Thermal Performance of Vernacular Chinese Buildings: Insights from Roemah Oei in Lasem, Indonesia

Ersa Sitompul[1] & Prasasto Satwiko[2]
[1&2] Department of Architecture, University of Atma Jaya, Yogyakarta
Corresponding author's email: prasasto.satwiko@uajy.ac.id

Abstract

This research examines the building performance of traditional Chinese architecture style buildings in the Vernacular settlements of Indonesia's tropical climate. It ascertains whether it could withstand climate change, while verifying the claims that living in these buildings are still comfortable. These aims can be fulfilled through identifying key elements embedded in the building/complex that significantly contribute to how a building performs.

It employs DesignBuilder and a case study in Semarang. Simulation findings indicate that due to the soaring heat in Lasem, Indonesia, both main building's outer terrace and kitchen receives an immense radiative heat all-year round with relatively high humidity levels. By modifying the outer terraces with window panes and rerouting heat from the kitchen, the author has managed to lower the overall operative temperature of the main building at the expense of higher relative humidity. However, even if it doesn't fit Indonesia's thermal comfort standards, PMV results show that the modifications have succeeded in reducing the overall heat absorbed into the building.

Keywords: Traditional Chinese architecture, building performance, tropical climate, climate change, thermal comfort, DesignBuilder simulation.

Introduction

Chinese architecture is an architectural style developed in China over millenia before spreading out its influence throughout East Asia. The style itself began its solidification in the early days of imperial era (Qin Dynasty, circa 221 BC). Significant changes made were only to the decorative elements of the style, while the structural principles remain mostly unchanged. By Tang Dynasty (circa AD 618), the architectural style has had a major influence on Japan, Korea, and Mongolia. It has also influenced the South and Southeast Asian countries including Sri Lanka, Vietnam, Thailand, Phillipines, and Indonesia (Steinhardt, 2004). One of the most popular features of the traditional Chinese architecture style is the incorporation of Feng shui – a pseudo-science originating from ancient China which claims to use energy forces to harmonize individuals with their surrounding environments (Matthews, 2017). Feng shui is one of the Five Arts of Chinese Metaphysics: classified as physiognomy (observation of appearances through formulas and calculations). The practice discusses architecture in terms of 'invisible forces' that bind the universe, earth, and humanity together – namely qi. Today, Feng shui is regarded as a uniquely ancient Asian architectural tradition (Park, et al., 1996), and is still being used by planners including architects, landscape ecologists, landscape architects, environmental scientists, and geographers.

On a topic of influence, East Asian countries have been among the very first ones to receive an input of a grand scale after the Tang Dynasty: an era when much of the Chinese culture was imported *en-masse* by the neighboring nations. In South East Asia, the architecture has underlying influences found in various countries. Certain Chinese architectural techniques were adopted by the Thai artisans leading to some temples and palace rooftops being built in the Chinese style. Chinese style buildings can be found in Ayutthaya – a nod towards the large numbers of Chinese shipbuilders, sailors, and traders who came to the country (Sthapitanonda & Mertens, 2012). In Indonesia, mosques bearing Chinese influence can be found in certain parts of the country. This influence is recent in comparison to other parts of Asia and is largely due to the sizable Chinese Indonesian community (Formichi, 2013). Chinese architectural sensibilities have also influenced Vietnam, where it would also adopt the East Asian hip and gable roof style (Steinhardt, 2004).

The first ever recorded movement of China into Maritime Southeast Asia was the arrival of Mongol forces under the Kublai Khan, culminated in the invasion of Java in 1293. This intervention would later lead to Singhasari's decline and the rise of the Majapahit Empire (Reid, 2001). On the next movement, Chinese muslim traders from the eastern coast of China arrived at the coastal towns of Indonesia and Malaysia in the early 15th century. Led by mariner Zheng He who commanded several expeditions to southeastern Asia between 1405-1433 – these traders settled along the northern coast of Java and the legacy left was documented into the book Yingya Shenglan (Ma, 2005). No particular settlements have been recorded/documented beyond the 16th century, yet it is likely for the muslim Chinese to have been absorbed into the majority of muslim population (Tan, 2005). Three cities were left with many of Zheng He and his men's legacy: Semarang (formerly Sampotoalang), Surabaya (formerly Ujung Galuh), and Lasem (formerly Lao Sam). Today, many of these legacy and ones that were built 300-400 years later still strictly follow the core principals of traditional Chinese architecture. The urban complexes that still exist in these cities have been established as the 'Chinatown' and has been preserved as cultural heritage districts.

The majority of traditional Chinese architecture in Indonesia have stood the test of time; and the everchanging climatic conditions. Although global temperature average kept fluctuating, the value keeps getting higher by the year and has since doubled ranging from the 18th century until the present day (NASA, 2019). Initially, most of the 15th-16th century Chinese style buildings in Indonesia were built by the Chinese themselves who were brought from the mainland. It does not take long for the Indonesian people to start adopting their methods and join the ranks of capable builders who know their way around the Chinese style architecture, also incorporating some of Indonesia's indigenous architecture values in the buildings. By the end of the 20th century, after the dual nationality dilemma faced by the Chinese Indonesians, some of the major Chinatowns in the country were burned, razed, and looted, following the anti-Chinese sentiments – a stereotype that emerged due to President Soeharto being too reliant on Chinese Indonesian businessmen to further his New Order agenda. Chinatowns that were left after the peak incidents in 1998 were then restored and revived as heritage districts with most of the original houses restored to their initial forms.

Today, there are still an abundance of traditional Chinese buildings in Indonesia adapted to be used in topical conditions. Through many factors, some have been installed with HVAC systems, renovated, and repurposed, while some are still using the same natural ventilation systems ever since they are built, regardless of their functions.

Studies regarding heritage buildings in Indonesia are typically about indigenous and/or colonial architecture and rarely discuss traditional Chinese architecture. Since traditional Chinese architecture in Indonesia is still everpresent, this research intends to determine if there are issues in traditional Chinese architecture in terms of thermal performance to light – particularly when faced against Indonesia's tropical climatic conditions.

