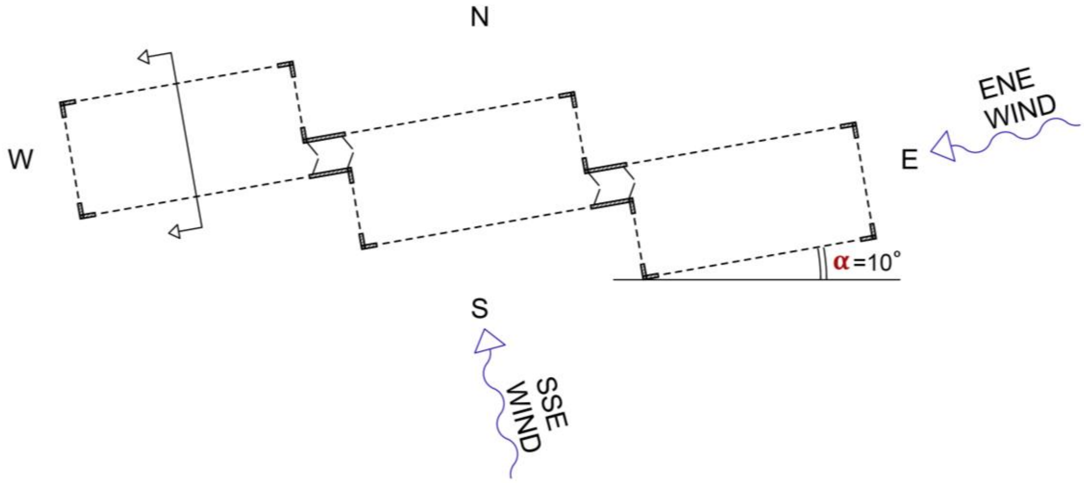
19) Instead of one big space, the different activities inside the garment factories should take place in different spaces to minimize the noise disturbance overflow. This could be done by making multiple small building volumes or by making good insulated compartments/floors within one bigger building. 20) walls or ceilings should ideally consist of materials that are not reflecting sounds, but (partly) absorb sounds. 21) Indoor vertical green walls can function as acoustic walls to mute the noise.

INTEGRATED DESIGN SOLUTIONS FOR BANDUNG

Although it is clear how passive building design strategies can positively influence each of the indoor environmental factors, the challenge is to integrate these different strategies into one design that maximizes the total level of health and comfort of the indoor environment. An attempt is made to optimize this integration within two conceptual building designs:

‘1 floor’-Design:

- Multiple smaller volumes chained together (for acoustics, ventilation and thermal comfort)
- Orientation of volumes in the direction that minimizes the solar radiation on the East and West facades and optimizes cross-ventilation from all directions (but especially from the two prevailing wind directions SSE and ENE) (for thermal comfort and ventilation)
- Facades on all sides are perforated from 0.9m till 2.0m above the indoor floor level for optimal cross-ventilation and a comfortable indoor air movement (for thermal comfort and ventilation)
- The height of the facade above the opening is 0,5 x [the height of the facade-opening] for optimal cross-ventilation and a comfortable indoor air movement (for thermal comfort and ventilation)
- Facades provide openings in a way that the workers can look outside (for view)
- Overhang of the roof is 2m to shade the facades during the hours with the highest solar radiation (for thermal comfort)
- The roof parts all have an angle of 30° with the horizontal to stimulate the airflow through and around the building (for ventilation and thermal comfort)
- Roof windows provide daylight throughout the whole floor-area, but don’t let direct sunlight get inside (for lighting)
- The green roof minimizes the heat gain via the roof (for thermal comfort)



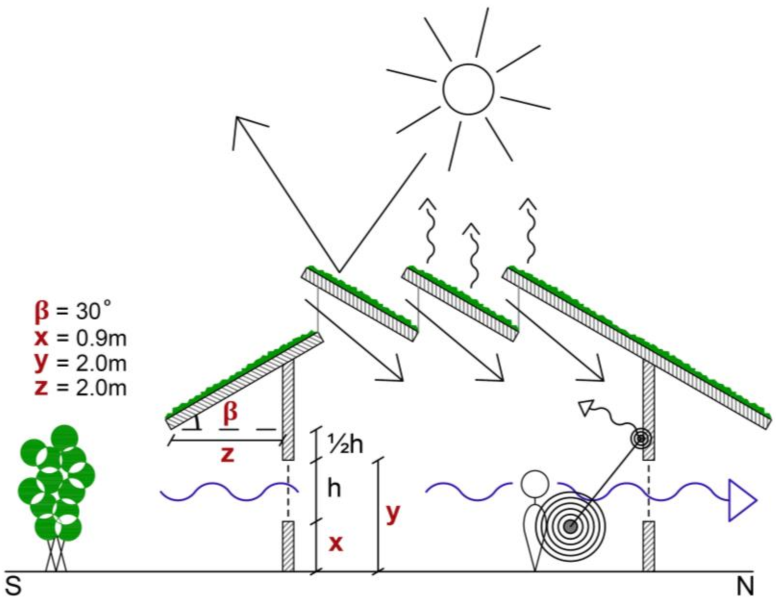
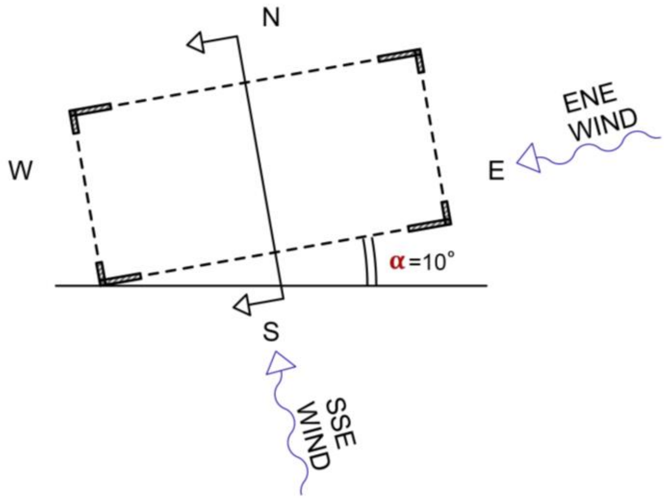


fig 2 | integration of different passive building design strategies into a ‘1 floor’ conceptual building design (own image)

'2^+ floors'-Design:

- One volume, but with good insulation between the various floors (for acoustics)
- Orientation of the volume in the direction that minimizes the solar radiation on the East and West facades and optimizes cross-ventilation (from all directions, but especially from the two prevailing wind directions SSE and ENE) (for thermal comfort and ventilation)
- The openings in the facades provide daylight throughout the whole floor area, since the width of the building is kept small to avoid dark areas in the middle of the floors (for lighting)
- The facade-openings are from 0.9m till 2.0m above the indoor floor levels for optimal cross-ventilation and a comfortable indoor air movement (for thermal comfort and ventilation)
- Facades provide openings in a way that the workers can look outside (for view)
- An extra green roof, placed above the building like a parasol, prevents solar radiation onto the underlying roof and provides shade for the whole building. Overhang of the roof is 2m for facade-shading during the hours with the highest solar radiation. (for thermal comfort)



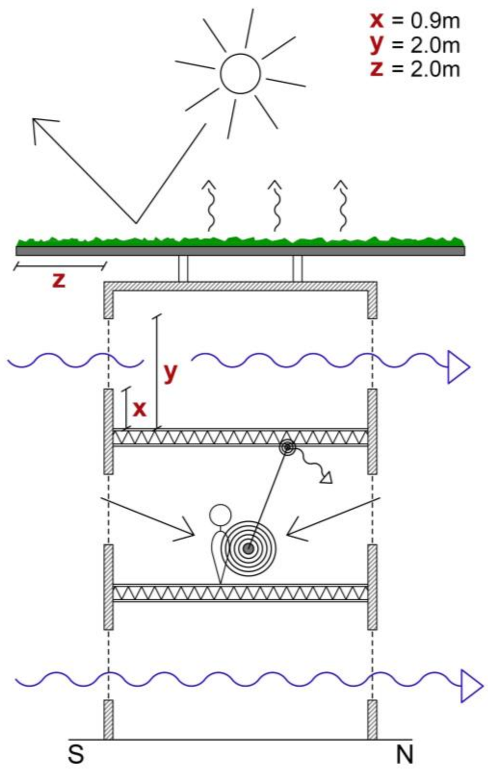


fig 3 | integration of different passive building design strategies into a '2^+ floors' conceptual building design (own image)

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APPENDICES

APPENDIX A | HISTORICAL OVERVIEW OF THE WORKING CONDITIONS IN GARMENT FACTORIES

1 | The emergence of garment factories

Before the 19th century, (farm) women made clothes for their family members. Furthermore there were clothes produced in small home workshops and 'cottage' industries to sell at outside markets. (NWHM, 2007) But the population grew, so there was more demand for products. Manufacturers discovered that it was cheaper and more efficient to make bulk production with the help of new developed machines. So during the Industrial Revolution (mid-18th century to the beginning of 19th century), which started in England, small cottage industries got replaced by large factories. (Jackson, 2017)

The factories had often very poor working conditions. The women worked 12-14 hours a day, 7 days a week at the sewing machines. There was no heating in the factory, no electricity, poor ventilation, poor lighting conditions and the spaces were overcrowded. (Jackson, 2017) "Because of these working conditions, women often suffered from serious workplace injuries, chronic migraines and fatigue, swollen feet and ankles, and contagious illnesses that spread quickly and easily in the cramped factories." (NWHM, 2007) "Cotton thread had to be spun in damp, warm conditions. Going straight out into the cold night air led to many cases of pneumonia. The air [inside the factories] was full of dust, which led to chest and lung diseases and loud noise made by the machines damaged workers' hearing." (BBC, 2014)

Starting around 1850, the garment factories got often named 'sweatshops', referring to the three major characteristics of "long hours, low pay, and unsafe or unhealthy working conditions." (encyclopedia.com, 2009) The sweatshops attracted the poor people from the countryside to the cities. Many moved between 1850 and 1900 to the garment districts of rapidly growing cities like London and New York. But with the growing amount of factories also the criticism towards the bad conditions within these factories increased. Factory workers started to form unions and showed protest to try to improve the working conditions. (BBC, 2014)

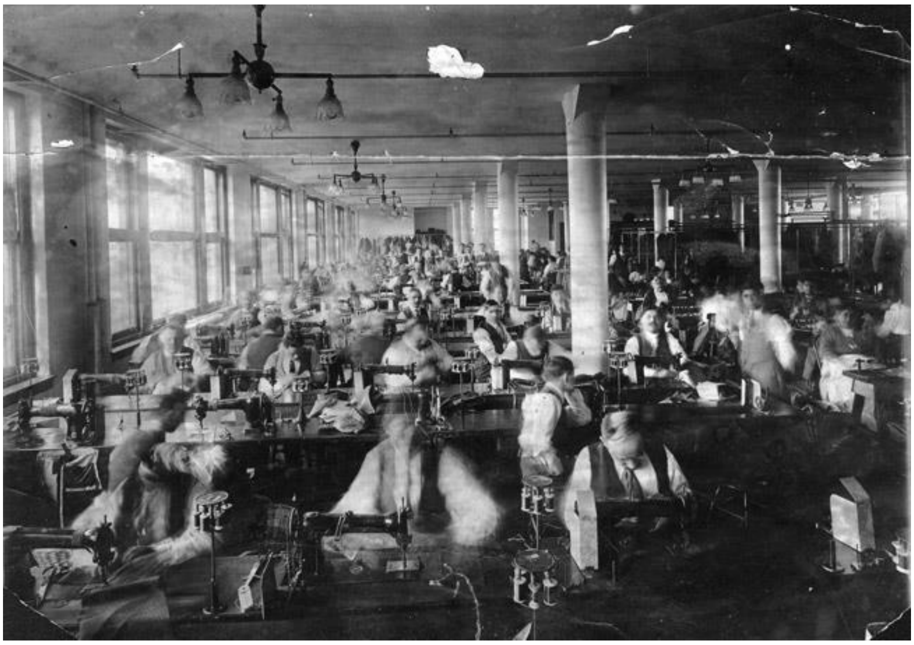

fig App.A.1 | garment sweatshop, New York, c. 1900 (Hermanson, 2011)

