THE SYNERGISTIC EFFECTS OF THERMAL ENVIRONMENT AND VISIBILITY UPON THE POPULARITY OF STREET RETAIL AREA.
----A CASE STUDY OF A RETAIL ARCADE IN GUANGZHOU

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----A CASE STUDY OF A RETAIL ARCADE IN GUANGZHOU

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LIST OF SYMBOLS AND ABBREVIATIONS

PET Physiologically Equivalent Temperature

UTCI Universal Thermal Climate Index

SUMMARY

For every building design process, three elements should be taken into considerations: building type, geometry and environment. These elements mutually influence one another; the aim of architectural design is to find the most appropriate combination of them. The three elements could be analyzed and modeled by using tools and methods in the fields of architecture typology, space syntax, and building performance simulation. The use of such tools supports not only qualitative research and evaluation, but also quantitative comparison.

This work focuses on the arcade, a type of street retail space in South China. The overhanging 2nd floor not only moderates the thermal and environmental quality of the passage beneath it, but also affects the visibility of store fronts. In this study the conditions created in arcaded environments are compared to those in a normal street retail environment. Several analysis tools are used: Isovist and daylighting analyses are combined in order to model the visibility of store fronts; environmental simulation is used to assess thermal performance (e.g. temperature, wind speed, and humidity).

The results are used to characterize the attraction of stores which are similar regarding size, location and retail type but are interfaced to different types of outdoor space. By combining the results of the analysis with observations of the stores' popularity the research concludes with recommendations about the design of store environments that are more likely to attract visitors.

Key words: arcade, building environment simulation, space syntax, isovist, daylighting, outdoor thermal performance, retail space

Tools: Depthmap, Grasshopper, Diva, Ladybug, Honeybee, IES-VE

CHAPTER 1. INTRODUCTION

1.1 Motivation

Typology, environment, geometry are three elements that interaction with each other. Architecture could be classified into different typologies with their design features. The performance simulation strategy or space syntax analyses tools might different based on different typologies. And these two technical tools could help architects making decisions or supporting the design strategies they made. A better processing for making design decisions should be considering both environmental performance and the geometry relationship. The parameter's change based one technical tool on should be tested using the other tool to verify if the change is in the positive direction or not.

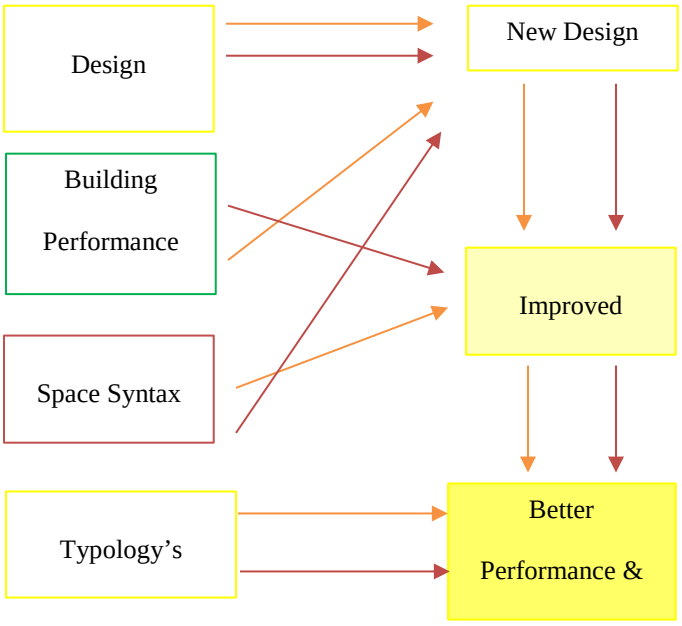


Figure 1 – design processing diagram.

However, before getting to the design processing, some case studies are needed to find out how geometry and environmental are synergistic influence the design results. This

thesis picked arcade commercial building in Guangzhou as a case study to find out how this two parameters got into a balance that could provide the best benefit to the retail owners.

Arcade is a pretty popular building type in south China. The stores located on the ground level of arcade building have an overhanging from the second level which provides a shaded outdoor corridor space for customers.[1] Meanwhile, the shading also provides a negative influence on visibility. The arcade building's design finally attracted more customers for the stores located on its ground level. So the study considered arcade store and its outdoor corridor space could be used as a case study to show how to find a balance between geometry and environmental performance in design works.

The case study's three research factors are visibility, thermal environment comfort, and popularity. Visibility and thermal environment are two factors that have interactions in different stores' model, and customer popularity is the factor to evaluate which store is more successful than others. Finally, the study wants to find out the stores with what kind of visibility and thermal environment conditions could have the highest popularity, and how could this result help retail space owners and commercial street designers to find or design a space to attract the most customers.

1.2 Background

1.2.1 Arcade retail space

1.2.1.1 Location regional and history

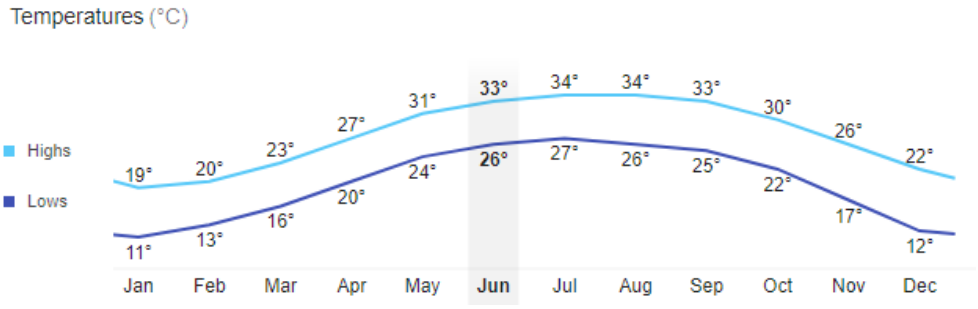
Guangzhou is located at south China costa area. Guangzhou, also known as Canton, is the capital and most populous city of the province of Guangdong. Located in southern China on the Pearl River about. Guangzhou has a history of over 2,200 years and was a major terminus of the maritime Silk Road and continues to serve as a major port and transportation hub today, as well as one of China's three largest cities. [2]

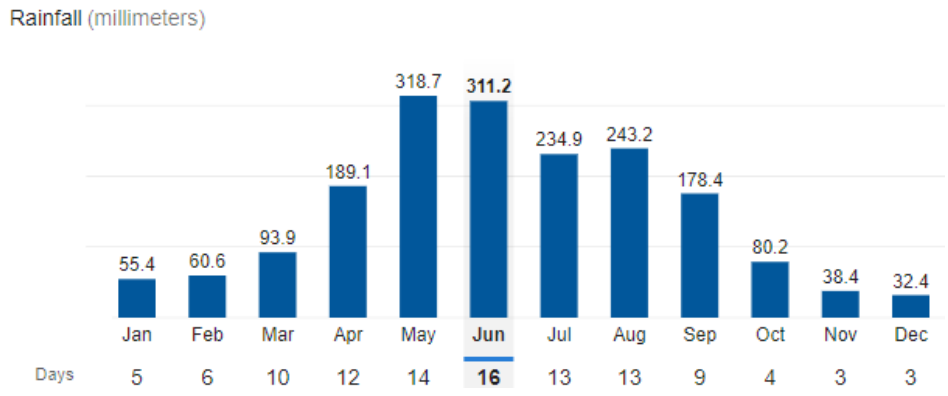
The history of arcade buildings dates to about 2,000 years ago in Greece. It took root in China only in the early 20th century. At the beginning of the 20th century, Guangzhou began a campaign of urban expansion by widening roads after Chinese businessmen returned from Southeast Asia. These businessmen combined the features of ancient Greek architecture with a Chinese style based on the traditional Cantonese residential buildings. Its ground level has normally been used as street retail space with the upper levels for residence.[3] With its protruding structure stretching skyward from the second level over the sidewalk, the arcade building was built to feature a traditional urban architectural style that combines Cantonese and Western styles. Because of the arcade buildings, the arcade commercial street seems like a shaded corridor that keeps the shops along the sidewalk as well as pedestrians safe from the scorching sun and rain that characterize Guangzhou's tropical climate.

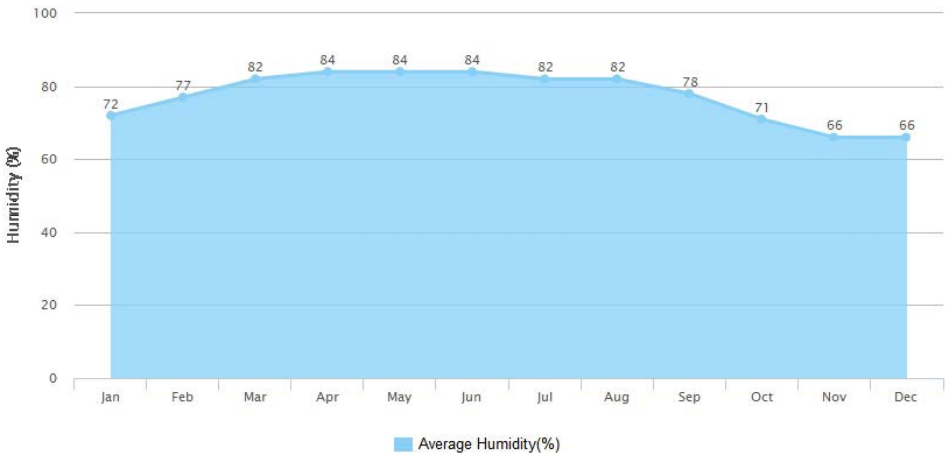
The Guangzhou city government started a face-lifting project to protect the old arcade building about 20 years ago. The arcade buildings district got the renovation at the same time. The renovation kept the most important feature of the building, which is the shaded corridor for ground level commercial space. As a result, the renovations formed the longest arcade-building street in Guangzhou.[1] Now it has become one of the busiest commercial areas in the city, and we have seen better business than before. The city's

figures bear that out. This arcade street district has become one of the most regularly visited commercial streets in Guangzhou, with about 400,000 visits per day. The stores picked for this study are located at this commercial district, on the Dishifu street (an arcade building street) and Baohua street (a normal retail building street).

