MINISTRY OF EDUCATION AND TRAINING MINISTRY OF CONSTRUCTION

HANOI ARCHITECTURAL UNIVERSITY

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THE MULTILAYER CLIMATIC ADAPTIVE SHOPHOUSE'S FRONT FAÇADE STRUCTURE IN HO CHI MINH CITY APPLYING PARAMETRIC METHOD

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The thesis is reviewed by Hanoi Architectural University's Doctorate dissertation review council

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More information can be found in:

- The National Library;
- Hanoi Architectural University Library

LIST OF THE PUBLISHED WORKS RELATING TO THE DOCTORAL THESIS

PUBLICATIONS

1. Pham Thanh Tra, "*Parametric method and building the parameter system for architecture",* Vietnam Journal of Construction – Ministry of Construction , 11, 68, 2018, **ISSN 0866-8762**.

2. Pham Thanh Tra, Le Thi Hong Na, *"Identifying the shophouse's façade space structure types in HCMC"*, Vietnam Journal of Construction – Ministry of Construction, 12, 37, 2018, **ISSN 0866-8762.**

3. Pham Thanh Tra, "*The concept of building envelope - space and shophouse's façade - space structure"*, Architecture Magazine, Vietnam Institute of Architects, 3, 76, 2019, **ISSN 0866-8617.**

RESEARCH WORKS

1. Pham Thanh Tra, *"The existing of shophouse's façade*- *space structure in HCMC",* research work for VIETNAM NATIONAL UNIVERSITY HO CHI MINH CITY - HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY, 2019, code: **T-KTXD-2018-54.**

INTRODUCTION

1. The need of doing this thesis

Climatic architectural design is a big part of "sustainable architectural development". For low-rise and adjacent buildings (especially the shophouses) on traditional or new streets in HCMC, the front façade plays an important role. This is the architectural component that separates the inside and the outside of the building, has the ability of creating a comfortable environment, so it must be studied systematically. In the second half of the 20th century, "performance-based building design" was formed and became an inevitable trend in the world. To consider the effectiveness of architectural solutions, the *parametric method (PM)* is one of the outstanding methods. Applying PM to architectural design is the process of checking the effectiveness of a series of architectural options, through computer softwares to choose the optimal one.

2. Research purposes and goals

Purposes: establishing the front facade of shophouses to adapt to the climate conditions in Ho Chi Minh City to solve the relationship between architecture and climate.

Goals:

- Structurizing the front facade and combining it into structural cases → parameterizing the front façade structure (building a parameter system for the structure) → parameterized model, variations and survey values of the parameter system (Building input data for PM)
- Simulation on the computer according to the survey values of the parameters
- Proposing a method to calculate the climatic adaptability according to the output simulation data → find the appropriate value for the parameter system according to this calculation (Processing the output data of PM)
- Detailize architectural solutions for the front façade

3. Research subject

The front facade of shophouses

4. Research scope and limitations

Scope of time: applying to 2040

Scope of space: Research shophouses on commercial and service streets in the old area of Ho Chi Minh City. The shophouses selected for the survey are those with front facades that have common features on the whole route and are heavily affected by the West sun.

Limitations:

- Consider the values of the climatic parameters as fixed, and the values of the architectural parameters to be varied to find the desired results.
- A set of components that belong to the front facade of a shophouse.
- Research on thermal and light comfort.

5. Research methodology

Survey methods; Methods of analysis and synthesis; Scientific simulation and experimental methods; Method of consulting experts; Parametric method.

6. The scientific and practical valuation of the thesis

- Create favorable conditions for architects to apply the parametric method by structurizing the facade of the shophouse and then parameterizing this structure.
- Helping architects simplify the choice of solutions & improve the efficiency of architectural design of shophouses in general and shophouses in HCMC in particular through a system of suitable variations.
- Adding to the content of architectural research, to the architect training framework program as well as to the database for the system of codes, standards and design manuals, contributing to improving the capacity in management administration.

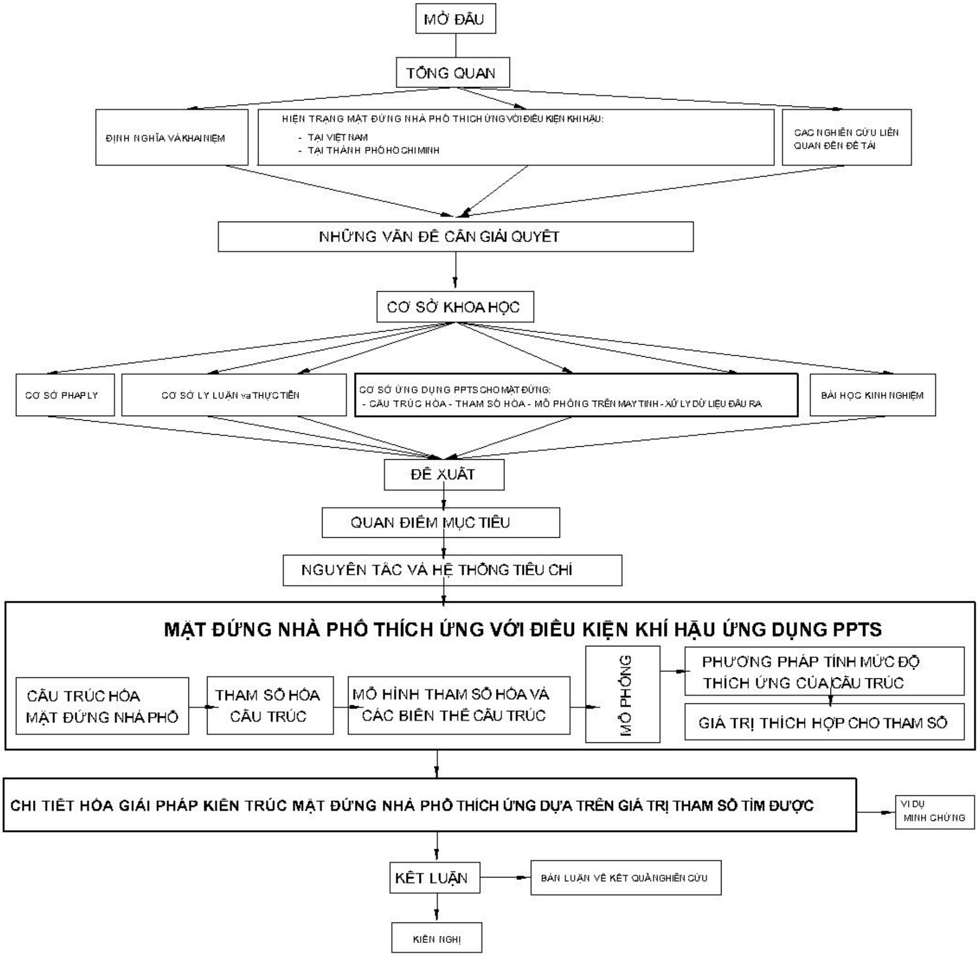
7. Results and Contributions

- Proposing opinions, principles and criteria system on building front facades of shophouses to adapt to the climate conditions of HCMC by applying PM
- Quantify the front facade through structurizing (dividing the facade into layers with components and relationships), parameterizing the structure (representing the structure into a parametric system), parameterized model and variations.

