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# Editorial Board




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# Message from the Editor in Chief

It is my pleasure to present to you the 18th issue of *Nakhara: Journal of Environmental Design and Planning (NJEDP).* The research papers in this issue cover a range of technical and socio-economic aspects of environmental design and planning in both urban and rural settings in Indonesia, Peru, the United States, and Thailand. The contributions to the journal continue to be multidisciplinary, reflecting the nature of the field of environmental planning and design.

NJEDP has been included in the Thai Journal Citation Index (TCI) since 2013 and the ASEAN Citation Index (ACI) since 2015. We are also now indexed in the Scopus abstract and citation database. From 2020 onwards, articles published in NJEDP will be indexed in the above databases, as well as Google Scholar.
I would like to extend my gratitude to the Dean of the Faculty of Architecture, Chulalongkorn University, Associate Professor Pinraj Kanjanusthiti, as well as Associate Editors, Dr. Pat Seeumpornroj and Dr. Sutee Anantsuksomsri, and other members of the Editorial Board for their continuing support. Last but not least, I would like to express my sincere gratitude to our reviewers for taking their time to review the manuscripts and provide valuable suggestions to the authors.

Apiwat Ratanawaraha
Editor in chief


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# Materiality and Sensibility:
## Phenomenological Studies of Brick as Architectural Material

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## ABSTRACT

An incessant challenge for the architects nowadays is how to design architectural projects that support the creation of meaningful experiences, benefitting from the interconnection between building materiality and human sensibility. The purpose of this study is to provide a phenomenological understanding of brick as an architectural material and how people perceive its architectural space and interpret its architectural meaning. Method of phenomenological analysis from Moustakas (1994) is adopted to guide the whole research procedures; using in-depth and multiple interviews with the users of three different buildings who shared experiences in inhibiting and interacting with the environment created with brick as an architectural material.

***Keywords:*** *phenomenology, materiality, sensibility, brick*

## INTRODUCTION

Brick is a material widely used for building purposes. Experiences of inhabitants who resided in a brick building are essential in understanding the materiality of brick in architecture. Merleau-Ponty (2002) remarks that in the pre-rational world, the five senses are crucial for human existence; they serve as gateways to the understanding of life world. Equally,the human senses also serve as a gateway to the understanding of materiality in architecture. Architects are now increasingly aware that material selection in architecture is of prime importance. It should be taken into consideration at the initial phase of the architectural design process to secure the materiality, the experiences, andthe meaning they wish to covey by the building. Pallasma (2012) confirms that architectural experiences, including material quality, space, and scale, are all based on the human senses that interact and support one another. Materiality, as intended by architects, can generate a variety of architectural experiences and meanings. This study will particularly explore the materiality of brick in architecture as conveyed by three brick buildings designed by contemporary architects in Indonesia.

This study has four aims: The first is to portray the relationship between the materiality of brick and the sensibility of peoples who occupy three buildings purposefully selected as cases of study. Second aims to depict architectural perceptions and interpretations generated by the materiality of brick in the three case study buildings. Third is provision of an alternative reference for architects who are interested in creating meaningful architectural experiences, based on the interconnection between building materiality and people's sensibility. Fourth initiates an inductive inquiry on materiality in architecture.

In inhabiting the built environment that they established, humans are continuously trying to relate to and understand the space by connecting it with distinct objects. Humans see objects in a certain area and understand them by connecting them with the sensation of being near or far from other objects. This kind of spatial relationship is applied unconsciously using sensory, perceptual, and conceptual systems. As stated by Merleau-Ponty, through the depth of our view, the speed, softness, and hardness of objects arise (Holl, 2006; Malnar, 2004).

Zumthor (2006) argues that humans cannot capture and experience a place directly. They experience it through "the atmosphere, all the things that exist, the people, the sound of airflow, nature sound, color, material presence, texture, and shape," through all forms that humans can appreciate. The atmosphere is the first impression that humans can get when entering a place, and soon they will find out whether they like it or not. Humans feel an atmosphere that directly affects their perception and mightily colors their spatial experiences (Griffero, 2017).

Steven Holl asserts that the reality of architectural experience is based on the tectonic language of buildings and comprehensible from the construction actions for the senses (Holl, 2006: 35). Architects prioritize the involvement of senses as a critical factor in designing built environments; while bearing in mind that pleasant architectural experiences would derive from intimate contact between building materiality and human sensibility.

## METHODOLOGY

This study discloses the interconnection between building materiality and human sensibility. It analyzes authentic experiences of peoples who have spent a certain time in the buildings made of brick as regular users. Three brick buildings are purposefully selected as case studies: (1) Katamama Resort in Seminyak, Bali; located beside the famous entertainment center, Potato head, designed by AndraMatin (Figure 1). (2) Herbal Company Headquarter Java Plant in Tawangmangu, Central Java; situated in Tawangmangu Highland, designed by AndraMatin (Figure 2). (3) GMT Institute Office in Menteng, Jakarta; situated adjacent to Sudirman Railway Station, Jakarta, designed by PHL Architects (Figure 3). Purposive sampling has resulted in 12 regular users of these buildings as eligible participants of this study. This study relies heavily on in-depth and multiple interviews with the participants to collect information on their personal experiences in their interaction with the brick buildings they occupied.

Amongst many methods and protocols applicable to phenomenological research, this study owed much to Moustakas (1994), Colaizzi (1978), and also Yüksel et al. (2015). The phenomenological analysis procedures adopted for this study can be summarized into three main phases, as graphically shown in Figure 4:

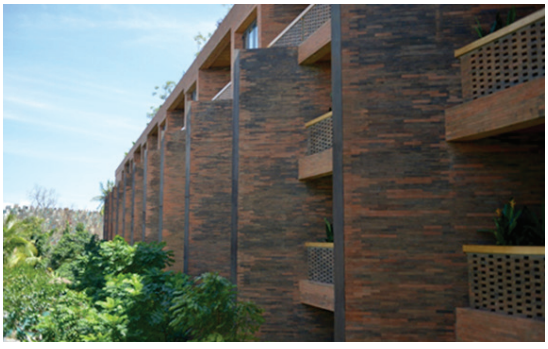

*Figure 1:*
*Katamama Resort in Seminyak, Bali*

*Figure 2:*
*Herbal Company Headquarter Java Plant in Tawangmangu, Central Java*

*Figure 3:*
*GMT Institute in Menteng, Jakarta*

I. Phenomenological Reduction, which consisted of 6 consecutive steps:
   1) Horizontalizing (Listing all relevant expressions);
   2) Reduction of experiences to invariant constituents;
   3) Thematic clustering to create core themes;
   4) Comparison of multiple data source to validate the invariant constituents;
   5) Crafting of individual textural descriptions of participants;
   6) Crafting of composite textural descriptions.

II. Imagination variation, which consisted of 2 consecutive steps:
   7) Construction of individual structural descriptions;
   8) Construction of composite structural descriptions.

III. Essence
   9) Synthesis of textural and structural descriptions into an expression.

The analysis of data follows a systematic procedure progressing from a small unit of analysis to the larger one. The researcher highlights statements, sentences, or important quotes (significant statements) that provide an understanding of what elements that have been experienced by participants, to a broader unit of analysis (units of meaning) which give a more detailed explanation on "how" they experience it (Moustakas, 1994).

In performing phenomenological analysis, the researcher should put ***epoché*** into practice: to bracket themselves from previous studies. Giorgi (2009) sees this bracketing action not as an act of forgetting all previous experiences but as a precaution not to allow prior knowledge to interfere with the ongoing study so that researchers can focus solely on the experiences of participants involved in the current study.

The ultimate purpose of this phenomenological analysis is to capture the essence of brick materiality as perceived by the peoples who sense and experience it in the context of three case study buildings.

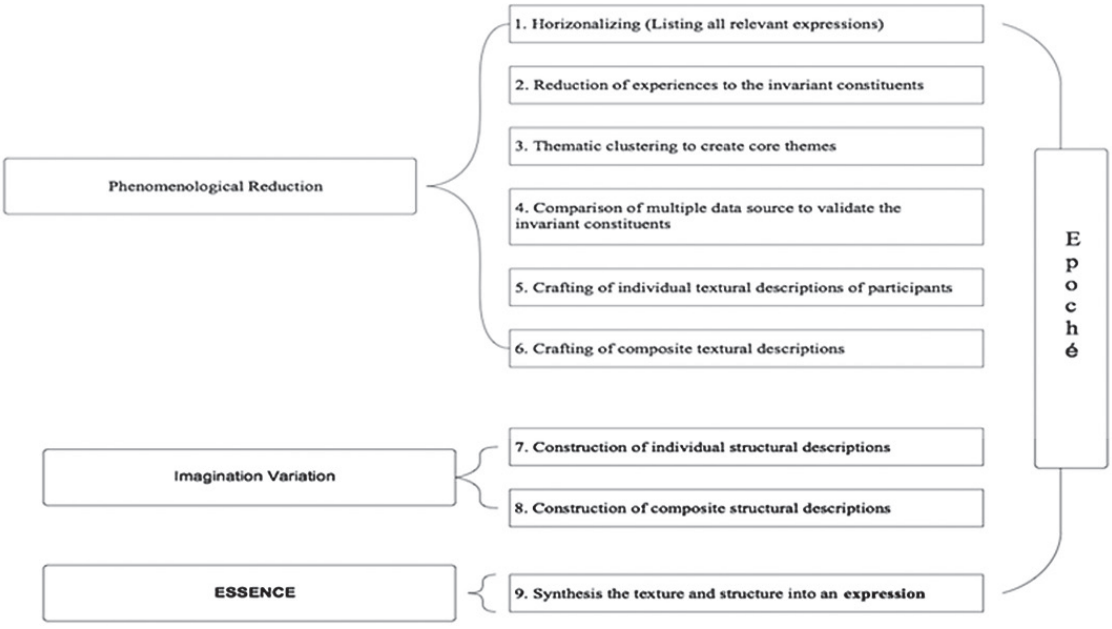


*Figure 4:*
*Three main phases in phenomenological analysis*
*(Source: Adopted from Moustakas, 1994)*

## DATA AND ANALYSIS

The data collected through in-depth interviews with 12 regular participants consisted of responses concerning the materiality of brick as experienced by participants in their daily interaction with the three respective buildings. The process of data analysis follows the procedures as already outlined in Table 1.

## I. Phenomenological Reduction:

In the horizontalizing process (step 1), the researcher extracts significant statements from116 formulated meanings. Table 1 shows three examples of significant statements and formulated meanings interpreted from participants' responses on three buildings, namely Katamama (from the participant no. 3), Java Plant (from the participant no 4), and GMT International Office (from the participant no 2).

**Table 1:** Examples of Significant Statements & Formulated Meanings on the Materiality of Brick

| Materiality of Brick | No | Participants | Significant Statements | Formulated Meanings |
|---|---|---|---|---|
| 3 of 116 Formulated Meanings on Materiality of brick | 1 | KM3 | We see the brick in terms of this color as if the color tells stories, especially with a combination. That is what makes us not feel lonely. | The different color combinations between bricks can form a story because the color patterns of each wall are different so that it does not feel lonely. |
| | 2 | JP4 | I am comfortable here. What is certain is that it is convenient, because the place is cool. The building is unique here. | People enjoy doing activities in unique brick buildings. |
| | 3 | GMT2 | It doesn't look like an office. It is cozy, so I cannot imagine if this is an office. Comfortable. I feel homey, like at home, not in an office. | I am doing activities inside a brick building that is comfortable and just like at home and not in the office. |

In step 2, the research proceeds with the reduction of participants' experiences as reflected in 116 formulated meanings to invariant constituents so that it can subsequently continue with thematic clustering of the materiality of brick (step 3). Table 2 displays 11 cluster themes on materiality of brick resulted from inferences drawn from 116 formulated meanings. By comparing multiple data sources, the researcher then validates all these invariant constituents (step 4).

**Table 2:** Cluster Themes on the Materiality of Brick

| |
|---|
| **1. Old buildings that create memories**<br>• Architecture can evoke childhood memories.<br>• Memories of a Brick building standing magnificently like an empire. |
| **2. Human intentions**<br>• Bricks made one by one using human hands to provide extraordinary energy.<br>• Making bricks takes a long time and a lot of costs.<br>• The unequal form of each shape and arrangement allows brick buildings to have a character that shows a human initiative. |
| **3. Timeless**<br>• The color of the bricks has timeless patterns. |
| **4. Modern and classic nuances of brick buildings**<br>• Brick buildings have a unique and classic impression, like being in a villa, not in an office. |
| **5. Unique flexible buildings**<br>• Brick material is a flexible material applied to any building designs.<br>• The shape of buildings made of brick material is different from each other. |
| **6. A simple structure with a relaxed atmosphere doesn't feel like working**<br>• Brick material is pure and has an artistic soul.<br>• Brick buildings are simple, beautiful though without being painted, more natural, and just the way they are. |
| **7. Quietness in brick buildings like being isolated**<br>• A room made of brick material feels like being sealed |
| **8. Natural scents of brick buildings**<br>• Bricks made of soil can arouse the smell of earth when exposed to rain.<br>• The natural aroma of bricks brings up attachment to the building itself, giving a nostalgic feeling. |
| **9. A sturdy building having an aging and industrial character**<br>• Moss is a natural aging process, making brick material more attractive, unique, and antique. |
| **10. Color patterns that tell stories**<br>• Bricks have different colors after being installed into walls and look like having patterns that can form a story. |
| **11. The wind greets through the gaps between bricks**<br>• Cool greeting |

As soon as the validation process of invariant constituents concluded, the researcher can start with crafting individual and composite textural descriptions on the materiality of brick (step 5 and step 6). Table 3 presents the result of composite textural description of the materiality of brick derived from individual textural description, cluster themes, and their descriptive formulated meanings. The composite textural descriptions reveal that "Brick is a material that can adapt to the context and have a variety of patterns, stories, and sensations."

**Table 3:** Textural Description of The Materiality of Brick

| Cluster Themes | Descriptive Formulated Meanings | Composite Textural Description of Brick Material |
|---|---|---|
| **1. Old buildings that create memories** | | Brick is a material that can adapt to the context and have a variety of patterns, stories, and sensations. |
| **2. Human intentions** | 1. Bricks made one by one using human hands to provide extraordinary energy.<br>2. Making bricks takes a long time and a lot of costs. Very Indonesian, very local.<br>3. The unequal form of each shape and arrangement allows brick buildings to have a character that shows a human initiative. | |
| **3. Timeless** | | |
| **4. Modern and classic nuances of brick buildings** | 4. Brick buildings have a unique and classic impression, like being in a villa, not in an office. | |
| **5. Unique flexible buildings** | 5. Brick material is a flexible material applied to any building designs.<br>6. The shape of buildings made of brick material is different from each other | |
| **6. A simple building with a relaxed atmosphere doesn't feel like working** | | |
| **7. Quietness in brick buildings like being isolated** | 7. A room made of brick material feels like being sealed | |
| **8. Natural scents of brick buildings** | 8. Bricks made of soil can arouse the smell of earth when exposed to rain.<br>9. The natural aroma of bricks brings up attachment to the building itself, giving a nostalgic feeling. | |
| **9. A sturdy building having an aging and industrial character** | 10. Moss is a natural aging process, making brick material more attractive, unique, and antique. | |
| **10. Color patterns that tell stories** | | |
| **11. The wind greets through the gaps between bricks** | | |

## II. Imagination Variation:

After finishing with the composite textural description, the researcher can jump into the second phase of phenomenological analysis: Imagination Variation. This phase consists of two consecutive steps; construction of individual structural descriptions (step 7), and construction of composite structural descriptions (step 8). Table 4 presents the result of composite structural description of the materiality of brick, derived from individual structural descriptions, cluster themes, and their imaginative formulated meanings. The composite structural descriptions reveal that "Brick is a material that emits a natural aura and expresses honest crafts."

Reduction phase (Phase I), the narrative of composite textural descriptions explains what the participants have experienced from the materiality of brick. Hence, in Imagination Variation, the narrative of composite structural descriptions explains how the participants experience and feel about the materiality of brick.

**Table 4:** Structural Description of The Materiality of Brick

| Cluster Themes | Imaginative Formulated Meanings | Composite Structural Description of Brick Material |
|---|---|---|
| **1. Old buildings that create memories** | 1. Architecture can evoke childhood memories.<br>2. Memories of a Brick building standing magnificently like an empire. | Brick is a material that emits a natural aura and expresses honest crafts. |
| **2. Human intentions** | | |
| **3. Timeless** | 3. The color of the bricks has timeless patterns. | |
| **4. Modern and classic nuances of brick buildings** | | |
| **5. Unique flexible buildings** | | |
| **6. A simple building with a relaxed atmosphere doesn't feel like working** | 4. Brick material is pure and has an artistic soul.<br>5. Brick buildings are simple, beautiful though without being painted, more natural, and just the way they are. | |
| **7. Quietness in brick buildings like being isolated** | | |
| **8. Natural scents of brick buildings** | | |
| **9. A sturdy building having an aging and industrial character** | | |
| **10. Color patterns that tell stories** | 6. Bricks have different colors after being installed into walls and look like having patterns that can form a story. | |
| **11. The wind greets through the gaps between bricks** | 7. Cool greeting | |

## III. Essence: Synthesis the Texture and Structure Into an Expression:

The outcome of this phenomenological analysis is the essence of the materiality of brick. The researcher will elaborate detailed descriptions of the essence of the materiality of brick in the following part.

# RESULT

## Textural Description: Brick as Unique and Organic Architectural Material

Buildings made of brick material are unique. Small openings on the brick wall allow natural air to circulate and natural scents to fill in the room. When it rains, water that soaks the ground outside the buildings permeates a fresh earthy scent. People are

feeling invigorated when breathing the unique aroma of the soil soaked by rainwater. Buildings made of brick material stimulate a feeling of not wanting to be far away and always wanting to return to nature.

As the brick materials ages, they undergo a color-changing process. Brick materials exposed repeatedly to sunlight and rain will develop white, green, and black mosses, which make them even more rustic and look harmonious with their natural environment. Brick materials have different patterns and textures that create unique impressions when seen and touched. Their texture is not smooth; the lines between bricks create gaps and bulges because the artisan laid them manually. Brick materials also produce residues that create sensations when touched.

The use of brick materials in buildings demands the involvement of artisans who mold the clay and lay the brick manually with crafts and cares. It is the imprecise and nonstandard form of brick material that creates the unique characters of brick buildings. Constructing large buildings made of brick materials is not an easy task as good brick makers and bricklayers are not easy to find nowadays. This is particularly true when erecting brick walls without plaster to reveal the natural character of brick as an architectural material.

Walls made of brick materials are capable of preventing noises from penetrating the building; hence, preserving the silence and peacefulness inside the building.The sound insulating quality make it possible for the inhabitants to enjoy a comfortable life and contemplative atmosphere.

## Structural Description: Brick as Living and Imaginative Architectural Material

A building composed of millions of bricks gives an impression of grand and magnificent architecture. It prompts admiration for the onlookers and reminds them of their memories in the past. Brick material reminds them of traditional buildings in the countryside. A building made of brick materials has a unique physical appearance due to the colors and minerals contained in them. Minerals, as elements of volcanic soil contained in bricks, can generate different colors to their visual appearances, such as red, orange, and black. This range of colors allows certain patterns and their related associative meanings or imaginations to develop on the surface of brick walls. Likewise, they also allow certain atmospheres to emerge conveying comfortability, suitability, and relaxing effects of buildings made of brick, such as house, villa, even office, or workplace.

Buildings made of brick allows air to circulate better through wall openings so that the inhabitants always feel cool and comfortable, never suffer from excessive sweating. Fresh air easily penetrates the building and amicably greet the human skins with a gentle breeze, giving a relaxing atmosphere and pleasant ambiance to the surrounding milieu. As flooring materials, brick offers unlimited possibilities in terms of patterns, textures, and aesthetic values. Stepping on the brick floor will significantly generate different impressions from stepping on the ceramic floor, marble floor, or other flooring materials.

Appreciation and disapproval of the use of brick as architectural material are attributable to its long process of production, its intensity of craft and labor, its lengthy construction time expenditure, and its tedious and costly maintenance requirement. But all of these exertions are worthy because buildings made of brick are capable of granting a classic impression like a temple and a shrine, expressing the spirit and energy of the artisans, and incites the admirations of the inhabitants and the onlookers.

## CONCLUSION

This study has initiated an inductive inquiry on the relationship between the materiality of brick and human sensibility. It adopted a phenomenological approach delineated by Moustakas (1994). It depicted architectural perceptions and interpretations that have been generated by the materiality of brick by analyzing authentic experiences of peoples who have spent a certain time in three different brick buildings, which are purposefully selected as case studies. The result of the study provides an alternative reference for architects who are interested in creating meaningful architectural experiences based on the interconnection between building materiality and people's sensibility. The reciprocal relationship indicates that there is a constant dialogue between human subjects and architectural objects. Human subjects learn and give a response to architectural objects according to their characteristics and properties; in return, architectural objects acquire their significances, values, and meanings in the mind of human subjects.

The materiality of brick expressed itself through its presence and function in the architecture of the building. Human subjects perceive, interpret, and understand the materiality of a brick through their bodily movement and sensibility; they store these experiences in their memories and occasionally express these experiences in their verbal responses. Brick, as an architectural material, has versatile tectonic properties in terms of its logic of construction. It has idiosyncratic imaginative properties, in terms of its distinctive aura and atmospheric creation. It also possesses socio-economical characters, in terms of its labor-intensive character in the construction processes of building made of brick.

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# A Generic Scenario on Urban Sustainability of a Historical City Center

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## ABSTRACT

In discussion on modern urban development issues, many researches have focused on those newly expanded areas, yet few researches have scrutinized what contributes to the vibrant life of the historical Central Business District (CBD) in inner cities. This research has examined a declined old city centre in central Taiwan by deploying Space Syntax analysis to verify possible contributions of parts-whole street network disconnection to the death of CBD in inner cities. The research findings suggest that linearity and critical street segments being properly integrated with the whole arterial street network could be crucial for future city planning.

***Keywords:*** *urban sprawl and sustainability, street network, Space Syntax, linearity, parts-whole integration*

## INTRODUCTION

This research has tried to disentangle fundamental attributes that may have a crucial impact on the issue of urban growth and sustainability. In her book *The Death and Life of Great American Cities*, Jacobs (1962) considered the life and death of urban areas related to socio-economic concerns. In this research, "sustainability" of an area means that the area continues to be socially and economically vibrant throughout time and is not restricted to an environmental position. The continuous socio-economic vibrancy of urban areas has been analyzed by Hillier (2009) who considers the nature of the part-whole structural relationship characterized in the city's street network. The relationship is the fundamental element influencing the sustainability of urban development due to its important effect on social interaction and commercial vitality. Areas designated with single land-use pattern and separated from the whole street network system tend to constrain accessibility for the public and are vulnerable to becoming un-competitive in economic development compared to others. Thus, the lack of sustainability emerges for these areas except when they are purposively designed for residential use only.

Very often, economic decay and displacement of vibrant street life within urban areas could be easily detected from on-site surveys. The reasons for this transformation in areas have rarely been explored thoroughly. Major attributes usually mentioned for the shift of social economy from one area to another include lack of parking lots or green spaces, traffic congestion or pollution, insufficient public transportation or pedestrian unfriendly problems, etc., whereas many believe uncompetitive commerce to be the fatal factor. From these surveys, street network patterns and related vehicular as well as pedestrian flows could be critical in affecting commerce outcomes in areas, which seems to be long overlooked. The Space Syntax approach (Hillier and Hanson, 1984) analyzes existing urban street networks and is able to simulate pedestrian and vehicular movements based on relative depth of these street networks. In this research, Space Syntax will be used as a diagnostic tool to analyze the urban area, and it will also project simulated changes in the street network to see what interventions could have a positive effect on the socio-economic sustainability of the area.

Study areas in this research focus on the historical Central Business District (CBD) in Taichung, Taiwan. Literature review on the issue of urban growth and sustainability is presented, and several research questions will be teased out for later study. Rationale and analytical models of the Space Syntax tool will be illustrated in the methodology part. Finally, findings from this research and several positions on city planning and sustainable development will be discussed in the conclusion.

## LITERATURE REVIEW

In the second half of the 20th century, the movement of urban modernization was largely inspired by Le Corbusier (1967) in his works *The Contemporary City* as well as *The Radiant City*. Positions of zoning based on land use (such as residential, work, business, etc.) and efficient transportation system (hierarchical vehicular networks segregated from pedestrian roots, etc.) have been adopted world-wide regardless of cultural differences. One of the most famous projects based on the above concepts was realized in Brasilia by Lucio Costa and Oscar Niemeyer (El-Dahdah, 2005, Krohn, 2003, p. 39-40).

In *The Death and Life of Great American Cities*, Jacobs (1962) criticized separated land use zoning strategies because they were seen as causing the disintegration of pedestrian movements and as creating vigorless areas whereas an inclusive pattern of vibrant activities can often be detected in most traditional city centres characterized with mixed commercial and residential use as well as pedestrians being together with vehicles (p. 15). As described by Holston (1989), the critical issue derived from separated land use zoning principles is reflected in the elimination of the synthesis of public and private social life on those corridor streets defined by continuous building facades in most traditional urban contexts (p. 103-105). As a result, the separated land use zoning development has contributed to the death of the street in newly developed areas where inhabitants often find "the absence of the social life of crowds that they expect to find in the public places of a city" (Holston, 1989, p. 105).

In spite of the criticism of "The Death of the Street" by Jacobs and Holston in modern urban development, many scholars believed in the contributions of

marketing, better infrastructures, healthy and safe environments developed from urban interventions and expansion. Victor Gruen created large malls and suburban shopping centres on the outskirts of cities starting the process of leaving the city centre (Gruen, 2017). Influenced by the modern movement ideologies of zoning and efficient vehicular circulation system, *Edge City* expansion asserted by Joel Garreau (1992) has emerged as the frontier proposal of secondary city centres and has been developed in rural areas of many American cities, such as Detroit's New Center, Miracle Mile in Los Angeles, etc. Moreover, led by Geoffrey Booth, the Urban Land Institute (ULI) established in 1936, the movement has invited a wide spectrum of land use and development disciplines to provide a holistic development scheme for creating Suburban Business Districts (SBD). To avoid the failed implementation of the edge city movement, ULI has reinvented the scheme of Compact SBD embracing mixed land use patterns and focusing on creating a pedestrian-friendly place integrated with public transportation system rather than the automobile dominant one (Booth, Leonard, & Pawlukiewicz, 2002).