1.2.1.2 Weather and climate







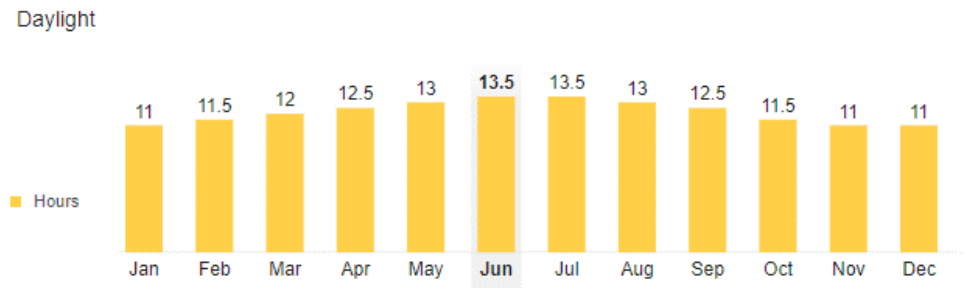


Figure 2– climate condition of Guangzhou.

Despite being located just south of the Tropic of Cancer, Guangzhou has a humid subtropical climate influenced by the East Asian monsoon.[4] Summers are wet with high temperatures, high humidity, and a high heat index. Winters are mild and comparatively dry. Guangzhou has a lengthy monsoon season, spanning from April through September. The highs temperature during the whole year is over 20 C, and half of the months' temperatures are higher than 30 C. Daylighting hours during the whole year is evenly around 12 hours, which means the solar radiance levels are similar for every month. There are six months (from March to August) that get rainfall for more than 10 days. The relative humidity level is also really high. The RH value is higher than 60% over the whole year, and more than half of the year's RH value is higher than 80%.[5]

High temperature with strong solar radiance level and lots of rainy days makes its important for street stores' customers to have a suitable outdoor space with a shady and dry thermal situation. Furthermore, the weather in Guangzhou is always changing, and arcade is suitable for the unpredictable climate here and provide great convenience for residents.

1.2.2 Related studies

1.2.2.1 Human thermal comfort level

With some research about others studies results, the human comfort level is an important factor for evaluating the thermal environment.[6][7][8] Thermal comfort index such as the Physiologically Equivalent Temperature (PET)[9] and Universal Thermal Climate Index (UTCI) [10] were utilized to assess the thermal comfort conditions of selected areas. Results from related studies indicated that the substantial role of environmental factors and thermal adaptation parameters strongly affect human thermal comfort level in outdoor spaces.[11][12]

1.2.2.2 Isovist, daylight, and visibility

An isovist is defined as the set of points visible from a given vantage point in space and with respect to an environment. The shape and size of an isovist are liable to change with position.[13] The isovist method is relevant to behavioral and perceptual studies in architecture, especially in the areas of view control, visibility, and spaciousness judgments.[14] The illumination of space is another parameter that would influence the visibility level of a space.[15] The visibility analysis of one surface should consider the isovist and illuminance together.[16] Although currently the possible measures of some of the properties in such combined analysis are still under developing,[17] the horizontal comparison of these two parameters in this study could illustrate some points for the results.

CHAPTER 2. METHODOLOGY

The study firstly picked two streets as a study area, one arcade commercial street and one normal commercial street. Then a series of analysis about street geometry relationships, traffic rush hours, and retail types were done to prove that the outdoor thermal environment and store front's visibility level were the only two parameters that might influence the popularity of the stores on the streets.

After the analysis for controlling variable, the following step is to simulate or analysis the outdoor thermal comfort and store front's visibility on two different streets using software tools. Three types of typical stores with their outdoor pedestrians' area were chosen to be used in these analyses. The integrated temperature, UTCI (Universal Thermal Climate Index), was used for showing outdoor corridor's thermal comfort level. The integrated visibility, Isovist combined with daylight factor, was used for showing the store front's visibility condition.

Meanwhile, the on-site counting of different pedestrians' popularity was done to evaluate the store's popularity. The more passengers that the store's front corridor or pedestrian has, the higher popularity the store would have. And the higher popularity the store has, it would more likely to be defined as a successful retail space. After observation and data analysis, five stores' popularity results could be used for later analysis. Three of them locate on the Dishifu street, and the other two stores that have different pedestrian types locate on the Baohua street.

The results analysis of this study will focus on two comparisons, one is between the stores on different streets, and the other is between the stores on the arcade street. Data about visibility, thermal, or popularity is used to find out their relationships with each other.

And then to finally find out what kind of store's outdoor pedestrian space could attract the most customers.

2.1 Study area

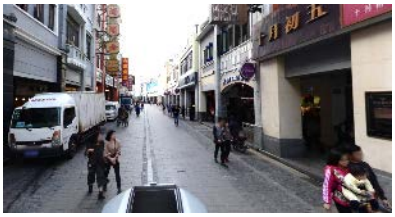
The study picked two streets, the Dishifu Street and the Baohua Street. They both located in the same commercial district. Dishifu Street is an arcade commercial street and Baihua Street is a commercial street with normal building type. Their pedestrian's shading solutions could divide them into three groups, normal store elevation without any shading, normal store elevation with trees in front, and the stores located at the arcade building shaded ground level.

The location of the study area and stores listed in the maps below.

Figure 3 –Location of two streets

Type B, normal store with trees in

Type B, normal store with trees in front



Type C, arcade store

Type A, normal store

Figure 4 – Location of store types on the streets

All three types of storefront have continuous elevations. And they all have a pedestrian space for customers and passengers. The openings of those storefronts are big enough for indoor cooled air to blow out into the outdoor pedestrian space. The attraction of cooler air flow on passing pedestrians is assumed to be similar in the three types.

2.2 Other variables that might influence the popularity

The study started with assuming both thermal comfort level and visibility level are different for these three groups' stores mentioned above. The following part is to show that

the differences in other factors for these three groups other than thermal comfort and visibility won’t be an influencing factor in this stud. This part’s analysis and interpretation would focus on the transportation system’s geometry analysis using space syntax,[18] streets’ traffic data from Baidu map online, and stores’ retail type summarizing.

2.2.1 Transportation system geometry

In order to show that the popularity of Baohua street and Dishifu street isn’t influenced by their geometry relationship with other streets, the study needs to prove that they have a similar connection level to the surroundings. In other words, some analysis needs to be done to show these two streets have the same reachable level for the users.

Space syntax is used for analyzing the geometry of the transportation system of Baohua street, Dishifu street, and the streets surrounded. Axial space is the type chosen to show the geometry analysis results. Axial space shows straight sight-line and possible path of the map.[19] Those sight-lines and possible path were drawn using single straight lines in AutoCAD, and then export them into Depthmap for further analysis.

Two parameters in axial space analysis results were chosen to show the connection level: Integration and Choice. Integration measures how many turns have to be made from a street segment to reach all other street segments in the network, using shortest paths. The street has the highest Integration value is the one with the highest connection level.[20] The Choice measure is easiest to understand as a 'water-flow' in the street network. Each time an intersection appears, the remaining value of flow is divided equally amongst the splitting streets, until all the other street segments in the graph are reached. The streets with the highest total values of accumulated flow are said to have the highest Choice values.[21] But some research has shown that the Choice result might be trickier than Integration, so here we just used Choice value as a reference value. Integration is the main value to be considered in this part of the analysis.[22]

Figure 5 – Integration result from Depthmap

This Integration map shows Baohua street and Dishifu street (marked with white dotted lines) have the Integration value around the same range. And that means the connection level of these two streets are similar within the range this map shows. Theoretically, the integration measure shows the cognitive complexity of reaching a street, and is often argued to 'predict' the pedestrian use of a street: the easier it is to reach a street,[23] the more popular it should be. If only consider the Integration analysis result, the Baohua street and Dishifu street should have the same popularity.

Figure 6 –Choice of study district

The Choice Depthmap analysis results for these two streets are around the same level too. This result gave another proof that the popularity level of Baohua street and Dishifu street should be the same.

Basing on the analysis above, we can tell that the transportation system geometry relationship's different of Baohua street and Dishifu street won't cause a popularity different between them.

2.2.2 Traffic rush hours for the selected street

Besides the transportation system geometry analysis of Baohua street and Dishifu street, the traffic rush hours of this two street is another parameter might influence the popularity level on the streets.

The traffic data could be gathered from Baidu map.[24] Since the simulation and gate counting (will discuss in detail later) were done based on the noon time period, so the traffic data picked from Baidu map is from 13:00 to 15:00. Weekdays and weekends traffic data are shown on different maps.

Sunday at 13:00

Sunday at 15:00

Thursday at 13:00

Thursday at 15:00

Figure 7 –Rush hours

Both Dishifu and Baohua get congestion at 15:00 on Sunday, and they both slow down at 13:00 on Sunday. Both Dishifu and Baohua slow down at 15:00 on Thursday, they

all get clear at 13:00 on Thursday. Overall, these two streets have similar traffic congestion levels during the same time period.

Same traffic congestions would bring a similar amount of customers to the streets. So the popularity on Baohua street and Dishifu street should be the same while only considering the traffic situations.

2.2.3 The retail store type

After the observation and survey about stores on Baohua street and Dishifu street, the following step is trying to find stores on both arcade street and the normal retail street that have similar size and retail type.