- Proposing a new approach for architects in quantitative design, especially the application of PPTS in architectural design in general and townhouses in particular..
- Contributing to the theoretical system of adaptive architecture by proposing methods to calculate the adaptability of the structure..

8. The thesis structure

THESIS STRUCTURE DIAGRAM



CHAPTER 1: OVERVIEW OF THE CLIMATIC ADAPTIVE SHOPHOUSE'S FRONT FACADE

1.1 Definitions, concepts and terminologys

As defined by The Pew Research Center on Global Climate Change, a *building envelope* is the interface between the inner space of the building and the outside environment, which includes walls, roofs, and foundations - functions as a thermal barrier, playing an important role in determining the amount of energy required to maintain a comfortable indoor environment.

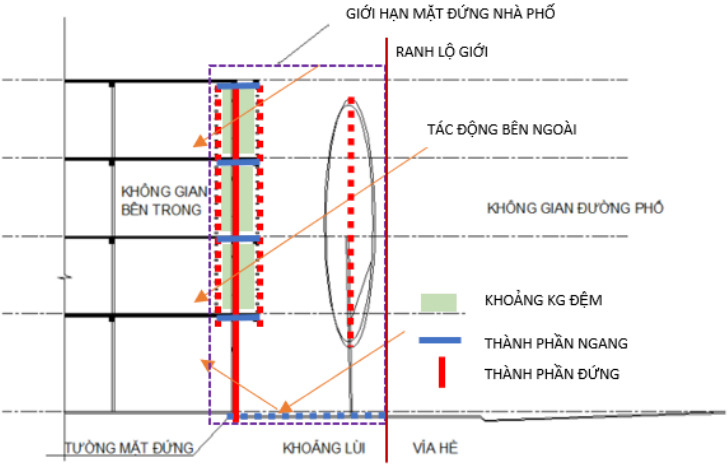
The *multi-layer building envelope* is a collection of architectural components and buffer spaces separating architectural space from urban space, which significantly affects the microclimate comfort inside the building.

The number of layers is the number of times the external impacts must pass through to reach innner space as well as the layout and number of components, which can be divided into the following types: 0.5-layer, 1-layer, 1.5-layer, 2 layers, 2.5 layers, 3 layers…

According to Loonen (2013), *Climate-adaptive building shell* (CABS) is a term in building engineering that describes the group of facades and roofs that interact with the variability in their environment in a dynamic way. Well-designed CABS have two main functions: they contribute to energy-saving for heating, cooling, ventilation, and lighting, and they induce a positive impact on the indoor environmental quality of buildings.

Service-commercial houses are considered as shophouses with lower floors for commercial business or service and upper floors for living. This type of building has a narrow front facade but has a considerable depth to the back, the two sides and the back are almost adjacent to the house next door, leading to natural impacts mainly on the front and roof of the building. In this thesis, Service-commercial houses are called *shophouses* for short.

The front facade of the shophouse is the vertical cover including many components and buffer spaces, acting as an intermediary between the inner space and the street space. Through the facade, the impacts of the natural environment are changed significantly before entering the house. The front façade of a shophouse that adapts to climate conditions is a façade that designed and built to limit the negative impacts and promote the good effects of local climatic conditions to ensure comfort inside. This facade consists of many components. These components need to be analyzed for their properties and the relationship between them should also be clarified.



Horizontal components are components whose surface conforms to the ground at an angle less than 45 degrees such as walkways, open courtyards, balconies, loggias, terraces, part of roof at standard height, flower, grass…

Vertical components are components whose surface conforms to the ground at an angle greater than 45 degrees such as trees, outer walls, windows, doors, fence gates, balcony planters, vertical louvers, advertisement frames …

1.2 The practical of shophouse's front façade in similar countries and Vietnam

Front facades of shophouses in some countries have similar conditions: Bangkok, Thailand; Pak chong town, Nakhon Ratchasima, Thailand; Capital Kuala Lumpur, Malaysia; Georgetown, Penang, Malaysia; Colombo, Sri Lankan, shows that this subject has been studied but not uniformly.

Front facade of shophouses in Vietnam: Hanoi Old Quarter; Hanoi Extension Quarter; Phu My Hung New Quarter, HCMC.

1.3 The existing of climatic adaptive shophouse’s front facade in HCMC

The existing of the shophouse’s front façade in HCMC

The current status of the shophouse’s front facade was surveyed through 201 houses in the old area of HCMC. The shophouses selected for the survey were built legally, especially to the regulation No. 135/2007/QD-UBND, which focuses on streets with a width of more than 8m that are heavily affected by the West sun.

Preliminary assessment, the front façades of the surveyed shophouses have differences in size, elevation, and morphology, as well as not having any relationship with each other but have difference styles from places. This is explained by the fact that these buildings were built and transformed through many historical periods as well as the interference of different cultures. Old and new houses are built and exist interwoven and mixed. Some houses have not yet complied with the city's regulations, especially with the situation of expansion and encroachment on allowed space. The architectural form of the front facade is mostly built simply, almost out of order, not really in harmony and not suitable for local climatic conditions.

Climatic conditions in HCMC and The indoor environmental quality (IEQ)

Survey of the indoor environmental quality (IEQ) of shophouses (including thermal comfort, natural ventilation and natural lighting) shows that most of the living space in shophouses in HCMC has not yet met the demand of IEQ including heat, wind and light (Dr. Le Thi Hong Na, 2017).

In general, the surveyed shophouses, although heavily affected by the West sun, have not been satisfactorily handled right from the initial design stage. Partly because people are not aware of the importance of design work, as well as most architects are still unfamiliar with "performance-based building design" and have not paid attention to applying quantitative solutions to the project.

1.4 Relevant research works

The research related to the topic includes the following contents: about the facade design of shophouses, about bioclimatic architecture, about the design of the building envelope, about the "double skin facade" (DSF), about the application of simulation software in architectural design. However, there seems to be no research about the shophouse’s front facades in a quantitative way to solve the relationship between architecture and climate in order to achieve comfortable conditions.

1.5 Remaining problems to be solved

It is necessary to set up the front facade of the shophouse to adapt to the outside climate and ensure the comfort inside the house in Ho Chi Minh City.

Need a new approach for architects to quantitative design methods.

CHAPTER 2: SCIENTIFIC BASIS FOR CLIMATIC ADAPTIVE SHOPHOUSE’S FRONT FACADE BY APPLYING PARAMETRIC METHOD

2.1 Legal foundations

National Technical Regulation No. 09:2017/BXD; Regulation QCVN 17:2013/BXD on outdoor advertising media; Regulation No. 135/2007/QD-UBND on architecture of shophouses in existing urban areas in HCMC; Decision No. 3457/QD-UBND approving “Regulation on management of space, urban landscape architecture in the existing central area of Ho Chi Minh City (930ha)”; Decision No. 836/QD-UB-VX in 1994 regarding “Regulations on outdoor advertising activities in Ho Chi Minh City”.