In a study on Jaffa and Tel Aviv, the authors argued that the Space Syntax methodology can be used to study the historical development of two divided cities. In these cases, it is clear that the physical configuration of the city street network can be seen as having a dominant influence on social life, yet at the same time, there are other social forces that may have a stronger influence on urban behaviour. This kind of study can help to improve historians' understanding of "the changing interplay of configurational and social forces in the actual use of space" (Aleksandrowicz, Yamu, & Van Nes, 2019, p. 452). Furthermore, a more recent study on historical districts in Beijing and London concludes that newly created urban areas and patches "can be characterised and differentiated according to the way they are spatially embedded into the surroundings" (Yang and Hillier, 2019, p. 29). The study suggests that interaction between internal part and external whole could possibly lead to socio-economic difference in its occupants and users.

Clearly, the edge city expansion and the Compact SBD scheme were provided as new alternatives to avoid critical issues of traffic congestion and high density in inner cities. However, many historical CBD were deserted and became examples of "The Death of the District" due to the replacement of business hubs by newly established successful SBD or Edge City projects.

Given the fact of urban sprawl and inner-city decay, the Urban Task Force led by Lord Rogers in Britain adopted the "Urban Growth Boundary" model postulated by the Portland Government in Oregon, USA. The boundary limited the city's expansion within five square miles to revitalize the declined central city through maximum usage of existing facilities and services, and it has allowed for the preservation of wild green fields surrounding the city. To deal with the economic sustainability issue on urban development, the Urban Task Force (1999) has advocated the "Compact and Well-Connected City" proposal to create an integrated pattern of streets and public spaces from centre to edge to regenerate the declined city centre (p. 54-57). In the proposal, the integrated street networks of the urban whole and well-connected public spaces of urban parts was designed to include mixed-use of pedestrians, bikes, automobile, buses, etc. to recreate the vital traditional street life described by Jacobs.

The part-whole issue of socio-culture-economic development and environmental protection in relation to street networks has also been advocated by Hillier (2009). He asserted that the primary spatial structure of the street network plays a crucial role in underpinning the city's sustainable development. This is done in ways of overlapping layers of linked centres and that of the residential network to integrate and sustain the development of complexity with regard to three forces, namely environmental, economic, and social-cultural forces (p. 16-35). Clearly, Hillier argues for clarifying the rationale of sustainability of a city, which should not be constrained within the ecological domain. Moreover, he also throws a new light on the holistic scenario out of environment-economic-cultural domains based on humanistic reason, which contributes to the generic function of urban sustainable development. Though the Urban Task Force and Hillier's writing both stressed the important attributes of a well-connected street network system in sustaining historical CBD development, no further discussion has been made to clarify what contributes to (vs. prevents) the decline of the CBD while the newly established SBD or edge city expansions were created successfully.

It is believed that attributes of vehicular as well as pedestrian movements should be crucial in affecting the life or death of economic development in areas regardless of locations. More vehicles and pedestrians naturally generate higher capacity of commercial momentum; the opposite is also true for less movement. Thus, the complexity of the life and

death issue on commercial development of urban areas can be put in two questions: “What could be the most plausible and reliable way to predict distribution patterns of pedestrian and vehicular movements in those urban areas under concern?” and furthermore “Could the degree of interaction between parts and the whole of the street network system be one of the major factors contributing to the life or death of commercial activities in parts of urban areas due to its crucial impact on the distribution of vehicle and pedestrian flows?” These two issues and related research design will be clarified in Method of Analysis.

## METHOD OF ANALYSIS

The Space Syntax approach will be deployed for this study due to its capacity of prediction of and simulation on pedestrian and vehicular movements, which relates to the first issue of this research mentioned above. Various parameters of this tool will be introduced to exhibit different modes of simulation on different types of movement potential. The simulated movements include vehicles, motorcycles, and pedestrians, etc. Moreover, the degree of interaction between the background residential street network and the skeletal structure of the foreground commercial street network (Hillier, 2009, p. 27-32) will be illustrated to distinguish the simulated potential on the distribution of commercial momentum in different scale in contrast to the residential scatters.

### Parameters of the Space Syntax analysis

Based on the software “DepthMap” three major spatial parameters of Space Syntax analysis will be introduced to illustrate ways to represent the various types of movements under concern. The parameters —measures include Global “Integration Rn” (i.e. Radius n), Local “Integration Rr” (i.e. Radius r), and “Relative Choice” as per distance. These depict different measurements of the configurational properties of each spatial element within the street network system. After the measurements are defined, the area network will be investigated for “scope of area (either local or global)” and modes of movement behavior.

Before carrying out parametric analysis, layout plans of an urban context or an architectural floor system need to be deconstructed into a more abstract spatial configuration of “axial lines map” (see Figure 1). In the axial line analysis, each axial line represents the degree of visual-access permeability, which very often appears to stretch to the longest passage crossing different intersections within the spatial network system (Hillier & Hanson, 1984, p. 91-92). On the other hand, the less abstract spatial configuration of “segments map” (see Figure 19) represents the proximal condition of topological direction and geometrical angle changes of the spatial system, and each segment will embark on and end with strategic centre points between two intersections along the passage within the spatial system. Definitions of those major spatial parameters for teasing out plausible modes of simulation on different types of movements mentioned earlier are to be illustrated as follows.

A first parameter of global integration Rn value depicting the “To movement” behavior pattern represents the level of “Accessibility” for each spatial element of axial lines or segments through calculating its relative mean linear depth from all other spatial elements in the system (Hillier & Hanson, 1984, p. 106-115). Furthermore, quantification data of the Rn value are decoded by a colour scheme in which the higher the level of Rn (i.e. higher accessibility or more integrated) the more reddish the colour will be, and the lower the level of Rn (i.e. less accessibility or more segregated) the more bluish and purplish the colour will be. The second parameter of local integration Rr represents the degree of accessibility within a designated scope of relative depth r (i.e. radius r). When the scope of radius r is assigned to 3, the integration R3 will be calculated up to three elements away from each element for representing the level of local accessibility of each spatial element within the designated spatial system. Hillier concluded that the global integration Rn can be the best parameter for simulating longer journeys of vehicular movements whereas the local integration R3 seems to correlate better with pedestrian movements of shorter journeys (Hillier, 1996, p. 134-135, p. 160-161).

Different from the simplest mode of axial lines analysis measuring how close each line is to all others, the street segments analysis not only provides the Integration value of each segment but the third parameter of “Relative Choice” as well. Based on the relative number of overlapping loops calculation (Hillier & Hanson, 1984, p. 103-104; Hillier, 2009), Relative Choice can be obtained for studying another type of movement behavior of the passing by “Through movement” pattern, which depicts how frequently a street segment would be selected as a route for trips within the designated scope of

distance. Moreover, in the segment analysis, three important attributes of distance can be included for the two types of parameter-movement study (i.e. To movement vs. Through movement) mentioned above. These are variables of the first distance between central points of two street segments, the second distance subjected to topological direction changes between two segments, and finally the third distance of geometrical angle changes between two segments. In most cases, the major segments analysis based on variables combining the first distance with the third distance can be the best model for teasing out the Integration and the Relative Choice values in order to simulate the two kinds of movement behavior mentioned above (Hillier, 2009, p. 20-21). From a spatial cognition point of view, the first distance model represents the actual "Length Distance" and the third distance model corresponds to the "Continuity Distance" that one naturally recognizes two intersecting street segments as one continuous segment when they intersect with the geometrical least angle change within 0º~45º. The second distance model of topological direction changes seems to be less useful as it truly depicts the pure turns of "Direction Distance" within the configurational complex, which tends to overlook and simplify the complexity of spatial cognitions that navigators daily use intuitively.

## Degree of interaction between foreground and background street networks

Prior to the analytical mode of the degree of interaction between foreground and background street networks, some theoretical positions related to a generic scenario on urban sustainability need to be introduced. Then, the different modes of analysis regarding the case study will be illustrated. From the viewpoint of a generic process of an organic city, each settlement's micro-commercial areas for daily products transactions can be created naturally on the central segment or an intersection, named the "central spatial seed" within the street network system. This central spatial seed could be located either on the higher local Integration R3, which depicts the local scale central spatial seed, or on the higher global integration Rn, which represents global intersection central seed. Thus, these central spatial seeds, either locally or globally highly accessible from all parts of a settlement, can be the starting point for later growth of commercial centres in different scales following the development of a city (Hillier, 2009, p. 24-25).

Amid the growing process of each centre within a settlement, reinforcing street segments will appear to strengthen the original seed to shape the integrated shallow core of that centre to become a commercial hub, again either locally or globally. Very often, the reinforcers occur to be orthogonal or up to 45º to the original spatial seed to form a "Linear Expansion", or on the parallel together with orthogonal alignment to exhibit a "Convex Expansion". Moreover, this pervasive solo central core of a settlement or a city tends to interact with the background residential street network and forms a multidirectional structure of routes seemingly like a "Deformed Wheel" pattern within the whole system, described by Hillier as the crucial foreground commercial street network, which would work as the driving force of various types of movements, including pedestrians, vehicles, etc., thus become the generic mechanism of sustaining the economic vitality in area (Hillier, 2009, p. 25-26).

To deal with urban sustainability, Hillier considers the foreground network to be shaped by economic factors whereas the background network is related to local social culture factors. The dual network structure in effect provides an optimizing movement efficiency model, and the fuel needed for vehicles should be minimized, i.e. energy efficiency, which contributes to environmental sustainability (Hillier, 2009, p. 27). Thus, Space Syntax analysis has shed a new light from a humanistic perspective on a generic as well as holistic development based on environment-economic-cultural scenarios.

Following urban expansion and the more frequent use of personal cars as preferred movement option, the development of edge cities and SBDs in the peripheral areas has transformed most cities from the single centre core of CBD to polycentric metropolitans. Hillier described this notion of polycentricism as "Pervasive Centrality" in that the foreground commercial network of linked centres at different scales tends to interact with the background residential network via a limited number of least angular distance called "Intelligible Distance" (Hillier, 2009, p. 24). Learning from empirical tests on the dual network study, Hillier (2009) reported that the Integration variable, measuring the to-movement potential, works better for residential predominant areas whereas the geometrical least angle segments "Relative Choice" as per distance ranging from 250, 500, 750, 1,000, 15,000 meters, etc. seems to be the most appropriate model for teasing out the foreground commercial network of linked centres as it measures mainly the through movement potential mentioned earlier (p. 21-30). Thus, studies on degrees of interaction between foreground and

background street networks may help to disentangle issues of intelligible distance between the dual network and its possible influence on areas vitality or other social outcomes.

## CASE STUDY

Based on the above theoretical positions, the case study selected for this research represents a typical city development growing from early village scale settlement to single CBD centre and to the latest polycentric metropolitan, which unexpectedly has suffered from a historical city centre decline for more than two decades. The analytical models of axial "Integration" and the segments "Relative Choice" as per distance will be deployed to examine the degree of interaction between the dual network to verify whether there are distinctive analytical models capable of simulating the foreground commercial network emerging at different stages of urban expansion and development. Once the most appropriate simulation model has been teased out, it is possible to clarify what attributes may lead to the death of the old CBD and further to tease out a plausible intervention proposal for reviving the declined area under discussion.

### Examining the Dual Network of the study area

Taichung City is located in central Taiwan and is the third largest metropolitan city of the nation, with a demographic of more than 2.75 million. In 2010, Taichung County, consisting of 21 separate towns, was administratively incorporated into Taichung City for political reasons. These towns were suddenly renamed as districts in Taichung City, although they were never part of the city from a historical perspective (Civil Affairs Bureau of Taichung City Government, 2016). The study will focus only on the current metropolitan area which consists of 8 major districts. Central (i.e. the historical CBD), North, South, East, West, Xitun, Nantun, and Beitun areas are the total areas for spatial analysis in the present study. The 'newly created' surrounding 21 districts will be excluded as they were not really part of the city and also due to time constraint. There are four stages of urban expansion and development of Taichung City, which will be studied through parameters of both "Integration" and "Relative Choice" on the degree of interaction between the dual network in each period.

Taichung City is located to the west of the mountain range that is running in the middle of the island from north to south. Taichung cannot develop to the south or to the east because of this mountain range. Furthermore, the mountain range is responsible for the fact that most of the settlement development and food cultivation is located on the western area of Taiwan. There is a river to the south of Taichung city, approximately 10 km to the south, running from east to west (from the mountains to the sea). There are also a few smaller rivers and canals, running from the north to the south (related to the elevation of the land), none of which can be navigated by boats. During 1873~1898, the late Ching Dynasty, the precinct of Donda Dun (bold dashed area in Figure 1) was a prosperous settlement due to its strategic location amid the surrounding settlements (Chen, 2012). Based on the Topographic map of Taiwan Bao Tu: 1898~1904 (Center for GIS RCHSS Academia Sinica), an axial map of those early settlements near Donda Dun has been constructed (Figure 1). The Integration Rn measure revealed that three different levels on global accessibility of the Donda Dun can be identified in the embedded system (Figure 2). The result of the Rn analysis by and large correlates the historical text described by Shen Zheng Lang (Shen et al., 1979). Most retail business, such as rice merchants' shops, grocery stores, etc., gathered around the highest accessible reddish lines on the Central Street area. The local religious temple was sited near the secondary accessible (orange) level of line on the Up Street area. In clear contrast, whole-sale open-air markets of vegetable and fish stock were to be found in the Bottom Street area where the level of global accessibility only ranked in the mid-low range of yellow color. At that time period, rice paddies, vegetable fields, and fishing area were all located outside the city boundary. The measure of Local Integration R3, though correspond with the retail business, is less pronounced than that of the Rn measure. It is noted that the global accessibility Rn measure can accurately capture and explain the notion of the later development of the Donda Dun area, which was naturally developed to form the single central core of business centre through "Linear Expansion" of "Pervasive Centrality" in the region due to reinforcers occurring to be orthogonal or up to 45º to the original spatial seed, i.e. the Central Street. However, other parameters, such as "Relative Choice" turned out to be insufficient measures for simulating the actual commercial distribution pattern occurred in that period mentioned above.

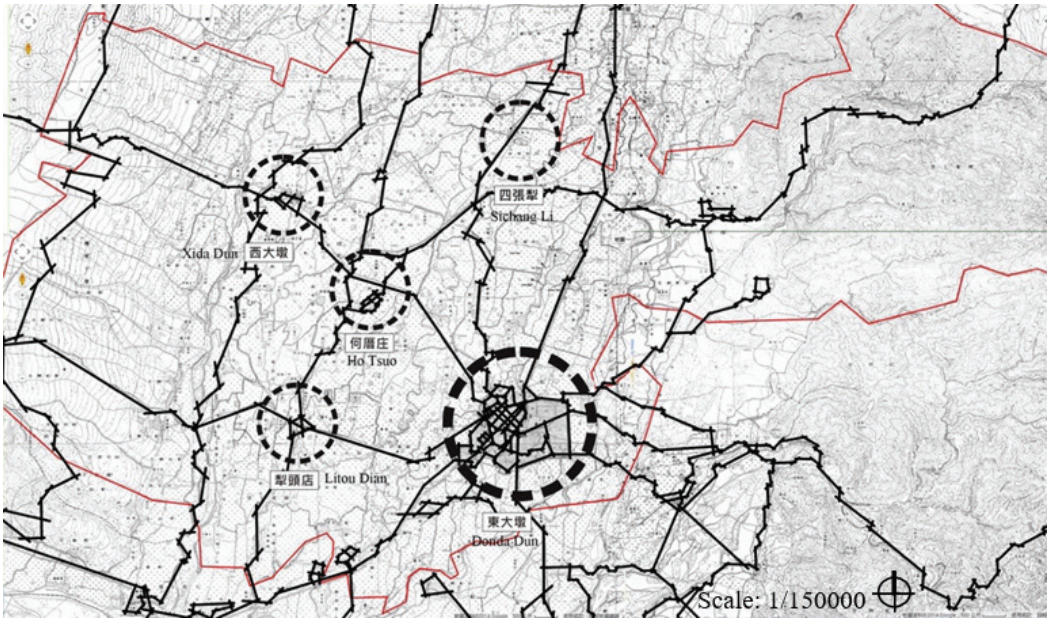


*Figure 1:*
*Axial line map of Donda Dun and surrounding settlements before the founding of Taichung City in Ching Dynasty (Adapted from Lin, 2015, p. 49)*

The red line shows the 8 districts of modern Taichung city. The circled areas were the settlements in the early period. The areas between the circled areas were paddy fields and vegetable plots. Some fields were close to the market, but many were not.

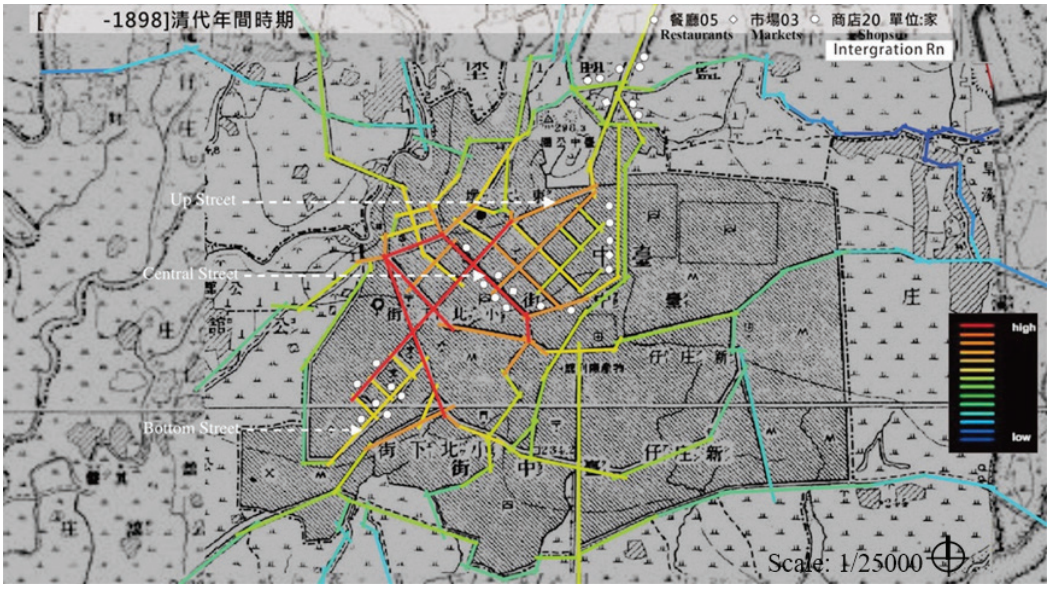


*Figure 2:*
*The Integration Rn of the Donda Dun settlement retrieved from the embedded larger system of all surrounding settlements (Adapted from Lin, 2015, p. 50)*

The name of Taichung City was laid down in the Japanese colonial period and the Donda Dun area was renamed Taichung Street in 1896. A new street network of the city was finally laid down in 1911 (Figure 3) and the street pattern was designed with a feature of 45º angle towards the north-west so that most buildings along grid pattern streets would receive enough sunlight for hygienic reason (Chen, 2012). Each square block is around 90-100 meters long on each side. The orientation of the new grid pattern also follows the axes of the two intersecting main streets of the Ching city. At this second stage development, the Taichung Railway Station was completed in 1917 and had become the major landmark of the city (Figure 4). Urban areas of administrative institutions, commercial mixed with residential for the Japanese community, commercial and residential use for the Taiwanese community, industrial areas, etc., were to be found around the train station (Shiu, 2015, p. 10).


*Figure 3:*
*Street layout of Taichung City in the Japanese colonial period in 1911 (Adopted from Lin, 2015, p. 36)*


*Figure 4:*
*Axial map of Taichung City in the Japanese colonial period in 1937 (Adapted from Lin, 2015, p. 59)*

When studying the correlation between the distribution patterns of commercial activities, which have been recorded on the map of that period (Figure 5) and confirmed (Chen, 2012, p. 174-240, Shen et al., 1979), and the Integration analysis on this second stage street network, it is noted that most retail shops and commercial business gathered on those reddish or orange streets with higher level of accessibility within the global Rn and local R3 spatial system (Figure 6, Figure 7). The above findings seem to confirm Hillier's position on the "Pervasive Centrality" that local small commercial centres exist due to the effect of local intensified grids whereas larger economic centres are to be found on those globally highly accessible street intersections (Hillier, 2009, p. 25). Meanwhile, the reinforcement of the parallel spatial seed together with orthogonal alignments have integrated with the original spatial seed to form the "Convex Expansion" of "Pervasive Centrality" of the city at this stage of development. Similar to the analytical result of the first stage development, parameters of "Relative Choice" are not sufficient to predict the commercial distribution patterns of this period.

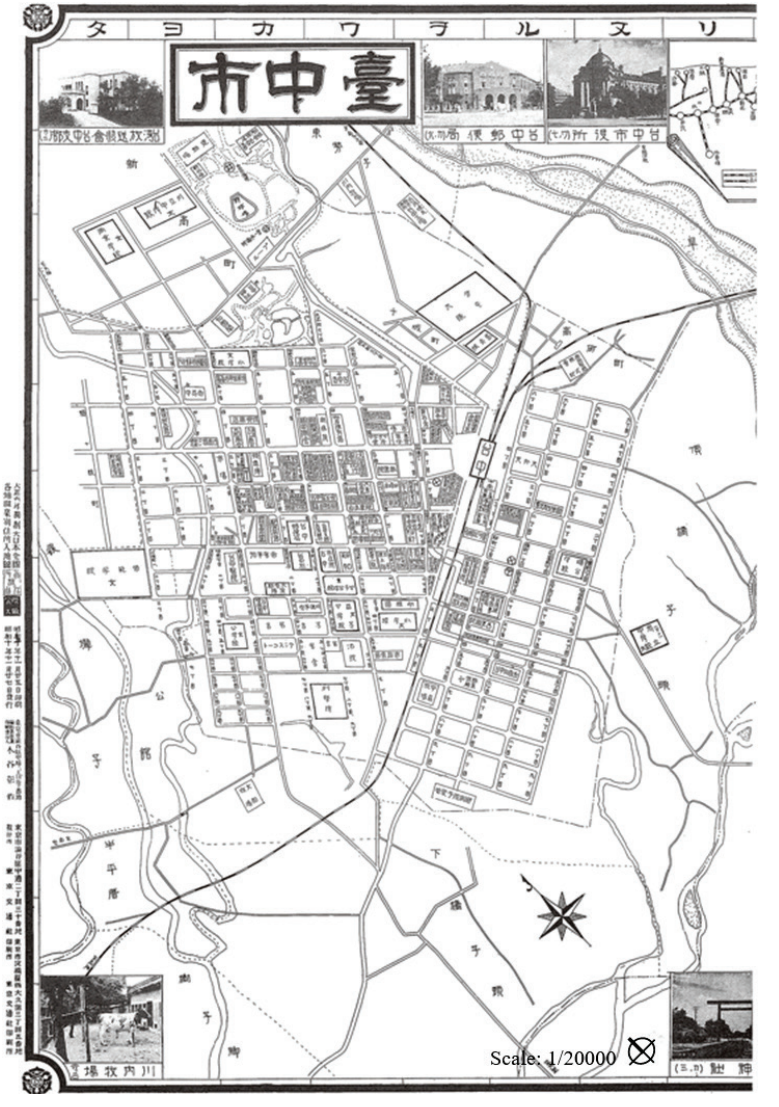


*Figure 5:*
*Distribution pattern of commercial activities in Taichung City during the Japanese colonial period in 1937 (the Center for GIS RCHSS Academia Sinica, 2008-2020)*


*Figure 6:*
*Global Integration Rn analysis of Taichung City in the Japanese colonial period in 1937 (Adapted from Lin, 2015, p. 60)*

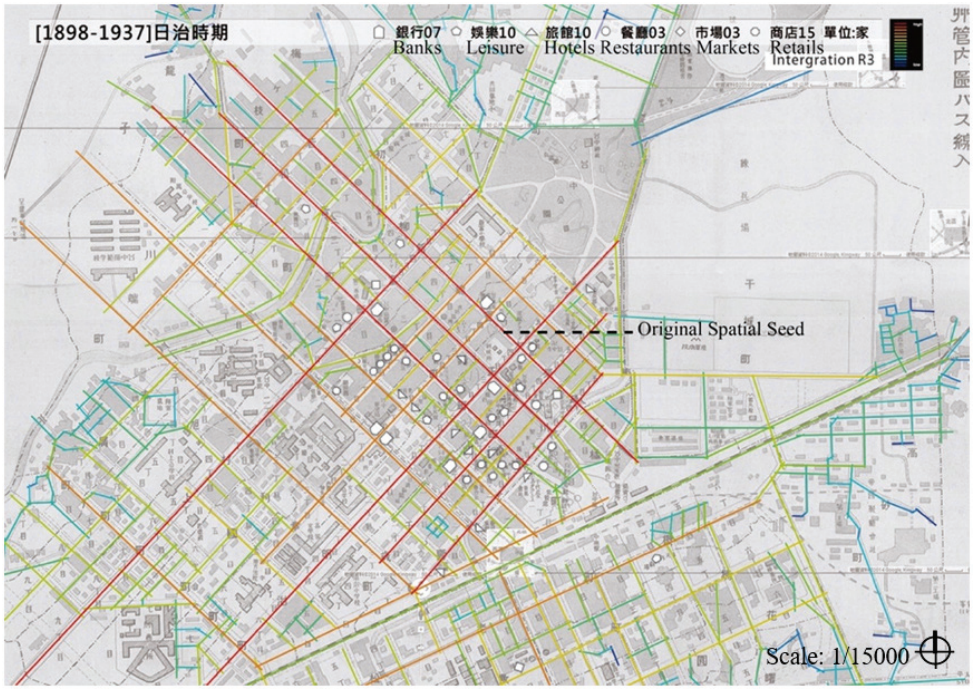


*Figure 7:*
*Local Integration R3 analysis of Taichung City in the Japanese colonial period in 1937 (Adapted from Lin, 2015, p. 61)*

During the early modern development from 1945 to 1974, the city has experienced the first phase of urban expansion in its third stage development following the original Ching settlement and after Taichung City was formally established in the Japanese colonial period. Due to the economic and demographic boom at this period, the street network drastically spread towards the north and west boundary of the city (Figure 8) from the original commercial centre developed in the Japanese colonial period (Huang & Chen, 2008). Given the wide spread of various business and retail shops, the newly emerged commercial activities of "night market" and "department store" have also occurred amid the pervasive old city centre to form the typical CBD of the city from 1960 onward.