Since the industrialization started in England, this was also where the first problems were recognized. Among the early critiques of writers and journalists was for example the book 'Cheap Clothes and Nasty', by Charles Kingsley in 1850. He described the bad conditions in textile and garment factories in London. The protests of the workers and the criticism of writers / journalists became a major force behind workplace safety regulation and labour laws. The first important law regarding the working conditions in sweatshops was the Factory Act of 1833, formulated in the United Kingdom. "When concerns were raised about the working conditions in factories, especially for children, reformers began to propose changes to improve working environments. The first supporters of reform were caring mill owners […] who were motivated mainly by their religion." (BBC, 2014) One of these factory owners was Robert Owen, who owned a cotton mill in New Lanark (Scotland). His 'inspiration' to provide better working conditions came from the idea that workers would work harder if they were healthy and if they were treated well, and that would lead to more production and thus more profit. Therefore Owen provided good houses and schools for workers and their families, and didn't allow children under the age of ten to work in the factory. In time more and more regulations and acts were set up, trying to regulate the working conditions to prevent / minimize physical harm. Though these regulations led to some improvements, they were often still "extremely vague in definition and totally unenforceable." (BBC, 2014)

2 | Health and comfort of the working conditions today

In the 20th century was the main garment production moved from the developed countries to the less-developed countries. This has to do with the low tax-prices, low land- and building-cost, lack of environmental policies and (probably most importantly) low minimum wages. (Morgan, 2015) It seems that, with this move of location, the problems around the working conditions in the factories have not been solved but have just moved to other continents. According to CCC (2013) is "the current state of health […] conditions in most garment factories extremely low. […] Workers not only get sick, but they also risk their lives." Today the term 'sweatshop' is still often used to refer to garment factories. In their report, Stokes, Jeszeck, Gordon & Hogan (1994) define this term as "an employer that violates more than one federal or state labor law governing minimum wage and overtime, child labor, industrial homework, occupational safety and health, workers' compensation, or industry registration."

Common health hazards in garment factories are exposure to chemicals, exposure to noise, mechanical accidents, and repetitive strain injury (Chen M. , 2014). The CCC (2013) writes about how in garment factories "working with chemicals and machines without proper protection can be very dangerous and sometimes fatal." There are also health issues that can develop on the long term because of the consequences of physical exhaustion of the work (long hours, repetitive work, ergonomic unfriendly furniture and working poses, etc.). (Chen M. , 2014)

According to Fatemi (2012) physical weakness and headaches are the most frequent work related illnesses under garment workers. Other problems that he noticed were "fatigue and drowsiness, dizziness, allergic reactions, nausea and depression", which could according to him all be caused by the 'stifling conditions' inside the factories. Also often mentioned problems are trouble breathing, hearing loss, and damaged eyesight. (Jailer, Lara-Meloy, & Robbins, 2015) According to Hossain, Ford & Lau (2014) are the most frequent health problems "headache (98%), respiratory problem (36%), vomiting (28%), fatigue (28%) and fainting (18%)."

Instead of preventing injuries, "managers routinely ignore complaints of pain and discomfort, and fire workers who can no longer keep up with the pace of production." (CCC, 2013) In most of the less-developed countries "occupational health of worker is a neglected part. […], management is not often concerned about the work place environment and health of the workers. As a result, the industrial management does not provide any attention to the work place injuries, sickness and environment. The workers bear the responsibility to their health and safety." (Khan, Ahmad, & Khan, 2011) So while trade unions, labour laws and health & safety regulations have made sweatshops nowadays rare in the developed countries, they still exist in abundance in the less-developed countries.

fig App.A.2 | garment sweatshop today, Bangladesh (Hasan, 2013)

3 | A brighter future?

There is a struggle going on for better working conditions in the garment industry. (CCC, 2013) But it is a slow process, with steps of very little improvement. One of the reasons why this issue is so hard to solve is because the problem is caused by the globalisation of our world economy. For financial reasons companies in developed countries outsource labour intensive work to the less-developed countries. Market competition puts the factories there under huge pressure. While factories used to have multiple-year contracts with fashion brands, today there are often only short-term contracts per production order. This gives a lot of financial insecurity to these factories. To compete with other factories, they have to safe costs in all possible ways. (Danny, 2017) Therefore as little money (and effort) as possible is spend on the indoor working environment. As a result, garment factories are not designed and organized in a way that it fits the basic human rights to a safe, healthy and comfortable workplace.

"The challenge is to connect and organize with other workers and consumers to win these changes from the factory owners, the international corporations that contract them (the "brands"), and the government." (Jailer, Lara-Meloy, & Robbins, 2015) With the growing critique of consumers on the poor working conditions in sweatshops, retailers from developed countries (and their intermediaries) are (really slowly) starting to choose factories also based on the quality of the working conditions. If that development continues, it could be that garment factories make the change towards more healthy and comfortable workplaces.

APPENDIX B | BUILDING TYPOLOGY OF GARMENT FACTORIES

Nowadays there are different sizes and shapes of garment factory buildings. These buildings can roughly be divided into five different types (van Berkel, 2016):

1. The Home Factory
2. The Hall
3. The Block
4. The Superblock
5. The High-rise

1.The Home Factory

Besides large (outsourcing) factories, also a lot of garment is manufactured in small local workshops called ‘Home Factories’. In the Indonesian garment sector the employment ratio of ‘factory-based’ versus ‘home-based’ is even 1:1 (Smit, Loen, Toledo, Yanindraputri, & Ingen-Housz, 2016). Some of these Home Factories make clothes for the local markets, whilst others produce for export. A home factory is often just a simple room inside a house or a shed attached to a house. Inside these small production spaces stand a few (mostly 5 to 10) tables with sewing machines. The furniture (tables and stools) is very basic. There is often hardly daylight, but there are a few light-bulbs or fluorescent beams installed. Since temperatures can get high inside, sometimes a fan is placed to improve the thermal comfort. There is only ‘natural ventilation’, which means that there is a window, door or just a gap in the roof or facade. (van Berkel, 2016)

fig App.B.1 (left) | home factory, Kampung Cigondewah, Bandung (own image)
fig App.B.2 (right) | home factory, Kampung Cigondewah, Bandung (own image)

2.The Hall

This type of factory building has an extensive footprint, but contain just one or two layers. The halls are often surrounded by large walls to separate the industrial zone from the outside world (like a compound). These factories consist out of one hall or more halls placed next to each other. Small halls are regularly around 0,5-1 hectare; big halls can cover an area of 1-1,5 hectare. These factories are often located in rural areas or suburbs, where the price of land is low. Within these large halls it is relatively easy to create efficient production lines and processes, which makes it possible for the plants to produce different types of clothing. The halls are often built as cheap and simple as possible: the constructions are made of steel columns and beams, roofs are made of lightweight material (plate-material), and walls are also made of lightweight plate-material or masonry. Ceilings of the halls are high, and there is often no daylight and no view to the outside. (van Berkel, 2016)


fig App.B.3 (left) | garment factory hall PT Perdana Firsta, Bandung (own image)
fig App.B.4 (right) | a garment factory hall, Bangladesh (van Berkel, 2016)

3.The Block

The Block is a factory building with three to five floors. In general they have an usable area between 1500m^2 and 3000m^2. These generally smaller buildings are often less suitable as a factory, since most of them were initially not built as a factory building (but as residential building). Therefore they are generally well integrated into the existing urban context. After inspection, some of these buildings have been addressed as problematic; especially because of fire safety and construction strength with regards to the people density of a small production plant. Though, there are some factories of this type that have been built for its current purpose. (van Berkel, 2016)

fig App.B.5 | a garment factory block, Bangladesh (van Berkel, 2016)

4.The Superblock

This kind of factories usually contain up to five or six floors, but sometimes even more. These buildings have a large footprint, so combined with the many floors the total floor areas are mostly around 16.000 m^2. Though sometimes these superblocks get up to sizes of 40.000 m^2. Most of these factories are fully constructed of concrete or they have a concrete skeleton with an infill of masonry. From perspective of safety, fire escape routes are a challenge in these big multiple-storey buildings. (van Berkel, 2016)

fig App.B.6 | a garment factory superblock (van Berkel, 2016)

5.The High-rise

High-rise factory buildings are buildings that have a relatively small footprint (of around 1500m^2 to 2000m^2) but contain six or more stories. These kind of factory buildings are mostly found in urban areas, where they have a commercial plinth to increase the value of the building and gain maximum real-estate profit (both contractors and sub-contractors make use of this type of buildings). They often contain a concrete skeleton, filled up with masonry. (van Berkel, 2016)

fig App.B.7 (left) | a high-rise garment factory, Bangladesh (van Berkel, 2016)
fig App.B.8 (right) | a high-rise garment factory, Bangladesh (van Berkel, 2016)

APPENDIX C | CLIMATE DATA OF BANDUNG

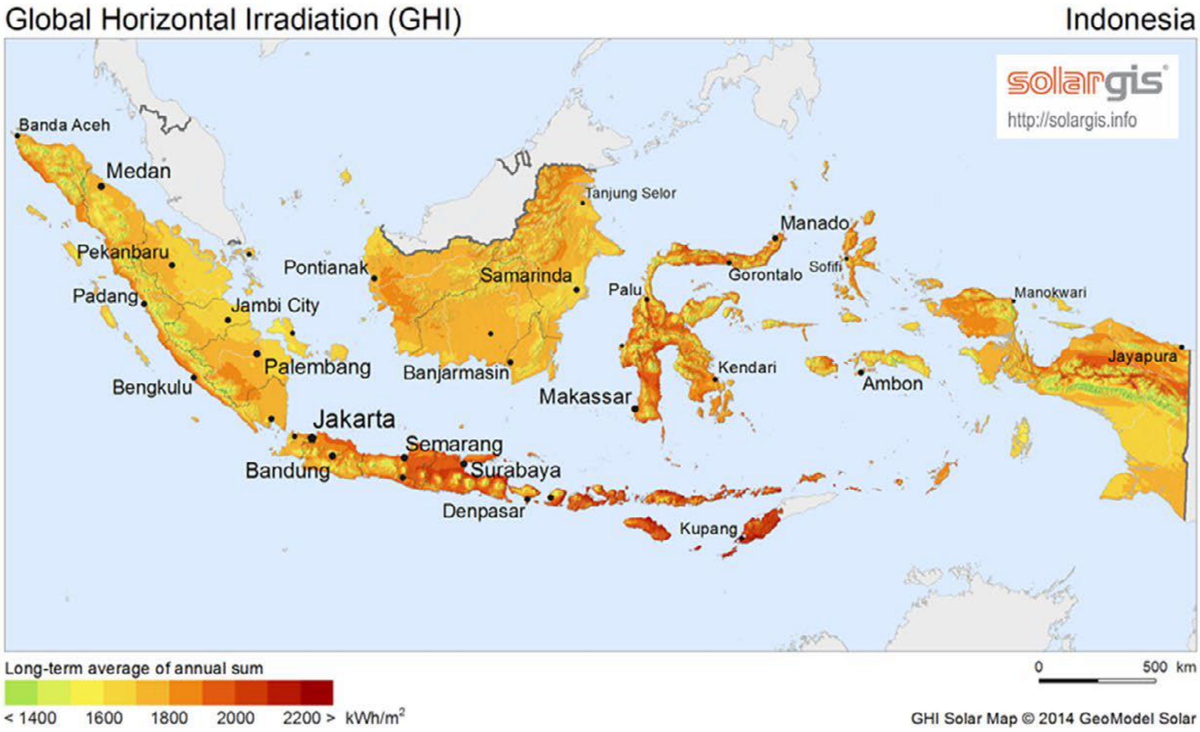

fig App.C.1 | Global Horizontal Irradiation in Indonesia (Solargis, 2014)
Bandung is coloured light orange.