2.2 Theoretical foundations

2.2.1 The relationship between architecture and climate

Architecture and climate have a two-way reciprocal relationship. The front facade of the shophouse also has a reciprocal relationship with the climate. Therefore, when studying the front facade, it is necessary to consider a system that includes both the facade and the climatic elements. In this study, the above relationship has to be solved by a quantitative method to ensure indoor comfort.

Heat and light was chosen to solve the relationship between architecture and climate.

2.2.2 Adaptive architecture

Adaptive Architecture is a multi-disciplinary field concerned with buildings that are designed to adapt to their environments, their inhabitants and objects as well as those buildings that are entirely driven by internal data.

2.2.3 Passive design

Passive design uses layout, fabric and form to reduce or remove mechanical cooling, heating, ventilation and lighting demand. Examples of passive design include optimising spatial planning and orientation to control solar gains and maximise daylighting, manipulating the building form and fabric to facilitate natural ventilation strategies and making effective use of thermal mass to help reduce peak internal temperatures.

2.2.4 Microclimate comfort conditions

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation (ANSI/ASHRAE Standard 55). The human body can be viewed as a heat engine where food is the input energy.

Visual comfort is a satisfying and pleasant feeling for the human eye's ability to see in the architectural spaces. Light is one of the environmental factors that play an important role, greatly affecting work productivity and human health.

2.2.5 Parametric method

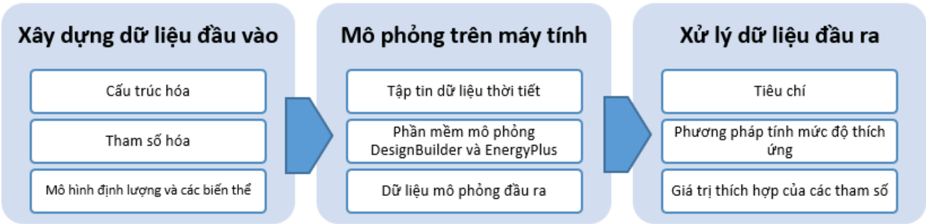
Within the limits of this thesis, the architectural design by the parametric method is a processes that represent the architecture as a system of parameters with survey values. When changing the value of the parameters, there will be a change in the result (output architecture state). Compare the results with each other to find the desired result with the corresponding parameter values.

2.3 Revelant practices

Energy efficient and environmentally friendly housing practices (the world's first passive house in Darmstadt, Germany); application of double skin facade (DSF) to architecture (GSW Headquaters project, Berlin, Germany); application of parametric design in architecture (new Council building (CH2) in Melbourne, Australia).

2.4 Applying parametric method to the climatic adaptive shophouse's front facade

Applying parametric method to architecture design is the process that involves several steps to try different values of the parameter, of which the most important steps include the construction of the input data (structurizing architectural system, parameterizing this structure, models and variations), simulation on computer and processing the output simulation data (find appropriate values of parameters) → architectural solutions



2.4.1 Structurizing the shophouse's front façade (clarifying the façade structure)

Structurizing the front facade of a shophouse is the identification of the main components constituting the facade and finding out the properties and relationships between those components. According to the survey, there are many Horizontal components (HC) and Vertical components (VC), but only a few components significantly affect the indoor microclimate, called needed components.

In total, there are 18 components of the shophouse's front facade. In which, there are 9 HC and 9 VC. However, based on the survey, it is possible to combine similar components and remove no-needed components to draw out 8 needed components (3 HC and 5 VC), those have a significant affect on the microclimate inside the building.

The components selected to be surveyed are 8 needed components based on actual data of 201 houses, in order to assess specifically about constitute, materials, distance, position.... Thereby, it is possible to draw out the common properties and relationships between the components to form the basis for the process of structurizing the shophouse's front façade.

2.4.2 Parameterizing the shophouse's front façade structure (building the parametric system for the façade structure)

Architectural parameters are data about the architecture itself such as total dimensions, number of floors, inclination, torsion, etc. or data on properties and characteristics of components and structures such as materials, colors, shapes, insulation... In addition, these can be a form of data representing relationships between architectural components such as the distance between those, the ratio of door holes and wall surfaces, porosity of the sunshade system...

Climatic parameters are climate data such as temperature, humidity, precipitation, amount of sunshine, wind speed, etc.

With PM, the architectural system needs to be parameterized (represented) into a parameter system (including architectural parameters and climatic parameters). Within the thesis, the climatic parameters are assigned a fixed value, so the parameter system for architecture is a collection of architectural parameters, changing the values of architectural parameters to change the output results. The value of the parameters when the architecture reaches the desired state is called the optimal or complete parameter value.

The basis to propose surveyed values of the parameter system to find the suitable values:

PM is a method of testing a series of surveyed values of the parameter to find the most suitable value. With the help of a computer and programming software, the process of testing takes place in a continuous and linear manner with a lot of values to obtain the optimal value of the parameter. However, be limited in resources and research time, the thesis only tests some surveyed values of the parameter. The selected parameter values for the survey include extreme values and current state-values.

2.4.3 Simulation on the computer

EnergyPlus (free and developed by The United States Department of Energy (USDOE)) is the simulation software selected to perform the simulation step in PM. This software has the ability to provide data on heat radiation, natural light, operation of HVAC systems, energy consumption, costs, project life cycle, CO2, NOx emissions prediction, CO… However, EnergyPlus does not have a user-friendly and easy-to-use interface for architects, so it is necessary to combine with DesignBuilder software to be able to perform simulations intuitively.

2.4.4 Processing the output simulation data

The data exported from the simulation software such as the amount of heat (kW), wind speed (m/s) or illuminance (lux) are called raw data. Data in its raw form does not return much value that is useful to an organization/business or an architect, so raw data needs to be processed by collecting and transforming it into usable information.

2.5 Experiences of applying parametric method to the climatic adaptive architectural design

2.5.1 Lessons of solving the relationship between architecture and climate by parametric method

Rossano Albatici and Francesco Passerini have researched: "*Building shape and heating requirements: a parametric approach in Italian climatic conditions*". According to that, the use of PM in Bioclimate design is mentioned to solve the relationship between architecture and climate to ensure comfortable indoor conditions and minimize energy requirements. In that relationship, the shape of the building plays an important role, so it needs to be studied. With 16 basic modular blocks, the author transforms the building shape into 4 forms based on the arrangement of these modular blocks to find the optimal shape corresponding to the appropriate value of the shape parameters.

2.5.2 Lessons of chosing the optimal building shape by parametric method

In 2010, Roland Hudson completed his doctoral thesis *"Strategies for parametric design in architecture"* at the University of Bath, UK. In it, the author has studied the ways of applying PM in architectural shaping and applying it to actual works to demonstrate. The construction of Lansdowne Road Stadium (LRS) was applied parametric design and the project information was published.

CHAPTER 3: PROPOSING CLIMATIC ADAPTIVE SHOPHOUSE'S FRONT FAÇADE IN HCMC BY APPLYING PARAMETRIC METHOD

3.1 Opinions

Solving a part of the relationship between architecture and climate in a quantitative way, towards "performance-based building design" through constructing the shophouse's front facades that can adapt to the climate conditions in HCMC by applying parametric method.