The correlation between measures of global integration Rn and local integration R3 of this third stage period turned out to be significantly synchronized: the global highly accessible streets that were also highly accessible locally (Figure 9, Figure 10). There is a strong correlation between the two parameters. When further cross-examined with the distribution patterns of commercial activities of this third stage period, one clearly finds that nearly all of those retail shops and commercial facilities were located on those globally and/or locally highly accessible streets ranging from reddish to orange colour (Figure 11, Figure 12). It is again noted that the pervasive centrality of the old city central core has further extended towards the outskirts of the city compared to the previous stage of development. This suggests that more spatial seeds have emerged to reinforce the previous integrated commercial convex expansion of pervasive centrality initially presented at the second stage development to form the central business district (i.e. the old CBD) defined by arterial roads of Cheng Kong, Chung-Cheng, Min-Chiuan, Liu-Chuan, Tzu-You, San-Min, etc. (Figure 11). This development is partly supported by American funding and a slow increase in car ownership. Moreover, several additional reinforcing spatial seeds including Xitun Road, Wu-Chiuan Road, Taichung Road, and Chung-Ming Road, etc. (Figure 9) were developed. They helped to further extend the deformed wheel pattern into a larger system so that the foreground commercial network could interact with the background residential network in an efficient way with fewest average turns of two to three topo-geometric changes (i.e. depth) between the two networks (i.e. commercial and residential). The above findings seem to further confirm the position regarding the "pervasive centrality theory" and "deformed wheel pattern" (Hillier, 2009, p. 25-26). Two reinforcing spatial seeds both have become

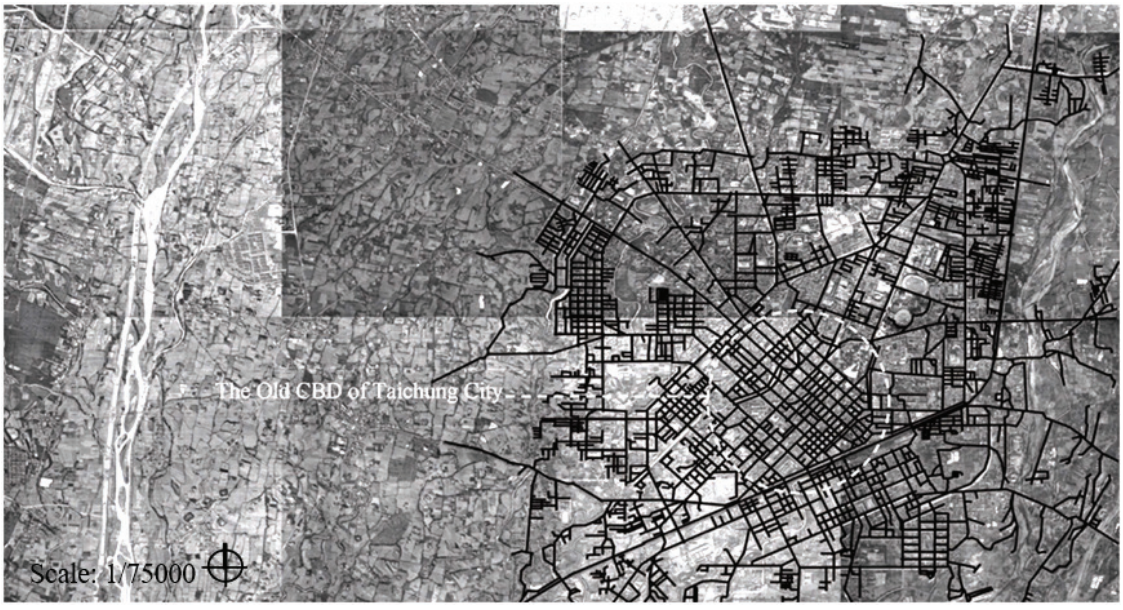


*Figure 8:*
*The first phase of urban expansion during the third stage development of Taichung City in 1974 (Adapted from Lin, 2015, p. 69)*

important elements in strengthening the larger scale of the foreground network amid the first expansion of the city. They are Xitun Road and Min-Chiuan Road. Xitun Road extends the original spatial seed of Cheng Kong Road of the old city centre towards the north-west whereas Min-Chiuan Road connects Taichung Road towards the south-east of the city. It is obvious that more attention should be paid to them in the next stage of expansion. Again, the measures of Relative Choice turned out to be insufficient in simulating the commercial distribution patterns as was the case in the first and second stage of the city's development.


*Figure 9:*
*Global Integration Rn analysis of Taichung City in 1974*

The outer residential areas are on north-south grids and the old CBD 45-degree angle grid was not extended. Therefore, there are local discontinuities and a reliance on main roads. The black areas between the CBD and the outer wheel are green spaces, large public institutions, and undeveloped areas at this time.

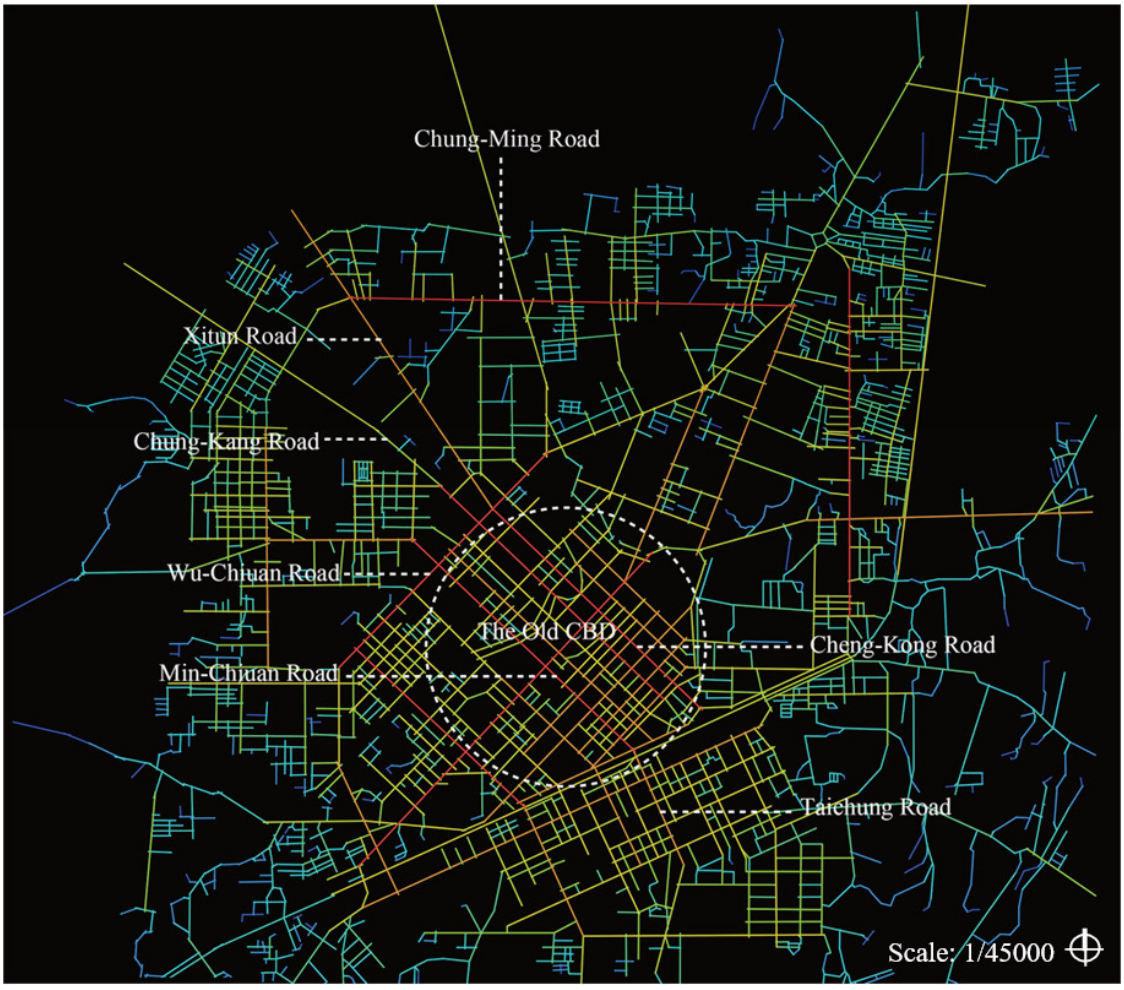


*Figure 10:*
*Local Integration R3 analysis of Taichung City in 1974*


*Figure 11:*
*Global Integration Rn vs. Commercial Activities of Taichung City in the first expansion period in 1974 (Adapted from Lin, 2015, p. 70)*


*Figure 12:*
*Local Integration R3 vs. Commercial Activities of Taichung City in the first expansion period in 1974 (Adapted from Lin, 2015, p. 71)*

In the fourth stage of the city's development, the second phase of urban expansion characterized by the major influence of "Edge City" and "SBD" has been implemented gradually from 1975 to the present date. The city has transformed from a single CBD in the downtown city centre into a polycentric metropolitan in 1990, and eight district centres at different scales can be identified within the city (Figure 13). However, the early CBD in the old city centre (the Central District) has become deserted and declined from the moment the polycentricism of the city appeared in 1990 (Shiu, 2015, p. 30). The other seven district centres have developed with great success, particularly with the case of the Xitun District where the development of "Edge City" and "SBD" has gradually replaced the old CBD. Xitun District became the new dominant commercial and administrative centre of the whole metropolitan. This is partly related to the low availability of car parking spaces in the old CBD as well as the fact that Xitun District is closer to the main interchange connecting to the national expressway and also has good links to the local airport and the seaport. On-site observation from selected samples of arterial commercial street segments, once extremely vibrant in the old CBD of the previous periods, reveals that nearly 65 % (303 out of 464 in total) of retail businesses have closed down for more than two decades, so that the suspended business rates range from Chung-Cheng Road (Figure 14) at 74% (90 out of 121), Cheng Kong Road (Figure 15) at 69% (77 out of 112), Liu-Chuan (Figure 16) at 68% (32 out of 47), Tzu-You Road at 63% (55 out of 88), San-Min Road at 52% (26 out of 50), to Min-Chiuan Road at 50% (23 out of 46). Due to length limitations, the various sub-stages of the urban expansion process from 1975 to 1990 and from 1990 onwards to the present time will not be discussed in detail, and the final analysis of the city's street network will only focus on the version in 2014.

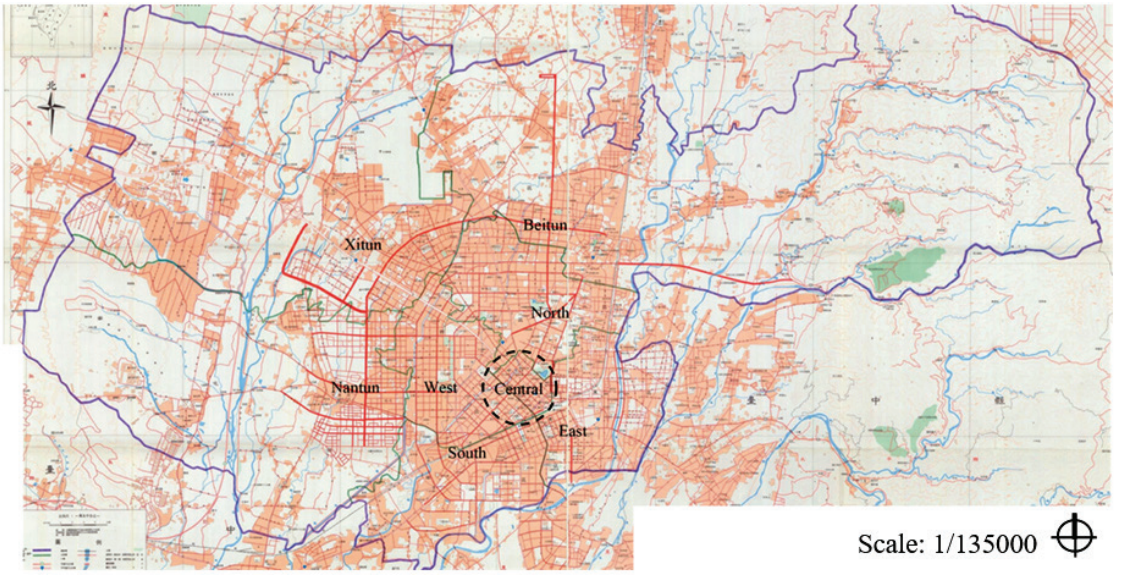


*Figure 13:*
*The polycentric metropolitan of Taichung and the eight district centres in 2014 (Green lines represent precinct demarcation of each district. Adapted from Lin, 2015, p. 79)*

*Figure 14:*
*Retail shops closed down on Chung-Cheng Road in the Central district of Metropolitan Taichung in 2014*

*Figure 15:*
*Retail shops closed down on Cheng Kong Road in the Central district of Metropolitan Taichung in 2014*

*Figure 16:*
*Department Stores deserted on Liu-Chuan Road in the Central district of Metropolitan Taichung in 2014*

In the integration analysis, measures of either global accessibility Rn (Figure 17) or local accessibility R3 (Figure 18) seem to be invalid in simulating the polycentric metropolitan at this fourth stage of urban development since none of the seven commercial district centres have been teased out by parameters mentioned above. This is likely related to the fact that these new developments are mainly accessible by car as opposed to the old CBD which is more accessible on foot and by public transport but has fewer parking spaces. Moreover, the old CBD area has mainly arcaded shop houses allowing for pedestrians to navigate whereas the new SBD areas are modern mixed-use complexes at the periphery. Also, the analytical results do not correlate to the given fact of the declined old Central district and, on the contrary, exhibit that the old Central CBD remained in the stage of the commercial core as before which is not really the case in reality.

However, different from the cases of the previous three stages in the development of the city, the segment length analyses of Relative Choice Radius 700 meters (Figure 19), 6000 meters (Figure 20), and 12000 meters (Figure 21) turn out to be powerful parameters in simulating the movement potential of pedestrian, motorcycle, and vehicle respectively. In each of these three maps the blue areas depict residential areas and the green, yellow, orange and reddish segments refer to different levels of commercial activity. The segment Choice R 700 measure clearly captures the distinctive seven district centres (refer to patches of green, yellow, orange, and reddish street segments) and the declined old CBD (refer to street segments all in bluish in the area). It is obvious that the old CBD has become a mainly pedestrian residential area whereas the seven district centres have more commercial activity (Figure 19). Moreover, the segment Choice R 6000 (Figure 20) and Choice R 12000 (Figure 21) measures seem to be quite sufficient in simulating the present major articulation of commercial street patterns (refer to those of green, yellow, orange, and reddish street segments) that connect closely and sometimes overlap with all seven vibrant district centres that are characterized by local commercial retail shops and night markets.

The segment Relative Choice R 700, R 6000, and R 12000 meters all together can be effective parameters for showing the integration between the foreground linked centres of the metropolitan city's commercial network with the background residential network. It mostly takes two to three turns

to move from the blue residential line to a warmer line in a more commercial district (Relative Choice R 700). Starting from the point, it takes another two to three turns to get the next intermediate level of commercial activity (Relative Choice R 6000). Finally, another two to three steps are needed to move to the highest density of commercial activity (Relative Choice R 12000). The old CBD (i.e. the deteriorated historical city centre) has clearly become isolated from the rest of the city and has been transformed into a background residential area due to its disconnection from the surrounding district centres and its insufficient connection with the foreground network of the whole city. As mentioned above, this overall structural shift of the city centre is related to the seaport, airport, national highway, and high-speed rail developments that have all pulled the city to the north and the west.

It is noted that the misfit parts of the two important reinforcing spatial seeds of Xitun Road and Min-Chiuan Road mentioned above have both become less active in strengthening the old CBD within the dual network whole amid this second expansion. It seems that the zig zag pattern of Xitun Road (see Figures 20, 21) at this stage has not only down-graded its weight of reinforcing spatial seed to the lower light blue level from the reddish vibrant one in the previous period, but it has surprisingly contributed to the imminent demise of the original spatial seed of Cheng-Kong Road. Furthermore, the disruption of linearity of Min-Chiuan Road, that split into two 45º angle intersected streets in the north-west direction from one straight street in the old Central district, has also weakened its weight of reinforcing spatial seed as that of Xitun Road mentioned above (Figure 20, Figure 21). The result of this case study reveals that linearity combined with continuous linear arrangement plays an important role in supporting the parts-whole integration within the dual network system (Hillier, 2009).

Despite the important factor of linearity on urban expansion, it is nonetheless not the absolute determinant factor that can warrant a promising outcome of sustaining the weight of those foreground original or reinforcing spatial seeds within the dual network system. One extraordinary outcome is that one of the reinforcing spatial seeds, Chung-Cheng Road, has turned out to become down-graded to the lowest level (bluish colour) of through movement and has converted from one of the reinforcing spatial seeds (reddish colour) of the foreground commercial network in the previous first expansion period to become a part of the background residential network in spite of its direct aligned connection with Chung-Kang Road (Figure 20, Figure 21). It seems that the linear extension of Chung-Kang Road has integrated the road with the current foreground network, and it has become the highest Choice level of through movement (Figure 21) in relation to the empowerment of the global economic momentum per se. However, Chung-Kang Road does not reinforce the early developed Chung-Cheng Road to sustain its previous status of commercial hub as discussed in the first expansion period since the important through movement of Relative Choice level has drastically decreased to the lowest degree. Thus, the degree of reinforcement, out of the factor of “linearity” on those closely connected street segments occurs during different stages of urban expansion, can only be concluded pending the investigation of each spatial seed within the larger dual network system under concern.


*Figure 17:*
*Global Integration Rn of the polycentric metropolitan of Taichung in 2014 (Adapted from Lin, 2015, p. 22)*

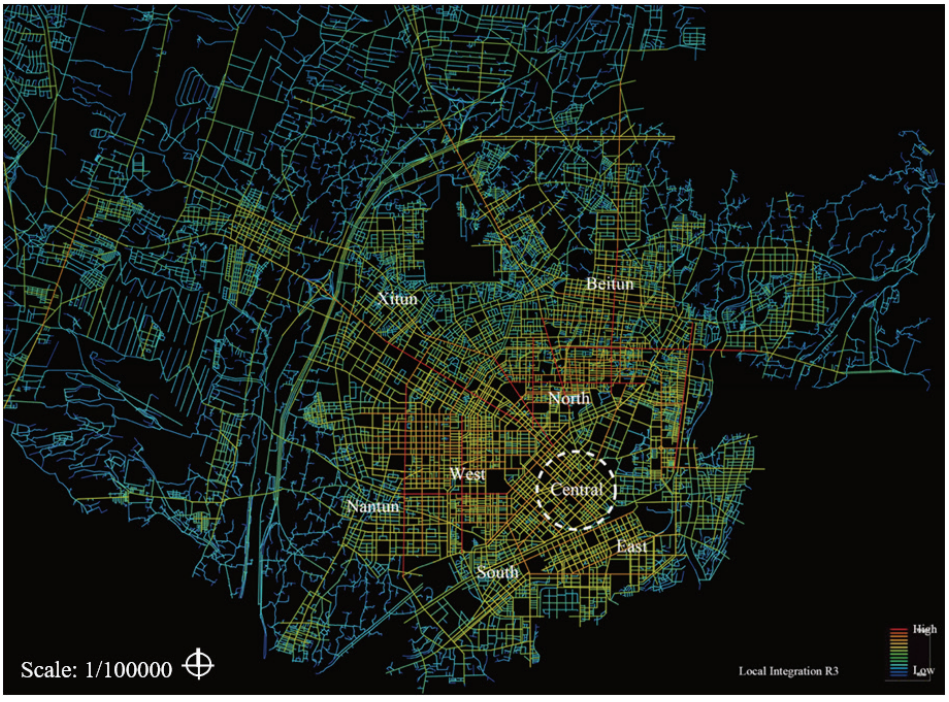


*Figure 18:*
*Local Integration R3 of the polycentric metropolitan of Taichung in 2014 (Adapted from Lin, 2015, p. 23)*


*Figure 19:*
*Relative Choice R 700 of the polycentric metropolitan of Taichung in 2014 (Adapted from Lin, 2015, p. 24)*


*Figure 20:*
*Relative Choice R 6000 of the polycentric metropolitan of Taichung in 2014 (Adapted from Lin, 2015, p. 134)*


*Figure 21:*
*Relative Choice R 12000 of the polycentric metropolitan of Taichung in 2014*

Several schemes of intervention on the misfit parts within the dual network of the metropolitan city have been carried out to verify whether the declined historical CBD mentioned above could be hypothetically regenerated. Of course, there are many factors involved in regenerating an historical CBD area. Two critical adjustments of the street connection pattern have been examined, which relates to the two reinforcing seeds of Min-Chiuan Road and Xitun Road. Based on the above position of linearity and its possible contribution of sustaining economic vitality, the strategy of continuous linear alignment has been tested for the above two reinforcing spatial seeds to verify whether the declined CBD in the Central district could be hypothetically revitalized through the proposed schemes of intervention. The first amendment is prolonging the original line of Min-Chiuan Road (Figure 22, Figure 23) towards north-west to be parallel to Chung-Kang Road (refer to the dashed oval area). From the segment length analysis of "Relative Choice" on the first amendment of Min-Chiuan Road, it is detected that the declined reinforcing spatial seeds of San-Min Road and Min-Chiuan Road seem to become more popular in terms of through movement potential as their weight has largely upgraded. Much so that they become parts of the foreground commercial network again compared to their previous conditions from the current second expansion period mentioned earlier (Figure 23). Whereas, Tzu-You Road has also been upgraded in its weight of through movement potential though less pronounced from being a part of the foreground network. The astonishing outcome of the intervention is that the initial night market area of Chung Hua Road has appeared unexpectedly to be upgraded in its weight of through movement potential though still far from being a pronounced part of the foreground network (Figure 23). Moreover, the initial reinforcing seeds of Liu-Chuan Road and Chung Cheng Road seem to be intact from the first intervention.

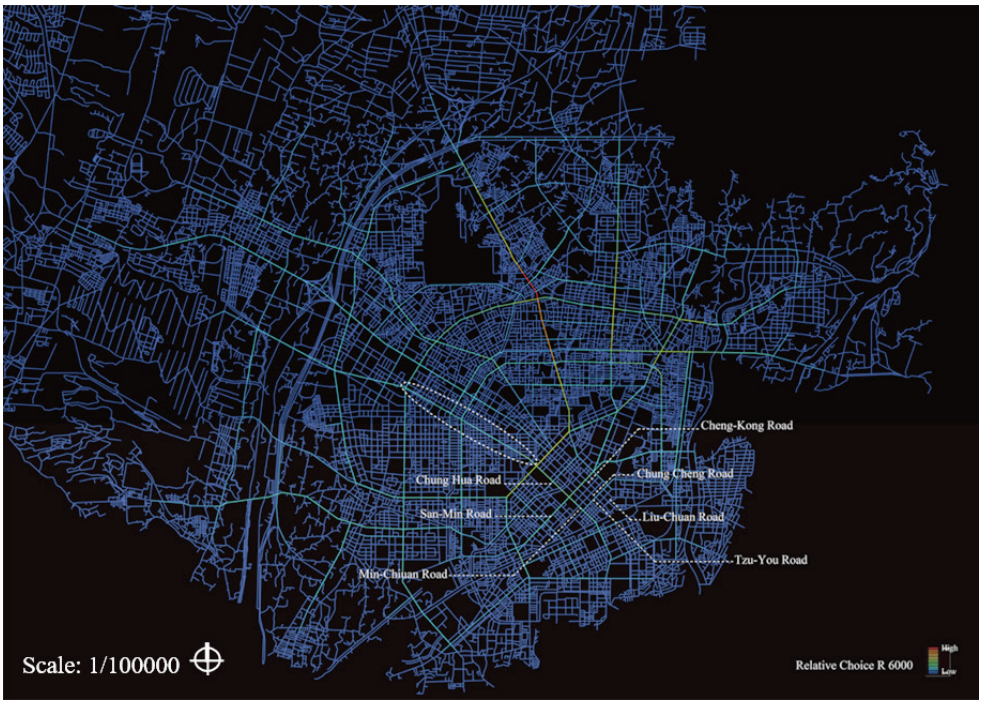


*Figure 22:*
*Relative Choice R 6000 of the first intervention scheme by prolonging Min-Chiuan Road*


*Figure 23:*
*Relative Choice R 12000 of the first intervention scheme on prolonging Min-Chiuan Road*

Furthermore, on top of the first adjustment, the second intervention scheme (Figure 24, Figure 25) deploys the same strategy of continuous linear alignment both to Xitun Road to modify the zig zagging pattern of the street into a long linear one and to Cheng-Kong Road to extend its route toward the south-east direction to cross through the ground level of the current elevated railway line (refer to the dashed oval areas). The result exhibits a quite pronounced improvement on through movement potential of the original spatial seed of Cheng-Kong Road. Through the intervention scheme, it regains its important role of commercial foreground within the dual network system (Figure 25) as was the case of the first expansion period. It seems that both reinforcing seeds, San-Min Road and Min-Chiuan Road, have not been further strengthened in their weight of through movement choice from the second intervention though both remain parts of the foreground network. Moreover, the other reinforcing seeds of Tzu-You Road, Chung Hua Road, Chung Cheng Road, and Liu-Chuan Road respectively haven't been further strengthened and remain less pronounced in the foreground network (Figure 25) as was the case discovered in the first intervention. However, again, it is noticed unexpectedly that most of the other parts of the foreground commercial network, located in the first urban expansion area, turn out to be further strengthened significantly in through movement potential from the second intervention scheme compared to the current situation. This means that the deformed wheel pattern of the integration core of the historical CBD, that was so obvious in the first expansion period but disappeared in the current situation, has become slightly more noticeable again after this intervention, but it is still less strong than in the first expansion period.