Claims from the citizens who live in these houses vary, yet in unison for the answer: traditional Chinese architecture style in Indonesia is still comfortable enough for the users to live in without the need of an AC system despite the temperature rise due to climate change. In this context, this study aims to understand how Chinese style buildings in Indonesia could withstand climate change in tropical conditions and to verify the claims of the people living in the houses through means of self-inducted surveys and software simulations. The end result will be to find out what parameters have to be modified in order for the buildings to reach comfortable standards in Indonesia's tropical climate. Results may change when this research is done to Chinese style buildings outside of Indonesia, on different climatic conditions and terrains.

Research Location

Lasem was chosen as a research location due to its preservation of traditional Chinese architecture in the small town, preceded by Zheng He's expedition arrival to Semarang and it's crews' spread into neighboring towns – spreading Islam in their wake. Bi Nang Un, one of Zheng He's captain voyaged to Lasem to establish a small community and establish diplomatic and trading relations as permitted by the adminisration of the Majapahit Empire. Even then, the captain's arrival into the town in 1413 was not the first one. *Sabda Badra Santi* (Exalted words of Badra Santi) – a local and spiritual book mentioned that some Chinese communities have been living side by side with the native years before Bi Nang Un's arrival. These communities consisted mainly of traders, exporting local rice back to China and importing clothing and textiles. From the start of the 15th century onwards, the population grew and built a permanent settlement on the eastern lowland part along Lasem River where a port was already used for commercial purposes (Pratiwo, 2010).

Mid-20th century was a harsh year for Lasem as anti-Chinese sentiments emerged. As President Soeharto tried to diminish everything related to China, some traditional buildings in Lasem were razed and burned leaving only a handful of them intact. Following independent restoration efforts, some of these buildings were repurposed as heritage sites, homestays, cafes, and batik houses. One of these is *Roemah Oei* (House of Huang) which was chosen as the research sample: a Hui-style heritage site and homestay with more than 200 year-old history.

Fig. 1: *Roemah Oei* Front Façade
Source: Author, 2022

Fig. 2: *Roemah Oei* Main Building Lobby Interior
Source: Author, 2022

Built in 1818, the house has seen many different usages throughout the years. From selling tapioca and ketan hitam – a local delicacy in its early days, to horse carriage business that was carried thoughout 2 generations, and a batik house started by the 4th generation before losing it's identity in 1965. The house has seen few to none efforts to restore and/or renovate due to the ongoing political issues, yet hopes to restore the glory of the house was reinvigorated after the President KH. Abdurrahman Wahid's election in 1999. It was finally restored and slightly renovated in 2016, opened for public, and crowned as a heritage site – along with a homestay built on its backyard named *Wisma Pamilie* (Family Home).

Ever since the *Roemah Oei*/House of Huang was built, there has been no major change to the complex except its mix-use function as a housing complex with several different bussineses throughout the generations and before its major renovation and repurposing as a heritage museum in 2016. The complex remains unused since 1965 and caused it to be in a state of disrepair. Yet its architectural elements, structural, and layout remained the same and largely intact throughout the centuries. The latest renovation efforts include repainting and repairing some parts of the complex and building a homestay as an extension of the back courtyard. Overall, every architectural, structural, and the layout aspects remain the same even after a massive change in function. Notable differences include the addition of the homestay, front shops beside the front gate and the food stalls on the side courtyard corridor.

Literature Review

Thermal comfort for traditional Chinese buildings have been a research topic long since before this research is conducted. To ensure that this research is not repeating/replacing any kind of previous researches done regarding this specific topic, a number of papers researching similar topic on different locations and different objects with different methods of research have been compiled into the following list:

1) The paper titled Chinese Climate and Vernacular Dwellings (Sun, 2013) explores five different climatic regions into which China is partitioned by the authorities: severe cold region, cold region, moderate region, hot summer – cold winter region, and hot summer – mild winter region. Analysis of each region cover the climate and its vernacular architecture with a special focus on how sustainability was addressed. After various exploration on the different climatic conditions that cover the different regions, it was concluded that the vernacular housing in each region is a form of rational response to the climate in terms of materals, passive cooling/heating techniques and local environment.
2) The paper titled The Climatic Design in Chinese Vernacular Courtyard House Settlement – A Wind Environmental Simulation (SHI & NG, 2014) aims to discover the key points of how the same architectural form provide wind environmental adaptability in different seasons with totally opposite weather conditions; through means of CFD simulations. Results show that there is an optimized courtyard shape with specific ratios which affects the wind environment within a building form. There also needs to be a balance between different needs in different seasons which may be combined with different wind speeds to achieve an optimally comfortable wind environment. By understanding the wind environment's key impact factors in the courtyard house building form, vernacular architecture form and its climatic adaptability strategies can be properly applied.
3) The paper titled The Effects of Courtyards on Indoor Thermal Conditions of Chinese Shophouse in Malacca (Zakaria, et al., 2015) focuses on the effects of courtyards on indoor thermal environment in a traditional shophouse in Malacca, Malaysia based on field measurement results. Taking into calculation local climate conditions and interior temperatures. The results showed that rooms bordering the courtyard have lower indoor air temperature than outside air temperature during daytime possibly due to relatively large ventilation rates in these rooms. During nighttime, inflows of cooled air from the roofs caused indoor air temperature to only be slightly higher than outside air temperature. Smoke tests also revealed different types of air flow patterns

during different time of day which further shows that the deep atrium-type courtyard functioned as a cooling source for the surrounding spaces particularly at night.

4) The paper titled Architectural Spatial Design Strategies for Summer Microclimate Control in Buildings: A Comparative Study of Chinese Vernacular and Modern Houses (Du, et al., 2018) aims to clarify the spatial design strategies used to control the microclimate of a Chinese vernacular house in summer by comparing the building with modern Chinese rural houses and presenting ideas for contemporary architectural design practice. Spatial and spatial boundary conditions, vegetations, and human activity were analyzed in order to reach the goal. The study shows that the design strategies used by Chinese vernacular houses still hold great value for a modern rural house design, especially the free-running ones. Optimal thermal comfort in modern houses may not be achievable without using the vernacular spatial design strategies.

According to the aforementioned list, the topics researched includes Chinese vernacular buildings' thermal performance in different climatic regions, the wind environmental adaptability of Chinese vernacular courtyard houses, the effects of courtyard on the thermal comfort of Chinese shophouses in Malacca, and a comparative study of Chinese vernacular houses and its modern counterparts in terms of microclimate control.