In particular, the front facade is the connecting part between architecture and climate, including man-made material components and buffer spaces on the facade, this is considered as a filter of the outside affects. Depending on the different affects, this filter needs to be changed through the selection and organization of components to achieve high efficiency in microclimate comfort and reduce the energy consumption of the building.. Quantitative adaptive facades are based on structurizing, parameterizing, building a parameterized model, identifying variations and selecting surveyed values. The effectiveness is considered through proposing a method to calculate the climatic adaptation of the structure. The impact factors selected for research are 3 factors including heat, light and wind with high impact and prominent on the facade....

3.2 Principles

Principles of ensuring quantification for PM, including identification of quantitative input data and processing of output data. These data are used for simulation and calculation in PM.

The principle of ensuring flexibility and freedom in architectural design through a system of suitable variations can be applied in many different cases.

The principle of ensuring adaptation to climatic conditions through the calculation of the working capabilities of the structure.

3.3 Criteria system

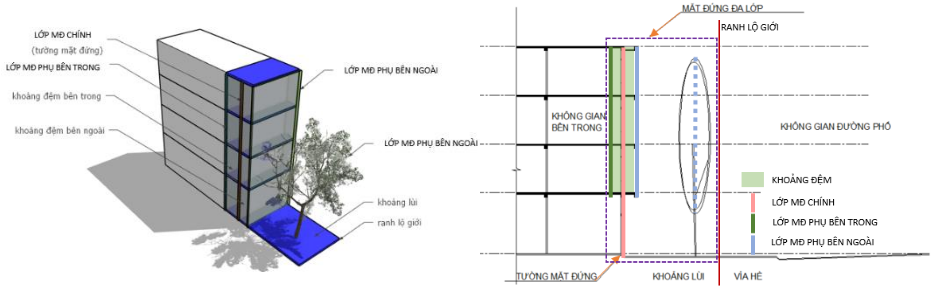
- *Criteria for structurizing:* Selection of components in the structure; combine into layers in the structure.

- *Criteria for the quantification of the structure:* Select the suitable parameters; Specifies the range of the parameter values and surveyed values.

- *Criteria for adaptability to climate conditions*: Ensure thermal comfort; Ensure visual comfort.

3.4 Proposing climatic adaptive shophouse's front façade in HCMC by applying parametric method

3.4.1 Structurizing the front facade and structural cases

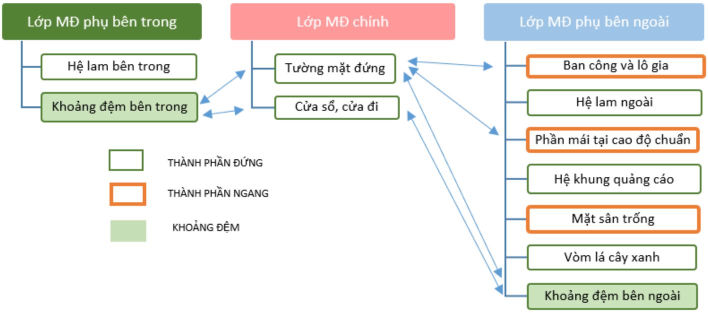


The front façade of the shophouse is proposed to be structurized into a multi-layer façade system (MLFS) which is determined through the architectural components, physical shapes, materials, correlation relationships, position, etc. At that time, front façade structure is created by façade layers and the buffers between the layers including the main facade layer, the inner sub-layer, the outer sub-layer, the inner and outer buffer spaces.

The main façade layer always appears in the structure including the main wall and components such as windows, doors, and voids. This is the common cover, meeting the requirements of basic cover for the protected area. With most of the surveyed shophouses, this layer stay at the position that the same with the land boundary line. Only a few shophouses set back from that boundary, then the main façade layer is also backed in accordingly.

The inner façade layer is made up of adjacent components inside the main wall. This layer is combined with the main layer by a small distance to form the inner buffer spaces.

The outer façade layer is made up of adjacent components outside the main wall, playing an important role in the relationship with the impact factors. For surveyed shophouses, this layer is usually located outside the land boundary line at a distance not greater than the allowed distance that components protrude on the streets. For shophouses set back from the land boundary line, this layer will include the components in the setback area. Usually, the more components in the outer layer, the smaller the influence of the impact factors. Therefore, architectural solutions need to use this opportunity to arrange and organize structural components in this layer. The outer layer is combined with the main layer by a common distance from a few centimeters to 1.4 meters to form the outer buffer spaces.



Each layer includes some of the eight needed components. The main layer includes main wall and doors. The inner layer includes the inner shading system and the inner buffer spaces. The outer layer includes the balcony/loggia, the outer shading system, the part of roof at the standard height, the advertising system, the empty courtyard and the trees in the setback area and the outer buffer spaces.

The surveyed data show that the main layer appears in all shophouses, so the appearance of the inner and outer sub-layers forms four types of arrangement including type K1, type K2 (2 types) and type K3. Each type of arrangement above has ways of combining different HC and VC to form different structural cases. Selecting and grouping similar cases into 12 cases of the structure.

STT	Trường hợp	Lớp MĐ chính	Lớp MĐ phụ bên trong	Lớp MĐ phụ bên ngoài		Tính phổ biến
				TPN	TPĐ	
1	K1	x	o	o	o	x
2	K2-1	x	x	o	o	x
3	K2-2	x	o	x	x	x
4	K2-3	x	o	x	o	x
5	K2-4	x	o	o hoặc x/2	x	x
6	K2-5	x	o	x	x	x
7	K2-6	x	o	x	x/2	x
8	K2-7	x	o	x/2	x	x
9	K3-1	x	x	x	x	
10	K3-2	x	x	x	o	
11	K3-3	x	x	o hoặc x/2	x	
12	K3-4	x	x	x	x	
Ghi chú: x-có xuất hiện và ảnh hưởng đến cấu trúc MĐĐL; x/2-bán xuất hiện; o-không xuất hiện						

For a complex front facade, it is necessary to divide it into separate façade pieces. Then, each façade piece will be a different structural case. A facade can be a combination of many structural cases.

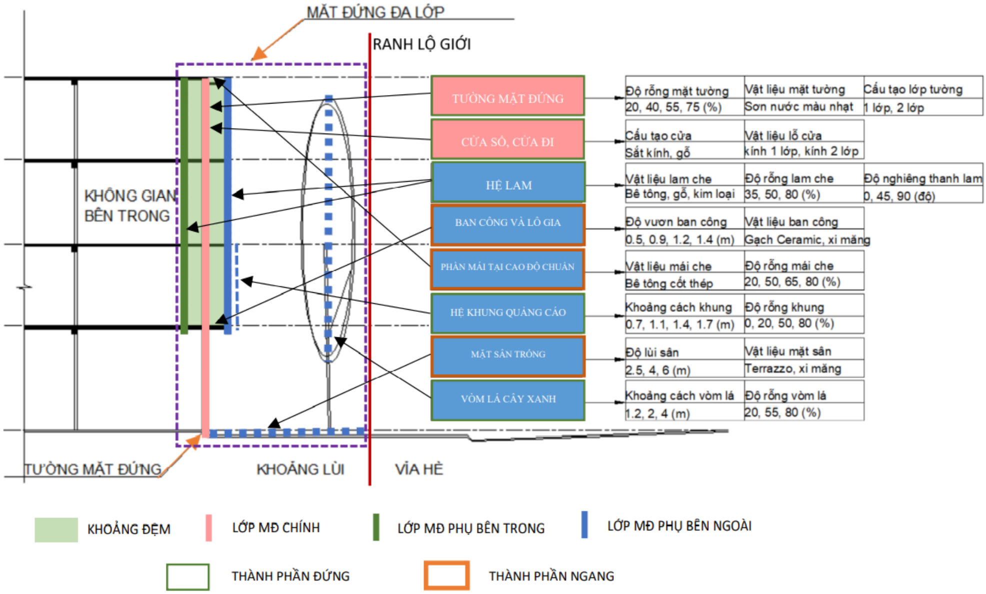
3.4.2 Parameterizing the front façade structure and survey values