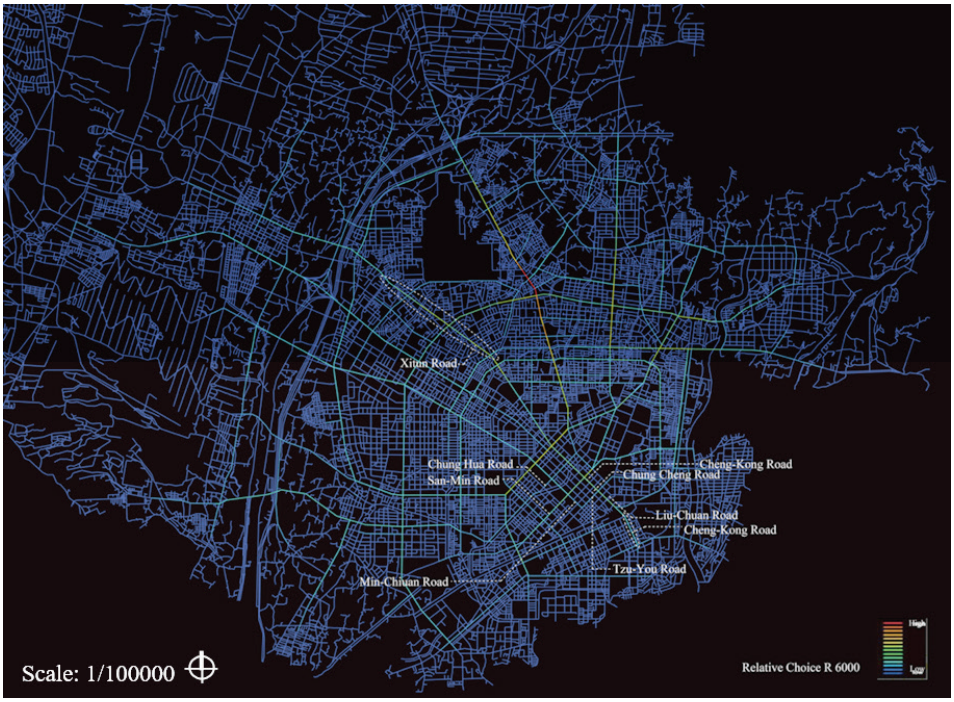


*Figure 24:*
*Relative Choice R 6000 of the second intervention scheme on modifying the zig zagging Xitun Road*


*Figure 25:*
*Relative Choice R 12000 of the second intervention scheme on modifying the zig zagging Xitun Road*

Research results from the two intervention schemes reveal that the first scheme of prolonging the crucial reinforcing spatial seed of Min-Chiuan Road seems to contribute to the reinforcement of the foreground commercial network only in the local area of the Central district. Whereas, the second scheme of further modifying the other important reinforcing spatial seed, the zig zagging pattern of Xitun Road into a linear alignment pattern, tends to produce an unexpected outcome of further strengthening the foreground commercial network to the global level. Though a zig zagging road may be more exciting for pedestrians, the changes to a linear pattern provide more overall benefits. These intervention schemes exhibit that different reinforcing spatial seeds play quite the distinctive roles in influencing the distribution patterns of the foreground commercial network in terms of scale; some related to global effect and others related to local effect. However, both levels of local and global reinforcement of the foreground network may benefit the revitalization of declined CBD in the historical district of the city as the deformed wheel pattern of the integration core is reinstated for the area in similar condition found in the first expansion period.

## Findings and Discussion

The case study shows that parameters of axial Integration can simulate the single commercial hub location in the city of Taichung. Segment Relative Choice is essentially valid for simulation on the movement modes of pedestrians (Relative Choice R 700), motorcycles (Relative Choice R 6000), and vehicles (Relative Choice R 12000) for polycentric areas and on the distribution patterns of commercial activities both for global and local levels in the fourth stage (i.e. the second expansion period) in Taichung. The axial Integration measure seems to work effectively for depicting the foreground commercial network of the single pervasive centre in a residential dominant urban system whereas the segment Relative Choice measure can better predict that of a polycentric metropolitan system notable with linked commercial centres in different scales. The study in Taichung also exhibits the relationship between Pervasive Centrality and the pattern of linearity characterized with continuous linear alignment. This link shows that the linearity factor, although it does not warrant definite influences, does play a crucial role

in sustaining the growth of the pervasive centrality from the local commercial part of an original spatial seed to the global level of the foreground commercial network. In this centrality, the linked deformed wheel integration core is further strengthened by those well connected linear reinforcing seeds within the whole dual network system. This is the case in every stage of the Taichung city development regardless of single central CBD or polycentric metropolitan. Moreover, some of the reinforcing spatial seeds may play a powerful impact on the final outcome of whether a local centre would be disconnected with the rest of linked centres; thus becoming isolated and deserted, or being effectively connected with other surrounding local centres to form an integrated parts and whole system based on this example.

## CONCLUSION

The present research on Taichung city has disentangled the issue of street network expansion in urban development through examination on the forms of "Pervasive Centrality" of the study area. It has teased out the fundamental factor of linearity characterized with continuous linear alignment in strengthening the different scale of pervasive centres. These centres range from the original spatial seed, linear expansion and/or convex expansion of the reinforcing spatial seeds, deformed wheel integration core of the single centre of a city, to linked district centres of the foreground commercial network in the polycentric metropolitan system.

To deal with the economic sustainability issue of urban areas in future development, one crucial task should be to carefully tease out those most effective reinforcing spatial seeds within the contemporary foreground network system. Alternative intervention schemes based on strategies of linearity alignment on those effective reinforcing seeds for examining parts-whole integrated relationship of the future dual network system should be further verified to assure the final scheme would work for sustainable development of economic vitality.

In response to issues of urban sustainability, there's no doubt that beyond the street network study, other factors of environ-biodiversity, dwelling density and green spaces, pollution reduction and public transportation, etc. should be included for initiating proper schemes of future urban development. Nevertheless, this research points out the important concern of how the local parts of the historical CBD, as well as the dispersed new SBD, could be further strengthened into the global level of the foreground commercial network to reach the model of an integrated parts-whole spatial structure of dual network following different stages of city expansion. This may not only play a crucial role in sustaining economic vitality of urban areas, but could be essential for working as the generic function of the sustainable development of a city to deal with interrelated issues out of environment-economic-cultural domains based on humanistic reason (Hillier, 2009, p. 16-35).

Although this case study used the Space Syntax approach, it is clear that there are limits to the simulation of different syntactic parameters against commercial distribution patterns. Differences in local cultural habits apart from the street network may play an influence as well. For example, the Relative Choice R 700 has less power to predict pedestrian movement flow as well as local commercial distribution compared to the Relative Choice R 6000 (motorbike) and Relative Choice R 12000 (car). This could be related to cultural tradition, especially the fact that people in Taiwan seldom walk anywhere since there are few pedestrian-friendly environments (i.e. no sidewalks, humid and hot climate, etc.), especially in those historical areas. As a result, many people use motorbikes to move locally rather than on foot. Further study needs to be carried out to compare the case of Taichung city to other historical centres in Taiwan and in other countries to see whether the above findings can be generalized.

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# Quantifying Real Estate Externalities:
## Evidence on the Whole Foods Effect

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## ABSTRACT

Real estate amenities can create both benefits and costs to local community, which economists call externalities. Quantification of externalities is challenging because of potential endogeneity problems that render simple statistical analyses inaccurate, necessitating the use of a more rigorous econometric technique. Exploiting store expansion activities of Whole Foods Market to infer the causal impact of the Whole Foods Effect using the difference-in-differences strategy, we find that property prices within 0.5 mile of a new Whole Foods Market store increase on average by 6.7% after a new store opens.

***Keywords:*** *externalities, hedonic prices, supermarket, Whole Foods Market*
*JEL Classification Code: R20*



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## INTRODUCTION

The fundamental determinant of a property's value is its location, which provides access to amenities such as workplace, stores and services. Because community members share the same location, independent changes brought about by an action of one agent (for example, an opening of a supermarket) will inherently affect the property value of others in the same vicinity. Economists often refer to this effect as "externalities", which can be positive or negative, and the idea encompasses a range of measures other than property value. One of the most studied real estate amenities is supermarket (particularly, Wal-Mart), due to its role in the modern lifestyle and potential influences it may bring. For example, the entry of Wal-Mart superstores has been linked to reductions in retail jobs and earnings (Basker, 2005a; Neumark et al., 2008) and increased crime (Wolfe and Pyrooz, 2014), but at the same time increased competition leads to improved product quality (Matsa, 2011), lower prices (Basker, 2005b; Hausman and Leibtag, 2007), accessible cheap drugs and reduced hospitalization (Borrescio-Higa, 2015), improved food security (Courtemanch et al., 2019) and higher property values (Pope and Pope, 2015). Other externalities that could affect local residents include pollution and traffic, which are also of great concern for urban planners.

In this article, we focus on property price rather than other outcomes for two reasons. First, as motivated by the microeconomic theory, price reflects willingness to pay, which depends on the utility derived from consumption. In other words, the impact of all relevant amenities should be capitalized into prices. Second, property price has many economic ramifications. Because default and foreclosure can be contagious (Agarwal et al., 2012; Guiso et al., 2013), the increase in property prices can reduce the likelihood of foreclosure. Property is part of household wealth, so higher property prices can spur local consumption (Mian and Sufi, 2011). One of the challenges of entrepreneurship is lack of access to finance (Fairlie and Krashinsky, 2012; Robb and Robinson, 2014) and housing collateral from increasing property prices has been shown to spur local entrepreneurial activities (Black et al., 1996; Adelino et al., 2015).

Understanding the causal effect of amenities on local community is an important policy question, as policymakers are often in the position to influence the provision of amenities, whether directly through public facilities or indirectly through urban planning tools and financial incentives such as grants or subsidies. Consider the "Whole Foods Effect", "Starbucks Effect", or "Waitrose Effect", which have long been casually used by real estate professionals to describe an idea that these amenities can increase property value in their proximity. To put it into context, Whole Foods Market is an upscale supermarket that purveys natural produce, local delicacies and environmentally friendly products based in the United States. It had more than 460 stores across Northern America and Britain and $16 billion in sales before it was acquired by Amazon for $13.4 billion in 2017. Every country has their own version of Whole Foods Market; for example, for the U.K., it is Waitrose & Partners.

There are several reasons why such amenities may increase property value. For example, they could be part of a neighborhood revitalization program that alter the real estate landscape, making the whole area more desirable. Slade (2018) finds that land prices increase by 39% over 4-year development of a Wal-Mart supercenter, while Pope and Pope (2015) showed that property prices increase by 2-3%.[1] In this article, we focus on Whole Foods Market because it is relevant to the ongoing discussion of gentrification. Upscale supermarkets and trendy coffee shops are appealing to wealthier residents who tend to be more concerned about safety, so they could serve as a sign of quality to potential residents (or an anchor), attracting more affluent residents and alter the economic landscape, which in turn drives up property value. This gentrification effect has been shown to reduce crime rate theoretically by O'Sullivan (2005) and empirically (the Starbucks Effect) by Papachristos et al. (2011). The notion of gentrification by Whole Foods Market has even entered popular media. For example, in an episode of South Park (the American satirical cartoon show) season nineteen which aired in 2015, one of the residents at the City Hall meeting proposes the idea of getting a Whole Foods Market to open as it would "instantly validate us as a town that cares about stuff". Local authorities often give concessions to private businesses to open in their community as the

[1] The methodologies used by the two articles are different and the focus of Pope and Pope (2015) is on property prices, while Slade (2018) focuses on land prices. Our approach is similar to Pope and Pope (2015), but our contribution lies in the linkage between Whole Foods Market and gentrification.

increased business activities and economic activity translate into local employment opportunities and tax income. For example, the Whole Foods Market Store in Detroit which opened in June 2013 received $4.2 million in direct incentives[2], while the Engelwood store (one of the poorest neighborhoods of Chicago) indirectly benefited from more than $10 million of public infrastructure improvements[3].

To illustrate why causality is important, imagine an analyst tasked with estimating the Whole Foods Effect. She conducts a simple analysis of proximity and prices, finds that properties near Whole Food tend to have higher prices, and use the result as the extent of effect.[4] But to an econometrician, one cannot conclude from the result that Whole Foods Market stores *cause* property prices to increase. Rather, it could be that Whole Foods Market chooses to locate where wealthy customers live, which also happen to be where property prices tend to higher; in other words, the direction of causality is reversed. Proximity and high prices could be due that fact that Whole Foods Market stores tend to be located near other amenities, such as public transport, a park or a Starbucks, so high property prices could be due to those amenities rather than supermarkets; in other words, the comparison omits the real cause. Economists refer to these challenges in causal inference as endogeneity problem, which implies that the outcome of a simple statistical analysis may not reflect the true effect of the phenomenon. Consequently, a more rigorous empirical methodology is required to identify the causal impact. In this article, we use the difference-in-differences strategy which involves comparing prices of properties before versus after store opening (the first difference) and closer versus further away (the second difference). The double comparison makes the distinction between the "control" group versus "treatment" more apparent and easier to argue that the effect is causal. More details of this strategy is provided in Section 2.2.

## DATA AND EMPIRICAL STRATEGY

We investigate the causal impact of the Whole Foods Effect by exploiting the expansion of Whole Foods Market between 2004 and 2010 and a micro dataset with very precise geographical identification of properties, thus allowing the calculation of distance to store (rather than proximity based on ZIP code). Using store openings as an event, we can address the potential endogeneity issues by using the difference-in-differences strategy that compares prices of properties closer and further away the stores (the first difference) before and after store openings (the second difference).

To motivate this strategy, consider Figure 1, which shows the average log prices at varying distances to stores around their opening dates. By considering prices of properties closer to the stores relative to properties further away, we are able to address the concern about other amenities in the neighborhood that could influence property value; the closer a property is to a store, the more benefit it derives. The relative log price allows us to interpret the values as multiples of the baseline, which in this case is average prices of properties 2 to 4 miles away from a store (which is used as the reference/control group) at the store opening date. The second point to look out for in this figure is that, if the effect were to be causal, we expect to find the relative log prices follow similar trends prior to store openings at all distances from the store (here, within 1 to 2 miles, 0.5 to 1 mile and 0 to 0.5 mile). This is the "parallel trend" assumption required by the difference-in-differences strategy to limit potential concern that the rise in price is caused by factors other than store openings. Figure 1 provides reassurance that the strategy to identify the Whole Foods Effect is valid.[5]

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[2] https://www.crainsdetroit.com/article/20110727/FREE/110729897/4-2-million-in-incentives-key-to-whole-foods-deal, accessed on March 5, 2020.

[3] https://www.chicagotribune.com/business/ct-detroit-whole-foods-met-20150316-story.html, accessed on March 5, 2020.

[4] A 2007 study by a consulting firm Johnson Reid use similar methodology and find that special grocers such as Whole Foods Market increase property values in Oregon by 17.5%. http://www.reconnectingamerica.org/assets/Uploads/JohnsonGardner-Urban-Living-Infra-Research-Report.pdf, accessed on March 5, 2020.

[5] However, we caution the readers that Figure 1 is intended as motivation only, as the prices are unadjusted for property characteristics such as size and age. Our result relies on a more rigorous multivariate analysis to be later described in Section 2.2.


*Figure 1:*
*Average Log Prices of Properties around Whole Foods Market Opening Dates*

The above graph plots the average log prices of single-family residences and condominiums near Whole Foods Market stores around opening dates. Only openings between 2007 and 2008 are included. During this time period, there are 37 stores openings in Arizona, California, Connecticut, Florida, Hawaii, Illinois, Michigan, Missouri, New Jersey, Nevada, New York, Ohio, Oregon, Rhode Island and Virginia. Quarter is defined relative to opening dates. Averages are taken by quarter for each proximity categories: 0 to 0.5 mile, 0.5 to 1 mile, 1 to 2 miles and 2 to 4 miles, then normalized by values of the 2 to 4 miles category. Distance is calculated based on geographical latitudes and longitudes of street addresses. Prices are normalized in each proximity category by the level of opening quarter (t=0)

## Data

This article employs two datasets containing store opening dates and housing transactions in the vicinity. The opening dates are hand-collected from the corporate website, map websites, local newspapers, weblogs, and review websites. There is a total of 100 new stores in 27 states opened between 2004 and 2010 that can be successfully linked to housing transaction data (to be described later). The locations and opening dates are matched to transactions of single-family residences and condominiums between 2002 and 2012 from CoreLogic, who aggregates public records from assessor's offices and recorders of deeds in individual towns and counties. For each arms-length transaction, where property ownership is transferred to unrelated buyer, data on price, sale date and property characteristics, such as the living area in square feet, lot size, number of bedrooms and bathrooms, and building age is recorded. One key characteristic of the dataset is the geographical coordinates of the property, which allows computation of straight-line distance to the store. We restrict the analysis to properties that are within 4 miles radius of stores and 10 quarters surrounding the opening dates to limit the influences of other spatial and temporal factors.

Table 1 shows the summary statistics of housing transactions. In the first column, we report the summary statistics for all properties. The second to fifth column report the summary statistics for properties within different proximity category per the empirical strategy.

**Table 1:** Summary Statistics

Summary statistics for single family residence and condominium transactions located near Whole Foods Market stores within 10 quarters of event dates are presented here. The statistics are provided separately for transactions prior to and after the opening. Standard deviations are presented in parentheses.

***Panel A: pre-opening***

| Distance to store | All properties | 0m-0.5m | 0.5m-1m | 1m-2m | 2m-4m |
|---|---|---|---|---|---|
| Distance in miles | 2.50 | | | | |
| | (0.99) | | | | |
| Transaction price | 415,337 | 411,767 | 454,465 | 441,861 | 403,019 |
| | (294,853) | (306,829) | (314,860) | (308,313) | (286,902) |
| Living area in square feet | 1,601 | 1,341 | 1,575 | 1,600 | 1,614 |
| | (815) | (635) | (852) | (826) | (811) |
| Lot size in acres | 0.23 | 0.30 | 0.22 | 0.23 | 0.23 |
| | (0.50) | (0.75) | (0.53) | (0.47) | (0.49) |
| Number of bedrooms | 2.61 | 2.25 | 2.52 | 2.63 | 2.63 |
| | (0.92) | (0.84) | (0.92) | (0.94) | (0.91) |
| Number of bathrooms | 1.97 | 1.71 | 1.94 | 1.99 | 1.98 |
| | (0.97) | (0.84) | (0.96) | (0.98) | (0.97) |
| Building age | 41.66 | 42.02 | 40.94 | 41.29 | 41.84 |
| | (30.02) | (29.50) | (30.62) | (30.48) | (29.82) |
| Recently renovated | 13.3% | 16.6% | 15.3% | 15.9% | 12.2% |
| Has garage or carport | 50.0% | 33.8% | 44.1% | 51.9% | 50.5% |
| Has fireplace | 29.4% | 21.8% | 29.1% | 33.2% | 28.5% |
| Has pool | 5.7% | 3.9% | 5.2% | 6.1% | 5.7% |
| Property is a condominium | 36.6% | 66.7% | 52.8% | 40.9% | 32.5% |
| N | 622,491 | 15,694 | 40,607 | 140,088 | 426,102 |
| % of total transactions | 100.0% | 2.5% | 6.5% | 22.5% | 68.5% |

**Table 1:** Summary Statistics (continued)

***Panel B: post-opening***

| Distance to store | All properties | 0m-0.5m | 0.5m-1m | 1m-2m | 2m-4m |
|---|---|---|---|---|---|
| Distance in miles | 2.51 | | | | |
| | (0.98) | | | | |
| Transaction price | 433,610 | 502,221 | 504,141 | 473,573 | 411,764 |
| | (329,290) | (363,342) | (355,250) | (343,835) | (318,084) |
| Living area in square feet | 1,594 | 1,339 | 1,558 | 1,592 | 1,607 |
| | (810) | (643) | (816) | (841) | (803) |
| Lot size in acres | 0.25 | 0.33 | 0.26 | 0.25 | 0.24 |
| | (0.51) | (0.75) | (0.57) | (0.50) | (0.50) |
| Number of bedrooms | 2.58 | 2.26 | 2.50 | 2.59 | 2.60 |
| | (0.91) | (0.83) | (0.93) | (0.93) | (0.90) |
| Number of bathrooms | 1.96 | 1.77 | 1.98 | 1.96 | 1.96 |
| | (0.97) | (0.85) | (0.95) | (0.99) | (0.97) |
| Building age | 42.78 | 42.09 | 42.65 | 43.54 | 42.58 |
| | (30.73) | (31.65) | (31.98) | (30.80) | (30.55) |
| Recently renovated | 12.7% | 16.0% | 16.0% | 15.1% | 11.5% |
| Has garage or carport | 47.1% | 30.7% | 42.2% | 47.8% | 47.9% |
| Has fireplace | 27.4% | 19.4% | 26.8% | 29.2% | 27.2% |
| Has pool | 5.6% | 3.6% | 4.4% | 5.7% | 5.8% |
| Property is a condominium | 38.9% | 68.1% | 53.1% | 42.8% | 35.3% |
| N | 466,354 | 11,442 | 29,433 | 104,093 | 321,386 |
| % of total transactions | 100.0% | 2.5% | 6.3% | 22.3% | 68.9% |

## Empirical Strategy

Looking at raw prices is uninformative as each housing unit is different. To uncover the values of such amenities, economists have relied on hedonic price regression developed by Rosen (1974), which regresses log prices on attributes that could influence their prices such as size, age and quality. Because consumers' marginal willingness to pay for a particular amenity is reflected in transaction prices, analysis of changes in property prices provides a market-based approach to quantify one dimension of externalities. The coefficients of log price regressions are conveniently interpreted as percentage change in housing price in relation to a unit change in an attribute. The simple cross-section regression is vulnerable to endogeneity issues described earlier, so the difference-in-differences strategy is preferred and has been used widely to document the extent of externalities capitalized into housing prices. For example, using cleanups of hazardous waste sites, measures of air quality, and openings and closings of toxic plants, Greenstone and Gallagher (2008), Bajari et al. (2012) and Currie et al. (2013) document that housing prices are negatively affected by pollution.

The difference-in-differences strategy involves estimating a linear regression equation with fixed effects as specified in Equation (1). The inclusion of fixed effects allows potential factors that influence property prices not observed by the econometrician (omitted variables) but does not require explicit explanation to be accounted for. We include location-time fixed effects, which allows housing price trends within 4 miles radius of each store to be unique. The advantage of including these fixed effects is that they represent local housing price trends around each store, so any price differences will be driven by proximity to store. In other words, the Whole Foods Effect will be estimated as deviations from unique local housing price trends, which gives more comfort to the econometrician about the true extent of the effect.[6]

$$y_{ist} = \alpha_{st} + \beta_0' R_i + \beta_1' R_i \cdot post_i + \gamma' X_i + \varepsilon_{ist} \quad (1)$$

The dependent variable  is the log transaction price of property that is within 4-mile radius of store at time. Since the time unit used for this analysis is monthly, the fixed effects  are defined for each store-year-month. For the first difference, we create an indicator variable  which takes value of 1 for transactions that occur after the store has opened. This is the first difference as described in the Introduction section. The proximity categories for the baseline analysis are (1) within 0 to 2 miles and (2) within 2 to 4 miles. The proximity categories are implemented as an indicator variable which take value of 1 for properties closer to the store, while the 2 to 4 miles category is omitted as control group for this experiment. In further analyses, we divide the 0 to 2 miles category into three sub-categories (0 to 0.5 mile, 0.5 to 1 mile, 1 to 2 miles) to allow for greater flexibility in estimating the Whole Foods Effect. Proximity is the second difference in the strategy. The control variables are living area in square feet, lot size in acres, number of bedrooms, number of bathrooms, property age in years at the time of transaction, age-squared, indicator variables for whether the property was recently renovated, has garage or carport, has fireplace or has pool. The coefficient of interest is, which represents the average log price difference (interpretable as percentage difference) after store opening relative to the control group. Standard errors are clustered at the store level.

## RESULTS

Column 1 in Table 2 reports the result for the baseline analysis. Controlling for observable property characteristics and unobserved heterogeneities that are allowed to vary monthly within 4 miles of a store, properties within 2 miles radius command 3.9% higher prices than properties that are further

[6] However, the econometrician has to tradeoff this "identification" with the ability to investigate other factors that could also influence property prices in the area.

away. A natural question to ask is whether the price externality varies over distance. Rossi-Hansberg et al. (2010) find that the positive effect of the urban renewal program decays with distance from the impact area. In column 2, we divide the proximity indicator into three subcategories and estimate the same regression. As expected, the effect declines with distance, with the closest properties (within 0.5 miles) experiencing more than 6.7% increase in price. An average property within half-mile radius sells for $410,000, so the impact of a Whole Foods Market store opening for a homeowner who lives nearby is approximately $27,000.

The analyses in column 1 and 2 are both based on the restriction that transactions must be within 10 quarters before and after the opening, thus the estimated coefficients represent average increases over a 2.5 years period. By altering the width of the post-opening window, one could examine how price externality propagates over time. Column 3 reduces the window to 4 quarters while Column extends the window to 20 quarters. The magnitudes of the coefficients are similar to the earlier result, suggesting that the amenity value is incorporated quickly and the price effect of externalities is not transient. The monotonicity of the price externality in all specifications is consistent with the view that externalities are closely related to proximity.

## CONCLUSION

In this article, we quantify the causal effect of a Whole Foods Market's store opening on the value of nearby residential properties. The average increase in price is 6.7% for properties within 0.5 miles of a new store, less than half of the less rigorous method that of Johnson Gardner (2007), and twice the effect found for Wal-Mart's store openings by Pope and Pope (2015), equivalent to approximately $27,000 increase in home equity for an average homeowner. Given its role in modern lifestyle, supermarket is an active research topic. From urban planner' perspective, the issue of negative externalities such as road congestion and urban trip generation have long been at the center stage. We hope that this article adds another dimension to the urban planning dialogue.

The objective of this article is not to pinpoint the mechanism(s) that lead to price increases, but we establish that the Whole Foods Effect is not a myth and highlights the role of rigorous econometric technique in identifying the magnitude and causality of the effect. The Whole Foods experience here can be viewed more broadly as an urban revitalization program, where policymakers often provide public support, both directly and indirectly. As the result is based on analysis of openings between 2004 and 2010, it should not be interpreted as how big the price uplift the next Whole Foods store would be; rather, it serves as a reminder that policy discussions should be based on estimates that do not suffer from endogeneity issues.

While the magnitude of the Whole Foods Effect is substantial, property price is only one of the multifaceted real estate externalities. It is worth noting that such price effect is intertwined with gentrification, which, despite positive externalities to the local economy by increasing entrepreneurs' borrowing capacity through higher collateral value (Black et al., 1996; Adelino et al., 2015) and reducing crime (O'Sullivan, 2005; Papachristos et al., 2011), such benefits are not captured by everyone and some community members may even be adversely affected. Weller and Hulten (2012) document an erosion of housing standards of lower-income household as a result of gentrification, as well as the dissolution of their local communities, highlighting the importance of affordable housing policies in urban planning.[7]

[7] Planners have long recognized the importance of affordable housing policies. For example, the Atlanta Beltline – a project that connects 45 neighborhoods via a loop of trails, tracks and parks in – set up a ring-fenced trust fund and advisory board for the of affordable housing (Immergluck and Balan, 2018). But the question of how the policies should be instituted, such as whether it should be mandatory or incentive-based (Karki, 2015) remains a topic of debate.