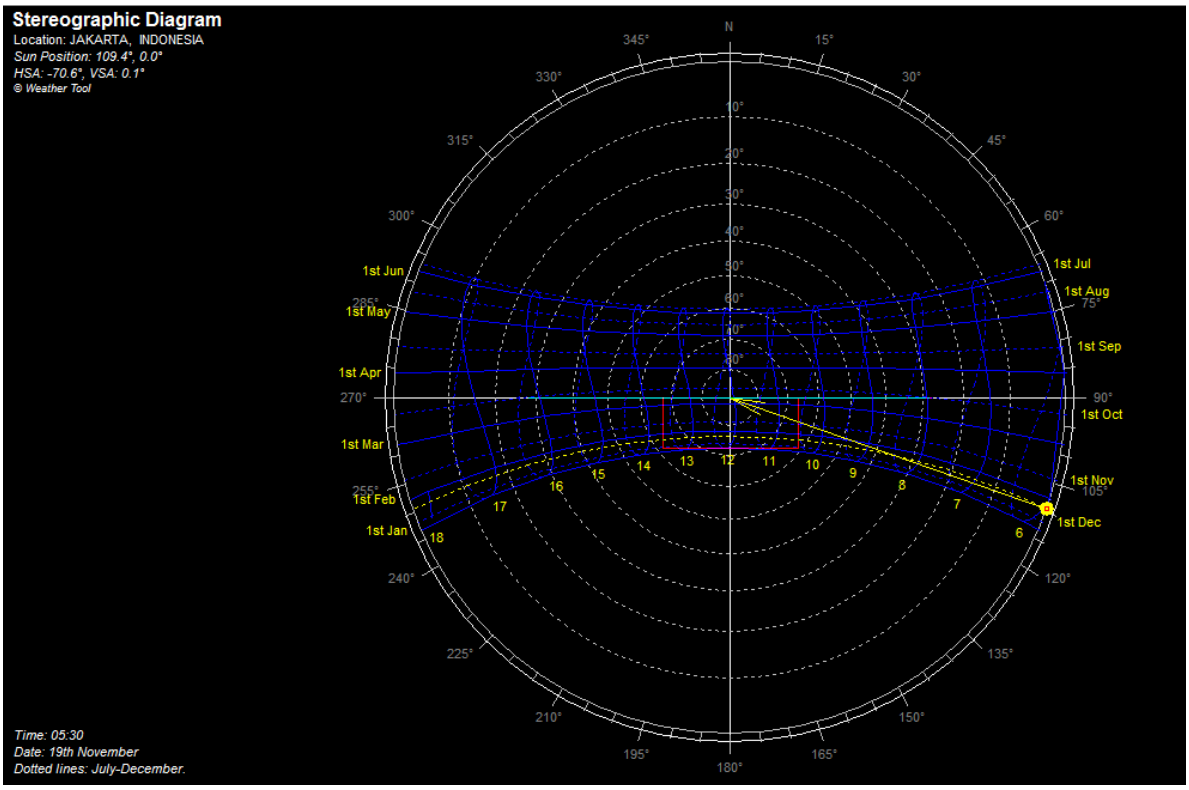

fig App.C.2 | simulation of the Sun Path Diagram of Jakarta* (Suhendri, 2017)

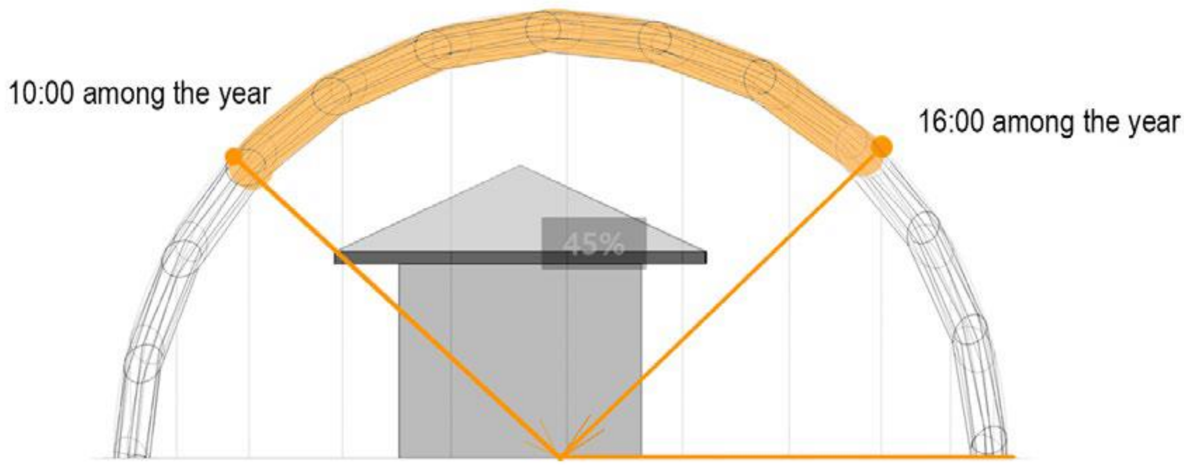

fig App.C.3 | simulation of the Sun Path Diagram of Singapore* (Chen B. , 2017)
The diagram shows the time that the solar altitude is above 45°.

*Note: the location and solar radiation condition of Bandung is very similar to both Jakarta and Singapore. Since the weather data of Bandung is not available in simulation programs, Suhendri used data of Jakarta and Chen used data of Singapore for this Sun Path Diagram.

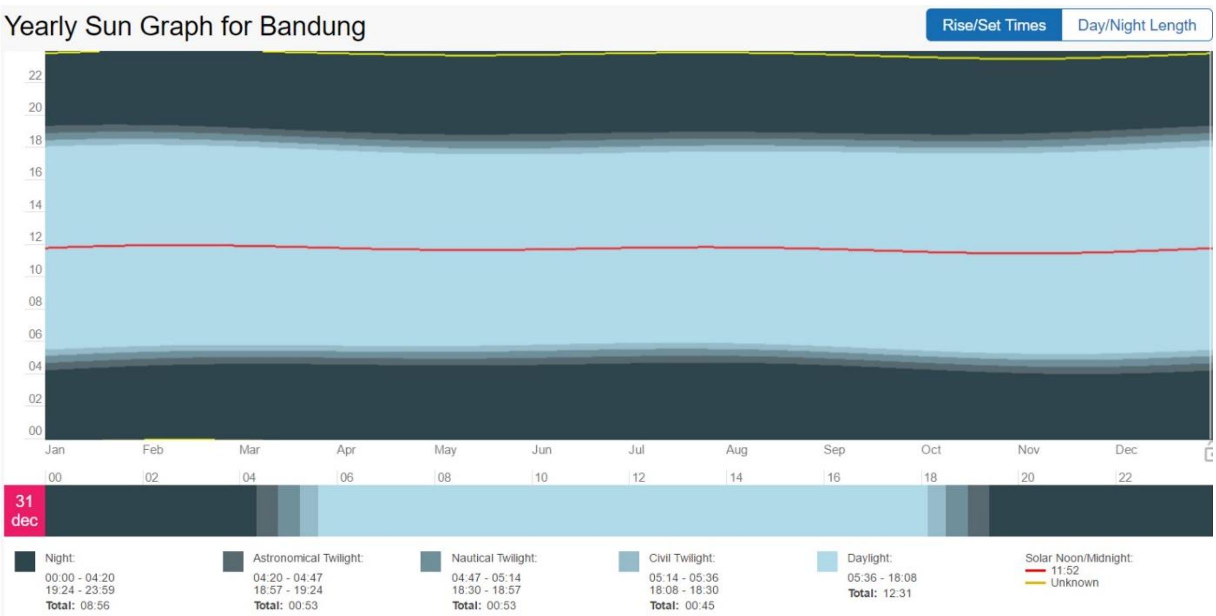

fig App.C.4 | year overview of hours with daylight in Bandung (timeanddate.com, 2017)

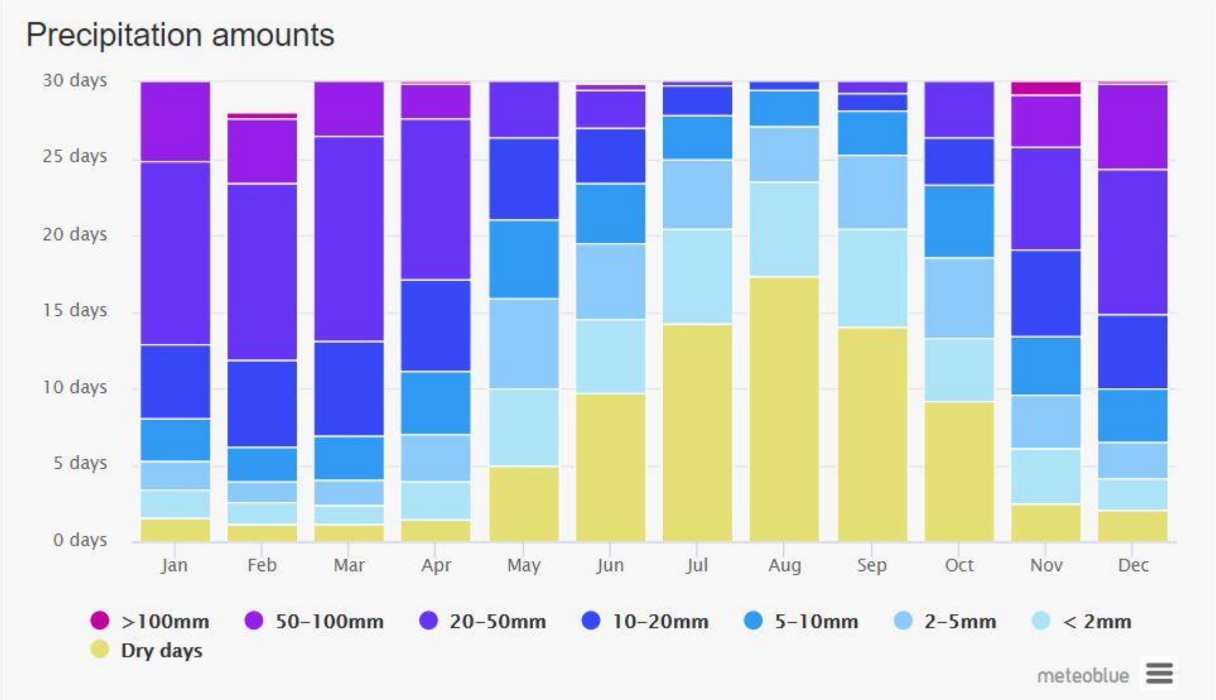

fig App.C.5 | precipitation amounts in Bandung (Climate Bandung, 2017)