The structure of the MLFS for PM needs to be parameterized into a parameter system. Selecting suitable parameters for this system through parameterization of properties, relationships of structural components, criteria for the quantification of the structure (Select the suitable parameters; Specifies the range of the parameter values and surveyed values)

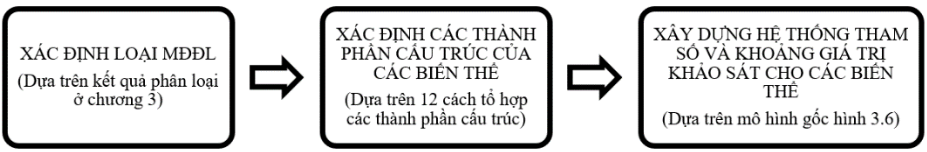
The structure of the shophouse's front facade was analyzed and then represented as an 18-parameter system. Depending on the different calculation goals, the needed parameters are selected and the parameter values used for survey are proposed.

3.4.3 Parameterized model and variations

Based on the results of structurizing and parameterizing, a parameterized model of multi-layers front façade structure has been proposed. This model can be used as an input to PM to find the desired output.



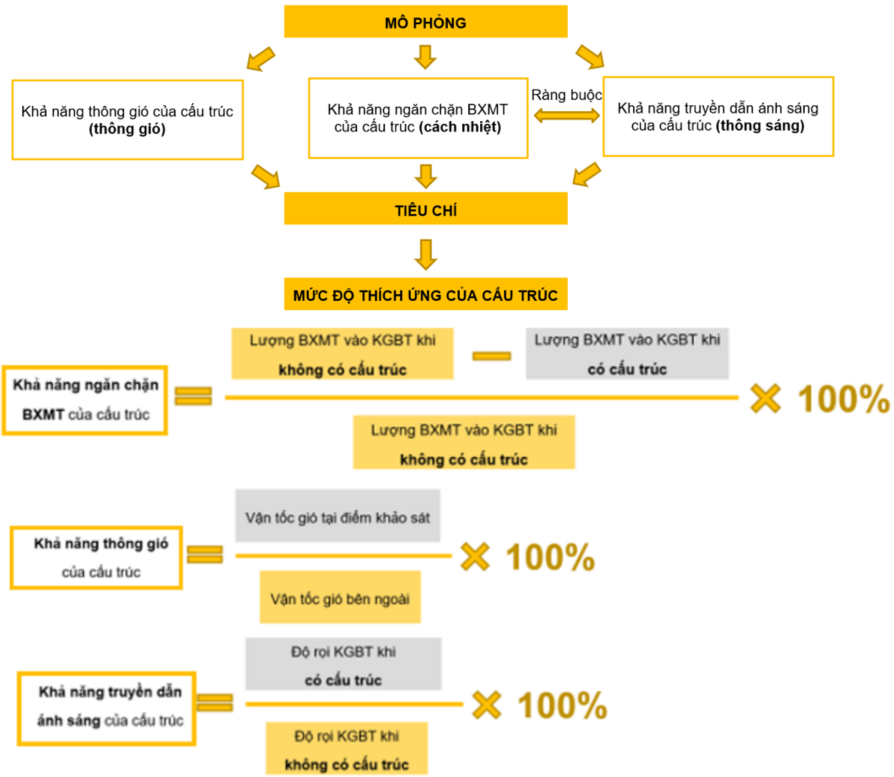
The proposed model is the original model for the most common case of the structure. The model, when applied to specific structural cases, needs to be modified accordingly in terms of the number and arrangement of structural components, this leads to the parameter system also being transformed to create variations of the model. Then, the model and variantions can meet different requirements in the architecture. Identify variations through the following steps:



3.4.4 Method to calculate the structure's climatic adaptability according to the output simulation data

To evaluate the adaptability of the structure after having the output simulation data (raw data), the method of calculating the adaptability of the structure has been proposed. This calculation method is based on the quantitative calculation of the working abilities of the structure, including the ability to blocking sun radiation (insulation), the ability to ventilate and the ability to transmit natural light.

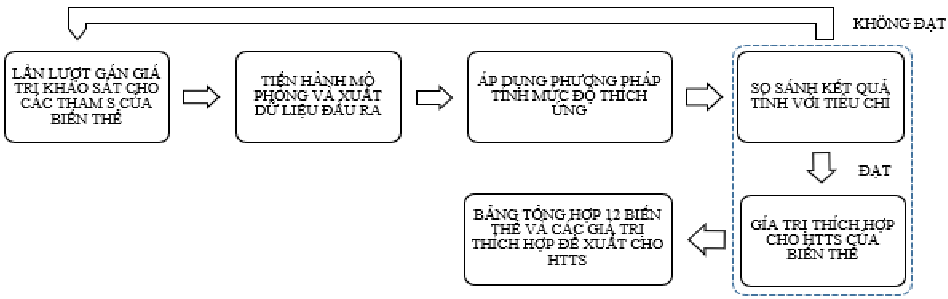
Based on the working abilities (sun radiation insulation, ventilation and light transmission), the degree of meeting the adaptability criteria is shown in the following table. In which, there are 4 levels from low to high as follows: Poor → Pass → Fair → Good.

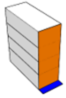
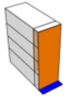
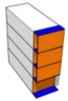
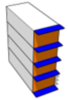
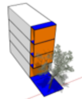
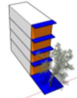
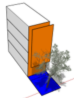
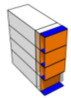
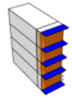
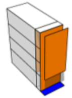
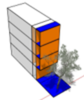


Đảm bảo tiện nghi nhiệt			**Đảm bảo tiện nghi ánh sáng**		**Đánh giá tính THÍCH ỨNG**
Khả năng ngăn chặn BMXT	**Khả năng thông gió**	Đánh giá nhiệt	**Khả năng truyền dẫn ánh sáng**	Đánh giá ánh sáng	
>85%	≥20%	Tốt	30-50%	Tốt	Tốt
			15-30%	Khá	
			9.132 - 15%	Đạt	
			< 9.132%	Kém	Khá
	< 20 %	Khá	>9.132%	Tốt/khá/đạt	Khá
70-85%	≥20%	Khá	30-50%	Tốt	Khá
			15-30%	Khá	
			9.132 - 15%	Đạt	
			< 9.132%	Kém	Đạt
	< 20 %	Đạt	>9.132%	Tốt/khá/đạt	Đạt
50-70%	≥20%	Đạt	30-50%	Tốt	Đạt
			15-30%	Khá	
			9.132 - 15%	Đạt	
			< 9.132%	Kém	
	< 20 %	Kém	>9.132%	Tốt/khá/đạt	Kém
<50%	≥0 %	Kém	Tốt/khá/đạt/kém		Kém
Ghi chú: 4 mức độ đánh giá từ cao đến thấp: Tốt → Khá → Đạt → Kém					