The on-site survey tells that most of the stores on these two streets are clothing store and restaurants. Obviously, the popularity of a restaurant changes based on the time of day. But clothing stores could have a more stable popularity number during most hours during the day. For this reason, this study chose clothing stores on arcade street and normal street as the case study objects. Observation and gate counting are done for the clothing stores with similar sizes. The geometry models used for thermal simulation and visibility analysis are made based on these stores too.

Within the early stage's on-site survey and observation results, the study then picked five clothing stores on Baohua street and Dishifu street as typical cases for later comparison and discussions. The outdoor pedestrian type, the outdoor shading devices' size, and the store front's visibility are the main factors been considered while choosing these stores. (The paper will discuss these factors in detail later)

The stores being picked are listed as below.

Store A: on arcade street, wider corridor, north side of the street, has two signs

Store B: on arcade street, narrower corridor, north side of the street, has two signs

Store C: on arcade street, narrower corridor, south side of the street, has one sign

Store D: on normal street, with trees on side, west side of the street, has one sign

Store E: on normal street, without trees on side, west side of the street, has one sign

Figure 8 –photos of storefront

2.3 Analysis objects and tools

Based on the controlling variable analysis results above, we can tell that the streets have similar connection level on geometry side, the streets have similar traffic rush hours, and the stores on the streets have similar retail types. Those parameters won't be a factor to influence the popularity level of the stores on the streets. So the factors that could influence the popularity of selected stores and their outdoor environment are limited to outdoor thermal comfort and store front's visibility in this research.

The coming part would be introducing the analysis tools used in the study. This study assumes that thermal and visibility are the only two factors that influence the popularity of different stores on the two streets. Thermal comfort and visibility are

simulated by software, and the store's popularity is counted on site. Software used for simulations are Honeybee for calculating the UTCI, Depthmap[25] for Isovist calculation, IES-VE[26] for daylighting analysis,[27] and Gate Counting to gather the popularity data. Furthermore, the results coming from Isovist and daylighting analysis are combined together as one factor to show the comprehensive visibility level under daylight conditions.

2.3.1 Thermal comfort

2.3.1.1 Comfort zone's T, RH

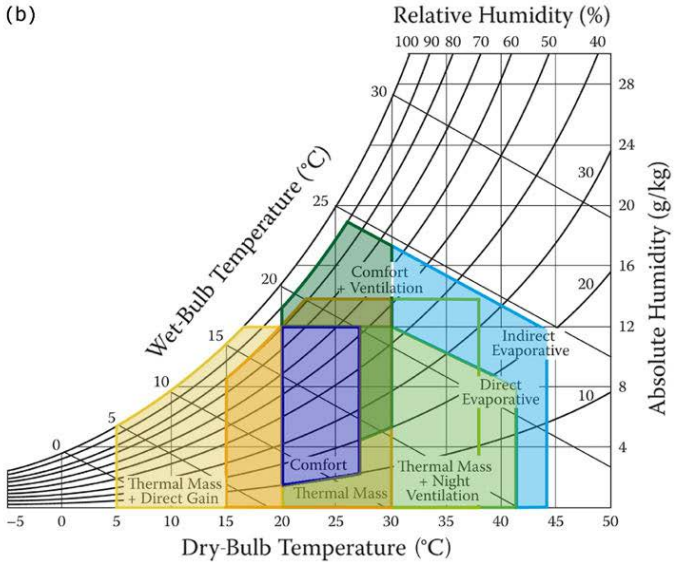


Figure 9 –Psychrometric chart with a comfort zone[28]

Basing on the psychrometric chart above, regardless of the relative humidity, dry bulb temperature needs to be lower than 28 C in order to make the thermal environment in the comfort zone. So most of the days during one year in Guangzhou couldn't have a comfortable environment (based on climate and weather data mentioned in background analysis). The solution for lowing somatosensory temperature is needed in order to get thermal environment conditions closer to the comfort zone.

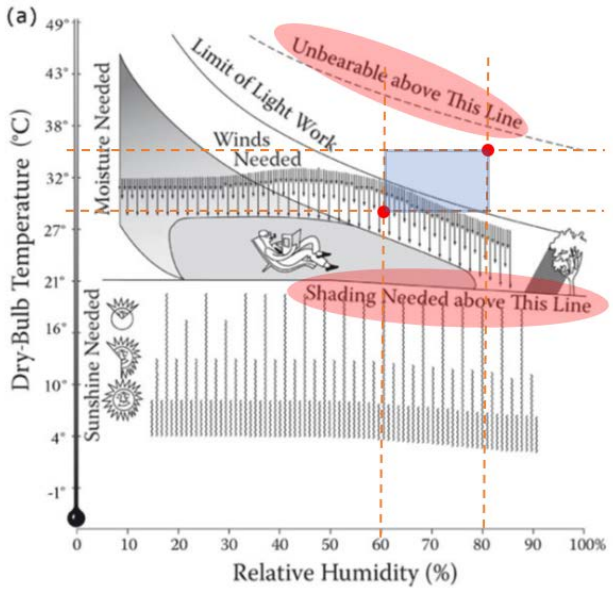


Figure 10 –Shading and wind solutions for uncomfortable thermal environment[28]

The chart above shows how to lower the somatosensory temperature in an uncomfortable thermal environment. For most of the days during one year, the RH and DT of Guangzhou are in the blue square in the chart. The square located above the line “shading needed above this line”, and more than half of it above the line “winds needed”. Having shading devices and higher wind speed could help lower the somatosensory temperature in this situation.

In summary, a higher relative humidity requires a lower dry bulb temperature to get the same comfortable environment for the users. Dry bulb temperature, wind speed, and relevant humidity are three parameters that will influence the somatosensory temperature. The integrated temperature chooses for later simulations should focus on the factors that combined these three parameters in the calculation.

2.3.1.2 Integrated temperature

Over 60 heat stress indices have been proposed to assess high-temperature environments and predict the possibility of heat strain for the body.[10] Each of these indices has their own advantages and drawbacks. The input data for calculating these indices include many atmospheric parameters like airflow velocity, temperature, humidity, solar radiation, and etc.[29] Two integrated temperature, PET (Physiologically Equivalent Temperature) and UTCI (Universal Thermal Climate Index), are chosen for comparison before decides which factor to be used for thermal comfort simulation.

The PET is a thermal index derived from the human energy balance. It is well suited to the evaluation of the thermal component of different climates. As well as having a detailed physiological basis, PET is preferable to other thermal indexes because of its unit (°C).[30][31] UTCI is a value considers dry temperature, relative humidity, solar radiation, and wind speed into account. The basis for the UTCI is defined as the capability of an organism to retain its body temperature within a particular limit even if the surrounding temperature is totally different.

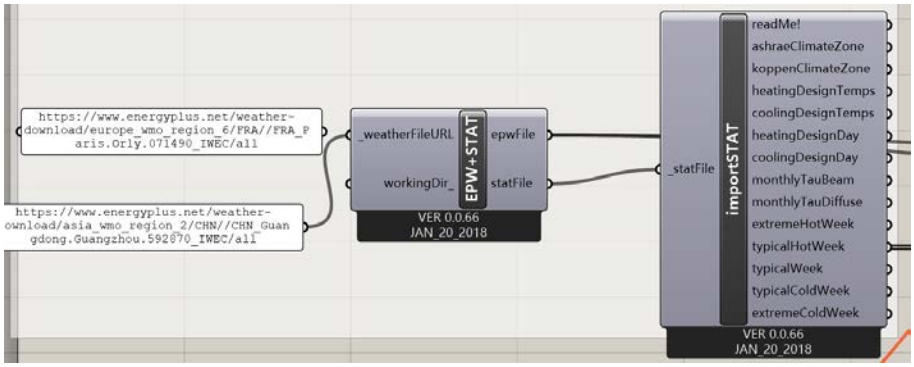
PET is one of the most commonly used indices for measuring heat stress in outdoor spaces, and UTCI is regarded as the reference environmental temperature causing strain. Based on some other studies' conclusion, UTCI has a strong correlative with PET. The r values of these two factors are around 0.9 based on relatively study's analysis.[10] So in this study, all thermal simulation outcomes are translated into UTCI as the main factor for comparison of the different cases.

2.3.1.3 Honeybee and the script used for UTCI calculation

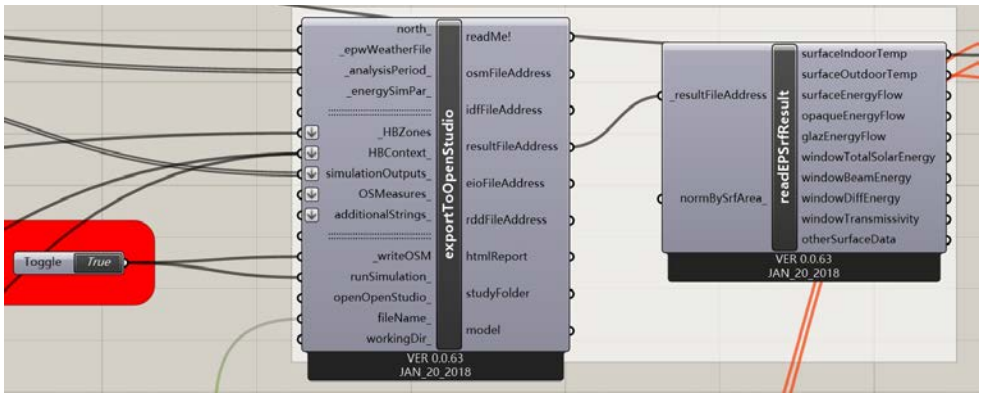
Honeybee is used for doing the UTCI analysis. The core for honeybee is EnergyPlus,[32] and the script[33] in honeybee that could do the UTCI calculation is based on dry bulb temperature, wind speed, solar radiance that came from TMY.[34] TMY (Typical Meteorological Year) data were used in Ladybug and Honeybee to calculate the solar radiation level and outdoor thermal environmental conditions. The TMY are data sets of hourly values of solar radiation and meteorological elements for a 1-year period. Because they represent typical rather than extreme conditions, they are suited for analyzing typical conditions at a location which could be both inside and outside of a building.