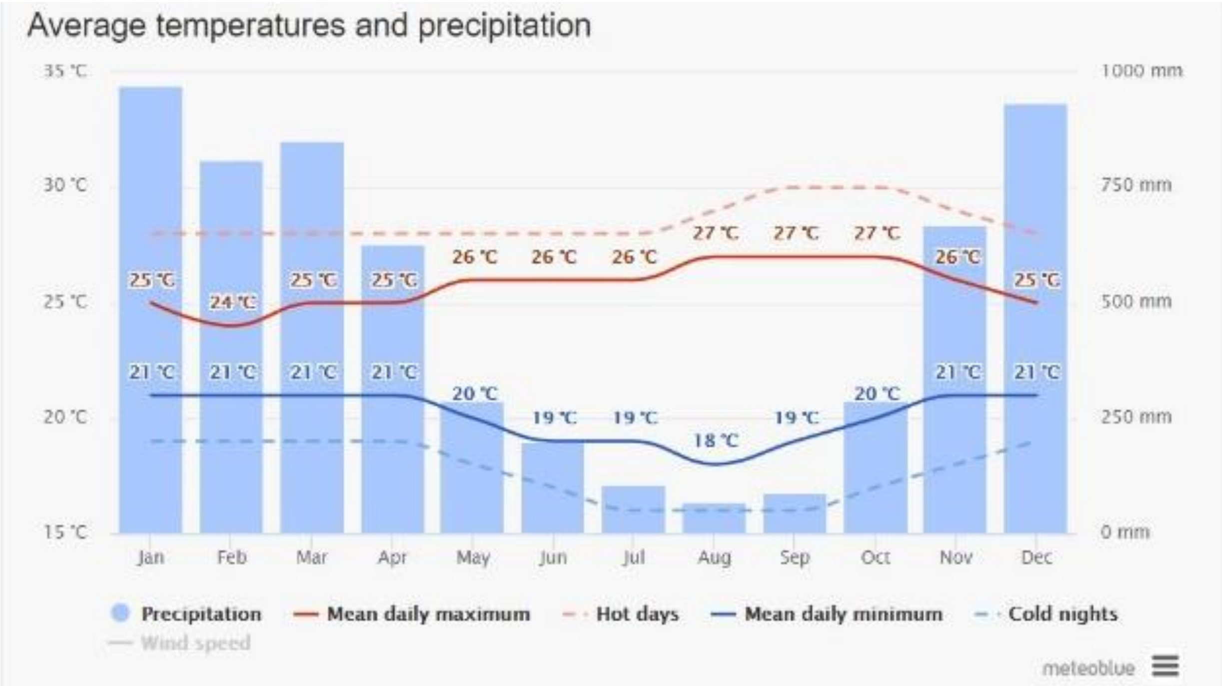

fig App.C.6 | average temperatures and precipitation in Bandung (Climate Bandung, 2017)

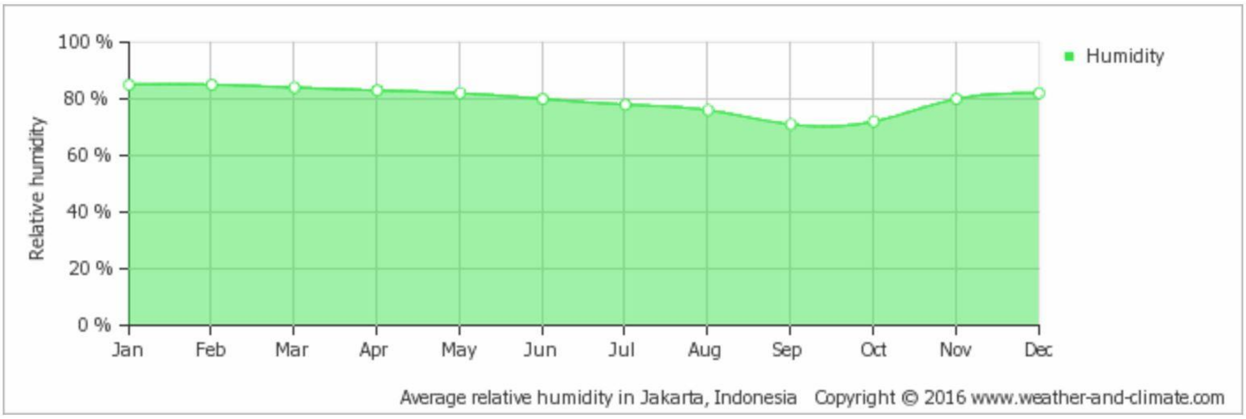

fig App.C.7 | average Relative Humidity in Jakarta (Humidity Bandung, 2016)

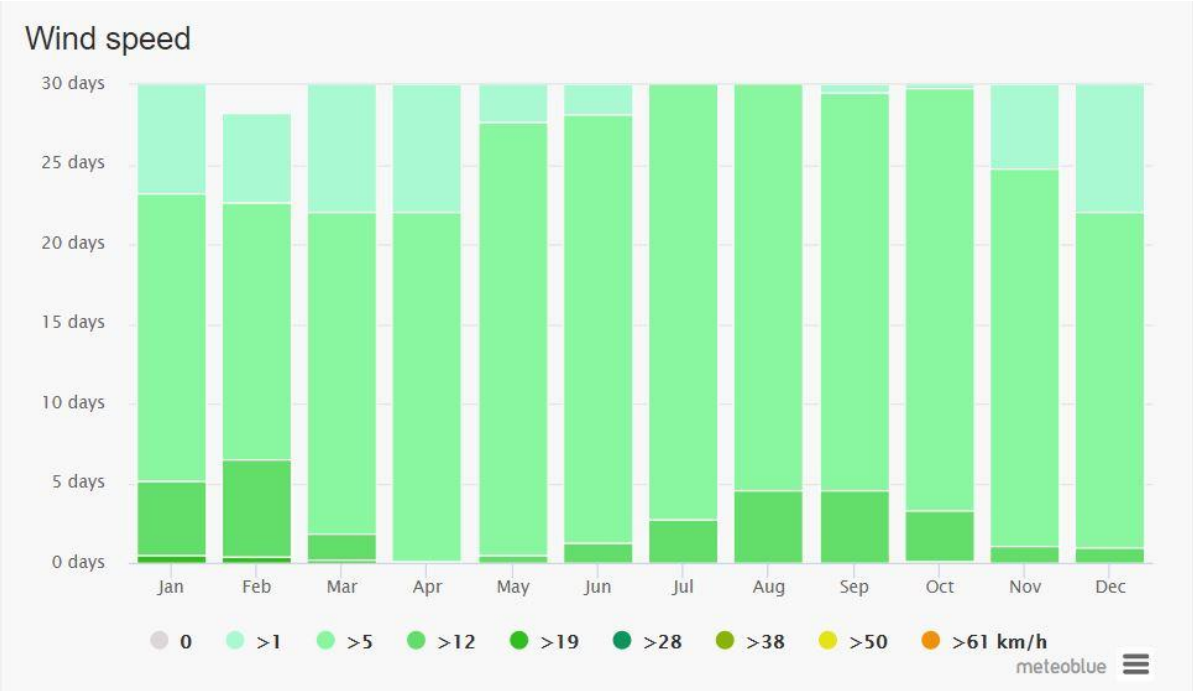

fig App.C.8 | wind speed in Bandung (Climate Bandung, 2017)

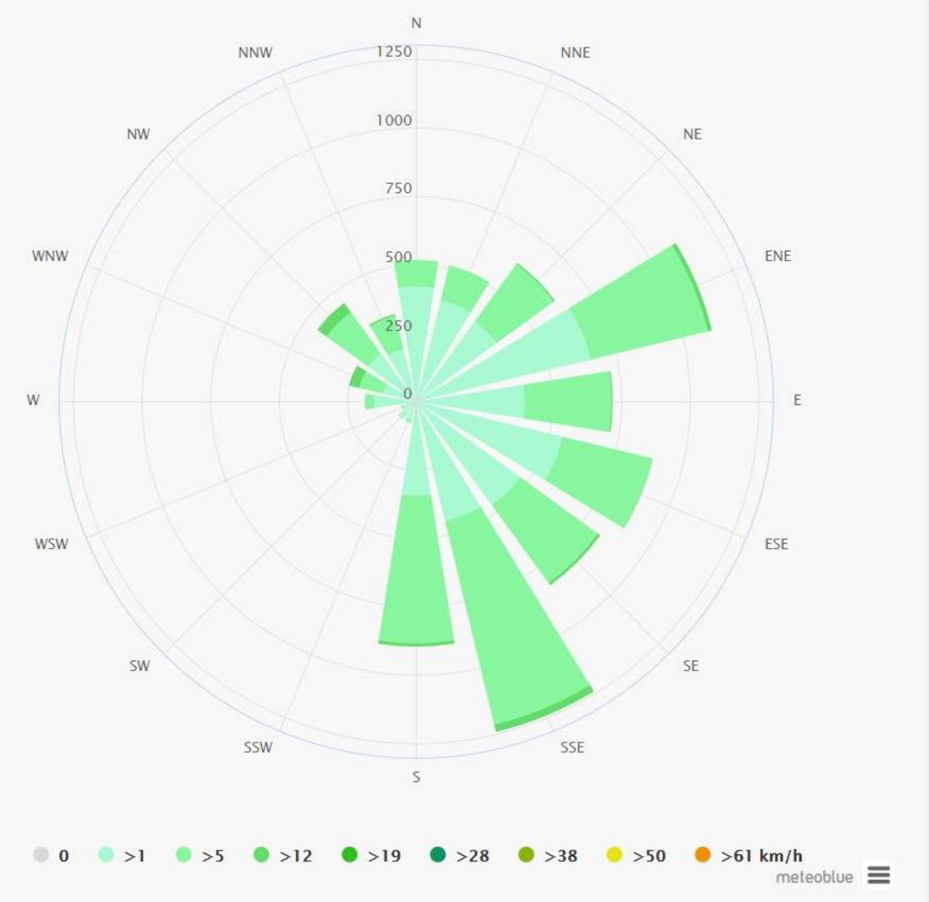

fig App.C.9 | wind rose of Bandung (Climate Bandung, 2017)