**Table 2:** Effect of Whole Foods Market Openings on Nearby Property Prices

The following table reports the results from estimating difference-in-differences OLS of hedonic pricing regressions. The main explanatory variable is the log price. Proximity categories are defined based on the distance between the geographical coordinates of the store and property street addresses in miles. The model in column 1 is estimated based on two proximity categories: 0 mile to 2 miles and 2 miles to 4 miles. The model in column 2 refines the first proximity category into 0 mile to 0.5 mile, 0.5 mile to 1 mile, 1 mile to 2 miles. Properties 2 miles to 4 miles from stores are used as control group. All models restrict transactions to occur at most 10 quarters before the event. Column 1 and 2 also restrict transactions to occur at most 10 quarters after the event. Columns 3 and 4 vary the post-opening window to 4 quarters and 20 quarters. Controls in all regressions include property characteristics and store-year-month fixed effects. Standard errors, clustered at the store level, are reported in parentheses. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Post-opening window (quarters) | 10 | 10 | 4 | 20 |
| VARIABLES | lnprice | lnprice | lnprice | lnprice |
| Within 2m radius | 0.0846*** | | | |
| | (0.0185) | | | |
| Within 0.5m radius | | 0.1195** | 0.1189** | 0.1225*** |
| | | (0.0462) | (0.0468) | (0.0454) |
| Within 0.5m to 1m radius | | 0.1158*** | 0.1170*** | 0.1157*** |
| | | (0.0328) | (0.0330) | (0.0322) |
| Within 1m to 2m radius | | 0.0725*** | 0.0731*** | 0.0724*** |
| | | (0.0154) | (0.0154) | (0.0152) |
| Within 2m radius * Post-opening | 0.0391** | | | |
| | (0.0157) | | | |
| Within 0.5m radius * Post-opening | | 0.0675** | 0.0761** | 0.0740** |
| | | (0.0328) | (0.0350) | (0.0354) |
| Within 0.5m to 1m radius * Post-opening | | 0.0506** | 0.0432** | 0.0567** |
| | | (0.0206) | (0.0200) | (0.0235) |
| Within 1m to 2m radius * Post-opening | | 0.0330** | 0.0276* | 0.0299* |
| | | (0.0150) | (0.0149) | (0.0160) |
| Housing characteristics as controls | Yes | Yes | Yes | Yes |
| Store ID * year * month fixed effects | Yes | Yes | Yes | Yes |
| Observations | 1,088,845 | 1,088,845 | 863,682 | 1,272,169 |
| Adj R-squared | 0.614 | 0.614 | 0.607 | 0.627 |
| Number of stores | 100 | 100 | 100 | 100 |

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# Development of Agro-Cultural Tourism Route Based on Spatial Configuration Analysis:

## The Case of a Rubber Planting Village, Songkhla Province, Thailand

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## ABSTRACT

This article proposes an alternative to develop agro-cultural tourism routes based on spatial configuration analysis. A village growing rubber trees in Songkhla Province, Thailand, was taken as the case study. The data analysis involved the theory of urban morphology and the space syntax. Given the characteristics of the area and the planters' socio-cultural characteristics, the results revealed that potential tourist attractions should be charted only on a movement network with high visibility and accessibility whereas those on a movement network with low visibility and accessibility should be left intact. However, some rules and regulations should be imposed to preserve the livelihood of the villagers and the ecosystem of the area.

***Keywords:*** *spatial configuration, space syntax, agro-cultural tourism, rubber planters, Songkhla*

## INTRODUCTION AND BACKGROUND

Since natural rubber is a major cash crop in Thailand, rubber trees are cultivated throughout the country. They were first cultivated in the South and, according to data obtained in 2017, most rubber trees are grown in the South, accounting for 59% (14.77 million rai) of the total rubber plantation area (Department of Agricultural Extension, 2017). The latex harvest starts at night until early morning, during the day, the rubber planters, therefore, can spend time growing other crops such as fruit trees, herbs and kitchen vegetables or raising animals. The rubber planters have practiced this livelihood for generations. Such practice is called integrated farming system — Suan Somrom — supports the ecosystem (Buncha Somboonsuke et al., 2010; Aramrat Duangechana, 1999). They also engage in other activities such as handicraft, food preservation, fresh-water fishery, artwork and participation in festive ceremonies. It can be said that their livelihood is simple yet sufficient and adapted to seasonal changes.

With the unique characteristics of the locals, their culture and their diverse products, these locals can offer an agro-tourism program to visitors. The program includes a wide range of activities from planting crops, harvesting and producing plant and animal products. Visitors can acquire not only a relaxing moment but also a hands-on experience during their visit while the locals earn more income (Holinhoij, 1996; Goldberg, 1997; Rampaipan Keawsuriya, 2001; Department of Tourism, 2009). However, agro-tourism related to rubber plantation is not so popular as that of other crops such as orchards, lotus farms, sunflower farms, tea plantations, coffee plantations, vineyards and strawberry farms. Those places are widely recommended because they have been designated as tourist attractions, and the most accessible routes to them have been identified. However, the other sites that are worth visiting along such routes have not been introduced; as a result, unfortunately, the visitors miss those places or even nearby attractions due to not being informed about the road network.

The simple yet sufficient livelihood settlement matches the agricultural society in the rural area. Even though the layout seems complicated and non-structured, the expansion of this society is in line with its topography. This is a cultural characteristic of a traditional village. Hillier and Hanson (1984) observe that culture is a mechanism that is used to manage a complex society so that the members of that society can lead peaceful lives and keep the level of disturbance to natural surroundings at a minimum. Given this concept, the area is divided into 2 parts – dwellings for inhabitants and meeting areas designated outside the dwellings where inhabitants and strangers socialize. The meeting areas are set aside to ensure inhabitants' privacy. However, the travelling routes in the Eastern agricultural society differ from those in the Western World in terms of how they are developed and how the agricultural society is developed into the urban society. In the Eastern World, a settlement takes place on an open space, and the routes are not systematically developed; they are extended when required (Pranom Tansukanun, 2006). The whole area in the society is considered a public area because there is no clear-cut boundary between the dwelling area and the agricultural area (Rawiwan Oranratmanee, 2013). A small open space accommodates routes and shortcuts known only to the community members (Khaisri Paksukcharern, 2008). Rubber planters also use the space between rubber trees as a shortcut and transportation routes accessible by small vehicles. This helps them save the transportation cost for carrying latex to the market. Additionally, nearby plantations can share these routes, and planters can rely on one another in watching over their plantation (Tapanee Rattanathavorn and Pornchai Jittiwasurat, 2013). The routes can take up both public and private areas (Nidhi Eawsriwong, 2011), including restricted and fragile areas, however, the private area is not clearly designated. The community members are aware of this fact. They are familiar with these paths and places that are worth visiting while outsiders or visitors can be easily disoriented during their first visit.

When a community growing rubber trees is developed into a tourist attraction, the essence of agro-tourism, therefore, should lie in the attractions and related activities without disturbing the locals' livelihood. By taking spatial characteristics that shape and form the morphology of the community into consideration, the disturbance can be kept minimal. Hillier and Hanson (1984) provided an insight into spatial structure that outlines the relationship between spatial configuration characteristics, the open space and transportation system and activities taking place in certain areas. The use of an area, whether a popular site or not, is also a factor to be taken into consideration. It is generally accepted that the spatial structure represents the relationship between a site and its activities (Jones and Larkham, 1991), which is in line with the concept "Social Logics of

Space and Spatial Logics of Society" in that a social structure corresponds to spatial characteristics. The social structure is a product of social organization and spatial morphology is influenced by society (Hillier and Hanson, 1984).

In the same vein as the theories or concepts mentioned above, the urban morphology takes open space and the transportation system into consideration because they can determine whether the site can be defined as an urban site or not. If a lot of people can readily access a site or space that can accommodate a variety of activities, such site can be classified as urban (Jacobs, 1961). The effective management of open space and transportation system can facilitate people to move to their destination, and through other spaces, introduce socio-economic activities (Hillier and Hanson, 1984). The theory of natural movement agrees that the level of movement varies according to the connectivity between the open space network and the transportation network. The activities carried out in a quiet area differ from those in a crowded area. The theory of the movement economy process (Hillier, 1996) asserts that an activity that does not require a lot of movement is found in a quiet area or a low potential area; in contrast, an activity that requires a lot of movement is found in a high potential area. Such activity acts as an attractor, creating multiple effects on people, trades and other activities. Eventually, this area becomes a live center as mentioned in the theory of spatial centrality as a process (Hillier, 2000).

This is an important aspect of urban morphology since it interacts with other aspects to form a spatial structure of that area. An insight into spatial characteristics benefits city planning at the global urban and local urban scales, and the planning process can be recycled (Khaisri Paksukcharern, 2005). Such characteristics can also be applied to the development of agro-cultural tourism routes for an agro-cultural community. With accurately identified characteristics, a community can designate potential routes and develop activities corresponding to the routes to ensure a safe visit for visitors. Visibility and accessibility encourage visitors to spend more time and more money in the community. This concept underlies agro-cultural tourism in a rubber growing village.

According to the statistics obtained from the Department of Agricultural Extension (2017), the rubber plantation in Songkhla province covers an area of 2.17 million rai or 15% of the whole area set aside for rubber plantation in the South. The rubber plantation in Songkhla province accounted for the second largest area in the South. The case study for this research was a village bordering Hat Yai District (Figure 1) because it is an important trading village at the provincial and regional level. Covering an area of 3.8 square kilometers, this village is located on


*Figure 1:*
*Location of Khuanjong Village, Songkhla Province, the South of Thailand (ArcGIS Desktop map devised by the author, 2018)*

the Songkhla Lake Basin, which favors agro-cultural practices (Figure 2). Seventy percent of the area is still covered with natural vegetation and that grown by planters. Most of the farmers grow rubber trees and other plants as their ancestors did. Regarding socio-cultural aspects, they are closely related and their livelihoods are similar. Most of them are farmers growing rubber and other plants. They strictly adhere to their religious and cultural beliefs and actively participate in religious and cultural activities.

All things considered, Khuanjong has the potential for becoming an exemplary village for agro-cultural tourism. Over the past years, these planters have been adjusting themselves to the adverse economic situations, one of which was the low pricing of rubber sheets, by planting more varieties of plants, processing food and producing other products. As a result, their agro-cultural practices have become more diverse. The government offices have equipped them with knowledge and tools so that their village can be a site for agro-cultural tourism. However, so far, it has not been materialized by the village leaders. The researcher, therefore, would like to take this village as a case study by proposing ways to develop agro-cultural routes specifically for a rubber growing village. With the application of the theory of urban morphology, such routes and related activities or suitable attractions along the routes can be identified. The objectives of this study were to: 1) analyze the relationship between the spatial characteristics and the physical and socio-cultural elements of the village to determine how to develop its agro-cultural tourism routes; and

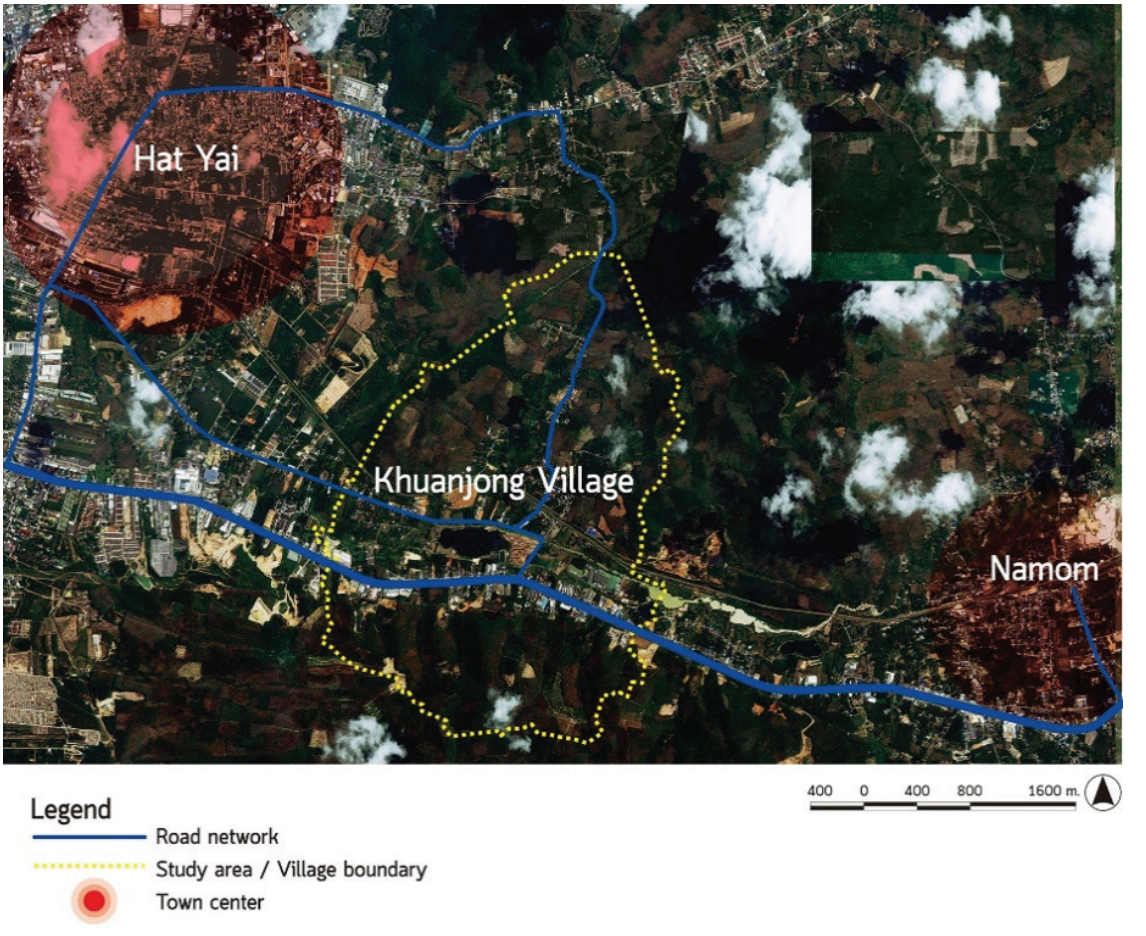



*Figure 2:*
*Boundary of Khuanjong Village and Routes Connecting Neighboring Villages (ArcGIS Desktop map devised by the author, 2018)*

2) develop appropriate agro-cultural tourism routes in Khuanjong Village based on urban morphology without disturbing the villagers' livelihood and their natural surroundings.

## RESEARCH METHODOLOGY

The research methodology includes the spatial configuration analysis to evaluate the effectiveness of open space and transportation network and the analysis of the physical, socio-cultural components of the village.

### Spatial Configuration Analysis

Based on spatial configuration analysis, a spatial configuration model or an axial map representing longest and fewest axial lines was created. These lines are drawn to form a transportation network that is publicly accessible and clearly visualized. Then Space Syntax is used to process the maps (Tuner, 2003) and the results are shown in colors ranging from warm to cool colors. The warm colors represent integration while the cool ones represent segregation. Red, therefore, represents the highest potential route or the highest integration in the urban fabric followed by orange, yellow, green and blue representing the highest segregation in the urban fabric. In general, the results of the axial map should reveal the temperature of all graduated colors and the urban center or node should be represented with warm colors showing that its permeability is so high that it is likely to be a live center (Hillier, 2000).

### Physical and Socio-cultural Analysis

The characteristics of physical and socio-cultural components were collected from March to June, 2018. The data collection involved 1) a field survey, 2) in-depth interviews and 3) a workshop. The field survey collected the physical data — locations, land use, buildings and important areas, natural settings and agro-cultural areas — and the socio-cultural data — activities concerning society, traditions, culture, religion, production and agriculture. The in-depth interviews involved 14 key informants who were community leaders, local intellectuals and farmers to obtain physical information about the society, culture, production and agro-cultural practices that could be applied to the tourism. Then data triangulation was conducted (Denzin, 1970). All of the data were classified by color and plotted on the community map referred to as a map representing the physical, socio-cultural components of rubber farmers. Then the community map and the spatial configuration model were analyzed to determine the routes. Two workshops based on the community participatory approach were organized for community leaders, local intellectuals, farmers and interested villagers. For each workshop, the development plans were proposed and the participants had to decide which was the most appropriate.

## RESULTS

### Spatial Configuration

The spatial configuration model in this study represents the movement in Khuanjong village including roads, alleys, walkways and shortcuts. They existed when the study was conducted. The data obtained from a geographical map and satellite images in 2018 via ArcGIS Desktop program represented land use, roads and public open space. The village covers an area of 3.8 square kilometers. The data obtained from the field survey were also taken into consideration (Figure 3-A).

**Global Integration Analysis (Rn) -** The analysis revealed all shades of color which indicated that, in this village, there were multiple levels of accessibility. The highest visibility and accessibility or the high integration values were at 0.7305, 0.7295 and 0.7275 as shown in red on Plakthong-Khuanjong Road, Bannairai-Khuanjong Road and Chantaro Uthit Road, respectively. It seems that these roads are important for the community; consequently, they are main roads while the low integration value was 0.2465 as shown in blue-dark blue on local streets and cul-de-sac. Yellow represented average potential areas that are local streets concentrated in the village center (Figure 3-B).

**Local Integration Analysis (R3) -** The warm colors were found in many areas. The highest visibility and accessibility or the high integration values were 2.4837, 1.9051 and 1.7852 as shown in red on Plakthong-Khuanjong Road, Chantaro Uthit Road and Bannairai-Khuanjong, respectively. It seems that they are the centers of the neighborhood evidenced by the connectivity of many local streets. The low integration value was 0.3333 as shown

in blue on cul-de-sacs. Yellow-green represented average-low potential areas that were found in other areas (Figure 3-C).

**Connectivity Integration Analysis -** On the map, there was only 1 spot with warm colors (red – orange) on Chantaro Uthit Road with a connectivity value at 5. This means that there are 5 roads connecting to this road translating into more movement than the other roads. In the other areas, the connectivity value was mostly at 1 meaning difficult accessibility (Figure 3-D).

It can be concluded that there are three important open space and transportation networks in Khuanjong village: Chantaro Uthit Road, Plakthong-Khuanjong Road and Bannairai-Khuanjong Road because of the highest global and local integration and the best connectivity integration. In addition, the junction where Plakthong-Khuanjong Road meets Chantaro Uthit Road and Bannairai-Khuanjong Road tends to be the center of this area where a lot of economic activities take place.

## Physical and Socio-cultural Characteristics

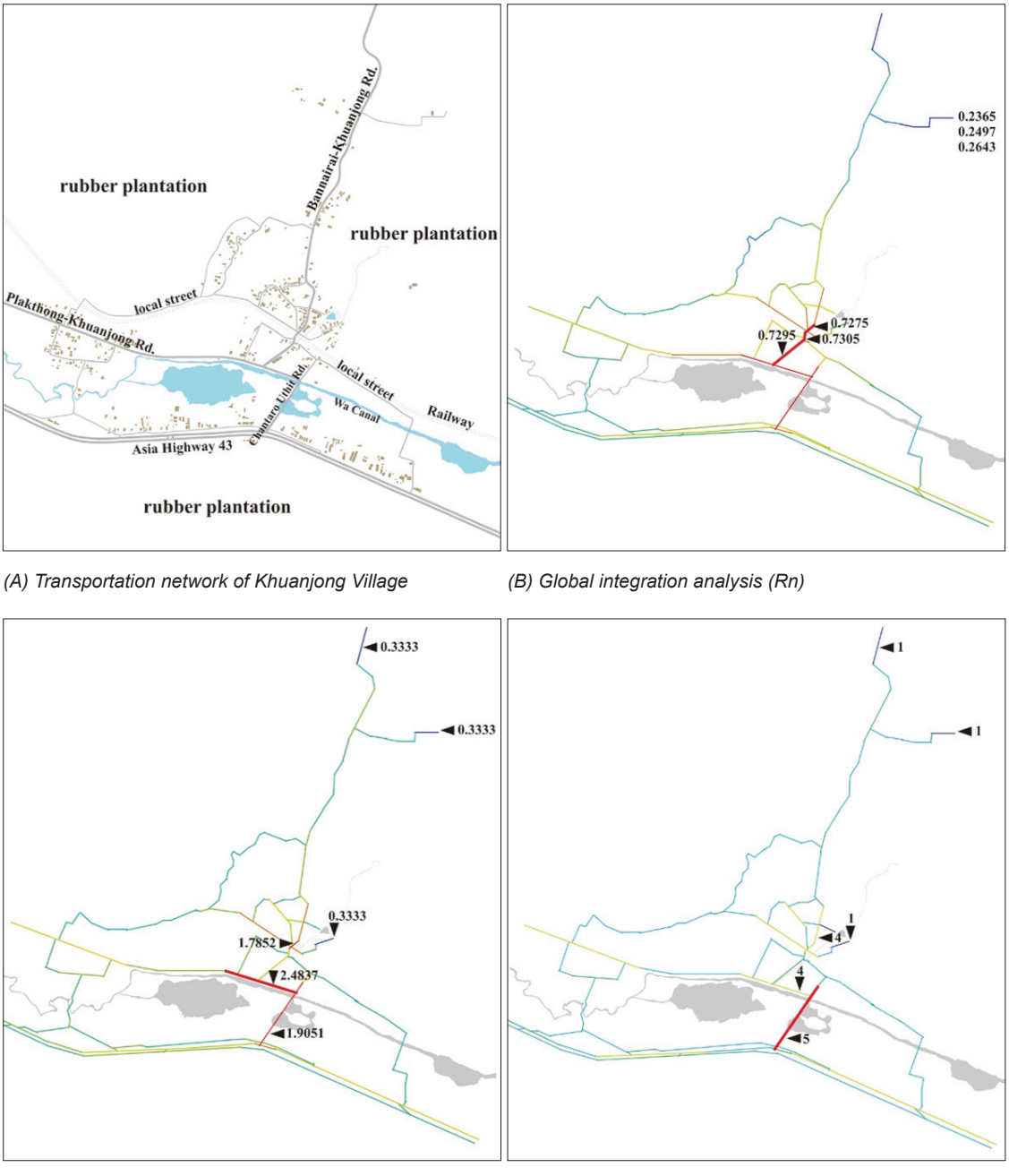
The data about the physical, social and cultural aspects of communities that have potential to be developed into tourist attractions were presented in the 1st Workshop and could be summarized as follows. These characteristics can be classified into 4 aspects: historical, natural, traditional and cultural, and livelihood (Figure 4-A). The aspects then are analyzed to determine the level of their importance and their potential to be a tourist attraction. According to the analysis, the four aspects can be further classified into three levels: a primary attraction, a secondary attraction and an attraction that can accommodate more visitors (Figure 4-B). The four aspects are outlined as follows (Figure 5):

**Historical aspect -** (1) Built in 1950, Khao Lom Temple is the main temple of the village. Within the compound, there is a forest providing a peaceful atmosphere and beautiful Buddhist structures. (2) Wang Ma Praw monk sleeping quarters, which were built in 1986, boast a beautiful Buddhist architecture. (3) Ban Khuanjong School, built in 1940, is a primary school but sometimes it is used as a venue for major events. (4) Khuanjong Railway Station is a part of the Southern Line. Although the station has not been in use since 1987, the train regularly passes through this station. (5) Only one vernacular southern-styled house has been preserved by the owner. (6) The banyan pavilion is an open space serving as a place for organizing the village activities. It is located near a canal where a large banyan tree is found and which is believed to be a sacred area.

**Natural aspect -** (1) Langka mountain is a beautiful mountain that can be seen from the distance. (2) Khuanklom mountain is a terraced rubber plantation. (3) Wa Canal is a natural canal with bamboo check dams. (4) Rubber Tunnel is a road lined with rubber trees creating a beautiful scenery that keeps changing due to the changing colors of the rubber leaves. (5) Waterfalls support many thickly growing trees that help provide sources of water to fill these waterfalls all year round. (6) The reservoir, a big and deep water source, is a suitable site for relaxation. (7) Offering a scenic view, the swamp is near the bend of the railway. (8) The community forestry is a place where one can find trees, rare plants and trees and local vegetation.

**Traditional and cultural aspect** - (1) Ritual performing such as paying respects to a spirit guarding an agro-cultural area. (2) There are many activities related to society, tradition, culture and religion, but most of them are Buddhist activities. The villagers also make merit to pay tribute to their dead relatives and ancestors.

**Livelihood aspect -** (1) The multipurpose building is for holding a meeting or organizing an activity. (2) The rubber production system indicates equal distance from one rubber tree to another. The latex collection is done between early morning and late morning. (3) The mixed plantation system is done by growing rubber trees and other trees or plants. The planters usually grow fruit trees because the products can be harvested throughout the year. (4) Growing kitchen vegetables and herbs. (5) Growing vegetables in a limited area is done in pots or small areas. These vegetables are grown in soil or without soil. (6) Three centers for fresh latex trading are in the village and it is sold directly to the factory. The planters can sell the latex every day. The centers can reflect the planters' livelihood. (7) Two trading zones where fresh food, fresh produce and cooked food are sold. One trading area is on the waterfront and the other is near the railway. (8) Cooking Southern food, (9) doing handicraft and (10) raising freshwater fish.