The analysis plan is divided into small squares for the calculation, and the accurate level of results is related with the size of squares comparing with the size of the analysis plan. The transparency level of objects creating shading could be adjusted from 0 to 1. This could be used to calculating the shading that created by trees, which isn't totally shaded like an overhanging roof or floor.

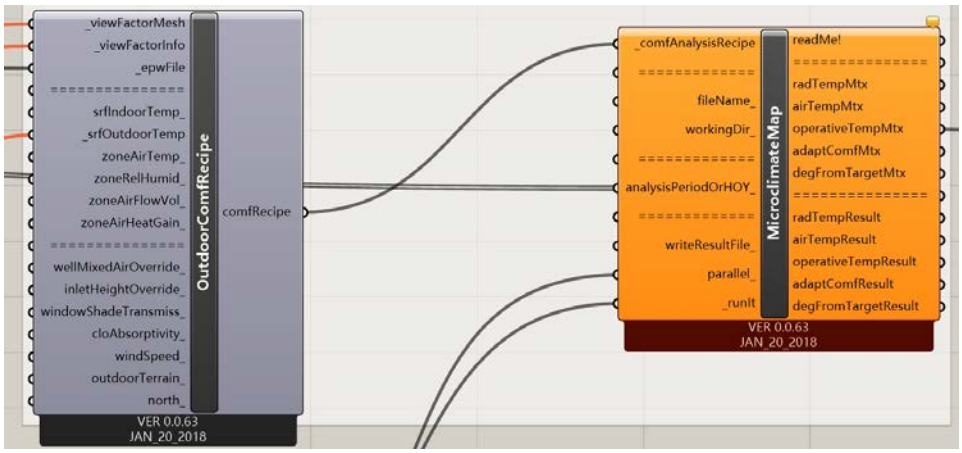
The script used in Honeybee is showing as below:



Step one, select weather file and running period



Step two, run energy simulation



Step three, run microclimate map simulation

Figure 11 –script for calculating UTCI in Honeybee

2.3.1.4 User thermal appreciation survey

Besides the simulation using software, this study also includes a survey about the pedestrians' appreciation of the thermal environment.[31] Temperature, wind speed, solar radiance are included in the survey's questions.[35] The aim of doing such a survey is to have another set of data that could help prove the thermal environment's difference on different streets and pavements.

2.3.2 Visibility level

2.3.2.1 Isovist

A 2D isovist calculated by Depthmap is used as one parameter for evaluating the visibility level of storefronts in this study. The viewer position for the isovist analysis has a big influence on the result.[13] Positions of pedestrians that are looking at a storefront can be separated into three groups: on the street and looking at stores on both sides (orange dot), under the overhanging and looking at stores on the same side (blue dot), under the overhanging and looking at stores on the opposite side (green dot).

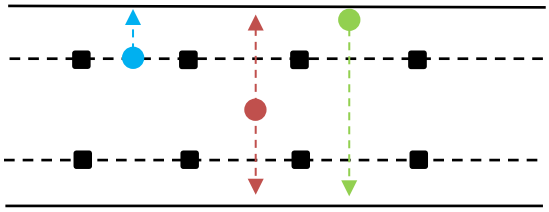


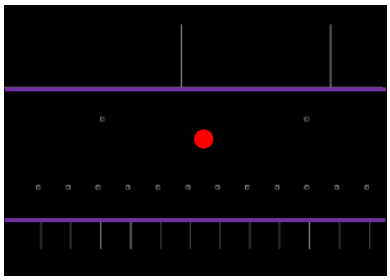
Figure 12 –The positions of calculating isovist

For people standing at the blue point, it is easy for them to know what is offered by the stores next to them. People on the street are mostly walking across the street (refer to the observation and survey results), so the visibility of a storefront is not the key factor for their action at this point. The green dot represents people walking along one side of the arcade street and looking towards the other side of the street's store. The visibility level of those stores' front is an important factor to attract people going across the street and shop. This study's isovist analysis is based on the green dot's location on pedestrian.

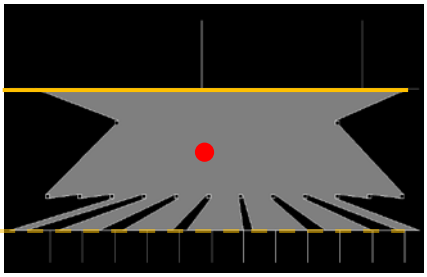
If the isovist result of one side's storefront is continuous, the storefront can be seen from this analysis point. But while the isovist result is not totally continuously, we need to do more analysis to define the visibility level of the storefront. For example, as the

diagrams showing below, purple lines show the two side's elevation used for Isovist analysis. The yellow line on one side shows that elevation has a continuously view while standing at the red dot and yellow dotted line on the other side shows that elevation has a not continuously line while standing at the red dot.

In order to have a more intuitive result for comparison, the study set an evaluation system for the isovist field results. The system tried to transfer the shape into a number that could reflect the relationship of Isovist field to the elevations. If one store's front can be seen continuously, the Isovist level of that store is set as 1. If one store's front is not in one continuously Isovist field, but more than half of the front could be seen, the Isovist level of that store is set as 0.5. If one store's front can't be seen continuously and less than half of the front could be seen, the Isovist level of that store is 0.



The store elevation



The elevation Isovist analysis result

Figure 13 –Isovist explanation diagram

2.3.2.2 Visibility of signage during daylighting

It is possible that some parts that could be seen based on the Isovist results but cannot be seen in reality due to insufficient daylighting level. IES-VE is used in this

research for analysis the daylighting situations of the stores' front. It is assumed that the arcade's corridor can be regarded as an indoor space with big holes on one side.

Daylighting analysis in IES-VE can do the simulation based on time, location, and geometry shape. And it can only choose a horizontal plan from indoor space as the simulation object.[36] In this study, the analysis plan is chosen based on the signage location, since that would be the most attractive thing for pedestrians on the other side to visit the stores located beneath the overhang. Based on signage position from elevation's photo, we set simulation plans on the height of 2.3 meters, 2.6 meters, and 2.9 meters to run simulation separately.

Daylighting factor result in IES-VE is chosen to be used as the parameter to evaluate the daylighting situation of the corridor's area. In architecture, a daylight factor (DF)[37] is the ratio of the light level inside a structure to the light level outside the structure. It is defined as:

$$DF = (Ei / Eo) \times 100\%$$

Where, Ei = illuminance due to daylight at a point on the indoors working plane, Eo = simultaneous outdoor illuminance on a horizontal plane from an unobstructed hemisphere of overcast sky. The result of daylighting factor from IES-VE could be presented as a colored diagram or with the detailed numbers for each subdivided square on the simulation plan. Calculating the average DF value that very next to the signage to show the mean DF of signage during the simulation time. The signage's mean DF of is related to its visibility level, and furthermore, it would influence the store front's integrated visibility level.

In order to have an integrated visibility result, the daylight factor results also need to be transferred into values between 0 to 1. If one store's signage DF is higher than 30, the DF level of that store is set as 1. And if the DF is lower than 5, the DF level of that store is set as 0.

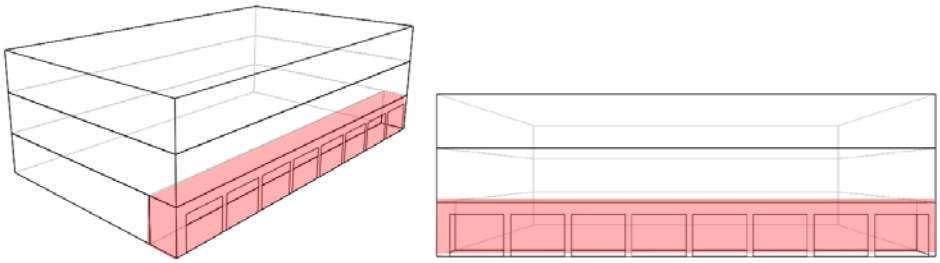


Figure 14 –The corridor's geometry in IES-VE model

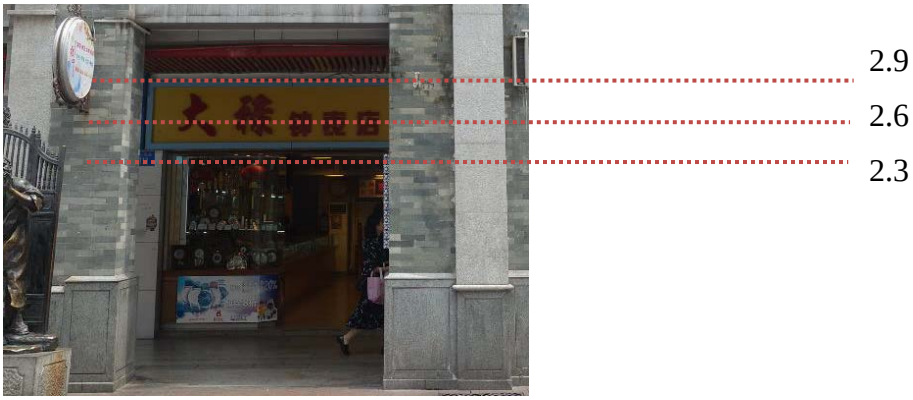


Figure 15 –Simulation plans location on arcade elevation

2.3.2.3 Combined visibility score

Table 1 – combine results from Depthmap and IES-VE

Isovist	Daylight factor on signage	Combined visibility
Yes/ continuously	Above 30	Yes, and attractive/1

Yes/ continuously	Above 5 and below 30	Yes, but not attractive/0.5
Yes/ continuously	Below 5	No/0
More than 50% can be seen/isn't continuously	Above 30	Yes, but not attractive/0.5
More than 50% can be seen/isn't continuously	Above 5 and below 30	Yes, but not attractive/0.25
More than 50% can be seen/isn't continuously	Below 5	No/ 0
Less than 50% and more than 30% can be seen/isn't continuously	Above 30	Yes, but not attractive/0.25
Less than 50% and more than 30% can be seen/isn't continuously	Below 30	No/ 0
Less than 30% can be seen/isn't continuously	Above 0	No/ 0

The combined visibility level can be scored 0 through 1 based on the attractivity levels. With a positive Isovist result, a higher daylighting factor could make a higher combined visibility score of the storefront. With a negative Isovist, no matter how high the daylighting factor of the store front's signage is, the combined visibility level would be zero.