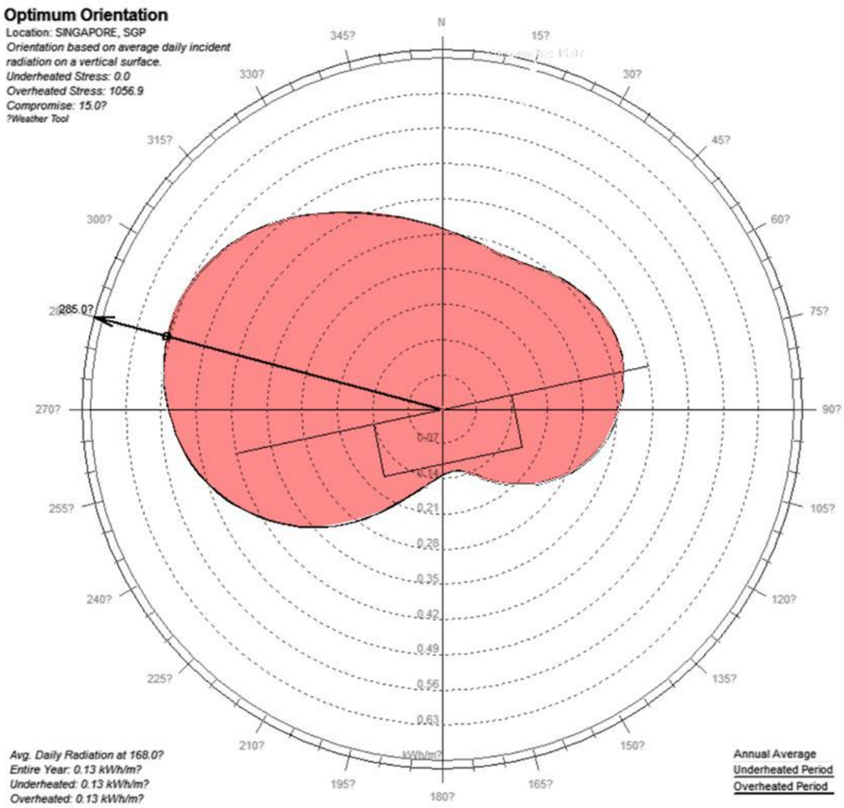

fig App.C.10 | solar radiant on facades in Singapore (Chen B. , 2017)
The solar radiation conditions of Bandung and Singapore are very similar.

APPENDIX D | PICTURES OF PT KAHATEX AND PT PERDANA FIRSTA

fig App.D.1 | several halls of garment factory PT Kahatex in Bandung
(Smit, Loen, Toledo, Yanindraputri, & Ingen-Housz, 2016)

fig App.D.2 (left) | garment workers at PT Perdana Firsta (own image)
fig App.D.3 (right) | garment workers at PT Perdana Firsta (own image)


fig App.D.4 (left) | fabric-check section (own image)
fig App.D.5 (right) | cutting section (own image)


fig App.D.6 (left) | | sewing section (own image)
fig App.D.7 (right) | quality-check section (own image)

fig App.D.8 | sewing operator with an extra LED-lamp shining onto her hands (own image)

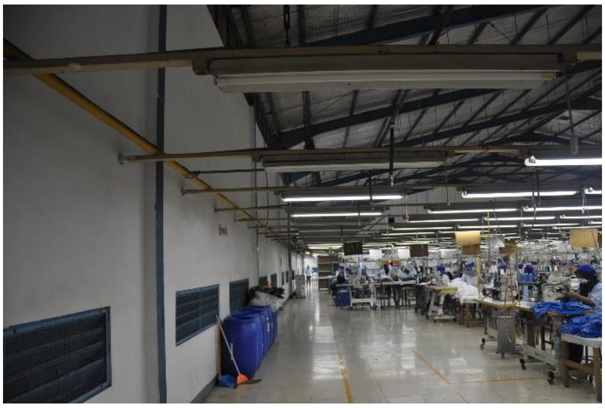


fig App.D.9 (left) | facade-grills for air inlet (own image)
fig App.D.10 (right) | facade-grill in close-up (own image)


fig App.D.11 (left) | air outlet via roof-openings with rooftop fans (own image)
fig App.D.12 (right) | rooftop fans for ventilation (air outlet) (Get Kaung Enterprise Co., 2011)

APPENDIX E | FIGURES REGARDING ACOUSTIC CONDITIONS

Level in dB	Common Noise Sources	Health Effects
140 and above	Jet Plane Gun shot Firework	**Sudden hearing damage** **Tinnitus**
130 to 139	Threshold of Pain	
120 to 129	Emergency siren Rock concert	
110 to 119	Night club Loud classical music.	
100 to 109	Motorcycle (50kph)	
90 to 99	Truck and heavy traffic (50kph) Railways,	
85	**Hearing protection provided by law.** Busy streets. Inside a bus	Hearing loss, tinnitus
75		Cardiovascular problems* Disturbed sleep* Stress when sound is undesired* Annoyance*
70	Average Car	
65	Normal Conversation	
60		
55	Natural outdoors	
50	Quiet conversation	

dB	Daily Dose
118	14 seconds
115	28 seconds
112	56 seconds
109	1 min 52 sec
106	3 mins 45 sec
103	7 mins 30 sec
100	15 mins
97	30 mins
94	1 hour
91	2 hours
88	4 hours
85	8 hours

fig App.E.1 | overview of sound levels with corresponding noise sources and the maximal allowed daily dose per sound level (Tinnitus Treatment Blog, 2017)

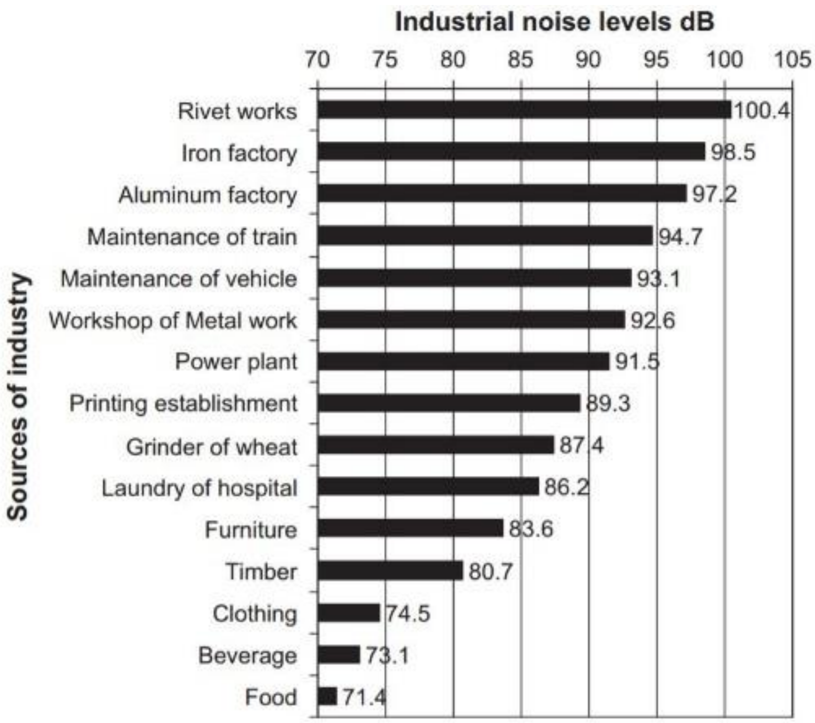

fig App.E.2 | measured noise levels for several industries in Egypt (Ali, 2010)

APPENDIX F | INTERVIEWS WITH FACTORY WORKERS

Interview with Factory Worker A

Factory Worker A (left), her daughter (middle) and myself
(picture by Mo Smit, 23-04-2017)

Q.1: how old are you?
"38."

Q.2: where do you work and what kind of work do you do?
"I work in PT Kahatex. I work with a weaving machine to make fabric out of yarn."

Q.3: for how long do you work already in the factory?
"For 6 months now."

Q.4: what did you do before that?
"I was a fulltime mother."

Q.5: how many hours a day do you work in the factory?
"Every day from 08.00 till 17.00. Sometimes longer if there is an order that needs to be finished."

Q.6: how do you sleep at night? Good, oke or bad? Do you have problems with falling asleep? Do you wake up often during the night?
"I don't have problems with sleeping. I'm often tired when I come home from work, so it is nice to go to sleep."

Q.7: how would you subscribe the temperature in the factory? Cold, oke or warm?
"It is warm."

Q.8: do you sometimes get headaches?
"Yes. And I know that some of my colleagues get also headaches."

Q.9: how often do you get headaches?
"Uhmm… I think about two days a week."

Q.10: are there fans inside the factory? Around your workplace?
"No."

Q.11: are there any air-conditioning units to cool the indoor air?
"No."

Q.12: how is the sound of the machines in the factory? Do they make noise?
"Yes, the weaving machines make noise."

Q.13: do you wear ear-protection?
"No."

Q.14: do you ever have pain in your ears during or after work?
"No."

Q.15: does the noise disturb you? Do you feel annoyed by the noise?
"Uhmm… No, it is oke. I'm used to it."

Q.16: is there daylight inside the factory?
"No."

Q.17: are there windows to look outside?
"No."

Q.18: how is the lighting? Is it too dark, oke or too bright?
"The lighting is bright.

Q.19: is it comfortable? Or not comfortable?
"It is oke."

Q.20: is there besides general lighting also an extra light that shines on your work?
"No, there is only general lighting."

Q.21: what kind of lighting is it? Light bulbs, fluorescent tubes, LED-lights?
"Only tubes."

Q.22: do you ever have pain in your eyes during or after working?
"No."

Q.23: how is the smell of the air inside the factory?
"You smell the yarn and the fabric."

Q.24: is there dust in the air?
"Yes."

Q.25: do you wear a mouth-cap when you are inside the factory?
"Yes."

Q.26: do you get them from the factory? Or do you buy it yourself?
"We get them from the factory."

Q.27: do you have a blocked or stuffy or runny nose when you are in the factory?
"No."

Q.28: do you have any problems with breathing inside the factory? Like chest tightness?
"No."

Q.29: is there a breeze inside the factory? Do you feel any air movement?
"No."

Q.30: are the facades fully closed or perforated?
"I think closed. I never saw any openings."

Q.31: is there mechanical ventilation inside the factory? Have you ever seen any metal ventilation canals on the ceiling or walls?
"I think not... No, not in my department."

Q.32: do you have any other health problems during or after work?
"Yes. I have often blisters on my hands from the yarn. We don't wear gloves. Some kinds of yarn have a burning effect on my skin. And I also have sometimes pain in my back after a long day of work."

"Thank you so much for this interview. Terima kasih."

Interview with Factory Workers B and C

Factory Worker B (left), myself (middle) and Factory Worker C (right)
(picture by Mo Smit, 23-04-2017)

Q.1: how old are you?
Factory Worker B: "I'm 19."
Factory Worker C: "I'm 18."

Q.2: where do you work and what kind of work do you do?
Factory Worker B: "I work in PT Kahatex, in the sewing department. I make t-shirts."
Factory Worker C: "I also work in PT Kahatex, but in the socks department. I work at a machine that knits socks."

Q.3: for how long do you work in this department of the factory? And did you work in another department before?
Factory Worker B: "I work 2 years in the factory. I have only worked in this department"
Factory Worker C: "I work now 1 year in the factory, only in this department."

Q.4: how many hours a day do you work in the factory?
Factory Worker B: "We start at 08.00 and finish at 17.00. Between 12.00 and 13.00 we have a lunch break."

Q.5: how do you sleep at night? Good, oke or bad? Do you have problems with falling asleep? Do you wake up often during the night?
Factory Worker B: "I sleep good. No problems."
Factory Worker C: "I also have no problems with falling asleep or sleeping."

Q.6: how would you subscribe the temperature in the factory? Cold, oke or warm?
Factory Worker B: "I would say warm."
Factory Worker C: "Yes, also in my department it is very warm."