This research is focused on the overall thermal performance of traditional Chinese buildings when faced with Indonesia's unique tropical climatic conditions by using an intact traditional Chinese building as a sample, a topic that has not been researched yet. This paper also aims to contribute to the broader topic of thermal performance of traditional Chinese buildings as a whole, providing insights on how it performs particularly in Indonesia's tropical climatic conditions under the influence of climate change.

Research Methods

1) The Physical Survey

Before the complex could be analyzed through any kind of software, a physical survey is required to get the exact measurements of the complex. The steps are as follows:

a) Dimension measurement – includes all exact measurements of the complex, using a tape measuring tool to precisely recreate the complex's base form in any software.
b) Building performance measurement – includes wind velocity and temperature and room temperature and humidity in every room of the complex to be used as a reference for the simulation results. Wind velocity and humidity is measured using Uni-T UT363BT Anemometer to measure the outdoor wind condition within a certain time frame, sufficient to determine a daily average to be used as a reference. Meanwhile, room temperature and humidity is measured using Elitech RC-4HC Data Logger which will be placed in each room of the complex, measuring operative temperature and humidity of the room within a certain time frame, sufficient to determine a daily average also to be used as a reference.
c) Documentation – this includes photographs and notes regarding the complex detailing certain shapes, materials, and/or any kinds of items inside the complex that may significantly influence the simulation results.

2) Model Simulation

Modelling and simulation is done through DesignBuilder. Modelling starts from generating the base form of the complex and detailing each room of the complex. Since the complex is an enclosure, no surrounding environment is required to be detailed in the overall model. Instead, a base form of each of the subject's immediate surrounding environment will take place to help simulate the wind patterns accurately.

The simulation starts after the model is completed. The rooms are assigned its current usage, and all building materials are set as accurately as its real life counterpart. After the standards found in SNI are manually converted for use in the DesignBuilder, all simulation results are compared to determine how many of the simulation results fit the SNI standards. If all simulation results are within the standards' parameters, no changes will be made to the model and the research can be concluded. If some or all of the results are not within the standards' parameters, the model will be modified accordingly until most – if not all of the simulation results are within the parameters. All changes and/or modifications made to the base model are documented later on for the conclusion of the research.

3) Research Steps

The specific research aim can be achieved by identifying the key elements embedded in the building/complex that significantly contribute to how it performs in the tropical climatic conditions. These steps are required to realize the aim:

a) Physically surveying the sample. Used to measure the exact dimensions and shape to then model the sample for use in the simulation software.
b) Physically measuring the building performance as comparison points to be used againts the simulation results.
c) Extracting any thermal comfort standard found in the Indonesian National Standard (SNI) to be used in the simulation software.
d) Running the simulation on the finished model and identifying the results to determine if it conforms with any thermal comfort standards extracted from the SNI.
e) Remodelling the original model to its previous usage as a housing complex to compare the present simulation results with its historical counterpart to determine if the building performance is affected by changes in activities and outside interferences.
f) Identifying which key elements of the sample significantly contribute to the simulation result – regardless if the sample fits all, partially, or even none of the thermal comfort standard – by altering/modifying the model and rerunning the simulation after each modification.

DesignBuilder

A building performance analysis software typically used by engineers, architects, and energy assessors. By combining several software used for thermal comfort, lighting, shading, CFD, and energy consumption, DesignBuilder is able to generate a wide range of building performance outputs to be easily compared with other designs being simulated within. The software has several core modules detailed below:

1) 3D modelling – primary modelling module for all types of buildings. This module can be used to model the buildings directly or be imported from BIM and CAD files.
2) Visualization – used mainly for material visualization and shading analysis. Replaces Ecotect's sun path visualizer and shadow reference.
3) EnergyPlus simulation – integrated and simplified EnergyPlus simulation tool for thermal comfort and energy consumption analyses.
4) Daylighting – calculates daylight factors and illuminance using Radiance.
5) HVAC – taken from EnergyPlus HVAC tools, DesignBuilder simplifies the interface to be used with thermal comfort and energy consumption analyses.
6) CFD – calculates air properties' distribution in and around buildings. Replaces Autodesk CFD.

Despite being an all-round software with many capabilities, DesignBuilder has some limitations when it comes to virtually every step along its usage. The interface itself is very complex and can get even advanced users to take time navigating and using it.

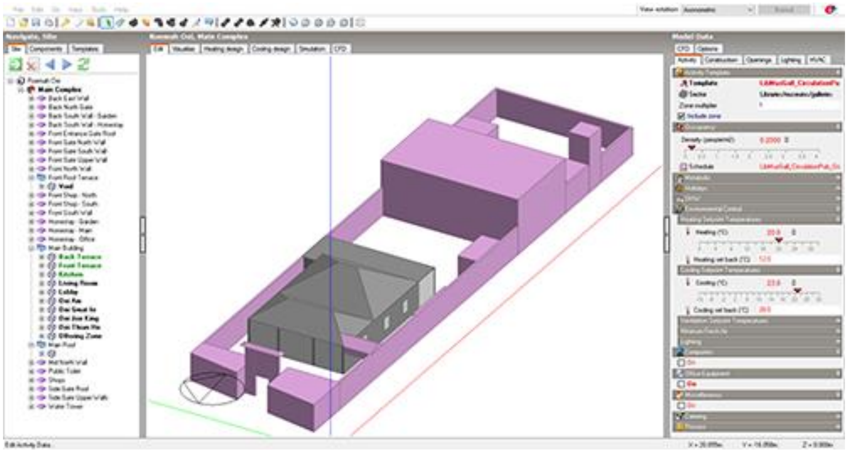


Fig. 3: Typical DesignBuilder Workspace
Source: Author, 2022

As an analysis software, DesignBuilder doesn't prioritize visual elements in its UI for its users. As such, modelling becomes slightly harder than any 3D modelling tools. There are some parameters used to define how a zone inside a building block behaves: activities, construction materials, openings, lighting, and HVAC. These parameters help users in defining what building is currently being modelled and analyzed, yet not all information regarding the contents of each parameter are detailed or even available.

Findings

The currently used national standard for design procedures and air conditioning systems in buildings, SNI 03-6572-2001 has two major ranges affecting heat gain and loss: human thermal comfort ranges, and room thermal comfort ranges. Both these major ranges can be applied in DesignBuilder from setting building template activities, zone-specific activities, and simulation results. Since this research is focused on studying the thermal comfort of the sample, only some of the output options need to be turned on such as environmental, comfort, and temperature distribution. SNI standards that can be compared with the simulation results includes dry air temperature, relative air humidity and operative temperature. In accordance with the standard, Indonesia has a thermal comfort range within 24-26˚C and 45-65% of relative humidity.