2.3.3 Observation and popularity counting

2.3.3.1 Observation

For the popularity survey, observe land use and urban design variables within the study area is the first step. Within the defined the study area, we need to collect data for urban form variables such as land use and urban design attractors.[38] Summarizing the

store type, entrance type, store size and outdoor corridor type based on collected data. Stores on different streets with similar store type, entrance type, and store size are chosen to be used for gate counting on the next step. (As mentioned above in *study area* and *retail type* sections).

2.3.3.2 Gate counting

Gate counting of the pedestrians on every part of streets is the following step for calculating the stores' popularity. After chose the stores on different streets, an imaginary line is drawn in front of store.[38] A time period is defined (mostly 5 minutes to 10 minutes for one period) for counting. The street is divided into three parts, two pedestrian pavements and the street in between, for separately pedestrian counting during the same time period. For every group, observe pedestrians and cyclists for both directions separately across the full width of the space as shown in diagram.

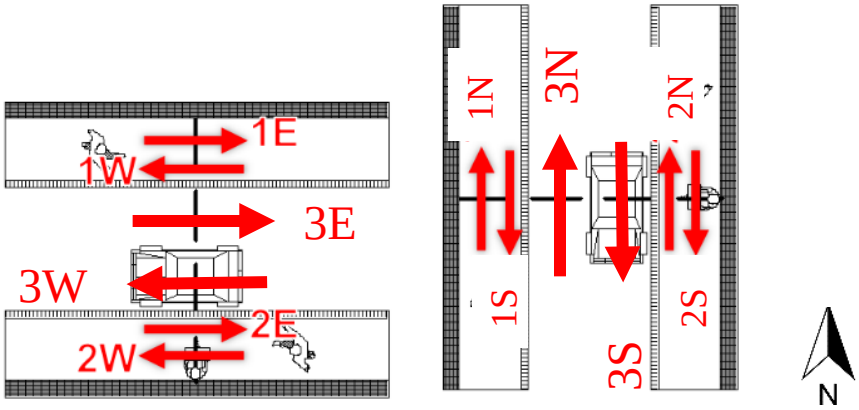
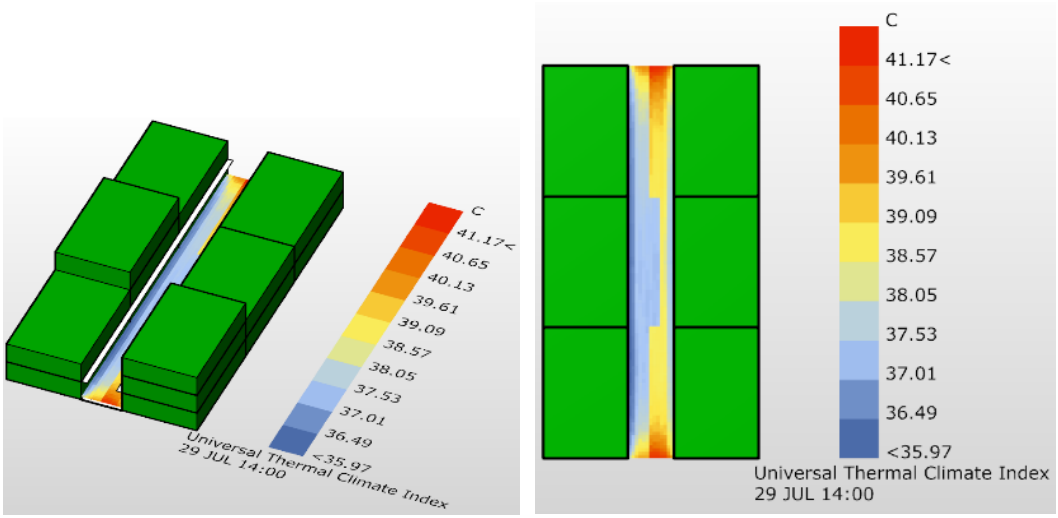


Figure 16 –Diagram showing the imagine line gate counting

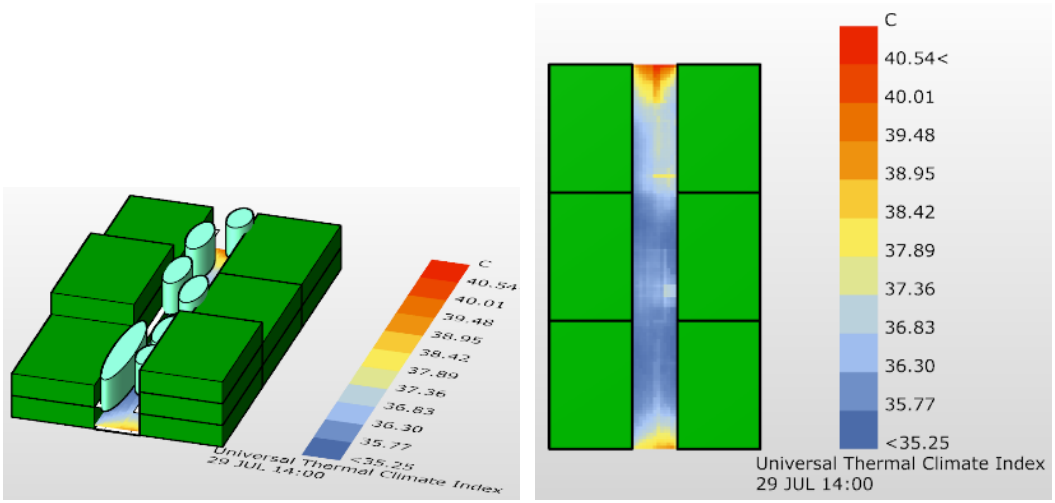
CHAPTER 3. RESULTS

3.1 Thermal simulation results

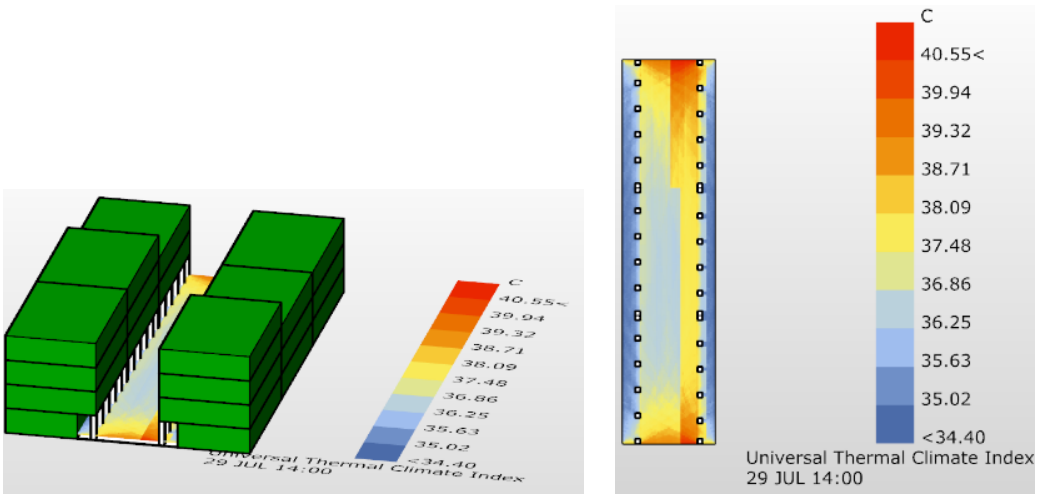
Grasshopper-honeybee results about UTCI



For normal plain elevation with no extra shading provided by trees.



For normal plain elevation with no extra shading provided by trees.



For arcade retail stores on Dishifu Street.

Figure 17 –Honeybee results of UTCI

As mentioned in the *Study Area* section, three types of outdoor environment are chosen to do the analysis. The three types of street environments are a normal street with plain storefront elevation and with no trees on the pedestrian, normal street with plain store font elevation and with trees on the pedestrian, and arcade ground level with pedestrian shaded by overhanging 2nd floor. Honeybee results could be seeing and read using the table on the side.

The time chosen for doing UTCI simulation in honeybee is based on the popularity observation time period. The gate counting of stores was done from 1 pm to 2 pm in late June. So the UTCI simulations' time was set for June 29th, at 2 pm.

UTCI is used for showing the outdoor thermal comfort level. The simulation here only chose a 30 meters' long section of the stores to run the Honeybee script in Grasshopper. The results on the section edge look not in the same tend as that in the middle of the section. But the street with retails on two sides chose for this study is a continuously street, so the outdoor environment should be continued and within the same condition

everywhere. For this simulation results, only the middle part of every section's result could be considered as accurate for further analysis.

The lowest UTCI value for pavement on the normal street without trees is 35.95℃, the lowest UTCI value for pavement on the normal street with trees on the side is 35.25℃, and the lowest UTCI value for corridor on the arcade street is 34.40℃. Set the highest temperature's situation, pavement on the Baohua Street without trees, as the comparison group. The temperature decreasing after having trees on the road is 1.9%, and the arcade store's outdoor corridor has a 4.3% temperature decreasing compared to the comparison group. The Dishifu street's arcade corridor doubled the effect of dropping the UTCI, which mean there is a significant thermal environmental different among these three types of pavements.