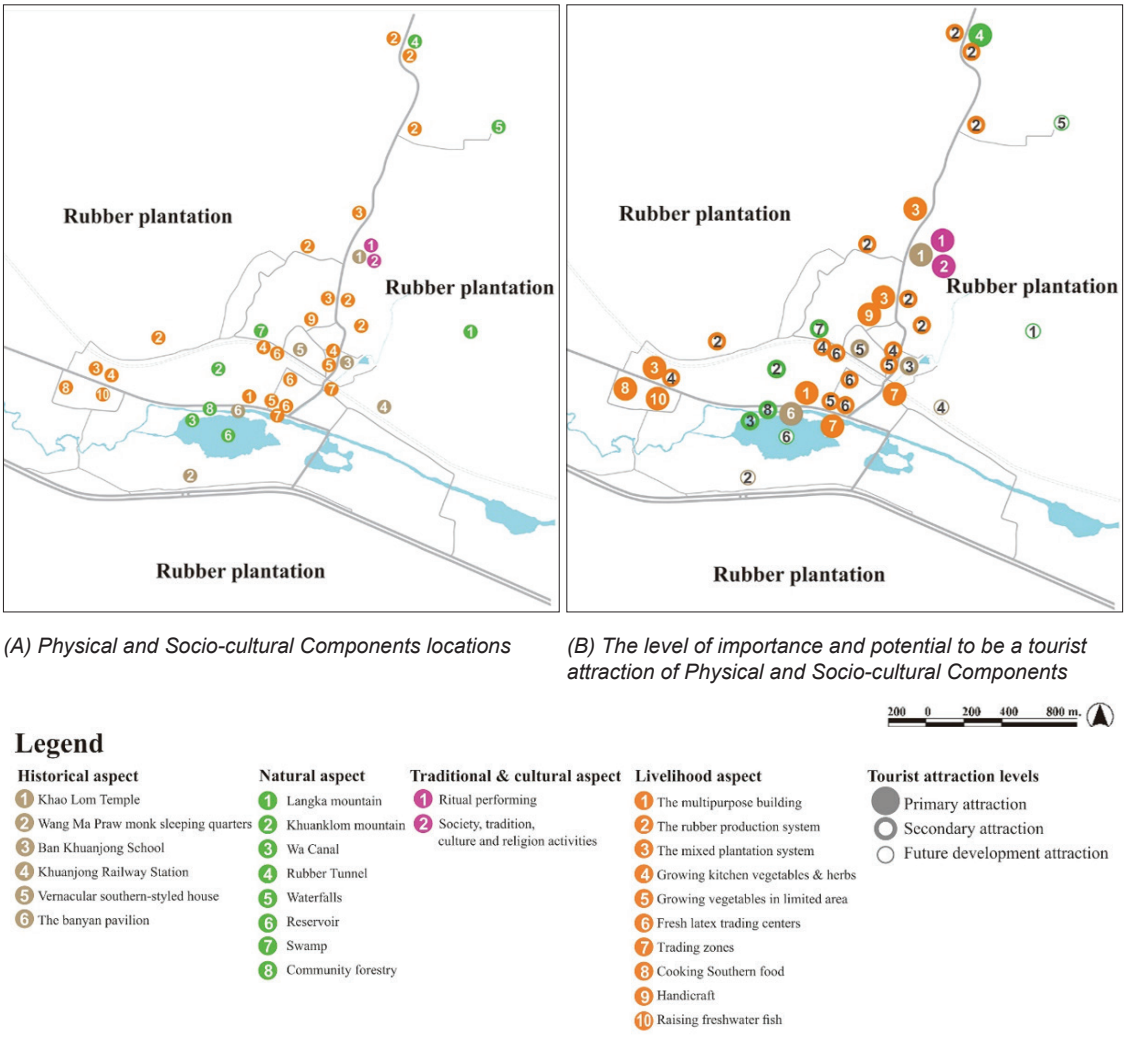

(A) Transportation network of Khuanjong Village

(B) Global integration analysis (Rn)

(C) Local integration analysis (R3)

(D) Connectivity integration analysis

*Figure 3:*
*Transportation Network and the Spatial Configuration Model of Khuanjong Village*




*(A) Physical and Socio-cultural Components locations*

*(B) The level of importance and potential to be a tourist attraction of Physical and Socio-cultural Components*

*Figure 4:*
*Physical and Socio-cultural Components of Rubber Planters in Khuanjong Village*

## Relationship between accessibility potential and physical and socio-cultural components

The data obtained from the spatial configuration model and those obtained from the map about physical and socio-cultural components are overlaid to determine the relationship between the open space and transportation system and the locations of the components. The results reveal the 4 aspects mentioned above and they are detailed as follows:

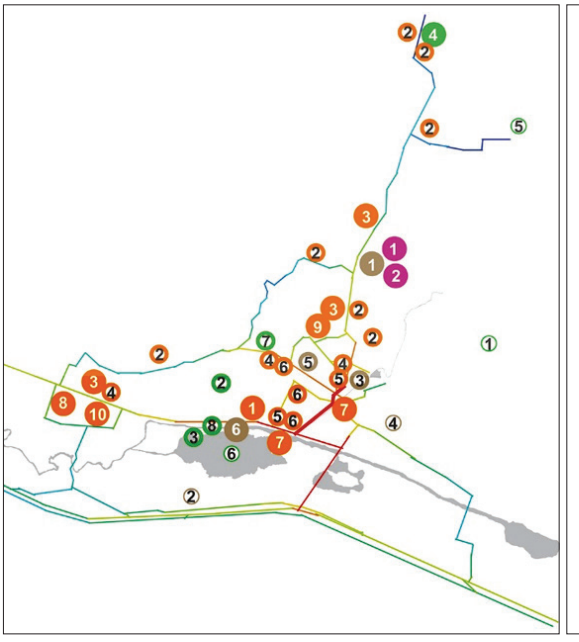
**Global integration analysis (Rn) and physical and socio-cultural components -** The potential movement networks with highest visibility and accessibility are Plankthong-Khuanjong Road and Bannairai-Khuanjong Road. All physical and socio-cultural components are found on these two networks. The components include a school, banyan pavilion, center for buying fresh latex, and multipurpose building. Such places are characteristics of the main road. The road integration with the highest potential results in a trading zone. Other important elements also spread to other potential movement networks. Centers for fresh latex trading, wetlands, areas for growing kitchen vegetables and herbs, and Southern vernacular houses are located on minor roads branching from Bannairai-Khuanjong Road. Khao Lom Temple, traditional and cultural aspects

*Figure 5:*
*Physical and Socio-cultural Components of Rubber Planters in Khuanjong Village*

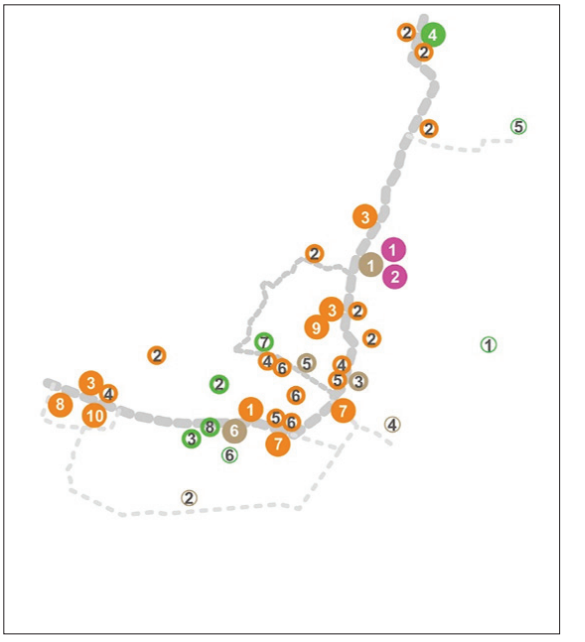
and livelihood aspects are found along some parts of this road whose potentials are average-low while the parts with low potential are the parts where waterfalls, Khao Langka and old railway station are located (Figures 6-A, B).

**Local integration analysis (R3) and physical and socio-cultural components -** The local integrations with high visibility and accessibility or an area that can serve as a community center are Plakthong-Khuanjong Road and Bannairai-Khuanjong. The components that are areas for holding activities are a school, banyan pavilion, center for fresh latex trading, multipurpose building and community trading area. These findings are in line with those of the global integration analysis. According to local integration analysis, the areas with average integration that are adjacent to the areas with high integration accommodate Khao Lom Temple, natural aspects, traditional and cultural aspects and livelihood aspects (Figures 6-C, D).

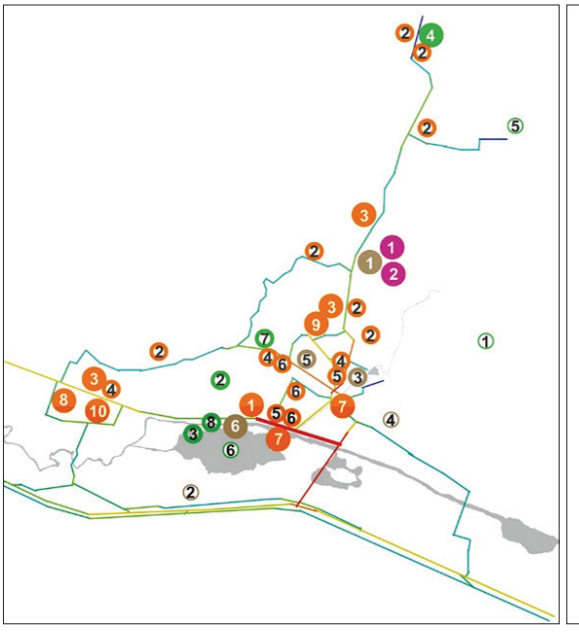
**Connectivity integration analysis and physical and socio-cultural components -** Chantaro Uthit is the most direct route; as a result, it can be designated as a high connectivity integration area. Plus, it can accommodate the largest number of roads, alleys and shortcuts. This road connects with Asia Highway 43, Plankthong-Khuanjong Road and Bannairai-Khuanjong Road; therefore, Chantaro Uthit has the highest potential to accommodate visitors to designated attractions via Phlakthong-



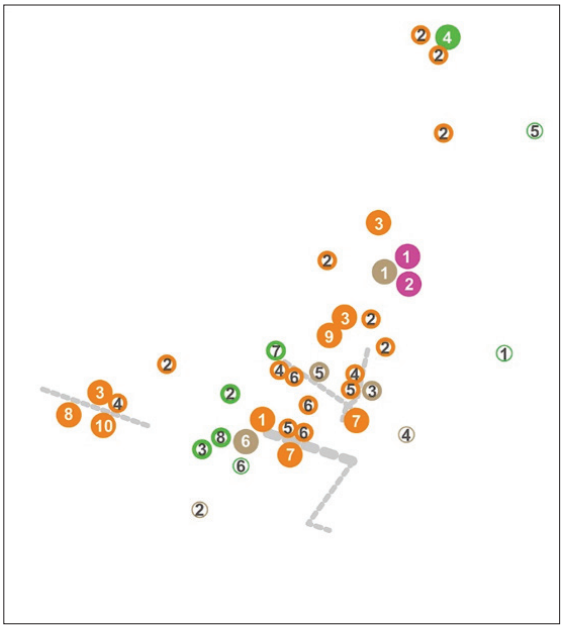
*(A) Global integration analysis (Rn) and physical and socio-cultural components*



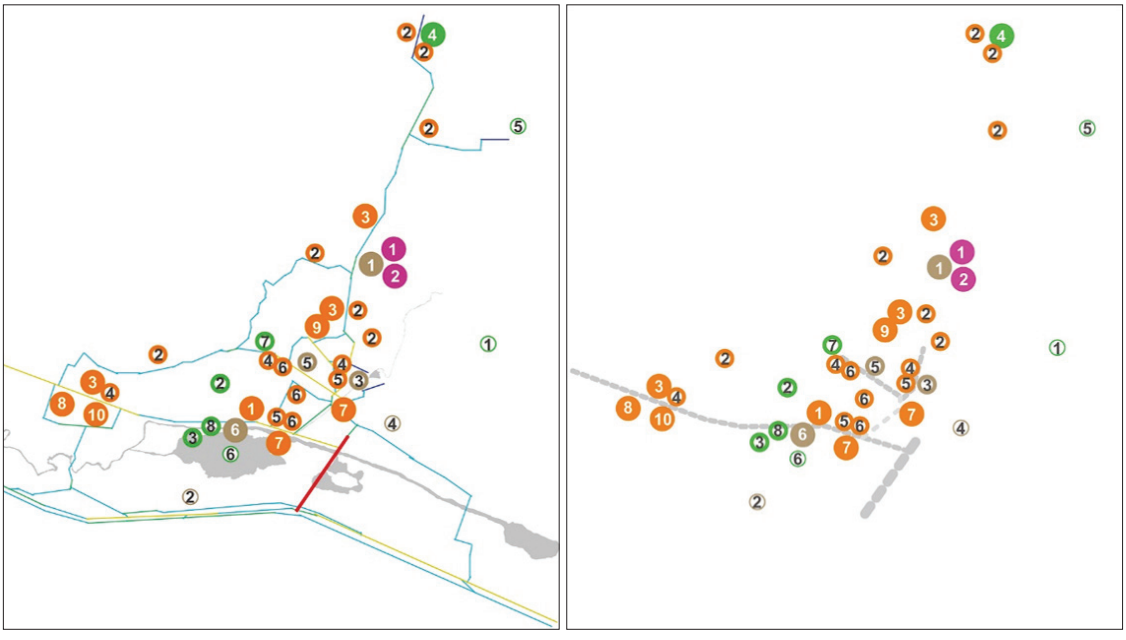
*(B) The potential of movement networks and physical and socio-cultural components*



*(C) Local integration analysis (R3) and physical and socio-cultural components*



*(D) The potential of movement networks and physical and socio-cultural components*



*(E) Connectivity integration analysis and physical and socio-cultural components*

*(F) The potential of movement networks and physical and socio-cultural components*

200 0 200 400 800 m.

**Legend**

Transportation network
Axial line network
Canal, Swamp, Resevior

**Integration Value**
Low — High

**Tourist attraction levels**
- Primary attraction
- Secondary attraction
- Future development attraction

**Potential of movement networks**
- Primary route
- Secondary route
- Future development route

**Historical aspect**
1. Khao Lom Temple
2. Wang Ma Praw monk sleeping quarters
3. Ban Khuanjong School
4. Khuanjong Railway Station
5. Vernacular southern-styled house
6. The banyan pavilion

**Natural aspect**
1. Langka mountain
2. Khuanklom mountain
3. Wa Canal
4. Rubber Tunnel
5. Waterfalls
6. Reservoir
7. Swamp
8. Community forestry

**Traditional & cultural aspect**
1. Ritual performing
2. Society, tradition, culture and religion activities

**Livelihood aspect**
1. The multipurpose building
2. The rubber production system
3. The mixed plantation system
4. Growing kitchen vegetables & herbs
5. Growing vegetables in limited area
6. Fresh latex trading centers
7. Trading zones
8. Cooking Southern food
9. Handicraft
10. Raising freshwater fish

*Figure 6:*
*Spatial Configuration Model Overlaying Physical, Socio-cultural Components*

Khuanjong. It can be said that this village is equipped with both global and local integration. Consequently, the development of tourism routes and attractions depends on the development of the road network, in that, a high accessible area is linked with a high connectivity area so that visitors can reach their destinations easily (Figures 6-E,F).

In conclusion, Plankthong-Khuanjong Road and Bannairai-Khuanjong Road can be developed into main roads for tourism and some sites along these roads can serve as major attractions. The other routes can be developed as alternative tourist attractions and to accommodate more demand in the future depending on the values of the physical and socio-cultural aspects along those routes.

## DEVELOPMENT OF ARO-CULTURAL TOURISM ROUTES IN KHUANJONG VILLAGE

The results obtained from the analysis of spatial configuration model and that of the axial map containing the physical and socio-cultural aspects of Khuanjong Village were presented in the 2nd Workshop and could be summarized as follows. According to the results obtained from the spatial configuration model and the map of physical and socio-cultural aspects, there are three guidelines for the development as follows: (1) development of tourist attractions, (2) development of agro-cultural tourism routes, and (3) patterns of accessibility.

### Development of Agro-cultural Tourist Attractions

**Major tourist attractions and activity types -** Whether a tourist attraction can be a major attraction depends on its location, types of activity to be organized there and availability to accommodate visitors. If a tourist attraction is located in an area with high integration, accommodating a wide variety of activities and a large number of tourists, it is considered a major attraction. In Khuanjong Village, there are 6 major tourist attractions: (1) Banyan pavilion, (2) multipurpose building, (3) Khao Lom Temple, (4) Mixed garden, (5) rubber plantation and (6) community market. The pavilion can be used as an information center for visitors and the building can be used for organizing activities for visitors to learn about the livelihood of rubber planters. Visitors can learn about the tradition, culture and religion of the villagers at Khao Lom Temple and learn how to do gardening at the garden and the plantation. They can also shop for souvenirs and food products at the market.

**Alternative tourist attractions and activity types -** If a tourist attraction is located in an area with high-average-low integration but its ecosystem is fragile so it cannot accommodate a large number of tourists, it is considered an alternative or a support attraction. In Khuanjong Village, there are 10 alternative attractions: (10 wetlands, (2) Rubber Tree Tunnel, (3) community forest, (4) Khuanklom, (5) Wa Canal, (6) Southern vernacular house, (7) kitchen vegetable and herb garden, (8) a place where vegetables are grown in a limited area, (9) a center for fresh latex trading and (10) Khuanjong School. The first five places are for visitors to enjoy natural settings and the sixth is for them to learn about southern architecture and the livelihood of the people living in those days. Models of people and clothing and items used in everyday life are on display along with related information. The map of the village and miniature Southern vernacular houses that were located in the village are also on display at the information center. Visitors can learn about growing vegetables at the gardens and buy fresh vegetables at the community market. They can also learn about fresh latex trading at the center while being informed about the history of the village and the other interesting places in the village.

**Tourist attractions and activity types that can accommodate more visitors in the future -** Some places can be developed as tourist attractions but are of low integration and with fragile ecosystems. The development, therefore, has to take these concerns into consideration to protect both the ecosystem and visitors. Such places should be developed when the community residents want to embrace the development. Such places are: (1) the old railway station, (2) Khao Langka, (3) waterfalls, (4) ponds and (5) Wang Mapraw monk quarters.

## Development of Agro-cultural Tourism Routes

The routes are designed anticlockwise except the U-turn to reduce the number of crosswalks and facilitate parking at the 6 attractions — Banyan pavilion, multipurpose building, rubber plantations, two mixed gardens, Khao Lom Temple, and community market. Visitors will pass all of the 10 alternative attractions. On the village map, visitors can also find the 5 tourist attractions that can accommodate more visitors in the future (Figure 7).

However, visitors can change route and stop by any attraction according to their desire. For example, if they are interested in agriculture, they can visit 4 main attractions (Figure 8): Banyan pavilion, multipurpose building, two mixed gardens and community market and they still pass all the alternative attractions. Or if they are interested in traditions and culture, they can visit 4 main attractions (Figure 9): Banyan pavilion, multipurpose building, one mixed garden, Khao Lom Temple and community market and they pass some alternative attractions.

## Patterns of Agro-cultural Tourism Accessibility

**Travel with villagers -** When visitors come to the information center, they will accompanied by the villagers that will take them to the attractions that the visitors have chosen. Transportation is available so they can go to all of the destinations within the timeframe. They will, furthermore, be informed of additional information about those places. The transportation can a trolley, a bicycle, a sided motorcycle to make this village more unique.

**Travel by themselves -** Visitors can reach the major attractions by car, motorcycle, or bicycle starting from Banyan pavilion, multipurpose building, Khao Lom Temple, mixed gardens, rubber plantation, community market, wetlands and Rubber Tree Tunnel. Visitors can visit as many places as they want and can spend time at a place as long as they want.

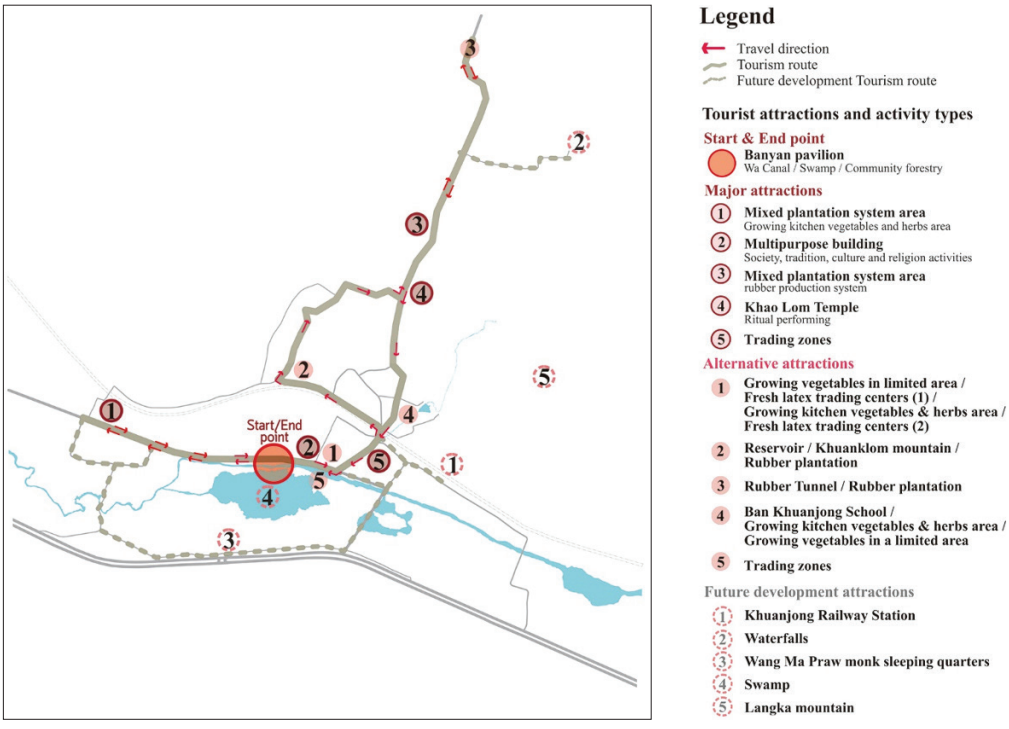



*Figure 7:*
*Agro-cultural Tourism Routes in Khuanjong village*

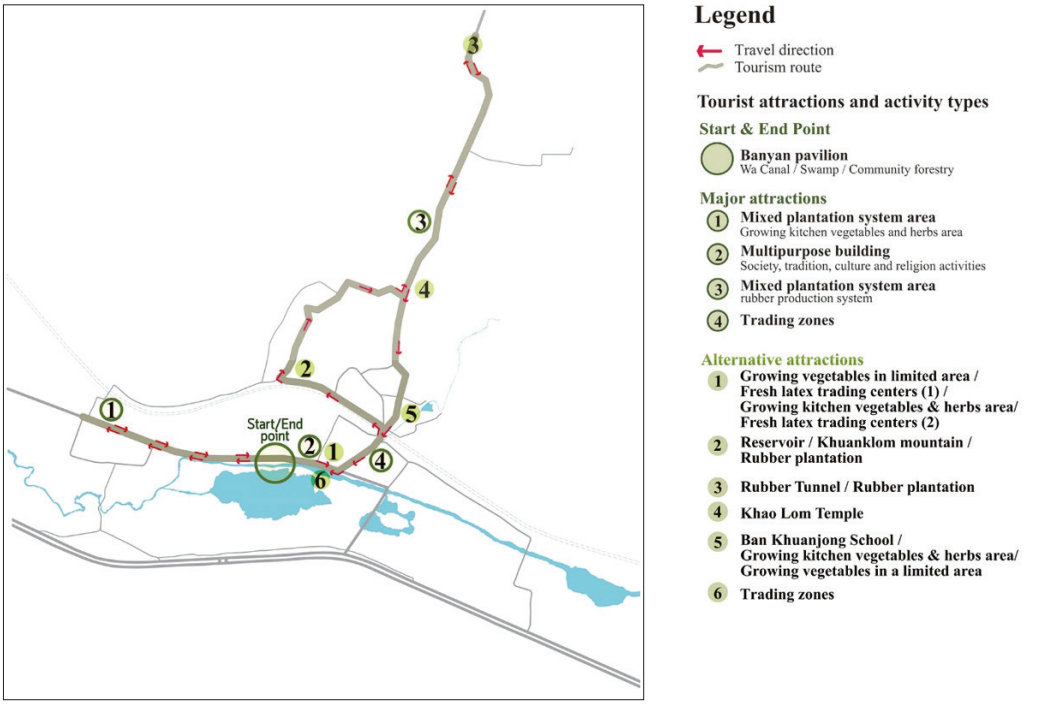



*Figure 8:*
*Agro-cultural Tourism Routes Focusing on Agriculture (Option 1)*

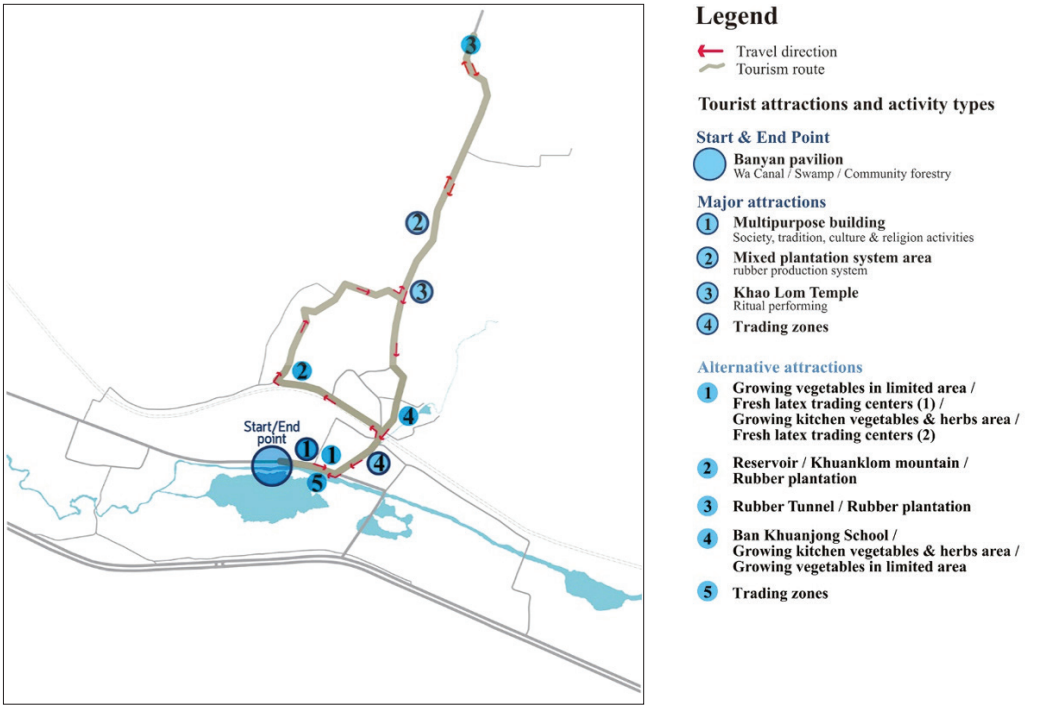



*Figure 9:*
*Agro-cultural Tourism Routes Focusing on Traditions and Culture (Option 2)*

## CONCLUSIONS AND RECOMMENDATIONS

According to the 3rd Workshop, there are 3 important aspects about the research process. The first is an insight into the effectiveness of the road network system through spatial configuration analysis so that tourist routes can be easily and appropriately determined and in line with the topography. In addition, in the future these routes can be extended systematically. Secondly, designated tourist attractions aiming to provide visitors with knowledge about rubber-growing communities indicate the potential of the sites, activities and persons in the community; as a result, main and supporting attractions as well as sites that are worth developing can be defined. These sites include important places in the village and activities should be offered by farmers who are willing to turn their farm into an attraction. Thirdly, the tourist routes should be accessible to the main, minor and local roads which are connected, creating a network. Such network facilitates the management of facilities, security and maintenance of the routes and attractions. Visitors can also easily understand the network. This will ensure that they will not get lost or miss important attractions.