Original sample DesignBuilder model and simulation results

The complex consists of a main front gate and two front facing souvenir shops on the west facing Jatirogo Street, the main building being researched, a chain of food stalls on its south side, a public toilet, a 2-story homestay with 2 other small buildings serving as a homestay extension and its office, a water tower serving the entirety of the complex, and 2 decorated courtyards both on the West and East side of the homestay.

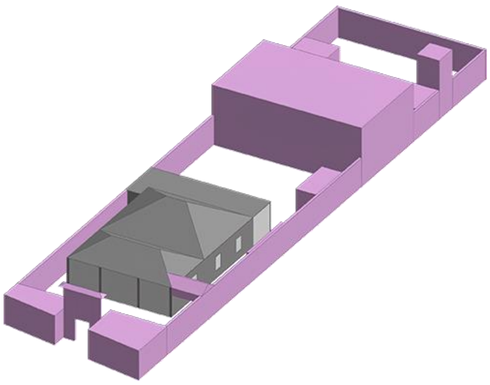


Fig. 4: *Roemah Oei* Complex Original Model in DesignBuilder
Source: Author, 2022

As presented in the figure above, only the gray-colored main block is analyzed, also to be referred further as the 'main building'. Other blocks in purple (component blocks) are included only in the model to account for the 'in-complex' airflow.

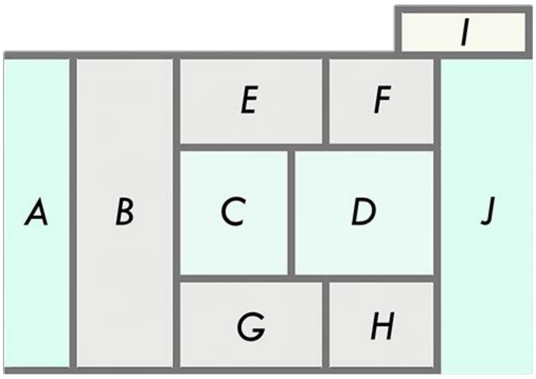


Fig. 5: Main Building Plan
Source: Author, 2022

The main building consists of front and back terraces with several communal and private rooms – now repurposed as display rooms. *Roemah Oei* has been repurposed as a Chinese heritage museum since its renovation in 2016. It's reflected in its DesignBuilder model with the main complex's activity being set to the *Libraries/Museums/Galleries* sector and its main template *LibMusGal_CirculationPub* (all public circulation areas where people walk and sit). Some zones in the main complex use different activity templates mainly in the same sector, detailed in the following table:

Table 1: Main Building Zone Activity Designations

Zone	Name	Sector	Template
A	Front terrace	Hotel	Hotel_EatDrink
B	Lobby	Libraries/Museums/Galleries	LibMusGall_Display
C	Offering zone	Libraries/Museums/Galleries	LibMusGall_CirculationPub
D	Living room	Libraries/Museums/Galleries	LibMusGall_CirculationPub
E	*Oei Joe King* (display room)	Libraries/Museums/Galleries	LibMusGall_Display
F	*Oei Am* (display room)	Libraries/Museums/Galleries	LibMusGall_Display
G	*Oei Gwat Ie* (display room)	Libraries/Museums/Galleries	LibMusGall_Display
H	*Oei Thian Ho* (display room)	Libraries/Museums/Galleries	LibMusGall_Display
I	Kitchen	Hotel	Hotel_FoodPrep
J	Back terrace	Hotel	Hotel_EatDrink

Source: Author, 2022

Simulation in DesignBuilder typically allows a year-round simulation starting in year 2002 due to most weather files provided by the software using the same timestamp. The results presented below are only from the site and the main building since only the gray blocks presented in Fig. 4 are able to be simulated. The simulation results for the original sample are as follows:

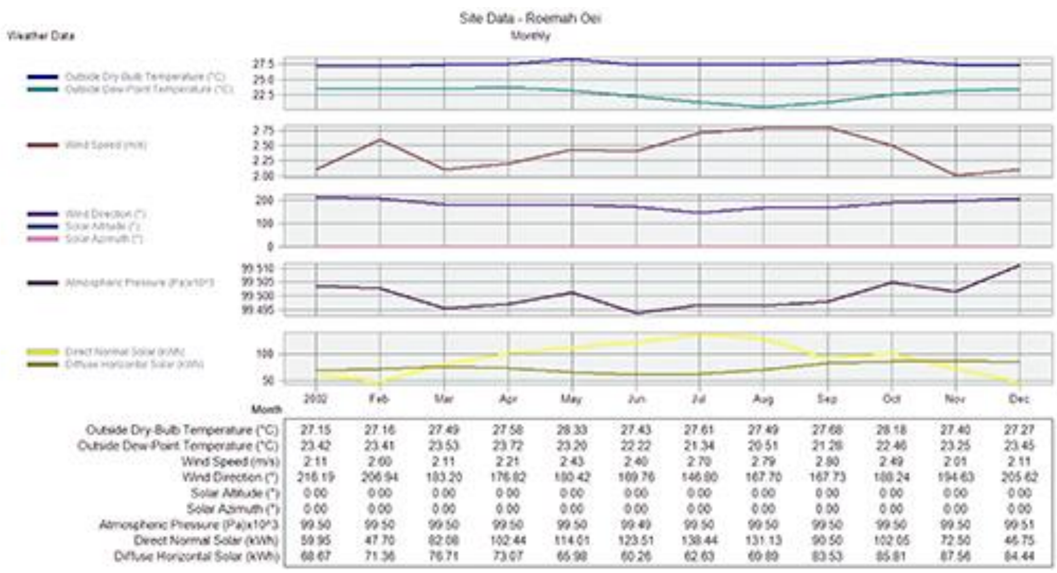


Chart 1: Site Data
Source: Author, 2022

Site's outside dry-bulb temperature stands at an annual average of 27.56˚C with the lowest point of 27.15˚C in January and 28.33˚C in May with annual wind speeds averaging at 2.4m/s; lowest point in November at 2.01m/s and highest point in September at 2.8m/s.