The results of applying the method of calculating the climatic adaptability to find the appropriate parameter values for the structure

The appropriate value for the parameter system of the variations can be determined through the steps of testing different survey values of the parameter and summarized in the following table:



	Tên các biến thể	K1	K2-1	K2-2	K2-3	K2-4	K2-5	K2-6	K2-7	K3-1	K3-2	K3-3	K3-4
													
Hệ thống tham số và giá trị đề xuất cho các biến thể	1 Vật liệu mặt tường	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu	sơn nước sáng màu
	2 Độ rỗng mặt tường	20%	40%	40%	70% / 40%	70%	70%	70%	70%	40%	40%	40%	40%
	3 Cấu tạo lớp tường	Thêm 1 lớp cách nhiệt	tường gạch 1 lớp / Thêm 1 lớp cách nhiệt	tường gạch 1 lớp	tường gạch 1 lớp / tường gạch 1 lớp	tường gạch 1 lớp	tường gạch 1 lớp	tường gạch 1 lớp	tường gạch 1 lớp	tường gạch 1 lớp	tường gạch 1 lớp	tường gạch 1 lớp	tường gạch 1 lớp
	4 Vật liệu lỗ cửa	kính 2 lớp low-e	kính 1 lớp thường / kính 1 lớp low-e dày 3mm	kính 2 lớp low-e / kính 1 lớp low-e dày 3mm	kính 2 lớp low-e / kính 1 lớp low-e dày 3mm	kính 1 lớp low-e dày 3mm	kính 1 lớp low-e dày 3mm	kính 1 lớp low-e dày 3mm	kính 1 lớp low-e dày 3mm	kính 1 lớp thường	kính 1 lớp thường	kính 1 lớp thường	kính 1 lớp thường
	5 Cấu tạo cửa	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên	Giữ nguyên
	6 Vật liệu lam che		Tùy chọn	Tùy chọn		Tùy chọn	Tùy chọn		Tùy chọn	Tùy chọn	Tùy chọn	Tùy chọn	Tùy chọn
	7 Độ rỗng lam che		35% / 50%	50%		50%	65%		65%	50%	50%	50%	80%
	8 Độ nghiêng thanh lam		0°	45°		45°	0°		0°	0°	0°	0°	0°
	9 Độ vươn ban công (lô gia)			Giữ nguyên (1.2m)	Giữ nguyên (1.2m)		Giữ nguyên (1.2m)	0.5m		Giữ nguyên (1.2m)	Giữ nguyên (1.2m)		Giữ nguyên (1.2m)
	10 Vật liệu ban công (lô gia)			Giữ nguyên	Giữ nguyên		Giữ nguyên	Giữ nguyên		Giữ nguyên	Giữ nguyên		Giữ nguyên
	11 Vật liệu mái che			Tùy chọn	Tùy chọn		Tùy chọn	Tùy chọn		Tùy chọn	Tùy chọn		Tùy chọn
	12 Độ rỗng mái che			0%	0%		80%	35%		Tùy chọn	Tùy chọn		Tùy chọn
	13 K.cách khung quảng cáo	0.2m	0.2m	Sử dụng hệ lam che bên ngoài làm quảng cáo	0.2m	Sử dụng hệ lam che bên ngoài làm quảng cáo	Sử dụng hệ lam che bên ngoài làm quảng cáo	0.2m	Sử dụng hệ lam che bên ngoài làm quảng cáo	Sử dụng hệ lam che bên ngoài làm quảng cáo	0.2m	Sử dụng hệ lam che bên ngoài làm quảng cáo	Sử dụng hệ lam che bên ngoài làm quảng cáo
	14 Độ rỗng khung quảng cáo	0%	0%		65%			0%			0%		
	15 Độ lùi sân trong						Giữ nguyên (4m)	Giữ nguyên (4m)	Giữ nguyên (4m)				Giữ nguyên (4m)
	16 Vật liệu sân trong						gạch terrazzo	gạch terrazzo	gạch terrazzo				gạch terrazzo
	17 Khoảng cách vòm lá						4m	4m	4m				4m
	18 Độ rỗng vòm lá						80%	80%	80%				80%
Tính toán các khả năng làm việc của cấu trúc ứng với các giá trị đề xuất cho HTTS ở trên (%)		82.74 / 26.8 / 13.1	88.4 / 26.8 / 5.94	78.57 / 23.8 / 16.86	78.97 / 9 / 39	79.32 / 37.2 / 14.98	91.78 / 43.6 / 6.83	91.9 / 17.6 / 8.54	92 / 52 / 5.25	88.53 / 23.8 / 10.78	85.37 / 9 / 12.88	88.39 / 37.2 / 10.87	84.8 / 43.6 / 4.4
Mức độ thích ứng theo tiêu chí		Khá	Khá	Khá	Đạt	Khá	Khá	Đạt	Khá	Tốt	Khá	Tốt	Đạt

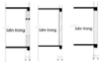
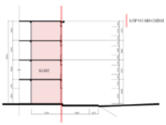
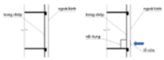
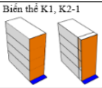
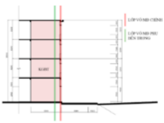
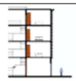
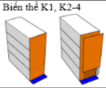
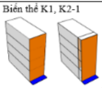
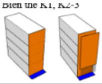
Ghi chú:
- Đối với các trường hợp không có hệ lam che, khung quảng cáo được đề xuất có chiều cao từ mép dưới sàn lầu 1 đến mép dưới cửa sổ lầu 1
- Bảng màu:

Vàng	Khả năng cách nhiệt với giá trị đề xuất (%)	Vàng nhạt	Giá trị ưu tiên 2	Xanh lam	Tham số thuộc lớp MĐ chính
Đỏ	Khả năng thông gió với giá trị đề xuất (%)	Xám	Tham số không xuất hiện	Cam nhạt	Tham số thuộc lớp MĐ bên trong
Tím	Khả năng truyền dẫn ánh sáng với giá trị đề xuất (%)	Hồng	Đánh giá chung với 4 mức: kém, đạt, khá, tốt	Xanh lá	Tham số thuộc lớp MĐ bên ngoài

3.5 Detailize architectural solutions for the front façade arcording to the found values of parameters

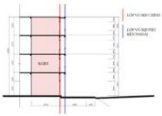
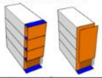
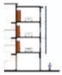
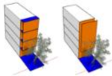
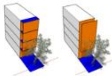
3.5.1 For 1-layer or 2-layer façade with inner sub-layer

These are types of facade structures with only one façade layer including main walls and doors (case K1) or with an additional inner layer (case K2-1). At that time, the main wall is directly affected by the radiation of the west sun and indirect radiation reflected from the road surface and pavement surface. The structural solutions for this case are to prioritize reducing the mass of inside space to enhance the buffer spaces on the façade by arranging structural layers for walls and doors, adding some material components. Or set back the main wall within a certain distance to switch to another type of more effectively structure.