3.2 Visibility analysis results

3.2.1 Isovist results from Depthmap

The isovist results of standing on one side of pavement looking to the other side of the street's storefront are showing as below. The red dot is the standing point of the pedestrian, and red lines show the length of a storefront that could be seen by the pedestrian standing at the red dot's location.

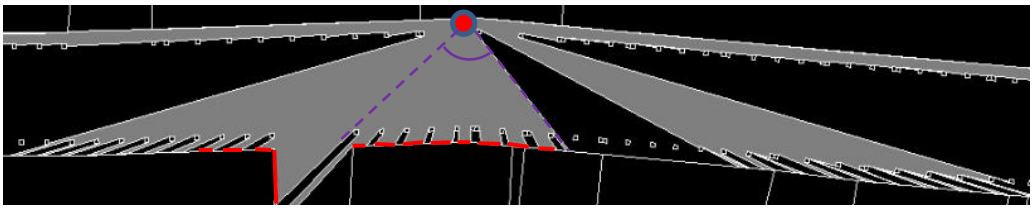


Figure 18 –Isovist result of stores on Dishifu Street

Figure 19 –Photo showing red dot's vision on Dishifu street

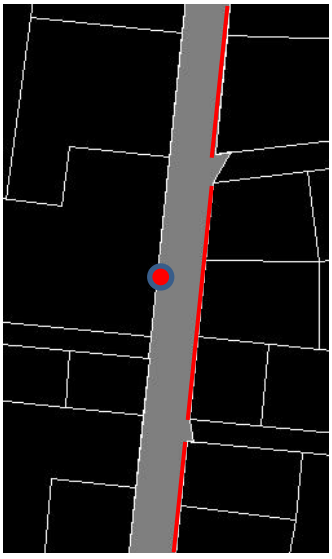


Figure 20 –The isovist results of stores on Baohua Street

Figure 21 –Photo showing red dot's vision on Baohua street

The diagram showing the result of Dishifu Street reflects the columns that obstruct the view across the street and make isovist not continuous, but more than 50% of the storefront can be seen within a view angle of 90 degrees (as the diagram above shows). And almost every store's front is lined up with columns, which means the store's opening and signage is exactly in between of two columns (as the photo above shows) that won't be blocked if you are standing at the front of it. So the pedestrian can clearly see at least three storefronts which do not have a big view angle in between. But there might be a problem if the view angle gets larger. The percentage of area that is blocked by columns could lead to isovist result of less than 50% for one storefront.

The diagram showing the result of Baohua Street reflects the Isovist of storefront is really high. A pedestrian standing at the red dot could have a totally continuous view of all the storefront across the street.

3.2.2 Daylighting on light

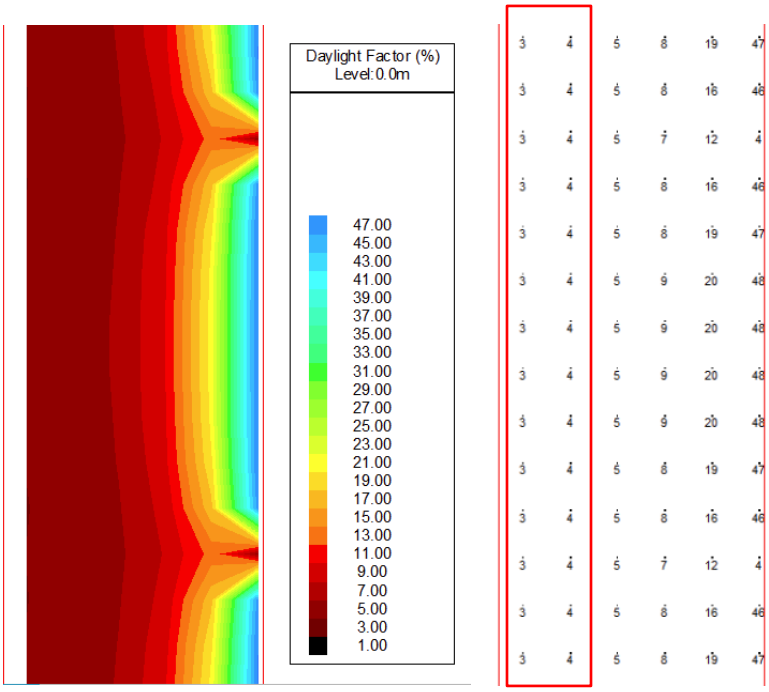


Figure 22 –Daylighting factor on the plan of 2.3 height

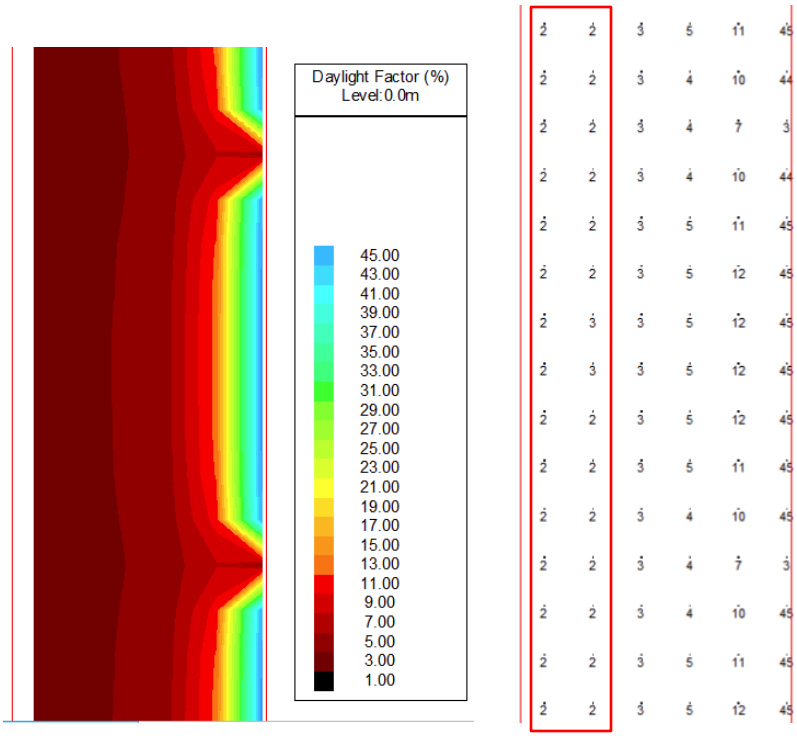


Figure 23 –Daylighting factor on the plan of 2.6 height

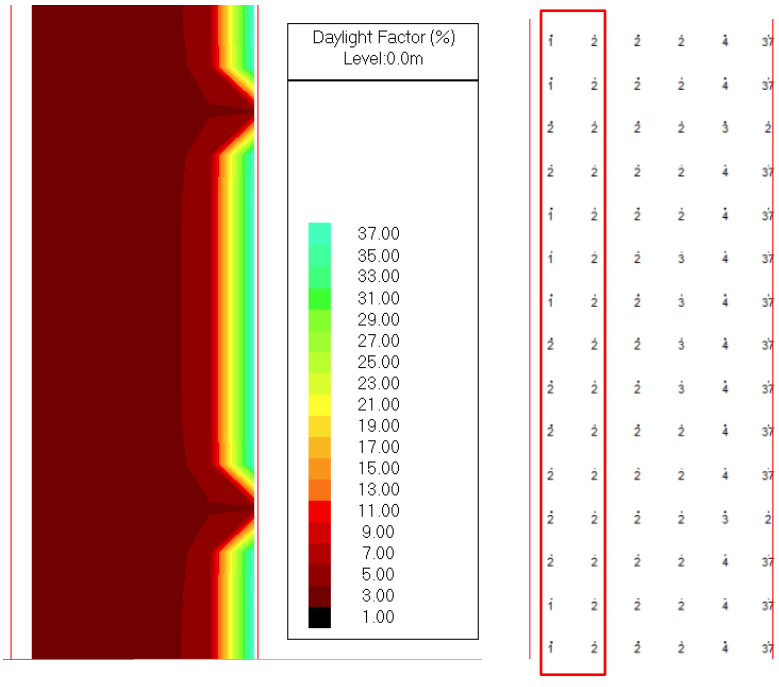


Figure 24 –Daylight factor on the plan of 2.9 height

Only the two columns of numbers that are most close to the signage should be considered as the daylight factor of the signage. The average value of daylight factor is calculated for evaluating the signage's visibility in this situation. The average value is (1.75+2.5+3.5)/3=2.5. Regarding the most external column's number as 100, which means no shading from other features. The daylight factor of signage after curving is 100*2.5/40=6.25. So in this situation, the score is in the range of 5 to 30. It can be seen by pedestrians, but it isn't an attractive feature.

Besides the situation discussed above, there are two other kinds of signage also been used by stores on the arcade street. The photo below shows the different visibility level of different kinds of signage s.

Figure 25 –Three kinds of signage on the arcade street

Store B is the one used for doing the daylighting factor. Store A's signage has LED light that made its visibility level higher than store B. Store C has two signage s, both beneath and on the arcade overhanging. The visibility levels of these stores are C>A>B. Stores with type A or type C signage should multiply by a factor higher than 1 to reflect its more accurate value of visibility.

Figure 26 –Stores on Baohua street with signage located above the shading features

Figure 27 –Stores on Baohua street with trees on the side

For signage on Baohua Street's stores, the daylighting factor isn't the main parameter that would influence their visibility level. The shading caused by trees that influence both the store's elevation and the street's illuminance. The other shading features are mostly located below the signage, and they are too narrow to be considered as a parameter to influence the illuminance. No need to analysis the daylighting factor of signage on Baohua Street.