The findings reveal that a transportation network with high visibility and accessibility can be a main route for entering and leaving a village. All of the physical and socio-cultural components that are shared by rubber planters are found in this network. Such components are the Banyan pavilion, multipurpose building, Khao Lom Temple, center for fresh latex trading. Global and local integration can lead to the establishment of a community market. The livelihood of farmers can be observed in the rubber plantation, the mixed gardening, the kitchen vegetable and herb gardening. These activities are found in residential areas so their accessibility potential is average-quite low in line with the Theory of Natural Movement (Hillier et al., 1993), the Theory of Movement Economy Process (Hillier, 1996) and the Theory of Spatial Centrality as a Process (Hillier, 2000). They point out that an effective movement network can propel socio-economic activities to spread along the network.

However, some activity types do not correspond to the accessibility potential of the area. For example, although the accessibility potential of Chantaro Uthit Road is high, its socio-economic activities are few. The amount of trading at some centers for fresh latex trading is low because they are located in an area whose accessibility potential is low. Therefore, it can be said that some factors such as specific socio-cultural characteristics also play a role in the number of socio-economic activities. Srisak Valipodom (2001: 191–194) said that people in society will design patterns of land use, designating which is for personal use and which for public use. This will lead to a system of the specific society and culture of living in an area, which is in line with the concept, “Social Logics of Space and Spatial Logics of Society” (Hillier and Handson, 1984) stating that social characteristics correspond to and are related to spatial characteristics.

The guidelines for developing agro-cultural tourism routes in Khuanjong Village are based on the analysis of spatial configuration. The guidelines are suitable for the spatial context and the livelihood of rubber planters. The agro-cultural tourism routes in this village comprise 3 main routes. The first includes the routes where the main tourist attractions are located. The main attractions are the Banyan pavilion, multipurpose building, rubber plantation, mixed gardens, Khao Lom Temple and community market. The second includes the routes where alternative attractions are located. They are the wetlands, Rubber Tree Tunnel, community forest, Khuanklom, Wa Canal, Southern vernacular house, kitchen vegetable and herb garden, a place where vegetables are grown in a limited space, center for fresh latex trading and Khuanjong School. Such places are physical, socio-cultural aspects that are valuable in the history, natural settings, traditions, culture and livelihood of rubber planters. Major attractions are designated on the movement network that have high visibility and accessibility to ensure visitors’ safe and comfortable travel within the village. The tourist attractions that are located on routes with average-low accessibility potential are classified as alternative attractions and attractions that can accommodate more visitors in the future, respectively. However, some measures should be imposed in areas that are supposed to be developed as attractions that can accommodate more visitors in the future because they are sensitive to ecological changes and can disrupt the residents’ livelihoods. Visitors can design their own travel plans to suit their interest and lengths of stay. For instance, they can follow an agro-cultural route or traditional and cultural route. Visitors can choose to have a villager as a tour guide or to visit the attractions by themselves.

It is recommended that in order to develop agro-cultural tourism routes, the spatial characteristics of a community, ecosystem of the agro-cultural areas and the natural settings and specific socio-cultural aspects of farmers have to be taken into consideration. This is so because this tourism is a combination of agriculture, traditions and culture of farmers and natural settings. These are important

components that distinguish the agro-cultural community from other communities. Successful agro-cultural tourism can generate more income and preserve the village identity. However, the villagers have to be willing to offer this tourism and to improve their infrastructure. When properly executed, the development of agro-cultural tourism routes based on spatial configuration analysis will be an effective tool for sustainable community development. Lastly, the development of agro-cultural tourism routes in Khuanjong Village can set a precedent, and other rubber plantation villages can adopt this tool to implement and develop their own agro-cultural tourism routes.

**ACKNOWLEDGEMENT**

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# Experimental Study on Thermal Comfort Towards Increasing Temperature Set-Points in Air-Conditioned Office Spaces in a Tropical Region:

## A Case Study in Thailand

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## ABSTRACT

Many countries propose indoor temperature set-points of air-conditioned offices to be comfortably sustainable and to reduce energy consumption. Even though there are recommendations for the optimum temperature-set-points, it is questionable how those values could be applied to the actual situation in a tropical region. This study aims to survey thermal performance and estimate thermal comfort in different set-points. In 2019, two air-conditioned office buildings were tested by increasing set-points from the actual value between 23 °C and 25 °C. Data loggers measuring thermal variables were installed in the offices and the questionnaire was distributed to evaluate human response. Considering the ASHRAE psychometric chart, thermal environments of both cases on the day of a normal set-point were low; falling inside in the 1.0 clo zone. Thermal environments gradually moved from the 1.0 clo zone to the 0.5 clo zone, however, some of them were out of both comfort zones due to high absolute humidity. The predicted mean vote (PMV) and the thermal sensation vote (TSV) show that the votes changed from the cold side to the neutral side, and the higher acceptance rate was at warmer temperatures. The comfort temperature calculated from Griffith's method was found to be 23.6–25.1 °C which was lower than the measured operative temperature. Adaptive clothing behavior is described to confirm a better condition at warmer temperatures. A possibility of increasing cooling set-points at 24–25 °C is applicable to office buildings in the tropics to remain comfortable.

***Keywords:*** *thermal comfort, air-conditioned, temperature set-point, office spaces, tropical region*

## INTRODUCTION

Because of the threat of global warming, many countries are seeking solutions to reduce the emission of greenhouse gas produced from energy use (Houghton, 2009). The concept of controlling the optimum temperature set-points in the building was presented internationally to promote energy saving (Tan, 2008). Increasing the temperature set-point by just one degree Celsius could generate a 6% saving in energy consumption of air-conditioning systems (Kongkiatumpai, 1999). In the UK, the temperature set-point is concerned by the British Council for Offices which suggests that the value should be warmer than 22 °C in summer for energy saving and comfort (BCO, 2010). The experimental study in London proves that there is a possibility of changing a set-point from 22 °C to 24 °C without an increase of discomfort (Lakeridou, Ucci, Marmot, & Ridley, 2012). In Japan, the government launched a "Cool Biz" campaign in 2005 that promoted people to wear loose-fitting clothes so that they continued to stay at the cooling set-point up to 28 °C in summer (Nakashima, 2013). This campaign provokes awareness of better living conditions in the optimum indoor thermal environment. In a tropical region, outdoor temperature and relative humidity are constantly high throughout the year. Cooling indoor environment needs to use a large energy consumption to maintain human comfort (Yamtraipat, Khedari, & Hirunlabh, 2005). In Singapore, the official regulation, SS 554 (S.P.R.I.N.G, 2016), is applied to air-conditioning performance to limit the room temperature between 24 °C and 26 °C. The government of Malaysia (Lau, Tan, Lee, & Mohamed, 2009) suggests that the acceptable temperature should be at least 24 °C to reduce cooling energy demand without sacrificing comfort. In Thailand, the government tries to promote a 25 °C set-point in the peak of summer to reduce electricity bills (Energy Policy and Planning Office (EPPO), 2018). To produce efficiency of air-conditioning systems to match with human thermal comfort, HVAC systems have continuously developed, i.e., a chilled beam system or a radiant cooling system that provides suitable thermal physiology (De Dear & Brager, 1998). Currently, an air-conditioning system that is typical to be used for large-scale offices is a water-cooled chiller system. A chilled beam system is an air-conditioning type that is rarely used for office buildings in the tropics due to the sensitive humification from outdoor environments (Yang et al., 2019). The study in the US found that the performance of an active chilled beam system used with a 100% dedicated outdoor air system in parallel might result in significant relative energy savings providing up to 12% for the office in hot and humid climates (Kim, Tzempelikos, & Braun, 2019). However, the recommended values tend to be used in a holistic approach. Thermal comfort could be more flexible depending on several factors, such as the type of occupants (Sattayakorn, Ichinose, & Sasaki, 2017), ages and genders (Indraganti, Ooka, & Rijal, 2015), air-conditioning systems (Kim et al., 2019), etc.

The climate characteristics of a tropical region result in the high outdoor temperature ranging between 20 °C and 34 °C when the outdoor humidity is generally 77–88% in summer (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006). To maintain the cooling environment, the air-conditioning system of large commercial buildings in this region consumes over half of the electrical energy use (59.09%) (Yamtraipat, Khedari, Hirunlabh, & Kunchornrat, 2006). It becomes more severe when cooling loads may increase to 200 GW of extra generation capacity in 2040, predicted by the International Energy Agency (IEA, 2019). The relative humidity is the main factor that is critically concerned when mechanical engineers design the air-conditioning system (ASHRAE, 2017). To reduce humidity levels, cooling loads from the air handling unit (AHU) are sometimes provided lower than the design (Mathews, Botha, Arndt, & Malan, 2001). The study of Foo and Poon argues that there was 60% of office staff experiencing indoor temperature under 24 °C (Foo & Phoon, 1987). The neutral temperature of occupants in the air-conditioned offices is found to be 26.4 °C in Singapore, 25.6 °C in Malaysia, and 26.4 °C in Indonesia (Damiati, Zaki, Rijal, & Wonorahardjo, 2016). It reports a similar situation in other offices in the tropics that indoor temperature was mostly overcooled throughout the year (Sekhar, 2016). Bangkok, Thailand is one of the biggest cities in South East Asian that has a critical issue of high temperature and humidity (Yamtraipat et al., 2005). Regarding the Köppen climate classification, Bangkok, Thailand is identified as a hot and humid region in the AW zone (typical savanna) at 13° 02' 19.93" N Latitude and 101° 29' 24.37" E Longitude (Kottek et al., 2006). Due to the growth of office spaces in the country (CBRE, 2019), the indoor environment is given priority when people spend most of the time inside office buildings (United & Bureau of Labor, 2003). Some field studies showed that air-conditioned offices observed in Thailand fulfill thermal comfort criteria (Busch, 1992; Yamtraipat et al., 2006). However, the recommendations from those results are used for all building types or

spaces. There is only a little evidence of open offices with a central air-conditioning unit investigated.

The awareness of thermal comfort is one of the criteria to obtain the well-known green building certifications around the world (Analytics, 2018). The green building accreditation organized by the World Green Building Council (WGBC) claims that indoor air quality is the major feature to be qualified (WGBC, 2018) while the International WELL Building Institute (IWBI) employs thermal comfort for long-term assessment of health and wellbeing aspects (IWBI, 2019). Sick building syndromes caused by poor indoor air quality could be solved by both passive and active design (CIBSE, 2006). Several building-related symptoms normally occur when temperature or humidity is uncontrolled (Amin, Akasah, & Razzaly, 2015). Indoor thermal environments that perform too cold temperatures or too high humidity strongly affect people in terms of physical health and mental health in the long run (Al horr et al., 2016). The study from the US found that setting room temperature higher than 23 °C is associated with a decrease in symptom reports (Mendell & Mirer, 2009). In air-conditioned offices, thermal environments may fit into the comfort zone, however, comfort does not always refer to be healthy because staying in an air-conditioning environment for the long term could make their bodies weak (Tham & Ullah, 1993). It is supportive of warm thermal performance to encourage a better health condition.

Based on the above-mentioned background, this study aims to survey the thermal performance of offices in a tropical region and to find the possibility and the obstacle of adjusting room temperature set-points to warmer values. It would be beneficial to the air-conditioned offices to improve building operating performance in order not only to save energy consumption but also to enhance satisfaction and health.

## METHODOLOGIES

To understand the actual thermal performance of office spaces in the tropics, two fully air-conditioned offices in Bangkok Metropolitan, Thailand, were selected to be case studies. The surveys were in May and September 2019. We selected the newly-constructed office buildings regarding the heating, ventilation, and air conditioning (HVAC) system that represents the typical indoor environment in Thailand. Office A is a commercial office occupied by a single private company that was opened in 2017. Working spaces are located in the east and the west with a high-performance façade. The measurement area covers about 46% of the total floor area. The air-conditioning system of Office A is a typical water-cooled chiller system in which the system operation usually starts half an hour before working time at 8:00. Office B belongs to a government sector that opened in the mid of 2019. The working areas face the south and the southwest. The distance approximately 1.8–2.0 m from the envelop is used for circulation spaces to keep people away from the heat from outside. The air-conditioning system of Office B is an active chilled beam system in which the system operation usually starts from 6:30. The cellular executive rooms located in the inner area are excluded from this study. There are thermostat displays showing temperature and humidity to occupants only in Office B. We installed 10 measuring devices (Point A to Point J) in all office spaces referring to the thermal environments of each person sitting nearby. Table 1 describes the information of both investigated offices.

To understand thermal environments of the case studies, we used automatic-record data loggers to collect them which are listed in Table 2. The room temperature and the relative humidity were measured by the devices set at a height of 1.1 m close to the occupants at the interior zone and the perimeter zone. There were 10 sets of measuring devices recording thermal variables at 1-minute intervals, namely A–J, respectively. An anemometer was also set on a tripod to measure the wind velocity near the reference data logger points every 60 seconds in each location. This study is the blind test of adjusting the temperature set-points ranging from 23 °C to 25 °C. The limitation of 2 °C higher than the actual value depends on permission from the authorities. Additionally, CIBSE suggests that the operative temperature should not vary higher than 1 °C from the previous day to avoid severe discomfort (CIBSE, 2006). The temperature set-point was controlled by the Building Management System (BMS) from the facility management section. In this study, we only focus on increasing temperatures to see the effect of this factor on other variables. Even if temperature is not only one factor that causes human comfort, people easily perceived it at first. It is useful to understand all thermal behaviors based on different temperatures. Therefore, we did not adjust other variables, including relative humidity, ventilation flow, and wind speed. Outdoor temperature and outdoor relative humidity were obtained from the online database (Underground, 2019).

**Table 1:** Building Information

| Building Code | A | B |
|---|---|---|
| **General Information** | | |
| Period of investigation | 22nd – 24th May 2019 | 9 – 11th September 2019 |
| Owner | Private | Government |
| Opening year | 2017 | 2019 |
| Gross area ($m^2$) | 56,000 | 22,000 |
| Number of floors | 25 | 20 |
| **Measuring floor details** | | |
| Floor level | 11 | 7 |
| Typical area ($m^2$) | 1,400 | 1,022 |
| Measuring area ($m^2$) | 674 | 576 |
| Office orientation | East, West | South, Southwest |
| Number of measuring points | 10 | 10 |
| Points in the perimeter zone | A, B, C, and J | A, B, C, and J |
| Points in the interior zone | D, E, F, G, H, and I | D, E, F, G, H, and I |
| Floor to floor (m) | 4.2 | 4.0 |
| Floor to ceiling (m) | 3.2 | 3.0 |
| Façade type | Laminated insulated glass | Laminated insulated glass |
| HVAC | | |
| System type | Water-cooled chiller | Chilled beam |
| Cooling set-point (°C) | 23 | 23 |
| Period of operation | 8:00–18:00 | 6:30–16:45 |

To understand the perception of occupants towards thermal environments, the questionnaire distributed to all occupants in the offices addressed the following details: 1) personal information, which was about gender, age, health condition; 2) clothing insulation, which was separated into 3 parts, including upper part, lower part, and shoes; 3) a 7-scale thermal sensation vote (TSV); 4) a 5-scale thermal comfort vote (TCV); a 5-scale thermal preference vote (TPV); and a 2-scale thermal acceptance vote (TAV). The total number of subjects was 110 persons (36 males and 74 females) from Office A and 78 persons from Office B (45 males and 33 females). Occupants answered the questionnaire twice a day in the morning and the afternoon (at 11:00 and 15:00) which were completely counted as 787 votes in total. A type of work is a computer-based task which that of Office A is related to human resource management while that of Office B is about policy planning. We informed occupants to avoid answering the questionnaire at the time when they left their seats or when they had a meeting.

**Table 2:** Measuring Devices and Methods

| IEQ parameters | Measuring devices | Record interval |
|---|---|---|
| Air temperature/ Humidity/ Illuminance | TR-74Uvi | 10 min |
| Mean radiant temperature ($T_{mrt}$) | RTR-52A 7" Globe | 10 min |
| CO2 concentration | TR-76Ui | 10 min |
| Air Speed | Anemometer | 60 sec |

**Table 3:** Scale for the Subjective Questionnaire

| Scale | Thermal sensation vote (TSV) | Thermal comfort vote (TCV) | Thermal acceptance vote (TAV) | Thermal preference vote (TPV) |
|---|---|---|---|---|
| -3 | Cold | | | |
| -2 | Slightly cold | Uncomfortable | | Colder |
| -1 | Cool | Slightly uncomfortable | | Slightly colder |
| 0 | Neutral | Neutral | Acceptable | No change |
| 1 | Warm | Slightly comfortable | Unacceptable | Slightly warmer |
| 2 | Slightly hot | Comfortable | | Warmer |
| 3 | Hot | | | |

For the calculation, the mean radiant temperature is estimated by using the equation from ISO 7726 (ISO, 1998) for a standard globe of 0.15 m, $MRT = ((GT_a+273)^4 + 2.5 \times 10^8 \times V_a^{0.6} (T_g - T_a)^{1/4} - 273)$, where $T_a$ = air temperature, $T_g$= globe temperature, and $v_a$ = wind velocity. The PMV calculation is used to estimate the data considering 1) thermal items that we measured during working hours, including temperature, relative humidity, wind velocity, 2) occupant's data; metabolic rate and clothing insulation. The value of metabolic rate is counted as 1.1 met according to a typical rate for occupants in the office written in ASHRAE 55 (ASHRAE, 2017). Clothing insulation rate is estimated from questionnaires applying the equation from ISO 9920 (ISO, 2007); $Icl = 0.161+0.835 \times \sum Iclu$, where Iclu is the effective thermal insulation according to the table of the insulation values of typical clothing ensembles. The operative temperature is used to compare the results with subjective votes calculated by $t_o = t_a +(1-A)(t_r - t_a)$, where $t_o$ is the operative temperature, $t_a$ is air temperature, and A is the coefficient related to air velocity (A = 0.5 when air velocity is ≤ 0.2 m/s). This study also considers the Predicted Mean Vote (PMV) which is a well-known calculation by using the results from thermal variables (room temperature, mean radiant temperature, humidity, and wind velocity) and human factors (metabolic rate and clothing insulation) (Fanger, 1970). This model is widely used to estimate thermal sensation which the recommended value ranges from -0.5 to 0.5 when the metabolic rate of occupants is 1.0–1.3 met. We use this model to realize how much thermal environments would suit the recommended zone.

## RESULTS AND DISCUSSION

As the results, the average room temperature and the average relative humidity were reading from 8:00 to 17:00 illustrated in Figure 1. The measuring Point A, B, C, and J were defined as the perimeter zone while measuring Point D, E, F, G, H, and I were defined as the interior zone. On the first day (set-point = 23 °C), the average room temperature of Office A started from 24.1 °C which was 1.1 °C higher than the set-point. The value reached 23.5 °C at 11:00 and it was stable around 23.7 °C until 17:00. There was only 14% of it dropping below 23 °C. Point C in the perimeter zone tended to be the most critical point when the temperature reached the highest value at 25.4 °C or +1.4 °C higher than the set-point. The average room temperature in Office B also started from 24.1 °C and began to be cooler at 23.2 °C nearly to the average of temperature in Office A. The main reason of the warm temperature in the morning was about the air-conditioning system that just began to operate on Monday after the weekend. Although the condition on Monday led higher temperatures than the set-point, there was 34% of the values dropping below 23 °C, especially at Point E and H, where the minimum value was 21.1–21.7 °C. The room temperature on the actual set-point day in Office A was less stable than that in Office B because of a small temperature gap. On the second day (set-point = 24 °C), the average temperature in Office A shifted from that on the first day by +0.1 °C on the average (23.6 °C). It increased

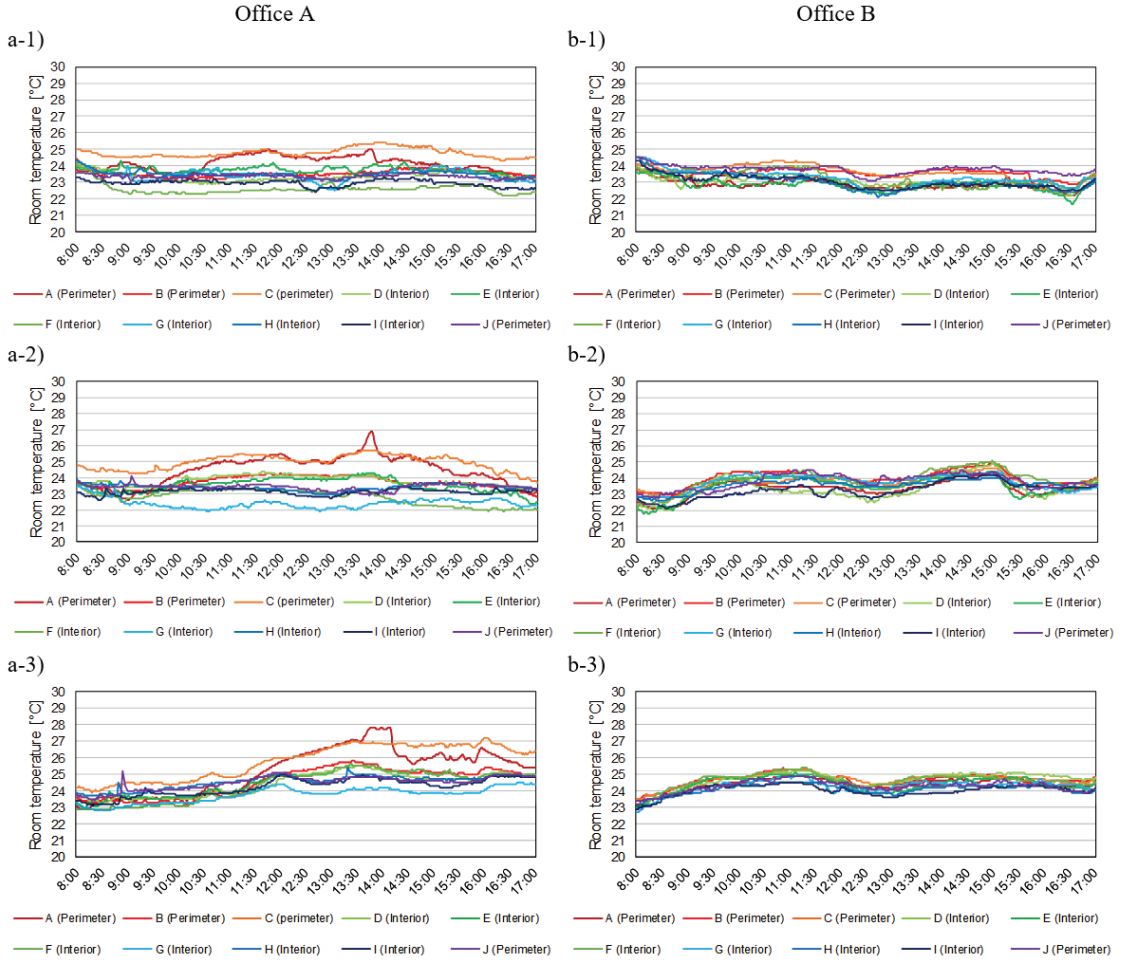


*Figure 1:*
*Room temperature of case studies a-1) Office A at set-point 23°C, a-2) Office A at set-point 24°C, a-3) Office A at set-point 25°C, b-1) Office B at set-point 23°C, b-2) Office B at set-point 24°C, b-3) Office A at set-point 25°C*

during the afternoon, particularly that at Point A and C, which was different from the mean by +0.9 °C and +1.4 °C, respectively. In contrast, the room temperature at Point G in the interior zone went lower than 24 °C dropping to 21 °C in the afternoon. High fluctuation depended on the cooling performance of air outlets when the set-point was changed. The temperature in Office B was 23.6 °C on average decreasing 0.6 °C cooler than the set-point. A temperature gap between the perimeter zone and the interior zone was not significantly different due to the high heat protection of façade performance. The highest gap zone between a minimum and a maximum was shown at Point F in the interior zone (ΔT = 3 K). On the third day (set-point = 25 °C), Office A performed high fluctuations mainly at Point A and Point C in the afternoon which were different from the average by 3.2 °C. The heat gained at Point A and Point C facing the west when the cooling from air outlets was insufficient. The values at Point G remained low at 22.8 °C in the morning and at 23.8 °C in the afternoon while Point A showed the highest level in the afternoon at 27.8 °C (ΔT = 5K). There was 68% of the values in Office A falling under 25 °C. That in Office B remained stable throughout the day at all points which the average was 24.4 °C. The difference between the lowest and the highest was only 2.7 °C (22.7 °C at Point G in the interior zone and 25.4 °C at Point B in the perimeter zone). The recorded data declared that 90% of the points in Office B were still under 25 °C, and 49% of them were higher than 24.5 °C.