Q.7: do you sometimes get headaches?
Factory Worker B: "No."
Factory Worker C: "No."

Q.8: are there fans inside the factory? Around your workplace?
Factory Worker B: "No."
Factory Worker C: "No."

Q.9: are there any air-conditioning units to cool the indoor air?
Factory Worker B: "No."
Factory Worker C: "No."

Q.10: how is the sound of the machines in the factory? Do they make noise?
Factory Worker B: "Yes, the sewing machines make quite some noise."
Factory Worker C: "The sock-knitting machines also."

Q.11: do you wear ear-protection?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.12: do you ever have pain in your ears during or after work?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.13: does the noise disturb you? Do you feel annoyed by the noise?
Factory Worker B: “No, I don’t mind the noise.”
Factory Worker C: “It is not disturbing.”

Q.14: is there daylight inside the factory?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.15: are there windows to look outside?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.16: how is the lighting? Is it too dark, oke or too bright?
Factory Worker B: “The lighting is quite bright.”
Factory Worker C: “Yes, there is bright light.”

Q.17: is it comfortable? Or not comfortable?
Factory Worker B: “Uhmm… It is good to do my work. But not really comfortable.”
Factory Worker C: “Yes, for me it is the same.”

Q.18: is there besides general lighting also an extra light that shines on your work?
Factory Worker B: “Yes, there is a small extra light for the sewing machine.”
Factory Worker C: “No, with me there is only general lighting.”

Q.19: what kind of lighting is it? Light bulbs, fluorescent tubes, LED-lights?
Factory Worker B: “The general lighting are tubes. The small extra lamp… I don’t know.
What does it look like?
Factory Worker B: “It has these small dots… I think that is an LED light then right?.”
Factory Worker C: “In my department there are only tubes.”

Q.20: do you ever have pain in your eyes during or after working? Dry or itchy eyes?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.21: how is the smell of the air inside the factory?
Factory Worker B: “Uhmm… It smells like fabric.”
Factory Worker C: “I don’t know. It smells different then the air outside the factory. You smell the yarn that we use for making the socks.”

Q.22: is there dust in the air?
Factory Worker B: “Yes.”
Factory Worker C: “No, I think not that much in my department.”

Q.23: do you wear a mouth-cap when you are inside the factory?
Factory Worker B: “Yes.”
Factory Worker C: “Yes.”

Q.24: do you get them from the factory? Or do you buy it yourself?
Factory Worker B: “We get them.”

Q.25: do you have a blocked or stuffy or runny nose when you are in the factory?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.26: do you have any problems with breathing inside the factory? Like chest tightness?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.27: is there a breeze inside the factory? Do you feel any air movement?
Factory Worker B: “No.”
Factory Worker C: “No.”

Q.28: are the facades fully closed or perforated?
Factory Worker B: “Fully closed.”
Factory Worker C: “Perforated. There is a pattern of small holes in the facade.”

Q.29: is there mechanical ventilation inside the factory? Have you ever seen any metal ventilation pipes on the ceiling or walls?
Factory Worker B: “No I think there is no ventilation system in our sewing department.”
Factory Worker C: “I don’t know. What is that?”
It is a machine that brings air from outside into the factory. It uses pipes to bring the air into a room.
Factory Worker C: “O… I’ve never noticed anything like that. So I think it is not there.”

Q.30: do you have any health problems during or after work?
Factory Worker B: “No. Well, yes. My feet get tired of operating the sewing machine. It hurts the last working hours and after work.”
Factory Worker C: “Yes my feet are also getting tired during work. I have to stand all day to work at the sock-knitting machine.”

“Thank you so much for this interview. Terima kasih.”

APPENDIX G | INTERVIEW WITH FACTORY MANAGERS

Note: garment factory PT Perdana Firsta, located just outside Bandung City, could be described as a chain of three big halls. Since this factory is part of the Fear Wear Foundation, it could be assumed that the working conditions within this factory are above average. Keeping this in mind when looking at the collected information will help to create a realistic understanding of the indoor environment inside Bandung's garment factories.

Interview with managers of PT Perdana Firsta

- Danny (Managing Director)
- Asni (Health & Safety Manager)

General information about the factory

Company name:	PT Perdana Firsta Garment
Address:	Jalan. Raya Batujajar No. 156 Km. 1,2 Desa Laksanamekar, Padalarang 40553 Bandung Barat, Jawa Barat – Indonesia
Email:	pfg@firstagarment.com
Website:	www.firstagarment.com
Date of establishment:	August 8, 1988
Land area:	34.000 m^2
Building area:	14.450 m^2
Amount of employees:	1870
Amount of machines:	1277
Unit production system:	8 Lines of Hanger System 14 - 22 Lines of Off Lines Sewing System
Production capacity / month:	250.000 pieces
Main product lines:	Sportswear & Casual Knittwear
Few examples of experience:	DKNY, O'Neill, Adidas, Puma, Reebok, Nike, Lacoste

Q.1: could you please explain the different departments and steps of the production process of this factory?

Danny: "The fabric is delivered by trucks. They drive close to the fabric warehouse to unload the fabric [unloading + fabric warehouse]. Here the fabric will be stored until it is needed. Then the fabric will be checked [fabric inspection]. After the check, when the fabric quality is good enough, the fabric will go to the cutting tables. Here it will be cut, according to the cut-patterns, into pieces [spreading & cutting]. The pieces are put together in trolleys [bundling + numbering]. They will be moved to the department of assembly if needed [for trousers, jackets, etc.] [sewing pre-assembly]. There the zippers and other elements are sewed on to the fabric pieces. Afterwards, or directly if no assembly is needed, the pieces will go to the sewing department [sewing]. After sewing the quality of the pieces is checked [quality check], and if the quality is good the size will be checked [size check]. If there is a piece of clothing with a dirty spot, it will be washed [washing]. After washing, or after the size check if washing was not necessary, the clothes will be ironed [ironing]. Then they will get a final quality check [final check] and will be packed in a plastic bag [packing]. Via the needle check [metal detector] the packed clothes will be stored in a warehouse [finishing good warehouse] to wait for transportation. Those are the steps of the production process. And then there are also other rooms and departments in the factory, like the office, where the cut-patterns are made in CAD according to the designs that brands send to us. And in the office is also the merchandising section. And there are meeting rooms. Ander there is a showroom for clients. There are prayer rooms, toilets, engineering rooms. And there is a room for HR [human resources]. There is a kitchen."

Q.2: how does the factory takes care of the workers?

Danny: "We have a doctor here in the building. So when someone gets ill or injured, the doctor can give immediate help. All the workers get a health-check once a year. We give the workers every Friday a glass of milk [to keep their bones healthy]. And we provide a good fresh lunch every day for the workers."

Asni: “I also take measurements to check if the indoor conditions are according to health & safety regulations. The temperature is measured three times a day [at 10.00, 13.00 and 15.00] at different places in the factory. The lighting [lux-levels] are measured once a month, also at different places. The acoustics [dBA-levels] are measured once every two months. Here we do one measurement at each kind of machine. And finally, once a year, there is a measurement of the indoor air quality [SO_2, NO_2, TSP, CO].”

Danny: “And we also help factory workers to get a loan from the bank if they want to buy a house. The factory has houses that factory workers can rent, but we’ve noticed that since the workers can buy scooters these houses have become less popular. The workers prefer to live with or close to their family instead of alone. So now, since we have connections at the bank, we can bring the workers in contact with the bank to get a loan for buying a house if they get married and want to start a family.”

Q.3: have you noticed any important changes during the last years in the garment industry?

Danny: “Well, there is one change that is difficult for us factories. Until some years ago, brands made three-year-contracts with factories. That means that we, as a factory, were guaranteed to get work from these brands. But now there are no long-term contracts anymore. Brands look for every edition which factory they want. So we only get short-term contracts for a few weeks, for one edition of cloths. That means that we never know if there will be enough work. Sometimes there are periods that we don’t have enough work, and we have to fire workers. And other times there is so much work that the workers need to work longer to finish deadlines. It is very hard.”

“Thank you so much for this interview. Terima kasih.”

APPENDIX H | MEASUREMENT DATA OF PT PERDANA FIRSTA'S INDOOR ENVIRONMENT

Note: garment factory PT Perdana Firsta, located just outside Bandung City, could be described as a chain of three big halls. Since this factory is part of the Fear Wear Foundation, it could be assumed that the working conditions within this factory are above average. Keeping this in mind when looking at the data will help to create a realistic understanding of the indoor environment inside Bandung's garment factories.

Temperature measurements (Asni, 2017)

Area	May			June		
	Average (◦C)			Average (◦C)		
	10 : 00	13:00	15 :00	10 : 00	13:00	15 :00
Building 1 (PFG 1)	29,2	29,8	29,6	27,8	28,6	29,2
Building 2 (PFG 2)	29,0	30,1	29,0	28,5	30,0	29,5
Inspect room	28,3	29,2	29,2	28,3	29,1	29,1
Building 3 (PFG 3)	28,3	29,8	28,8	27,7	29,1	28,3
Sample room	30,0	30,2	30,3	29,7	30,2	30,4
Finishing Ironing room	31,5	33,0	32,5	29,8	31,8	32,5
Finishing good warehouse	28,2	28,9	29,2	28,3	28,9	29,2
Building 4 (PFG 4)	29,3	31,2	30,5	31,3	30,9	29,8

sum	233,8	242,1	239,0	231,4	238,6	237,9
avg. temp this daytime	29,2	30,3	29,9	28,9	29,8	29,7
		715,0			707,9	
avg. temp. this month		29,8			29,5	
		347,3				
total avg. temp. over whole year		28,9				

Area	July			August		
	Average (◦C)			Average (◦C)		
	10 : 00	13:00	15 :00	10 : 00	13:00	15 :00
Building 1 (PFG 1)	28,2	29,2	29,6	28,2	29,5	29,1
Building 2 (PFG 2)	27,8	29,2	28,4	27,7	29,0	28,6
Inspect room	28,1	29,4	29,3	28,4	29,4	29,2
Building 3 (PFG 3)	28,2	29,4	28,4	27,5	28,6	27,5
Sample room	30,1	30,6	30,5	29,7	30,0	30,3
Finishing Ironing room	29,7	31,4	32,1	29,5	31,9	32,2
Finishing good warehouse	27,9	28,4	28,8	28,0	28,7	29,0
Building 4 (PFG 4)	29,1	30,7	30,4	29,0	30,8	30,4

sum	229,1	238,3	237,4	228,1	237,8	236,2
avg. temp this daytime	28,6	29,8	29,7	28,5	29,7	29,5
		704,8			702,1	
avg. temp. this month		29,4			29,3	

Area	September			October		
	Average (◦C)			Average (◦C)		
	10 : 00	13:00	15 :00	10 : 00	13:00	15 :00
Building 1 (PFG 1)	27,9	28,4	29,1	27,5	27,5	27,6
Building 2 (PFG 2)	27,3	28,2	28,8	26,8	27,7	27,2
Inspect room	27,4	27,7	27,7	27,9	28,2	28,0
Building 3 (PFG 3)	27,3	28,0	27,4	27,5	28,5	27,4
Sample room	29,4	30,1	30,0	29,4	29,8	29,7
Finishing Ironing room	30,0	31,9	32,4	30,2	31,2	30,8
Finishing good warehouse	28,2	29,0	29,3	28,1	28,5	28,7
Building 4 (PFG 4)	29,2	30,5	30,7	29,5	30,1	29,7

sum	226,7	233,9	235,3	226,8	231,6	229,0
avg. temp this daytime	28,3	29,2	29,4	28,3	28,9	28,6
		695,8			687,3	
avg. temp. this month		29,0			28,6	