3.3 Popularity observation results

3.3.1 Gate counting on different streets

3.3.1.1 On arcade retail street, Dishifu Street

Table 2 – gate counting result on Dishifu street

1:30-11:40		
on Dishifu Street		
1W	45	132
1E	87	
2W	99	173
2E	74	
3W	26	58
3E	32	
customer enter the store	14	
1:45-1:55		
on Dishifu Street		
1W	78	175
1E	97	
2W	97	175
2E	78	
3W	14	39
3E	25	
customer enter the store	17	

The gate counting result of the arcade street shows that the pedestrian on two corridor space (group 1 and 2) are similar and much higher than the number of a pedestrian on street (group 3). And based on observation results, most of the pedestrians on the street are going from one side to the other.

3.3.1.2 On the normal retail street, Baohua street

Table 3 – gate counting result on Baohua street (with trees)

12:30~12:40		
on Baohua Street (in front of one store)		
1N	22	98
1S	76	
2N	48	168
2S	120	
3N	54	118
3S	64	
number of people enter store 4		
12:45~12:55		
on Baohua Street (in front of one store)		
1N	40	102
1S	62	
2N	78	176
2S	98	
3N	42	117
3S	75	
number of people enter store 6		

Table 4 – gate counting result on Baohua street (without trees)

14:10~14:20		
on Baohua Street (in front of one store)		
1N	15	64
1S	49	
2N	71	170
2S	99	
3N	54	135
3S	81	
number of people enter store 2		
14:25~14:35		
on Baohua Street (in front of one store)		
1N	29	85
1S	56	
2N	65	182
2S	117	
3N	47	119
3S	72	
number of people enter store 0		

The pedestrians went through the imaginary gate on the Baohua street are similar to pedestrians went through the gate on the pavements.

3.3.2 Gate counting on arcade stores with different corridor sizes

Table 5 – gate counting result on Dishifu street (wider corridor)

mozi		
13:05~13:15		
on Dishifu Street (in front of one store)		
1W	60	183
1E	123	
2W	45	98
2E	53	
3W	44	98
3E	54	
number of people enter store 0		
13:20~13:30		
on Dishifu Street (in front of one store)		
1W	74	189
1E	115	
2W	62	138
2E	76	
3W	20	55
3E	35	
number of people enter store 2		

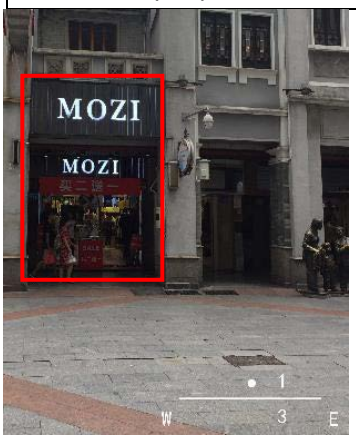


Figure 28 –Photo of MOZI front (arcade store with wider corridor)

Table 6 – gate counting result on Dishifu street (narrower corridor)

chie		
13:35~13:45		
on Dishifu Street (in front of one store)		
1W	92	204
1E	112	
2W	58	128
2E	70	
3W	22	62
3E	40	
number of people enter store 13		
13:50~14:00		
on Dishifu Street (in front of one store)		
1W	79	199
1E	120	
2W	64	136
2E	72	
3W	32	83
3E	51	
number of people enter store 7		

Figure 29 –Photo of Chie front (arcade store with narrower corridor)

These two store's pedestrian quantity that passing by their front is similar (although Chie is a little bit higher). But the store with narrower corridor has more people entering the store.

3.4 Thermal appreciation survey results

3.4.1 On Dishifu street pavement

Table 7 – survey result on Dishifu street

At the moment, do you find it:	
	very cold
	cool
1	neither cool nor warm
1	warm
2	very hot
What do you think of the sun at this moment?	
	You would prefer more
1	OK
3	too much sun
What do you think of the wind at this moment?	
1	stale
3	little wind
	OK
	windy
	too much wind
What do you think of the humidity at this moment?	
2	damp
2	OK
	dry
Are you feeling comfortable?	
3	yes
1	no

3.4.2 On Baohua street pavement

Table 8 – survey result on Baohua street

At the moment, do you find it:	
	very cold
	cool
	neither cool nor warm
1	warm
3	very hot
What do you think of the sun at this moment?	
	You would prefer more
	OK
4	too much sun
What do you think of the wind at this moment?	
3	stale
1	little wind
	OK
	windy
	too much wind
What do you think of the humidity at this moment?	
3	damp
1	OK
	dry
Are you feeling comfortable?	
	yes
4	no

The survey result shows that the users on arcade street corridor feel a lower temperature, a dryer air, and feel more wind.

CHAPTER 4. COMPARISON AND DISCUSSION

For comparison, we combine thermal and visibility quantity results to compare with popularity results. As mention above, five clothing stores were picked for popularity gate counting. The stores have been picked are listed as below. Store A, store B, and store C locate on Dishifu street. Store D and Store E locate on Baohua street.

Store A Store B Store C Store D Store E

Figure 30 –Photo of five storefront

4.1 The influence of one factor on the other twos

4.1.1 Thermal with visibility

To have one value that would be easier for comparison, the study needs to calculate the visibility level for each store integrated with Isovist and daylighting on signage.

Store A: the signage on overhanging helped the daylighting on signage, but it's location limited its isovist value. The total visibility factor is 0.75 * 1 =0.75

Store B: the signage on overhanging is smaller than that of store A, and it's location limited its isovist value. The total visibility factor is 0.65 * 1 =0.65

Store C: the signage beneath overhanging made the daylighting on signage pretty low, and it's location limited its isovist value. The total visibility factor is 0.25 * 0.5 =0.125

Store D: continuously isovist with very little shading device. The total visibility factor is

1 * 0.85 =0.85

Store E: continuously isovist with no shading device above the signage. Total visibility factor is 1 * 1 =1

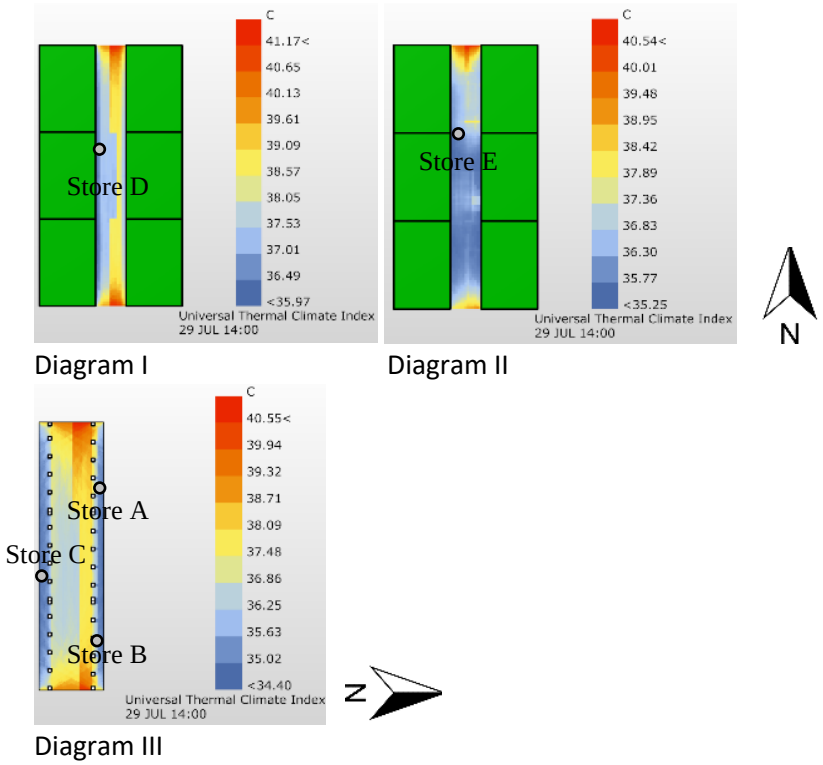


Figure 31 –The thermal comfort simulation results

UTCI values for every store are store A, 34.4℃; store B, 34.4℃; store C, 34.2℃; store D, 36℃; store E, 35.25℃. In order to show a more significant changing of the temperatures, minus every UTCI by 33 for making the chart. All the UTCI values are still higher than 34℃, which are still in the “feel warm or hot” zone. In this zone, a lower UTCI value means a higher thermal comfort level.

Table 9 – thermal comfort with visibility

	Store A	Store B	Store C	Store D	Store E
Thermal	1.4	1.4	1.2	3	2.3
Visibility	0.75	0.65	0.125	0.85	1

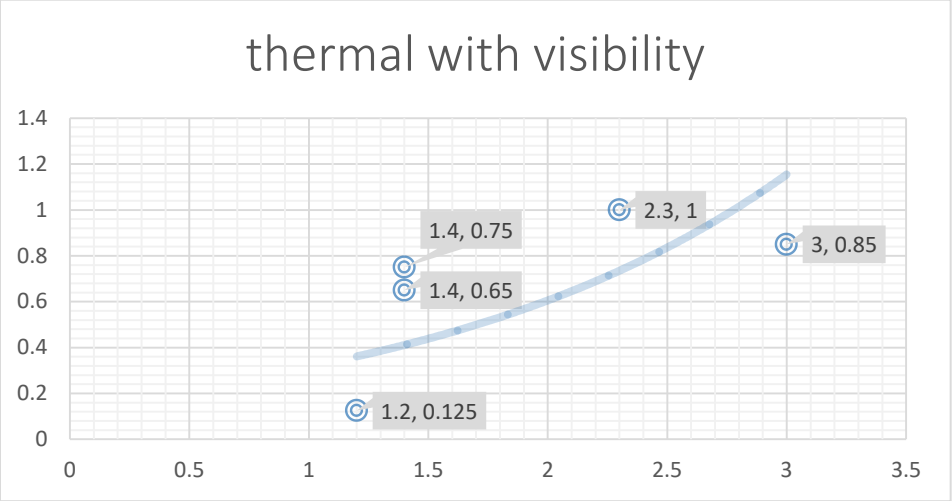


Figure 32 –chart of thermal comfort and visibility

Although store A and store B are located on the arcade street, they have the similar visibility level with store E and store D. That benefits from the second signage on the overhanging. Store C doesn't have a signage on the overhanging, which influenced its integrated visibility level.