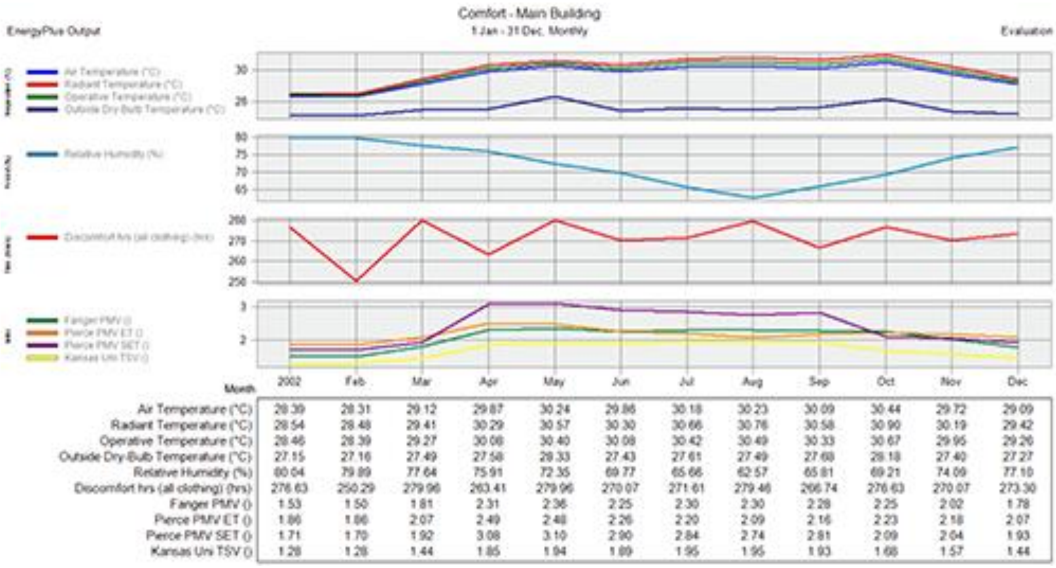


Chart 2: Original Sample Main Building Comfort Results
Source: Author, 2022

The main building refers to the average of all of the simulation results in all the occupied zones. The main takeaway from the comfort graph is to find out the operative temperature, relative humidity, and PMV of the research sample. In this case, the original research sample has an annual average detailed below:

Operative temperature	: 29.83˚C (low 28.46˚C, high 30.67˚C)
Relative humidity	: 72.45% (low 62.57%, high 80.04%)
Fanger PMV	: 2.06 (low 1.5, high 2.36)

Both annual operative temperature and the relative humidity averages are 3.83˚C and 7.45% above Indonesia's thermal comfort zone margins. Relative humidity falls between the thermal comfort margin only in August at 62.57%. Fanger PMV sits at a value of 2.06 – warm all year-round.

Table 2: Original Sample Simulation Results Zone Breakdown

Zone	Operative Temperature (˚C)	Relative Humidity (%)	Fanger PMV
	Annual Average	Annual Average	Annual Average
A	35.74	57.17	3.72
B	29.04	69.84	1.64
C	25.43	89.94	1.14
D	26.04	86.3	1.26
E	26.11	81.02	0.89
F	27.03	77.34	1.12
G	25.61	83	0.8
H	26.33	80.04	0.99
I	34.21	62.19	2.9
J	36.88	55.23	4.18

Source: Author, 2022

There are only two zones with an annual operative temperature average between 24-26˚C – offering zone, and *Oei Gwat Ie* display room. Their annual relative humidity averages however, are way above 45-65%. The only zones fitting the relative humidity standard are both front and back terraces and the kitchen. Even these zones still fail to reach the operative temperature standard. The most neutrally comfortable zone taken from the PMV values is *Oei Gwat Ie* display room with an index of 0.8 (slightly warm). Zones generating the most heat are located at the outermost part of the main building – front and back terraces, and the kitchen – with PMV values ranging from 2.9-4.18 (hot-very hot).

Historical Sample DesignBuilder Model and Simulation Results

The sample currently stands as a heritage museum, renovated and repurposed from its former usage as a house. These renovations and repurposing may have changed to original building performance as a housing complex. Therefore, to compare the results between the present day Roemah Oei and its previous state as a housing complex, the author has remodeled the complex as it was before the homestay was built. This model is to be referred as the historical model.

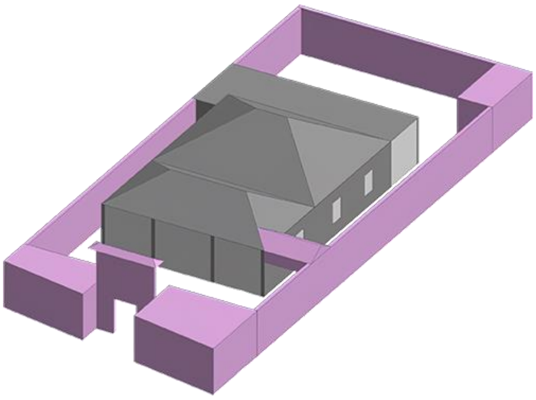


Fig. 6: *Roemah Oei* Complex Historical Model in the DesignBuilder
Source: Author, 2023

The historical model also has a set of different activities in accordance with its usage in the past as a dwelling. The complete activity sector and templates are detailed in the following table:

Table 3: Historical Model Main Building Zone Activity Designations

Zone	Name	Sector	Template
A	Front terrace	Dwelling	Dwell_DomLounge
B	Lobby	Dwelling	Dwell_DomLounge
C	Offering zone	Dwelling	Dwell_DomLounge
D	Living room	Dwelling	Dwell_DomLounge

E	*Oei Joe King* (display room)	Dwelling	Dwell_DomBed
F	*Oei Am* (display room)	Dwelling	Dwell_DomBed
G	*Oei Gwat Ie* (display room)	Dwelling	Dwell_DomBed
H	*Oei Thian Ho* (display room)	Dwelling	Dwell_DomBed
I	Kitchen	Dwelling	Dwell_DomKitchen
J	Back terrace	Dwelling	Dwell_DomLounge