Loại cấu trúc theo số lớp vỏ MĐ	Giải pháp					
	Mô tả		Khoảng giá trị các tham số về cấu tạo không gian	Khoảng giá trị các tham số về đặc tính các thành phần chi tiết	Biến thể được áp dụng	Minh họa 3D
	1. Tường đôi 2 lớp/ tường đơn dày 330mm		Khoảng cách giữa 2 lớp tường: <110mm	Độ rỗng mặt tường: khoảng 20% Vật liệu lỗ cửa: kính 2 lớp low-e	Biến thể K1 	
- Loại MĐĐL có 1 lớp 	2. Tường 2 lớp (trong chớp ngoài kính)		Khoảng cách giữa lớp kính và lớp chớp: 40 -110mm	Độ rỗng mặt tường: khoảng 20% Vật liệu lỗ cửa: kính 1 lớp thường Tường đơn dày 250-330mm	Biến thể K1 	
	3. Kết hợp lô gia và tường 2 lớp		Độ lùi lô gia: 1.5-3m Bề rộng lô gia: 1.2-1.5m Tường 2 lớp: khoảng cách giữa 2 lớp tường: <110mm	Độ rỗng mặt tường: khoảng 20% Vật liệu thông sáng: kính 2 lớp low-e	Biến thể K1, K2-1 	
- Loại MĐĐL 2 lớp có lớp MĐ bên trong 	4. Lam/ cây leo bên trong tường MĐ		Khoảng cách giữa tường ngoài và hệ lam/cây leo bên trong: 0,2-2m	Độ rỗng mặt tường: 40% Vật liệu lỗ cửa: kính 2 lớp low-e Tường gạch 1 lớp thường Độ rỗng lam: khoảng 50% Độ nghiêng thanh lam: 45	Biến thể K2-1 	
	5. Tấm chắn nắng/ cây leo sát mặt ngoài tường MĐ		Khoảng cách giữa tường và hệ lam/cây leo bên ngoài: <0,2m	Độ rỗng mặt tường: khoảng 40% Vật liệu lỗ cửa: kính 2 lớp low-e Tường gạch 1 lớp thường Độ rỗng lam: khoảng 50% Độ nghiêng thanh lam: 45	Biến thể K1, K2-4 	
	6. Tầng 1,2,3: tường ngoài lùi vào 1,5-3m kết hợp tấm chắn nắng Tầng 4: tường 2 lớp		Độ lùi tầng 1,2,3: 1,5-3m Tường tầng 4 hai lớp cách nhau <110mm	Độ rỗng mặt tường tầng 1,2,3: 70% Vật liệu lỗ cửa tầng 1,2,3: kính 2 lớp thường Độ rỗng mặt tường tầng 4: 20% Vật liệu lỗ cửa tầng 4: kính 2 lớp low-e Tường tầng 1,2,3 đơn dày 220mm thông thường	Biến thể K1, K2-1 	
	7. Tấm chắn nắng/ cây leo		Độ vươn hệ chắn nắng: Hết bề ngang tuyến đường(cần có đề xuất về độ vươn với các tuyến phố chịu ảnh hưởng nhiều bởi nắng Tây)	Độ rỗng hệ chắn nắng: 65% Độ nghiêng thanh lam: 90	Biến thể K1, K2-5 	

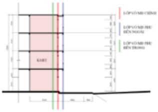
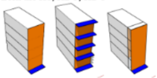
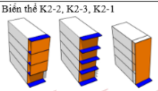
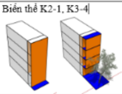
3.5.2 For 2-layer façade with outer sub-layer

This type of structure is common on the streets including the structural cases K2-2, K2-3, K2-4, K2-5, K2-6, K2-7. Shophouses with this type of facade structure already have an external buffer space with different arrangement of components. Therefore, the solutions for this type of structure are mainly to modify and change a small extent of the existing structural elements belonging to the two layers in order to find a suitable and most effective value for the parameter system.

Loại cấu trúc theo số lớp vỏ MĐ	Giải pháp					
	Mô tả		Khoảng giá trị các tham số về cấu tạo không gian	Khoảng giá trị các tham số về đặc tính các thành phần chi tiết	Biến thể được áp dụng	Minh họa 3D
- Loại MĐĐL 2 lớp có lớp MĐ bên ngoài 	1. Lan can, tấm chắn nắng bằng kính gắn ở mép trên và dưới ban công.		Độ vươn ban công tối đa theo quy định: 0,9-1,4m	Độ rỗng mặt tường: khoảng 40% Tường gạch 1 lớp thường Vật liệu lỗ cửa: kính 2 lớp thường Độ rỗng mảng kính 1 tầng: 50%	Biến thể K2-2 	
	2. Tấm chắn nắng/ cây leo hình L tại mỗi tầng		Độ vươn ban công tối đa theo quy định: 0,9-1,4m	Độ rỗng mặt tường: khoảng 40% Tường gạch 1 lớp thường Vật liệu lỗ cửa: kính 2 lớp thường Độ rỗng hệ chắn nắng: khoảng 50% Độ nghiêng thanh lam: 45	Biến thể K2-2 	
	3. Tấm chắn nắng/ cây leo hình L lớn cách tầng		Độ vươn ban công tối đa theo quy định: 0,9-1,4m	Độ rỗng mặt tường: khoảng 40% Tường gạch 1 lớp thường Vật liệu lỗ cửa: kính 2 lớp thường Độ rỗng hệ chắn nắng: khoảng 50% Độ nghiêng thanh lam: 45	Biến thể K2-2, K2-4 	
	4. Tấm chắn nắng ngang/ cây leo toàn bộ MĐ		Độ vươn ban công tối đa theo quy định: 0,9-1,4m	Độ rỗng mặt tường: khoảng 40% Tường gạch 1 lớp thường Vật liệu lỗ cửa: kính 2 lớp thường Độ rỗng hệ chắn nắng: khoảng 50% Độ nghiêng thanh lam: 45	Biến thể K2-4 	
	5. Tấm chắn nắng/ cây leo hình L cho tầng trên cùng		Khoảng cách vòm lá:<4m Khoảng cách hệ chắn nắng với tường -tối đa theo quy định: 0,9-1,4m	Độ rỗng vòm lá: 80% Tường và cửa tầng 1,2,3 thông thường Độ rỗng mặt tường tầng 4: 40% Vật liệu lỗ cửa tầng 4: kính 2 lớp low-e Độ rỗng hệ chắn nắng: khoảng 50% Độ nghiêng thanh lam: 45	Biến thể K2-5, K2-7 	
	6. Tấm chắn nắng/ cây leo tầng trên cùng		Khoảng cách vòm lá:<4m Độ vươn hệ chắn nắng: 2,5-4m (cần có đề xuất về độ vươn với các tuyến phố chịu ảnh hưởng nhiều bởi nắng Tây)	Độ rỗng vòm lá: 80% Tường và cửa tầng 1,2,3 thông thường Độ rỗng mặt tường tầng 4: 40% Vật liệu lỗ cửa tầng 4: kính 2 lớp low-e Độ rỗng hệ chắn nắng: 50% Độ nghiêng thanh lam: 0	Biến thể K2-5, K2-7 	

3.5.3 For 3-layer facade

This type of shophouse has a lot of components inside and outside the main wall, including the structural cases K3-1, K3-2, K3-3 and K3-4. At that time, radiation when penetrating the structure was mostly reduced before entering the protected area. Cases with green components in front (K3-4) will significantly reduce the amount of direct radiation and the amount of indirect radiation reflected from the street surface. The main structural solution is to increase light transmission into the protected space by creating "light traps" or arranging more skylights in the middle of the house to enhance light and ventilation for these cases. In addition, in the absence of a horizontal component (K3-3), additional sun protection solutions for the top floor should be added.