4.1.2 Thermal with popularity

The popularity of different stores are:

Store A: 183+189=372

Store B: 204+199=403

Store C: 98+183=281

Store D: 98+102=200

Store E: 64+170=234

In order to show a more significant changing of the popularity, minus every popularity number by 150 for making the chart.

Table 10 – thermal comfort with popularity

	Store A	Store B	Store C	Store D	Store E
Thermal	1.4	1.4	1.2	3	2.3
Popularity	222	253	131	50	84

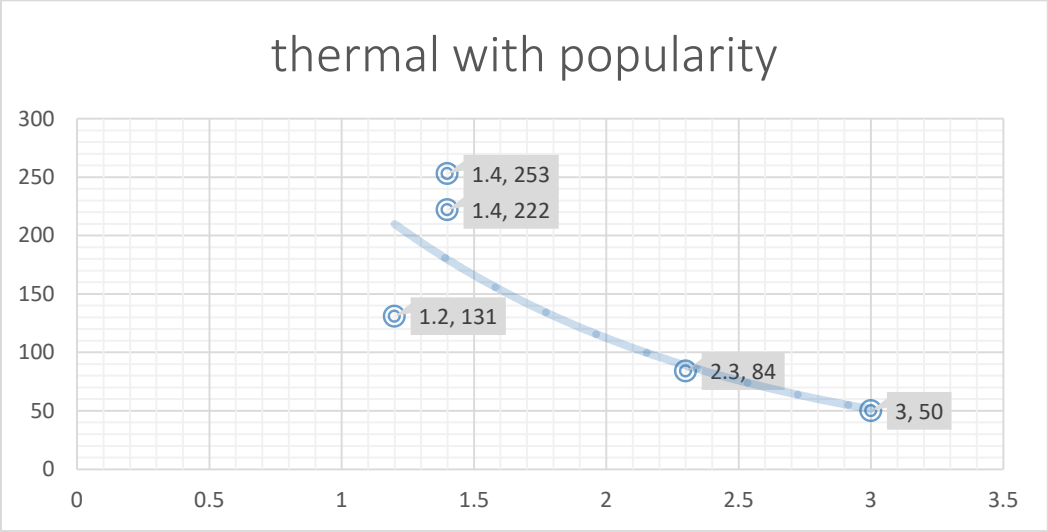


Figure 33 –chart of thermal comfort and popularity

Store C has the best thermal comfort level, but it isn't the store with the highest popularity. Store A and store B have a similar thermal comfort level, and store B has a higher popularity. This part of comparison tells us that the popularity level doesn't exactly go up with the thermal comfort level.

4.1.3 Visibility with popularity

Table 11 – visibility with popularity

	Store A	Store B	Store C	Store D	Store E
Visibility	0.75	0.65	0.125	0.85	1
Popularity	222	253	131	50	84

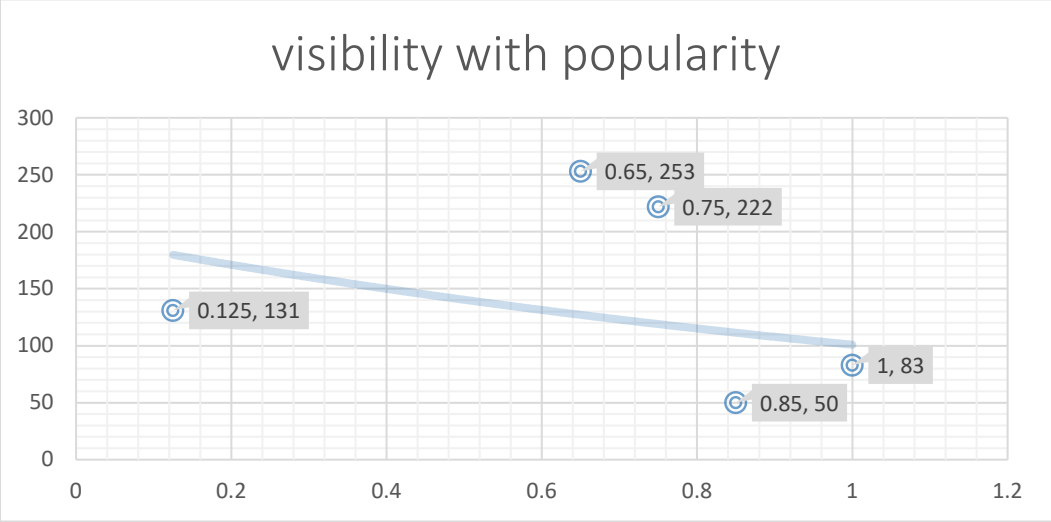


Figure 34 –chart of visibility and popularity

This chart, we can find out that store C has a much lower visibility level than the other four stores, but the popularity of store C is in the middle of five stores. That could be the benefit from its high thermal comfort level. Store B and store A have similar visibility levels (while B is slightly lower than A), and they also get similar popularity (although store A is slightly lower than B). This comparison shows that the popularity value isn't directly going up with a higher visibility level.

4.2 Way to combine the thermal condition and visibility level

4.2.1 The chart for three factors

Table 12 – visibility, thermal comfort with popularity

	Store A	Store B	Store C	Store D	Store E
Visibility	0.75	0.65	0.125	0.85	1
Thermal	1.4	1.4	1.2	3	2.3
Popularity	222	253	131	50	84

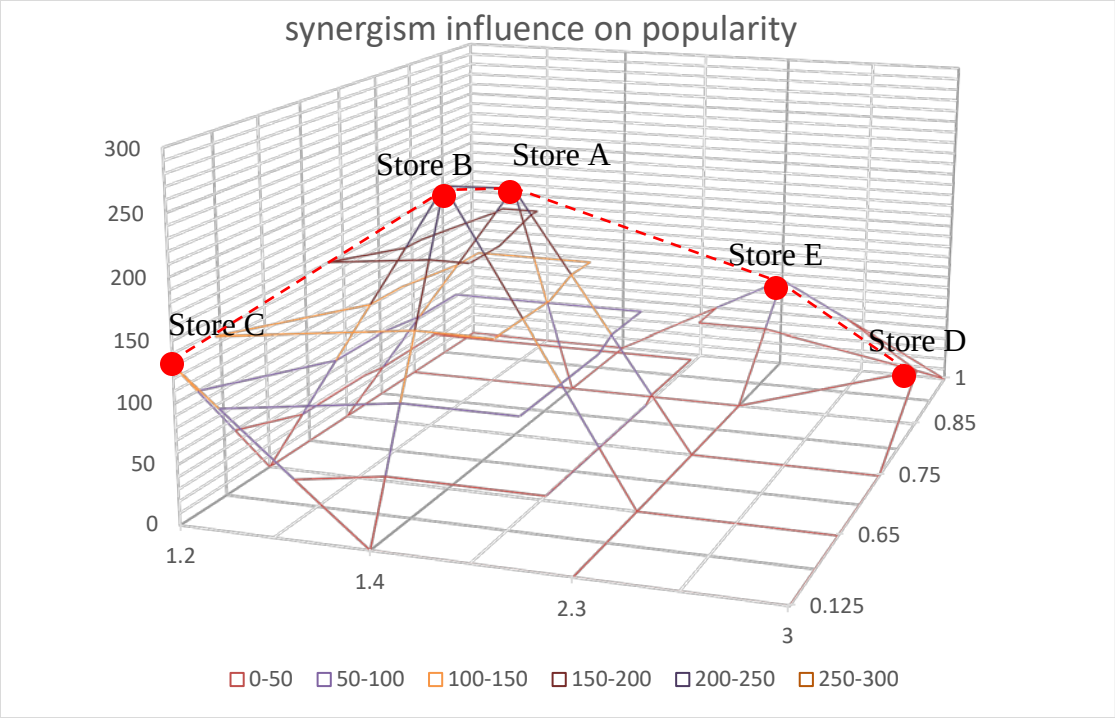


Figure 35 –chart of synergism influence on popularity

Store B, which has a narrower corridor and two signage on the arcade street, has the highest popularity. We can find out that store B isn't the one with the lowest UTCI value or highest visibility level. But it seems that store B has found a balance between these two factors that could help it attract more customers.

CHAPTER 5. SUMMARY

This study used a thermal comfort level and visibility as two simulation parameters and using popularity as the evaluation index for the retail space. As for the retail space, a higher popularity could directly mean that space has a higher success grade. The result and comparison chart above shows how the two parameters did a synergism influence on the success grades of those stores. And there is an area of integrated visibility and thermal comfort that could lead to a high popularity level. Outside of that area, even with a higher visibility or a higher thermal comfort level, the popularity will go down.

This study combined computer simulation with an on-site survey result and tried to give some suggestions to the retail owner while finding a space to run their business. Although the study background limited the research results to a specific group of retail spaces, that could still be a reference to the owners. For example, add another signage on the shading device could help attract more passengers' attention. And that could help them get a higher popularity.

Furthermore, this study result could be a case to confirm the theory that a design process should consider the simulation tools together. Rather than individually using each tool, the synergism impact from every design parameters is more important to be considered and use as a guide for design improvement.

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