Source: Author, 2022

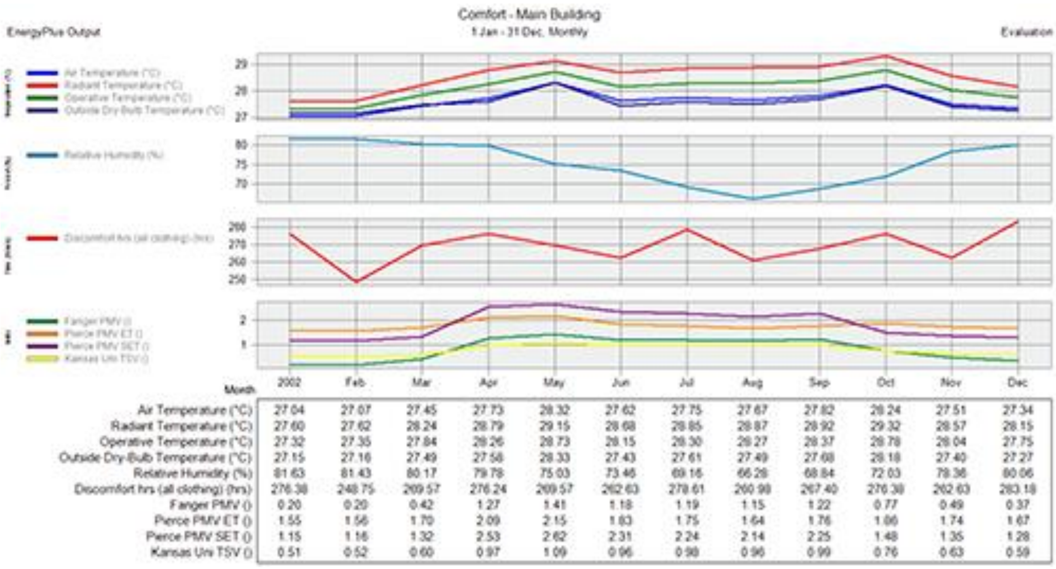


Chart 3: Historical Sample Main Building Comfort Results
Source: Author, 2023

Annual averages:
Operative temperature : 28.1˚C (low 27.32˚C, high 28.78˚C)
Relative humidity : 75.48% (low 66.28%, high 81.63%)
Fanger PMV : 0.83 (low 0.2, high 1.41)

Both annual operative temperature and relative humidity averages are 2.1˚C and 10.48% above Indonesia's thermal comfort zone margins. Fanger PMV sits within the value of 0.2-1.41 – neutral to slightly warm all year-round.

Table 4: Historical Sample Simulation Results Zone Breakdown

Zone	**Operative Temperature (˚C)**	**Relative Humidity (%)**	**Fanger PMV**
	Annual Average	**Annual Average**	**Annual Average**
A	30.12	73.99	1.89
B	27.81	74.07	0.93
C	26.59	76.59	1.33
D	26.34	78.45	0.51
E	26.94	76.77	-0.1
F	27.24	76	0.03
G	26.69	77.42	-0.16
H	27.04	76.46	-0.02
I	29.54	72.49	1.85
J	30.74	73.94	1.23

Source: Author, 2022

There are no zones with an annual operative temperature average between 24-26˚C; only some zones fall within the 'comfortably warm' standard – offering zone, living room, Oei Joe King's bedroom, Oei Gwat Ie's bedroom, and Oei Thian Ho's bedroom. None of the zones also fit within the relative humidity standards sitting on 45-65%. PMV values show all zones fall within neutral to warm within an index range of -0.1 to 1.89. Zones generating the most heat are located at the outermost part of the main building – front terrace and the kitchen – with PMV values ranging from 1.85-1.89 (warm). Compared to the simulation results of the present (original) model, this proves that the homestay played a role in changing the airflow pattern and heat gains inside the complex – resulting in more heat gains in the original model. This can be seen from the overall PMV results between the original and the historical model.

Indonesia's Heritage Building Preservation Principles

Before any modification is done on any part of the complex, Indonesia's Ministry of Public Works and Public Housing (PUPR) has several principles for heritage building preservation that need to be followed. These principles are detailed as follows:

1) Maintain significancy
   Every tangible and intangible element of a historical building must be preserved as a priority in every preservation effort.
2) Minimal interference
   If applicable and whenever possible, every survivable element of a historical building must be preserved. Any kind of interference be it structural, architectural, and/or functional must be kept at a minimum to prevent further damages (if the building is already in a state of disrepair).
3) Recognition and ease of reversal
   Every intervention made in an effort to preserve a historical building must be recognizable and reversible; allowing better interventions – should it be available – to be done in the future. Each step of the effort to preserve by modification must be documented and archived.

Lasem has been decreed as a Cultural Heritage Region in 2020 by the Ministry of Public Works and Public Housing, granting Roemah Oei/House of Huang the heritage building status. Therefore, any modifications made in the complex to allow for better thermal comfort must follow these specific guidelines:

1) No modifications to building layout/plan.
2) No modifications to all original building materials.
3) Minimal modifications allowed for zones with extreme conditions.
4) All modifications must be easily recognizable and reversible.

Modified Sample DesignBuilder Model and Simulation Results

As presented in the original sample simulation results, simulation results of most zones in the main building doesn't fit Indonesian thermal comfort zone margins, whether by operative temperature or relative humidity resulting in most of the zones having slightly warm to warm tendencies. To remedy this, the author has modified the sample's elements to better fit the Indonesian climate and its thermal comfort zone margins, also taking into account climate change and acclimatization. All modifications done in the model follows Indonesia's heritage building preservations standards and guidelines. The modifications made to the original sample is detailed as follows:

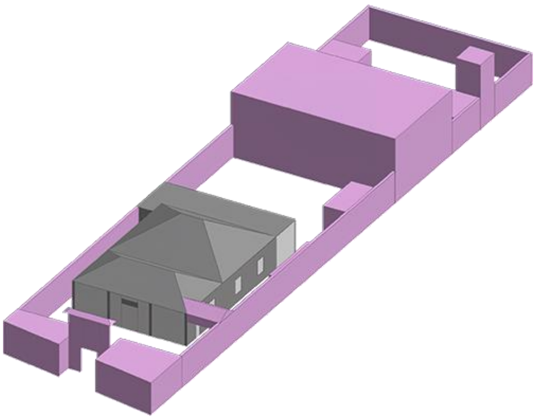
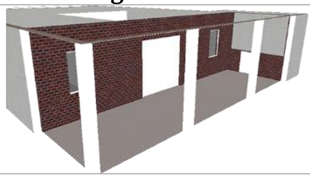
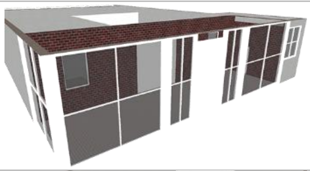
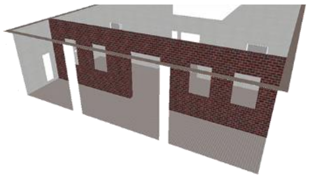
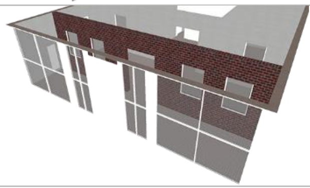
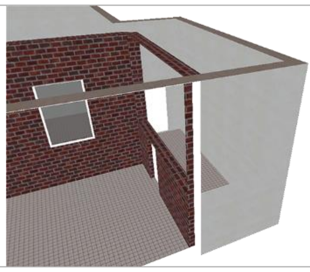
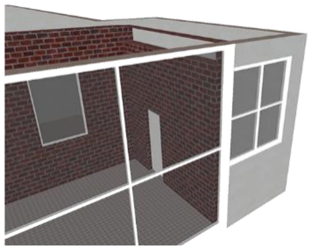


Fig. 7: *Roemah Oei* Complex Modified Model in DesignBuilder
Source: Author, 2022

After several attempts to modify the sample using available methods and modifiable elements, it is concluded that this model yields the best results possible. All the modifications are listed as follows:

Table 5: Original Sample Modifications

Zone	Original Model	Modified Model
Back Terrace		
Front Terrace		
Kitchen		

Source: Author, 2022

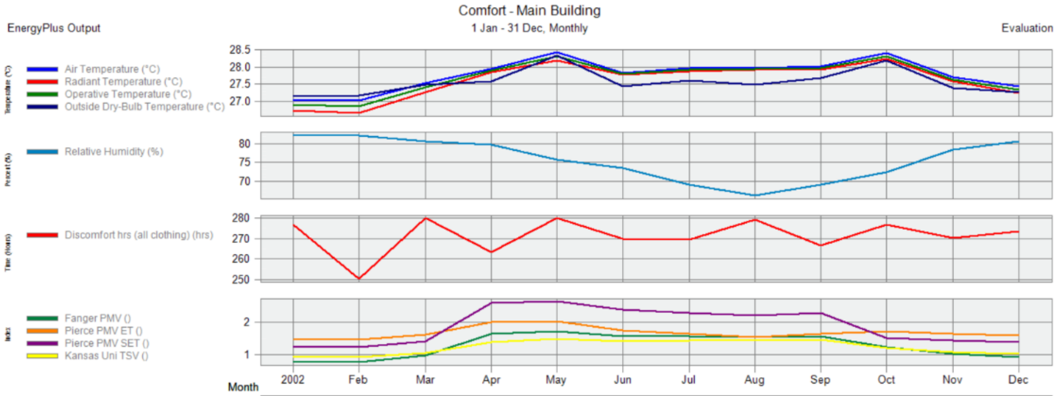
a) Back terrace
   - Replaced wooden balustrades with framed windows. The frames use similar wooden materials with the columns. This helps reduce the extreme heat that radiates from the middle courtyard.
   - Added a small ventilator on top of the door for air exchange.

b) Front terrace
   - Added framed windows in-between the wooden columns. The frames also use similar wooden material with the columns. This helps reduce the extreme heat coming from the front gate.
   - Added a small ventilator on top of the door for air exchange.

c) Kitchen
   - Replaced the hole on the serving side with a wall with a ventilator on top to reduce heat from cooking from reaching the back terrace zone.

- Replaced the hole on the middle courtyard side with a window and a ventilator to further allow heat from cooking to dissipate faster while reducing radiative heat from the outside.

Chart 4: Modified Sample Main Building Comfort Results



	2002	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Air Temperature (°C)	27.06	27.03	27.54	27.95	28.42	27.83	27.98	27.96	28.01	28.40	27.70	27.44
Radiant Temperature (°C)	26.73	26.67	27.27	27.85	28.19	27.77	27.88	27.92	27.91	28.23	27.59	27.24
Operative Temperature (°C)	26.90	26.85	27.41	27.90	28.31	27.80	27.93	27.94	27.96	28.31	27.64	27.34
Outside Dry-Bulb Temperature (°C)	27.15	27.16	27.49	27.58	28.33	27.43	27.61	27.49	27.68	28.18	27.40	27.27
Relative Humidity (%)	82.48	82.35	80.81	79.89	75.74	73.53	69.13	66.17	69.00	72.44	78.57	80.71
Discomfort hrs (all clothing) (hrs)	276.63	250.29	279.96	263.41	279.96	269.94	269.24	279.16	266.43	276.63	270.07	273.30
Fanger PMV ()	0.79	0.77	0.97	1.63	1.72	1.56	1.56	1.53	1.57	1.22	1.03	0.93
Pierce PMV ET ()	1.47	1.46	1.62	2.01	2.03	1.75	1.64	1.54	1.64	1.71	1.64	1.59
Pierce PMV SET ()	1.25	1.24	1.41	2.60	2.64	2.38	2.29	2.20	2.29	1.50	1.43	1.37
Kansas Uni TSV ()	0.94	0.93	1.04	1.38	1.48	1.41	1.45	1.45	1.45	1.20	1.08	1.03

Source: Author, 2022

Annual averages:
Operative temperature : 27.7˚C (low 26.85˚C, high 28.31˚C)
Relative humidity : 75.86% (low 66.17%, high 82.48%)
Fanger PMV : 1.28 (low 0.77, high 1.72)

Both operative temperature and relative humidity annual average is still above Indonesia's thermal comfort zone margins. Operative temperature sits at 1.7˚C above the margins; lower than the original sample results. Meanwhile relative humidity is at 10.86% above the margins; higher than the original sample results. However, the annual PMV average results indicate that the modified one is at 0.78 points lower than the original sample results. This indicates that the modified sample actually performs better than the original.