Area	November			December		
	Average (◦C)			Average (◦C)		
	10 : 00	13:00	15 :00	10 : 00	13:00	15 :00
Building 1 (PFG 1)	28,8	28,9	28,9	29,0	30,0	29,3
Building 2 (PFG 2)	27,0	26,9	27,0	26,5	27,6	27,3
Inspect room	28,7	29,3	28,9	28,3	29,8	29,4
Building 3 (PFG 3)	27,9	28,9	27,3	29,1	29,8	29,7
Sample room	29,4	29,8	29,5	29,9	30,6	30,5
Finishing Ironing room	30,8	31,4	31,7	30,7	32,7	33,1
Finishing good warehouse	28,1	28,7	28,8	28,3	29,1	29,4
Building 4 (PFG 4)	29,6	30,5	30,1	29,7	31,3	31,1

sum	230,3	234,3	232,3	231,5	240,8	239,8
avg. temp this daytime	28,8	29,3	29,0	28,9	30,1	30,0
		696,9			712,1	
avg. temp. this month		29,0			29,7	

Area	jan-17 Average (◦C)			feb-17 Average (◦C)		
	10 : 00	13:00	15 :00	10 : 00	13:00	15 :00
Building 1 (PFG 1)	27,0	27,6	27,6	26,9	27,7	27,6
Building 2 (PFG 2)	26,6	26,2	26,7	26,6	26,2	26,7
Inspect room	27,5	28,0	28,0	27,5	28,0	28,0
Building 3 (PFG 3)	27,2	27,7	27,6	27,3	27,8	27,7
Sample room	29,0	29,3	28,9	29,0	29,3	28,1
Finishing Ironing room	27,4	28,9	29,4	27,4	28,9	29,4
Finishing good warehouse	27,6	28,1	28,2	27,7	28,1	28,2
Building 4 (PFG 4)	27,7	28,7	28,7	27,8	28,8	28,7
sum	220,1	224,7	225,2	220,0	224,7	224,3
avg. temp this daytime	27,5	28,1	28,1	27,5	28,1	28,0
		669,9			669,0	
avg. temp. this month		27,9			27,9	

Area	mrt-17 Average (◦C)			apr-17 Average (◦C)		
	10 : 00	13:00	15 :00	10 : 00	13:00	15 :00
Building 1 (PFG 1)	27,0	27,9	28,1	27,6	27,8	27,9
Building 2 (PFG 2)	27,0	28,0	27,0	26,4	27,7	27,5
Inspect room	28,5	29,9	29,5	27,8	28,7	28,1
Building 3 (PFG 3)	28,5	29,1	29,0	28,0	29,5	29,2
Sample room	29,3	29,6	29,2	29,2	29,6	29,3
Finishing Ironing room	27,5	29,1	29,4	28,1	29,4	29,6
Finishing good warehouse	28,1	28,5	28,9	28,1	28,8	29,1
Building 4 (PFG 4)	29,2	30,2	30,0	29,2	30,6	29,9
sum	225,1	232,2	231,2	224,2	232,1	230,5
avg. temp this daytime	28,1	29,0	28,9	28,0	29,0	28,8
		688,5			686,8	
avg. temp. this month		28,7			28,6	

Lighting measurements (Asni, 2017)

Area / Section	Unit	Months of measurment					
		mei-16	jun-16	jul-16	aug-16	sep-16	okt-16
Fabric Warehouse (Storage)	Lux	40,4	63,1	41	45,7	41,3	49,1
Fabric Warehouse (Inspect)	Lux	646	2620	975	1009	661	1201
Accesoris Warehouse (Storage)	Lux	21,5	40,3	265	84,3	24,7	81,3
Accesoris Warehouse (Distribution)	Lux	100,1	79,5	99	235	108	247
Cutting (Spreading)	Lux	554	588	446	639	521	661
Cutting	Lux	483	312,3	474	502	497	363
Cutting (Bundling & Numbering)	Lux	332	252,5	648	384	340	363
Sewing Line 1 (Stitching Section)	Lux	367	311,9	2330	1604	386	1353
Sewing Line 1 (QC Section)	Lux	1052	613	730	677	1101	658
Sewing Line 2 (Stitching Section)	Lux	392	145,8	275,3	2829	408	1610
Sewing Line 2 (QC Section)	Lux	1102	366,1	710	832	1298	664
Sewing Line 3 (Stitching Section)	Lux	495	958	368	325	527	325
Sewing Line 3 (QC Section)	Lux	1075	362,8	681	319	1191	286,2
Sewing Line 4 (Stitching Section)	Lux	339	150,2	367	1032	321	1128
Sewing Line 4 (QC Section)	Lux	524	834	629	613	498	523
Fabric check PFG 1	Lux	418	393	376	347	432	313,6
Finishing PFG 1 (Checking)	Lux	665	723	497	697	678	743
Finishing PFG 1 (Packing)	Lux	432	406	291	722	440	329
Finishing PFG 1 (Ironing)	Lux	603	364	297	344	618	341
Sewing Line 5 (Stitching Section)	Lux	703	1044	272	395	742	397
Sewing Line 5 (QC Section)	Lux	1013	635	334	640	987	765
Sewing Line 6 (Stitching Section)	Lux	320	241,9	444	504	331	324
Sewing Line 6 (QC Section)	Lux	1200	530	573	689	1310	716
Sewing Line 7 (Stitching Section)	Lux	642	554	362	338	642	326
Sewing Line 7 (QC Section)	Lux	1170	384	417	873	940	1431
Sewing Line Baseball (Stitching)	Lux	381	1054	268	443	296	261
Fabric check PFG 2	Lux	580	615	462	676	669	647
Fabric check PFG 3	Lux	781	437	781	612	742	631
Sewing Line 8 (Stitching Section)	Lux	480	297	353	445	421	445
Sewing Line 8 (QC Section)	Lux	620	603	512	581	598	547
Sewing Line 9 (Stitching Section)	Lux	415	934	487	295	398	295
Sewing Line 9 (QC Section)	Lux	223	780	750	418	249	571
Sewing Line 10 (Stitching Section)	Lux	521	579	322	346	641	326
Sewing Line 10 (QC Section)	Lux	752	504	566	453	681	473
Sewing Line 11 (Stitching Section)	Lux	439	557	366	324	591	297
Sewing Line 11 (QC Section)	Lux	729	590	602	401	651	402
Sewing Line 12 (Stitching Section)	Lux	431	423	278	394	512	474
Sewing Line 12 (QC Section)	Lux	411	582	728	505	411	561
Sewing Line 13 (Stitching Section)	Lux	569	245,6	351	276	341	294
Sewing Line 13 (QC Section)	Lux	895	334	512	816	651	749
Sewing Line 20 (Stitching Section)	Lux	324	1147	340,1	281	490	321
Sewing Line 20 (QC Section)	Lux	704	568	792	569	801	569
Sample Room (Stitching Section)	Lux	240	1822	242	286,1	341	315
Sample Room (Cutting)	Lux	212	116,6	232	228	308	104
Finishing PFG 3 (Washing)	Lux	351,8	297,5	340,5	417	418	543
Finishing PFG 3 (Ironing)	Lux	229,2	384,6	367,1	379	351	452
Aplikasi	Lux	667	865	752	687	781	681
Transfer Print	Lux	406	277,6	361	397	358	411
Sewing Line Nina (Stitching Section)	Lux	243	223,8	313	248	257	316
Sewing Line Nina (QC Section)	Lux	309	314	592	662	419	673
Sewing Line Ratna (Stitching Section)	Lux	385	419	253	372	409	297
Sewing Line Ratna (QC Section)	Lux	385	722	488	753	571	698
Fabric check PFG 4	Lux	441	478	467	483	561	571

Area / Section	Unit	Months of measurment					
		nov-16	dec-16	jan-17	feb-17	mrt-17	apr-17
Fabric Warehouse (Storage)	Lux	42	50,5	48,3	51	38,5	61,4
Fabric Warehouse (Inspect)	Lux	1021	1340	1293	390	691	964
Accesoris Warehouse (Storage)	Lux	307	130	125,8	414	27,1	47,5
Accesoris Warehouse (Distribution)	Lux	289	319,3	325,1	333	138,9	68,7
Cutting (Spreading)	Lux	457	689	670	498	145	407
Cutting	Lux	481	341,9	339,6	435	631	561
Cutting (Bundling & Numbering)	Lux	340	348	326,8	576	427	643
Sewing Line 1 (Stitching Section)	Lux	2413	1409	1335	1615	1429	788
Sewing Line 1 (QC Section)	Lux	716	673	671	632	1201	749
Sewing Line 2 (Stitching Section)	Lux	361	1864	1405	2337	911	1506
Sewing Line 2 (QC Section)	Lux	687	642	634	855	587	906
Sewing Line 3 (Stitching Section)	Lux	1836	334	326,7	957	867	248
Sewing Line 3 (QC Section)	Lux	692	478	497	762	387	418
Sewing Line 4 (Stitching Section)	Lux	317	1028	1130	2049	941	1011
Sewing Line 4 (QC Section)	Lux	726	546	567	811	498	641
Fabric check PFG 1	Lux	364	319,9	320,4	739	354	418
Finishing PFG 1 (Checking)	Lux	452	765	678	678	581	809
Finishing PFG 1 (Packing)	Lux	315	346	351,3	410	324	378
Finishing PFG 1 (Ironing)	Lux	364	330	343,8	346	1191	351
Sewing Line 5 (Stitching Section)	Lux	1657	409	361,8	256	804	291,4
Sewing Line 5 (QC Section)	Lux	471	747	679	646	1456	747
Sewing Line 6 (Stitching Section)	Lux	387	341	337,8	383	813	459
Sewing Line 6 (QC Section)	Lux	607	608	607	484	625	409
Sewing Line 7 (Stitching Section)	Lux	367	358	347	396	733	363,4
Sewing Line 7 (QC Section)	Lux	516	874	865	865	640	809
Sewing Line Baseball (Stitching)	Lux	327	284	296	236	965	3964
Fabric check PFG 2	Lux	448	650	647	647	609	688
Fabric check PFG 3	Lux	631	645	653	653	888	698
Sewing Line 8 (Stitching Section)	Lux	349	361	370,1	395	1012	692
Sewing Line 8 (QC Section)	Lux	542	582	571	539	603	723
Sewing Line 9 (Stitching Section)	Lux	371	267	278	498	1018	1932
Sewing Line 9 (QC Section)	Lux	684	569	578	539	357	617
Sewing Line 10 (Stitching Section)	Lux	364	314	323	316	1089	201,1
Sewing Line 10 (QC Section)	Lux	653	461	447	340	423	501
Sewing Line 11 (Stitching Section)	Lux	345	301	329	316	942	332,4
Sewing Line 11 (QC Section)	Lux	584	418	416	340	582	481
Sewing Line 12 (Stitching Section)	Lux	284	470	467	410	1495	891
Sewing Line 12 (QC Section)	Lux	729	589	597	590	512	682
Sewing Line 13 (Stitching Section)	Lux	372	305	312,9	318	363	531
Sewing Line 13 (QC Section)	Lux	473	759	747	720	831	965
Sewing Line 20 (Stitching Section)	Lux	337	298	301,7	301,7	1574	254
Sewing Line 20 (QC Section)	Lux	693	592	589	589	556	648
Sample Room (Stitching Section)	Lux	279	314	317	252	666	210,4
Sample Room (Cutting)	Lux	241	105	115	243	236	301
Finishing PFG 3 (Washing)	Lux	367	533	548	548	476	413
Finishing PFG 3 (Ironing)	Lux	349	448	456	456	571	682
Aplikasi	Lux	784	676	598	665	795	1000
Transfer Print	Lux	349	433	424,1	350	415	402
Sewing Line Nina (Stitching Section)	Lux	361	303	324,7	288	236	1221
Sewing Line Nina (QC Section)	Lux	581	667	658	627	591	581
Sewing Line Ratna (Stitching Section)	Lux	283	299	313,5	338	1031	227,9
Sewing Line Ratna (QC Section)	Lux	488	681	667	590	622	649
Fabric check PFG 4	Lux	477	561	554	499	463	545