Loại cấu trúc theo số lớp vỏ MĐ	Giải pháp					
	Mô tả		Khoảng giá trị các tham số về cấu tạo không gian	Khoảng giá trị các tham số về đặc tính các thành phần chi tiết	Biến thể được áp dụng	Minh họa 3D
- Loại MĐĐL có 3 lớp 	1. Tạo KG đệm: tường ngoài tầng 1,3 lùi vào		Độ lùi tầng 1 và 3: 1,5-3m	Độ rỗng mặt tường tầng 1,3: khoảng 70% Vật liệu lỗ cửa tầng 1,3: kính 2 lớp low-e Độ rỗng mặt tường tầng 2,4: 20% Vật liệu lỗ cửa tầng 2,4: kính 2 lớp low-e Tường đơn dày 220mm thông thường	Biến thể K1, K2-3, K2-1 	
	2. Tạo KG đệm: tường ngoài tầng 2,3 lùi vào 1,5-3m		Độ lùi tầng 1 và 3: 1,5-3m	Độ rỗng mặt tường tầng 1,3: 70% Vật liệu lỗ cửa tầng 1,3: kính 2 lớp low-e Độ rỗng mặt tường tầng 2,4: 20% Vật liệu lỗ cửa tầng 2,4: kính 2 lớp low-e Tường đơn dày 220mm thông thường	Biến thể K2-2, K2-3, K2-1 	
	3. Lam/ cây leo bên trong tường MĐ, trồng cây xanh tại khoảng lùi		Khoảng cách giữa tường ngoài và hệ lam/cây leo bên trong: 0,2-2m	Độ rỗng mặt tường: 40% Vật liệu lỗ cửa: kính 2 lớp low-e Tường gạch 1 lớp thường Độ rỗng lam: khoảng 50% Độ nghiêng thanh lam: 45	Biến thể K2-1, K3-4 	

3.6 Examples to prove

To demonstrate the effectiveness after applying the model and solution for renovation and new construction, shophouse No. 174, Tran Quoc Thao, District 3 (surveyed in chapter 1) was selected. This shophouse belongs to the busy street, 30m wide, has 4 floors with the ground floor being business space and the upper 3 floors for living. The building is heavily influenced by the sun from the west, however, the solutions to block the sun radiation and prevent heat are still do not guarantee effectiveness as well as lose the beauty of the street. At that time, the working abilities of the current structure are calculated as follows:

o The ability to block sun radiation of current structure:

$$BXT_{HT} = BXT_{TMDV} + BXT_{PN1} + BXT_{PN2} + BXT_{PN3}$$
$$= 3.71 + 1.26 + 1.29 + 1.29 = 7.55 \text{ kW}$$
$$KNNBX_{HT} = (BXT0/5x4 - BXT_{HT})/(BXT0/5x4)x100\%$$
$$= (42.038/5x4-7.55)/(42.038)/5x4)x100\% = \mathbf{77.55\%}$$

o The ability to ventilate of current structure:

$$KNTG_{HT} = (VHT/V0)\ x100\% = 0.1/5\ x\ 100\% = \mathbf{2\%}$$

o The ability to transmite the light of current structure:

$$ĐR_{HT} = (ĐR_{PN1} + ĐR_{PN2} + ĐR_{PN3})/3 = (204+213+217)/3$$
$$= 211.33 \text{ lux}$$
$$KNTAS_{HT} = ĐR_{HT}/\ ĐR0\ x\ 100\% = 211.33/1095 = \mathbf{19.3\ \%}$$

3.6.1 In case of renovation

Calculation results show that the ability to block radiation of the renovated structure is significantly improved from 77.55% up to 88.76% and the ventilation ability is kept the same, then the level of thermal comfort criteria is met from pass to fair. However, the light transmittance was reduced from 19.3% to 11.32%, which means that the level of meeting the light comfort criterion was reduced from fair to pass.

3.6.2 In case of new building

Calculation results show that the radiation blocking ability of the new structure is 85.9% along with the ventilation ability of 48.4%. This results in a good level of thermal comfort. The light transmission ability of 16.9% only meets the light criteria at a fair level. Thus, the proposed new shophouses are more efficient than the existing ones, improving the adaptability from pass to good.

3.7 Discussion and applicability

The thesis has proposed a new approach in applying PM in architecture and applied to the shophouse’s front facade in particular.

Determining the needed components to find the needed parameter in the process of parameterizing the structure needs to be demonstrated more clearly through other simulations. In addition, the limit range needs to be widened and the survey values of the parameter need to be numerically enhanced.

In addition to the three working abilities of the structure proposed in the thesis, it is necessary to study and expand others such as the ability to prevent noise from entering, dust resistance, sound insulation ability, etc…

Because the number of survey values of the parameter is not large (only some extreme values in the limited range are checked), the obtained results are close to the optimal results. Architects use these results as a quantitative benchmark to develop their plans in the right direction.

The reliability and accuracy of the EnergyPlus software have been proven through the actual studies of Assoc.Prof.PhD. Nguyen Anh Tuan (Da Nang University of Technology).

It is possible to expand the study area and research scope for different climate conditions.

Further studies may be related to shophouse construction management solutions so that the thesis's recommendations can be put into practice in the process of building and developing shophouses to help adapt to climate conditions by applying PM.

CONCLUSIONS AND RECOMMENDATIONS

1. Conclusions

- The results of façade structurizing, parameterizing, parameterized model, variations and detailize architectural solutions for the front façade → established the front façades that adapt to climate conditions.
- The method of calculating the climatic adaptability and the appropriate parameter values for the structure → have solved the relationship between architecture and climate in a quantitative way.

Thus, the thesis has solved 2 key problems that the thesis has pointed out, suitable for the purpose and towards performance-based building design.

2. Recommendations

In order for the results of the thesis to be widely applicable in practice and effective, the thesis has the following recommendations:

- Architects and design consultants need to raise their attention, awareness, and responsibility for ensuring efficiency in architecture based on quantitative solutions and building energy problems.
- It is necessary to build a synchronous legal mechanism, to mobilize the movement of architectural design to adapt to local climate conditions towards "performance-based building design", which is an inevitable trend today.

In the near future, shophouses are still the type of house that have a large number of buildings in Ho Chi Minh City, so shophouses play a big role, especially the front façade component. It is necessary to have separate policies and documents to suit the shophouses on the streets heavily influenced by the westward sun in Ho Chi Minh City.