Table 6: Modified Sample Simulation Results Zone Breakdown

Zone	Operative Temperature (˚C) Annual Average	Relative Humidity (%) Annual Average	Fanger PMV Annual Average
A	29.37	73.1	1.5
B	27.27	76.25	1.21
C	26.3	78.82	0.98
D	26.02	81.38	0.91
E	26.53	78.74	1.01
F	26.81	77.73	1.09
G	26.29	79.28	0.97
H	26.61	78.16	1.05
I	30.31	68	2.03
J	30.4	68.84	1.88

Source: Author, 2022

There are no zones with an annual operative temperature average between 24-26˚C; yet most zones fall within the 'comfortably warm' standard. None of the zones also fit within the relative humidity standards sitting on 45-65%. PMV values show that all the zones fall within slightly warm to warm within an index range of 0.91 to 2.03. Zones generating the most heat are located at the outermost part of the main building – front and back terraces and the kitchen – with PMV values ranging from 1.5-2.03 (warm). Compared to the simulation results of the original model, the modifications succeded in significantly reducing the heat gains accumulated in the outermost zones of the main building, effectively reducing the overall heat gains in the main building even at the cost of higher annual relative humidity average. This can be seen through the overall reduction of annual PMV average values.

Conclusions

This research aimed to identify the building performance of traditional Chinese architecture in different climatic conditions, primarily in the Indonesian climate. This research also aimed to find what elements need to be modified in order to reach Indonesian building performance standards and comfort standards. After conducting the necessary steps to complete the research, following conclusions have been derived:

1) Traditional Chinese architecture – in this case *Roemah Oei*/House of Huang as it stands now fails to reach Indonesian thermal comfort standards. The management of the complex however, states that the complex is still comfortably warm even in the soaring heat of ±30˚C all year round. This proves that acclimatization has played a part in helping people adapt to the tropical climate.
2) After the simulation, it has been discovered that most of the heat came from the front gate and the middle courtyard in the form of radiative heat. The modification done to the model includes reducing radiative heat from both the front gate and the courtyard, and rerouting heat from the cooking activities. All of these modifications use window panes to help absorb the radiative heat and reflect some of it. All modifications presented follows the guideline for Indonesia's principles for heritage building preservation.
3) Historical model simulation also shows that constructing the homestay as the complex's extension by being a heritage museum played a significant part in changing the in-complex airflows and solar radiation distribution thoughout the whole complex. It is shown that while activities do change how a zone behaves, adding another building in a specific part of the complex will change its airflow signature.
4) Post-modification simulation, it has been concluded that the modifications mentioned in the previous point yield the closest results to reaching Indonesian thermal comfort standards, yet still – it fails to reach the margins presented by SNI. However, since the PMV results show a trend of decreasing across the board post-modification, it shows that the modifications succeed in reducing the overall heat absorbed into the building, even at the expense of being more humid.

The thermal comfort study conducted in this research has implications regarding a traditional Chinese architecture style building performance in tropical conditions; in particular the Indonesia's tropical climate. Every country has its own biome distributions and different climatic conditions (Beck, et al., 2018) that may lead to different results in simulations if done in different countries. For example, Indonesia shares the same classification of Af (tropical rainforest) in the Köppen-Geiger climate classification map with several regions in countries along the equatorial zone according to an improved climate classification map by the same authors (Beck, et al., 2018). Assuming the same site conditions, combination of factors such as daily maximum/minimum temperatures, relative humidity, precipitation, rain days, and hours of sunshine will affect the simulation differently. However, this specific study can be used as a reference point for the future studies regarding thermal comfort and building performance of traditional Chinese architecture style buildings in the tropical climates.

In this research, the architectural style used in the sample (Hui-style) has an origin in the Anhui Province – a province with a classification of Cfa (humid subtropical). Since the indigenous style is designed and built to adapt to such climate, a trend in temperature increase which leads to a higher PMV index in simulated tropical environments is to be expected. Same methods used in this research may also be reproduced in other research with similar topics.

References

Beck, H. E. et al., (2018) Present and Future Köppen-Geiger Climate Classification Maps at 1-km Resolution. *Scientific Data,* 30 October, 5 (180214), p. 12.

Du, X., Bokel, R. & Dobbelsteen, A. v. d., (2018) Architectural Spatial Design Strategies for Summer Microclimate Control in Buildings: A Comparative Case Study of Chinese Vernacular and Modern Houses. *Journal of Asian Architecture and Building Engineering,* 24 October, 15(2), pp. 327-334.

Formichi, C., ed., (2013) *Religious Pluralism, State, & Society in Asia.* Oxfordshire: Routledge.

Ma, R. W., (2005) Hui Diaspora. *Encyclopedia of Diasporas: Immigrant & Refugee Cultures Around the World,* pp. 113-124.

Matthews, M. R., (2017) *History, Philosophy, & Science Teaching: New Perspective.* Zürich: Springer.

NASA, (2019) *Vital Signs: Global Temperature.* [Online]
Available at: https://climate.nasa.gov/vital-signs/global-temperature/

Park, C. P., Furukawa, N. & Yamada, M., (1996) A Study on the Spatial Composition of Folk Houses & Village in Taiwan for the Geomancy (Feng-Shui). *Journal of Architecture Institute of Korea,* 12(9), pp. 129-140.

Pratiwo, (2010) *Arsitektur Tradisional Tionghoa dan Perkembangan Kota.* Yogyakarta: Ombak.

Reid, A., (2001) Flows & Seepages in the Long-term Chinese Interaction with Southeast Asia. *Sojourners & Settlers: Histories of Southeast Asia & the Chinese,* pp. 15-50.

SHI, Y. & NG, E., (2014) *The Climatic Design in Chinese Vernacular Courtyard House Settlement – A Wind Environmental Simulation.* Ahmedabad, CEPT University.

Steinhardt, N. S., (2004) The Tang Architectural Icon & the Politics of Chinese Architectural History. *The Art Bulletin (Vol.86, No.2),* p. 228.

Sthapitanonda, N. & Mertens, B., (2012) *Architecture of Thailand: A Guide to Tradition & Contemporary Forms.* Singapore: Editions Didier Millet.

Sun, F., (2013) Chinese Climate and Vernacular Dwellings. *Buildings,* 31 January, Volume 3, pp. 143-172.

Tan, M. G., (2005) Ethnic Chinese in Indonesia. *Encyclopedia of Diasporas: Immigrant & Refugee Cultures Around the World*, pp. 795-807.

Zakaria, M. A., Kubota, T. & Toe, D. H. C., (2015) The Effects of Courtyards on Indoor Thermal Conditions of Chinese Shophouse in Malacca. *Procedia Engineering*, Issue 121, pp. 468-476.