PART IV - APPENDICES

Noise measurements (Asni, 2017)

Noise measurment - March 2017			
Building	Area	Measurment Result	Unit
PFG 1	Sewing machine (1 needle)	53	Decible Ampere (dBA)
	full plat seamer machine	63	
	Compressor area	69	
	Automatic sewing machine	64	
	full plat seamer machine	66	
	ironing steam machine	65	
PFG 2	Automatic sewing machine (2 needle)	61	
	Automatic sewing machine	59	
	kansai sewing machine	59	
	overdeck sewing machine	62	
PFG 4	Full plat seamer machine	66	
	Rolling Thread machine	58	
Cutting	Handheld Cutting Machine	55	
	Auto cutter machine	64	
	Bandknife machine	67	
PFG 3	overdeck sewing machine	50	
	6 Thread overdeck machine	64	
	4 Thread overdeck machine	55	
	4 Thread overlock sewing machine	53	
	Mesin obras	56	
Sample Room	Buttonhole machine	63	
Finishing	Ironing machine PFG 3	70	
	Washing machine PFG 3	64	
Transfer Print	Double up sliding heat transfer machine	60	

Noise measurment - January 2017			
Building	Area	Measurment Result	Unit
PFG 1	Sewing machine (1 needle)	55	Decible Ampere (dBA)
	full plat seamer machine	64	
	Compressor area	71	
	Automatic sewing machine	66	
	full plat seamer machine	64	
	ironing steam machine	67	
PFG 2	Automatic sewing machine (2 needle)	64	
	Automatic sewing machine	54	
	kansai sewing machine	64	
	overdeck sewing machine	63	
PFG 4	Full plat seamer machine	65	
	Rolling Thread machine	52	
Cutting	Handheld Cutting Machine	57	
	Auto cutter machine	66	
	Bandknife machine	70	
PFG 3	overdeck sewing machine	53	
	6 Thread overdeck machine	69	
	4 Thread overdeck machine	54	
	4 Thread overlock sewing machine	57	
	Mesin obras	52	
Sample Room	Buttonhole machine	60	
Finishing	Ironing machine PFG 3	67	
	Washing machine PFG 3	70	
Transfer Print	Double up sliding heat transfer machine	56	

Noise measurment - November 2016			
Building	Area	Measurment Result	Unit
PFG 1	Sewing machine (1 needle)	54	Decible Ampere (dBA)
	full plat seamer machine	65	
	Compressor area	73	
	Automatic sewing machine	65	
	ironing steam machine PFG 1	67	
PFG 2	Automatic sewing machine (2 needle)	63	
	Automatic sewing machine	54	
	kansai sewing machine	62	
	overdeck sewing machine	64	
PFG 4	Full plat seamer machine	65	
	Rolling Thread machine	53	
Cutting	Handheld Cutting Machine	59	
	Auto cutter machine	65	
	Bandknife machine	71	
PFG 3	Overdeck sewing machine	54	
	6 Thread overdeck machine	70	
	4 Thread overdeck machine	56	
	4 Thread overlock sewing machine	54	
	Hemming machine	51	
Sample Room	Buttonhole machine	59	
Finishing	Ironing machine PFG 3	68	
	Washing machine PFG 3	70	
Transfer Print	Double up sliding heat transfer machine	56	

Noise measurment - September 2016			
Building	Area	Measurment Result	Unit
PFG 1	Sewing machine (1 needle)	66	Decible Ampere (dBA)
	Hemming machine	63	
	Compressor area	74	
	Overdeck sewing machine	65	
	ironing steaming machine	67	
PFG 2			
	Automatic sewing machine	61	
	hemming machine	65	
	full plat seamer machine	66	
PFG 4	Full plat seamer machine	70	
	Rolling Thread machine	61	
Cutting	Handheld Cutting Machine	65	
	Auto cutter machine	72	
	Bandknife machine	72	
PFG 3	Overdeck machine	60	
	overdeck sewing machine	59	
	Automatic sewing machine	66	
	overdeck sewing machine	69	
	overlock sewing machine	59	
Sample Room	sewing machine	61	
Finishing	Ironing machine finishing PFG 3	70	
	Washing machine PFG 3	72	
Transfer Print	Double up sliding heat transfer machine	55	

Noise measurment - July 2016			
Building	Area	Measurment Result	Unit
PFG 1	Sewing machine (1 needle)	55	Decible Ampere (dBA)
	full plat seamer machine	68	
	Compressor area	74	
	Automatic sewing machine	64	
	ironing steaming machine	65	
PFG 2	Automatic sewing machine (2 needle)	67	
	Automatic sewing machine	59	
	kansai sewing machine	66	
	overdeck sewing machine	68	
PFG 4	Full plat seamer machine	70	
	Rolling Thread machine	59	
Cutting	Handheld Cutting Machine	57	
	Auto cutter machine	69	
	Bandknife machine	75	
PFG 3	Overdeck machine	57	
	6 Thread overdeck machine	73	
	4 Thread overdeck machine	55	
	4 Thread overlock sewing machine	57	
	Hemming machine	53	
Sample Room	Buttonhole machine	62	
Finishing	Ironing machine finishing PFG 3	71	
	Washing machine PFG 3	71	
Transfer Print	Double up sliding heat transfer machine	53	

Noise measurment - May 2016			
Building	Area	Measurment Result	Unit
PFG 1	Ironing	68	Decible Ampere (dBA)
	Overdeck machine	59	
	Small Cilinder Bed	60	
	Ironing	68	
	Washing	73	
PFG 2	sewing machine	62	
	Hemming machine	64	
	Overdeck Machine	64	
	Buttonhole machine	66	
PFG 4	Overdeck Machine	63	
	Hemming machine	57	
	Mini boiler	70	
Cutting	Spreading Machine	64	
	Auto Cutter Machine	60	
	Bandknife Machine	73	
PFG 3	Hemming machine	66	
	Sewing Machine	67	
	Full Flatseamer Machine	57	
	Overdeck Machine	58	
Sample Room	Ironing	69	
	Cutting	51	
	Overdeck Machine	56	
	Overlock Machine	55	
	Sewing Machine	55	
Finishing	Washing	70	
	Ironing	72	
Aplikasi	Aplikasi	49	
Transfer Print	Laser Cut	58	
	Heat Transfer	57	

Indoor Air Quality measurements (Binalab, 2016)

BINALAB
LABORATORIUM PENGUJIAN KUALITAS LINGKUNGAN
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KAN Komite Akreditasi Nasional
Laboratorium Penguji
LP - 412 - IDN

HASIL PENGUJIAN KUALITAS UDARA

Nomor Sertifikat	: 603/RK/BINA/IX/2016
Nama Pemohon	: **PT. PERDANA FIRSTA GARMENT**
Lokasi Pemohon	: Jl. Raya Batujajar No. 156 Km. 1,2 Padalarang, Bandung Barat
Tanggal Pengambilan Contoh Uji	: 08 September 2016
Titik Pengambilan Contoh Uji	: **Ruang Produksi** (06°52'29,9"LS; 107°30'06,2"BT)

No.	Parameter	Satuan	Hasil Pengujian	Baku Mutu	Metoda
1	Sulfur Dioksida (SO_2)	µg/Nm^3	<6,45	250	SNI 19-7119.7-2005
2	Nitrogen Dioksida (NO_2)	µg/Nm^3	7,48	5.600	SNI 19-7119.2-2005
3	T S P	µg/Nm^3	171,95	10.000	Gravimetri
4	Karbon Monoksida (CO)	µg/Nm^3	<102	29.000	CO Meter
5	Kebisingan	dBA	62,26	70$^{2)}$	Sound Level Meter
	Keterangan Pengambilan Contoh Uji				
1	Temperatur udara	°C	31,9	-	Termometer
2	Kelembaban	%	56,5	-	Higrometer

Keterangan :
Nilai Ambang Batas Faktor Fisika dan Faktor Kimia ditempat kerja Berdasarkan Permenakertrans No.Per-13/MEN/X/2011
Tanda < menunjukkan hasil dibawah limit deteksi.

BINALAB

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LABORATORIUM PENGUJIAN KUALITAS LINGKUNGAN
BANDUNG : Jl. Venus Barat No. 15 Margahayu Raya, Bandung (40286)
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KAN Komite Akreditasi Nasional
Laboratorium Penguji
LP - 412 - IDN

HASIL PENGUJIAN KUALITAS UDARA

Nomor Sertifikat	: 630/UA/BINA/IX/2016
Nama Pemohon	: **PT. PERDANA FIRSTA GARMENT**
Lokasi Pemohon	: Jl. Raya Batujajar No. 156 Km. 1,2 Padalarang, Bandung Barat
Tanggal Pengambilan Contoh Uji	: 08 September 2016
Titik Pengambilan Contoh Uji	: **Belakang Pabrik** (06°52'30,9"LS; 107°30'06,3"BT)

No.	Parameter	Satuan	Hasil Pengujian	Baku Mutu	Metoda
1	Sulfur Dioksida (SO_2)*	µg/Nm^3	<6,45	900	SNI 19-7119.7-2005
2	Nitrogen Dioksida (NO_2)*	µg/Nm^3	20,40	400	SNI 19-7119.2-2005
3	T S P	µg/Nm^3	171,76	-	Gravimetri
4	Karbon Monoksida (CO)	µg/Nm^3	<102	30.000	CO Meter
5	Kebisingan	dBA	58,90	70$^{2)}$	Sound Level Meter
Keterangan Pengambilan Contoh Uji					
1	Temperatur udara	°C	32,0	-	Termometer
2	Kelembaban	%	46,5	-	Higrometer
3	Angin dari Arah	°	130	-	Kompas
4	Kecepatan Angin	m/dt	0,0 – 0,6	-	Anemometer
5	Kondisi Cuaca	-	Cerah	-	-

Keterangan :
- Baku Mutu Kualitas Udara Ambient Nasional Peraturan Pemerintah No. 41 Tahun 1999.
- Tanda < menunjukkan hasil dibawah limit deteksi.
- Tanda * masuk lingkup KAN.
- TSP dilakukan 1 jam tidak bisa dibandingkan dengan baku mutu TSP pada Peraturan Pemerintah No. 41 Tahun 1999, 24 jam.

BINALAB