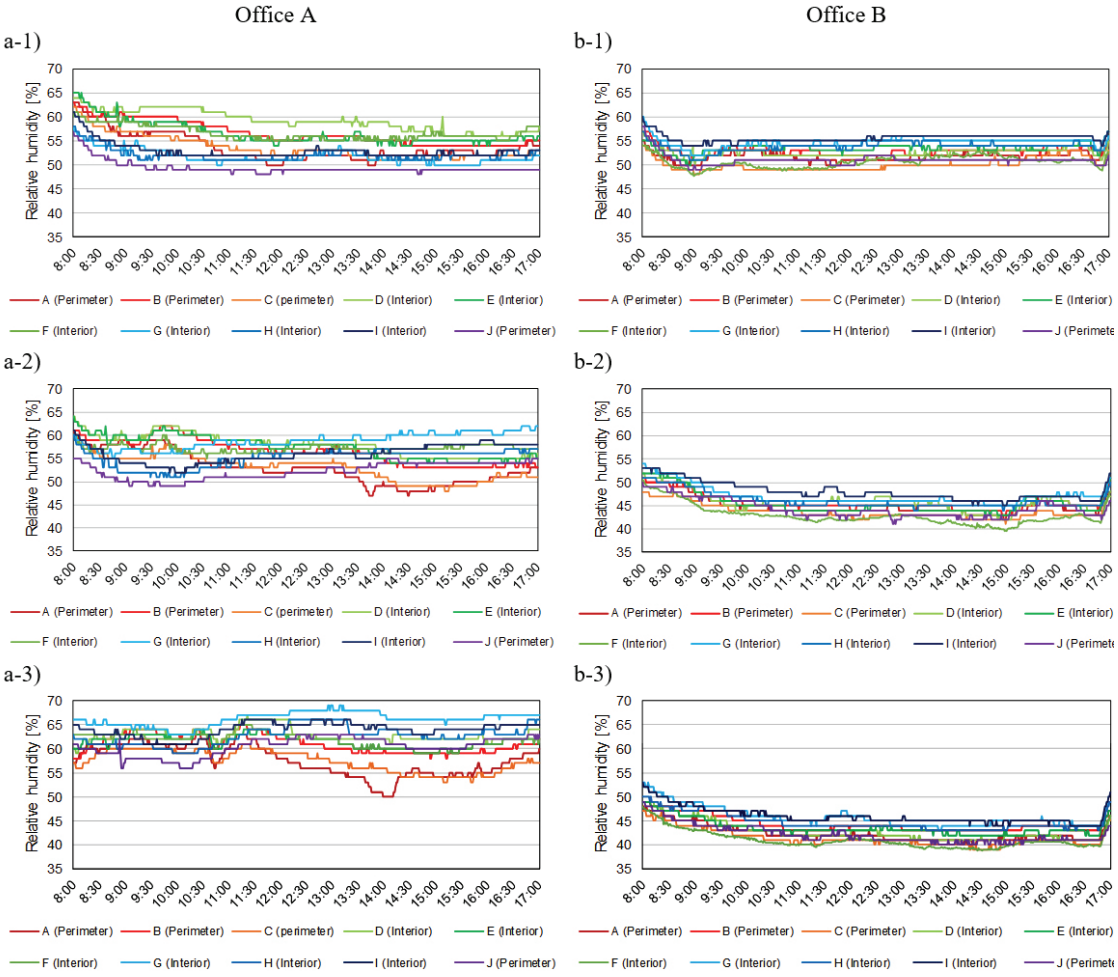


*Figure 2:*
*Relative humidity of case studies a-1) Office A at set-point 23°C, a-2) Office A at set-point 24°C, a-3) Office A at set-point 25°C, b-1) Office B at set-point 23°C, b-2) Office B at set-point 24°C, b-3) Office A at set-point 25°C*

Figure 2 shows the relative humidity from 8:00 to 17:00 in both offices. On the first day, the average relative humidity in Office A started at 60.9% before decreasing to 55.3% at 11:00 and it was ranging 54 – 56% during the day. The highest value was located at Point D in the interior zone at 59% when the lowest value was at Point J in the perimeter zone at 49%. On the other hand, the average relative humidity in Office B started at 57% and continued to be stable ranging as 50–56%. The highest average value was 56% at Point I in the interior zone while the lowest one was 50% at Point C in the perimeter zone. The humidity levels in both offices were in the optimum range (40–60%). On the second day, the results in Office A showed a similar tendency to those on the first day. The highest average value was at Point G in the interior zone at 59% and the lowest average value was at Point J in the perimeter zone at 52%. The values at Point A and B were dropped to 47% in the afternoon relevant to the highest room temperature at 26.9 °C. In Office B, the value slightly dropped to 45% and was constant throughout the day. On the third day, the average in Office A reached 66% at Point G which was over the recommendation of the ASHRAE standard, while the lowest value at Point C went below 57%. The difference of RH in Office A was about 20 when the average in Office B was still well controlled at 43% during the day. The excessive humidity could happen in a conventional air-conditioning system when it could reduce humidity from outside in time. This evidence is correlated with office cases in Singapore (Tham & Ullah, 1993) that the air-conditioning system is normally concerned with the indoor relative humidity which the value should not be over 70%. It requires to remove water vapor from the intake air and lead a high lantern heat load. The airflow through the cooling coil condenses immoderate moisture.

Table 4 describes the results of collected thermal variables. It is advantageous to compare those values by finding the correlation between each thermal index. We measured several temperature indices in order to confirm that the building is well-insulated so that we could increase temperature set-points with less effect of the heat near the perimeter zone. Trendlines of those indices could be different when the insulation of the envelop is insufficient, for example, glass window types that could not protect the heat radiation from outside (Damiati et al., 2016). Since the trendlines are almost diagonal as shown in Figure 3, we could use all temperature indices for the estimation. However, this study mainly uses the operative temperature to define thermal comfort compare with subjective votes. Changing temperature set-points does not affect other thermal indices such as outdoor temperature and outdoor humidity. According to the online data (Underground, 2019), the outdoor weather during the survey was mostly sunny but sometimes it was partly cloudy. The average outdoor temperature of Office A was 30.8–31.6 °C with 63.2–68.9% RH, respectively. That of Office B was constant at 31.3–31.6 °C with 63.2–68.9% RH. The temperature difference between indoor and outdoor was quite stable at 6.7–8 °C. Wind velocity was not significantly different which the average was 0.06–0.1 m/s. This rate was a normal condition on air-conditioned offices in the tropics. In addition, there is a study of thermal comfort in a hot-mid condition in Japan referring that increasing air velocity up to 0.2 m/s would be beneficial to the building in the tropic with lower energy consumption (Tanabe & Kimura, 1994). However, to emphasize on a temperature factor, this study did not set wind speed.

Thermal environments were plotted on the ASHRAE psychometric chart by using the operative temperature against the absolute humidity. Figure 4 defines 2 comfort zones; 1) the 1.0 clo comfort zone which fits to people who wear suits and ties or sweaters, 2) the 0.5 clo comfort zone which is recommended to people who wear light shirts like those in the tropics normally wear. Thermal environments of Office A slightly shifted from the 1.0 clo zone to the 0.5 clo zone as 20%, 25%, and 54% respectively, while those of Office B progressively changed to the recommended zone by 6%, 21%, and 82%, respectively. Most values of Office B on the last day fell inside the recommended zone with the highest rate. In contrast, those in Office A on the third day moved out from the comfort zone at 42% when absolute humidity reached over 0.012 g/g (DA). The main reason is humidification of a water-cooled chiller system might not effectively reduce humidity in time.

To find the aspect of occupants experiencing thermal variables, the study declares the subjective votes of each experimental set-point. The thermal sensation votes (TSV) illustrated in Figure 5 shows that most occupants in both cases felt neutral in every day of the survey. The average TSV changed from negative values to positive values which that of Office A was -0.6, -0.3, and 0.6, while that of Office B was -1, -0.4, and 0, respectively. TSV was classified into 3 categories; a colder-than-neutral group (TSV = -3, -2, and -1 or TSV-), a warmer-than neutral group (TSV = 1, 2, and 3 or TSV+), and a neutral group (TSV = 0). In Office A, the ratio of these three groups was

**Table 4:** Thermal variables of case studies

| Set-point (°C) | | $T_r$ (°C) | $T_g$ (°C) | $T_{mrt}$ (°C) | $T_{op}$ (°C) | RH (%) | AH (g/g(D/A)) | AV (m/s) | $T_{out}$ (°C) | $RH_{out}$ (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| **A** | | | | | | | | | | |
| 23 | Min | 22.2 | 21.7 | 21.0 | 21.8 | 48.0 | 0.009 | 0.04 | 27.2 | 52.0 |
| | Max | 25.4 | 25.2 | 25.4 | 25.2 | 65.0 | 0.012 | 0.21 | 33.9 | 89.0 |
| | Mean | 23.5 | 23.5 | 23.4 | 23.5 | 54.2 | 0.010 | 0.10 | 30.8 | 63.2 |
| | SD | 0.6 | 0.7 | 0.9 | 0.7 | 3.4 | 0.001 | 0.04 | 2.4 | 11.0 |
| 24 | Min | 21.9 | 21.6 | 21.4 | 21.6 | 47.0 | 0.009 | 0.03 | 27.2 | 59.0 |
| | Max | 26.9 | 26.7 | 27.5 | 26.7 | 64.0 | 0.012 | 0.12 | 33.9 | 89.0 |
| | Mean | 23.6 | 23.6 | 23.7 | 23.6 | 55.7 | 0.010 | 0.07 | 31.6 | 68.9 |
| | SD | 0.8 | 0.9 | 1.0 | 0.9 | 3.1 | 0.001 | 0.03 | 2.1 | 9.1 |
| 25 | Min | 22.8 | 22.7 | 22.5 | 22.7 | 50.0 | 0.010 | 0.02 | 27.8 | 52.0 |
| | Max | 27.8 | 28.0 | 28.2 | 28.0 | 69.0 | 0.013 | 0.20 | 33.9 | 89.0 |
| | Mean | 24.6 | 24.6 | 24.6 | 24.6 | 61.5 | 0.012 | 0.07 | 31.3 | 63.2 |
| | SD | 1.0 | 0.9 | 1.0 | 0.9 | 3.2 | 0.001 | 0.05 | 1.8 | 11.0 |
| **B** | | | | | | | | | | |
| 23 | Min | 21.7 | 21.4 | 20.7 | 21.4 | 41.7 | 0.0088 | 0.03 | 27.8 | 55.0 |
| | Max | 24.5 | 24.9 | 25.7 | 24.9 | 60.0 | 0.0117 | 0.16 | 32.8 | 79.0 |
| | Mean | 23.2 | 23.2 | 23.2 | 23.2 | 52.7 | 0.0095 | 0.09 | 31.5 | 62.2 |
| | SD | 0.5 | 0.6 | 0.8 | 0.6 | 2.0 | 0.0004 | 0.04 | 1.6 | 7.1 |
| 24 | Min | 21.8 | 21.5 | 20.8 | 21.6 | 39.5 | 0.0077 | 0.04 | 28.9 | 59.0 |
| | Max | 25.1 | 25.1 | 25.32 | 25.1 | 54.0 | 0.0096 | 0.017 | 32.8 | 74.0 |
| | Mean | 23.6 | 23.6 | 23.6 | 23.6 | 45.4 | 0.0084 | 0.08 | 31.6 | 64.8 |
| | SD | 0.6 | 24.4 | 0.7 | 0.6 | 2.4 | 0.0003 | 0.04 | 1.4 | 4.3 |
| 25 | Min | 22.7 | 22.6 | 22.5 | 22.6 | 38.8 | 0.0076 | 0.03 | 27.8 | 52.0 |
| | Max | 25.4 | 25.6 | 25.9 | 25.6 | 53.0 | 0.0097 | 0.10 | 33.9 | 89.0 |
| | Mean | 24.4 | 24.4 | 24.4 | 24.4 | 43.4 | 0.0084 | 0.06 | 31.3 | 63.2 |
| | SD | 0.4 | 0.5 | 0.6 | 0.5 | 2.4 | 0.0004 | 0.02 | 1.8 | 11.0 |

*Note: $T_r$: Room temperature; $T_{mrt}$: Mean radiant temperature; $T_{op}$: Operative temperature; RH: Relative humidity; AH: Absolute humidity; AV: Air velocity; $T_{out}$: Outdoor temperature; $RH_{out}$: Outdoor relative humidity*

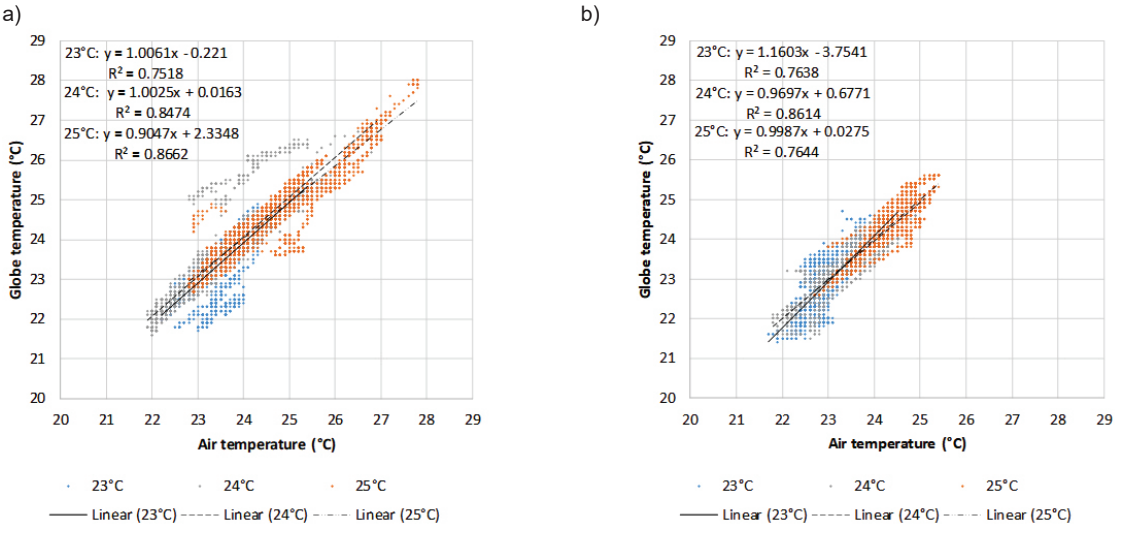


*Figure 3:*
*Correlation between air temperature and globe temperature: a) Office A, b) Office B*

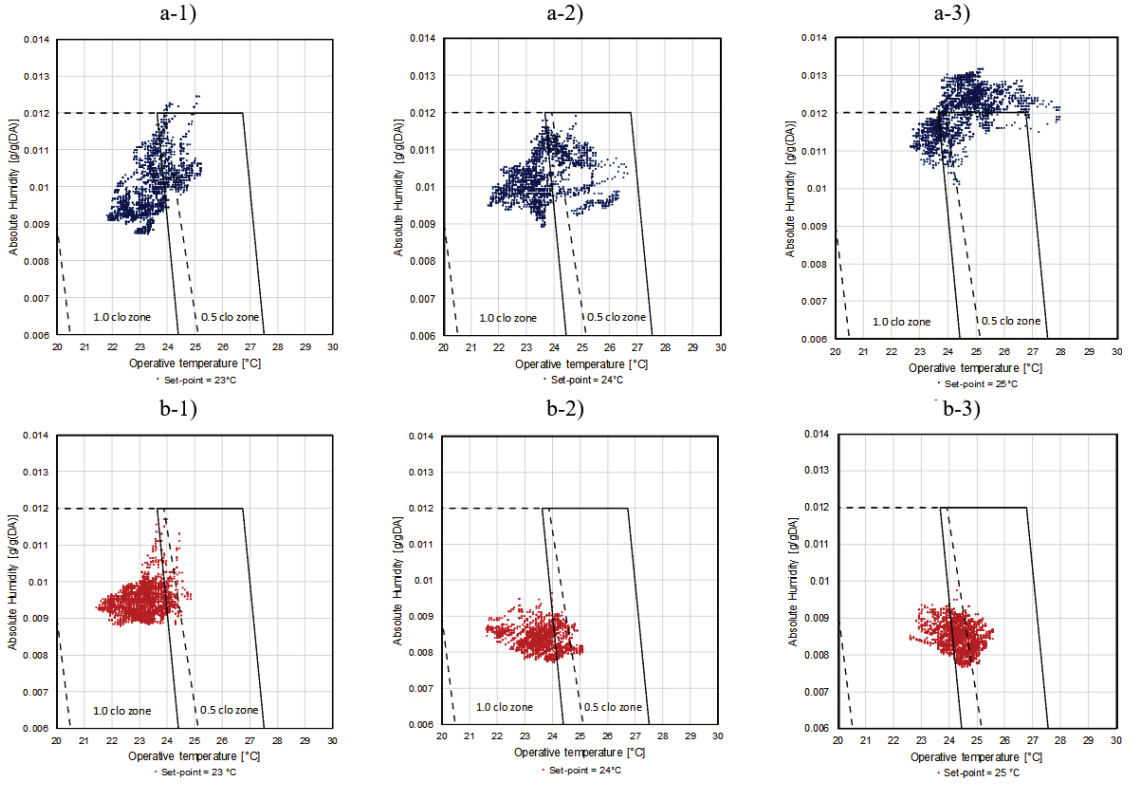


*Figure 4:*
*Psychometric charts of ASHRAE55-2013 Standard: a-1) Office A at 23 °C, a-2) Office A at 24°C, a-3) Office A at 25 °C, b-1) Office B at 23 °C, b-2) Office B at 24 °C, b-3) Office A at 25 °C*

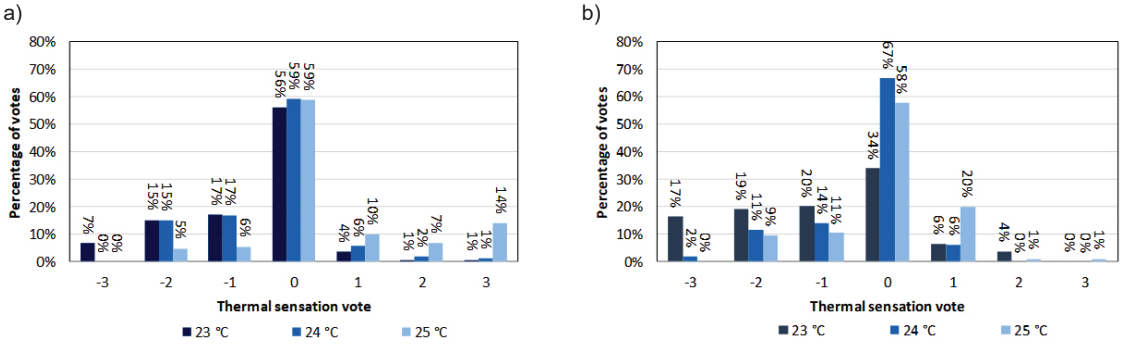


*Figure 5:*
*Thermal sensation votes of case studies: a) Office A, b) Office B*

counted as 56: 34: 10, 27: 64: 6, and 20: 58: 22. In Office B, the ratio was 39: 56: 5, 32: 59: 9, and 20: 58: 22. The percentage of neutral votes of Office B rapidly changed two times higher when we changed one higher set-point at 24 °C. Regardless of TSV = 0, the votes belonged to a colder-than-neutral side (-1 to -3) rather than a warmer-than-neutral side (1 to 3). When we set higher temperatures, more thermal environments changed to the recommended points between -1 and 1 that should be more than 80% of the total (ASHRAE, 2017). In Office A, the votes between -1 and 1 were increased from 77% to 82%, but it slightly decreased to 74% on the last day. In Office B, those votes increased from 61% to 87% and 88%, respectively. In terms of TSV, it was more suitable when changing higher temperatures to 24 °C or 25 °C. Especially, the rapid change happened in Office B which had more thermal environments in the 1.0 clo zone. The study was similar to a previous study in cellular rooms when the acceptable TSV at 24–25 °C was higher than that at 23 °C (Yamtraipat et al., 2006).

Thermal comfort votes (TCV) are shown in Figure 6. The percentage of comfortable votes (TCV = 1 and 2 or TCV+) was ranging from 29% to 35% (Office A) and from 30% to 35% (Office B). The rate of uncomfortable votes (TCV = -2 and -1 or TCV-) in Office A was 25%, 18%, and 26%, respectively, while that in Office B was 24%, 12%, and 20%, respectively. Regarding 20% of discomfort, thermal environments in Office A could meet up the requirement at 24 °C, while those of Office B was satisfied at 24–25 °C. The reason for high discomfort may cause by high relative humidity in a warmer environment which is sensitive to occupants who usually stay in a cold environment (Jing, Li, Tan, & Liu, 2013).

Figure 7 illustrates the relation between TSV and TCV by divided into 3 groups following the set-point. Both cases display a similar trend of sensation and comfort. People in a discomfort side (TCV-) gave the higher votes for feeling cold at 23–24 °C. In Office A, TSV- at 23 °C was the highest rate in the uncomfortable votes. TSV- of the slightly uncomfortable votes was reading

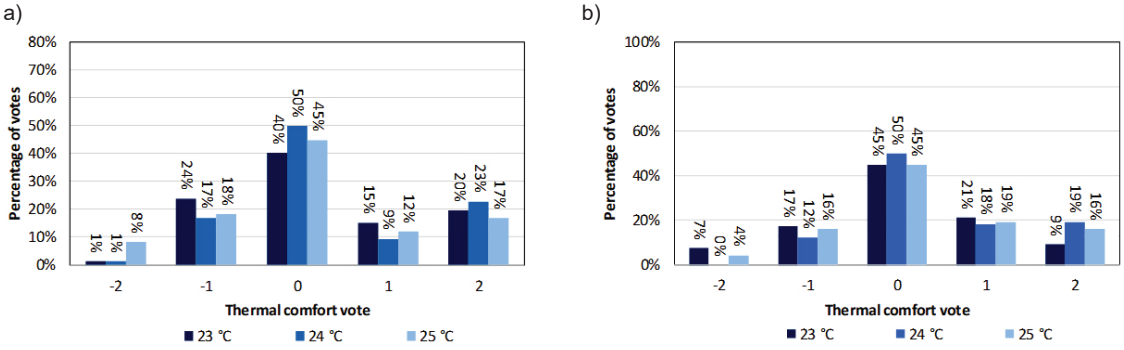


*Figure 6:*
*Thermal comfort votes of case studies: a) Office A, b) Office B*

as 87% at 23 °C and 78% at 24 °C, respectively (see the data in the purple dash line in Figure 7 (a)). In Office B, TSV- at 23 °C belonged to the uncomfortable votes by 88% and the slightly uncomfortable vote by 79% (see the data in the purple dash line in Figure 7 (b)). On the other hand, the discomfort votes highly changed to TSV+ when thermal environments were controlled at 25 °C. In Office A, TSV+ highly belonged to the uncomfortable votes (92%) and the slightly uncomfortable votes (77%) (see the data in the red dash line in Figure 7 (a)). Correspondingly, TSV+ of Office B matched with the uncomfortable votes (60%) and in the slightly uncomfortable votes (64%) (see the data in the red dash line in Figure 7

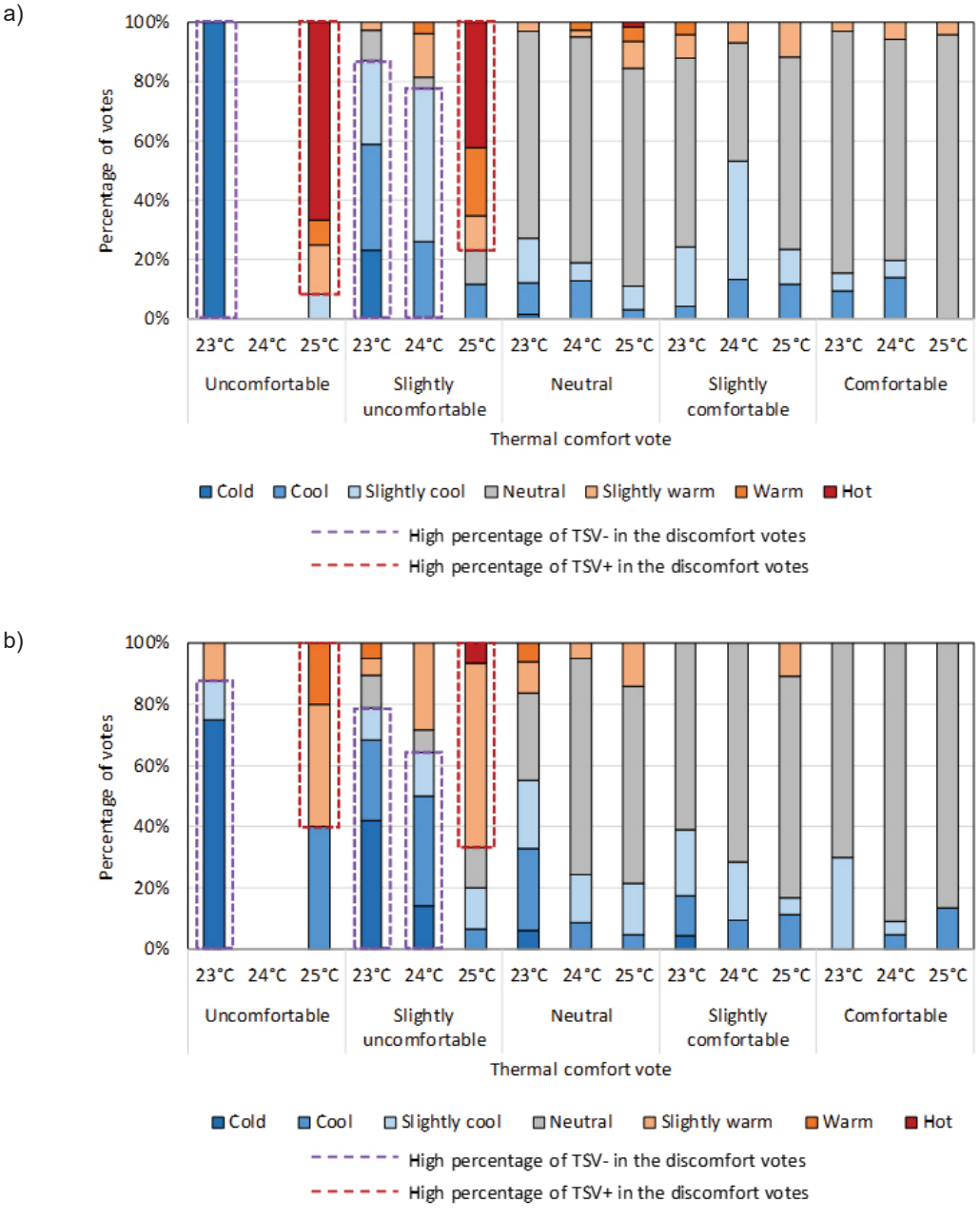


*Figure 7:*
*Relation between TSV and TCV: a) Office A, b) Office B*

(b)). The comfortable votes were mainly derived from people who voted for the neutral side and the cold side. TSV = 0 declared the comfort votes ranging from 40% to 96% (Office A) and from 61–91% (Office B). The comfortable votes of TSV- show the value from 15% to 23% (Office A) and from 10 to 39% (Office B). TCV on the second day (24°C) was the most effective when no one voted for feeling uncomfortable (TSV = -3 or +3).

The thermal acceptance votes (TAV) are shown in Figure 8. This kind of voting provided two choices to be chosen in order to confirm the decision of occupants whether thermal environments they exposed to was acceptable or not. We found that the unacceptable rate on the first day was lower than that on the second day. If we count 80% of acceptability, thermal environments in Office A were acceptable on the first day and the second day while those of Office B were acceptable for all three days. It is identified that increasing 1 degree Celsius higher (24 °C) was most acceptable, nevertheless, occupants in Office A accepted to stay at 23 °C more than at 25 °C.

The thermal preference votes in Figure 9 was determined by asking whether occupants preferred to change the temperature in the office or not. On a normal set-point day, although most of them in both offices answered that they did not want to change the temperature (64%, and 51%, respectively), there was 28% of them in Office A and 36% of them in Office B preferred warmer temperatures. The colder temperature preference was significantly lower than the warmer temperature preference. When we changed into a warmer temperature, the colder temperature preference reduced from 28% to 7% (Office A) and 36% to 10% (Office B). The ratio between the "prefer-colder" votes and the "prefer-warmer" votes of Office A was reading as 13:36, 8:18, and 21:10, respectively. It was similar trends with that of Office B which was 13:16, 8:19, and 21:10, respectively. Correlation between TSV and TPV was found to be a negative value (-0.59) at the 0.01 significant level (2-tailed). Occupants who felt cold preferred warmer temperatures and ones who felt warm preferred to change temperature into colder.

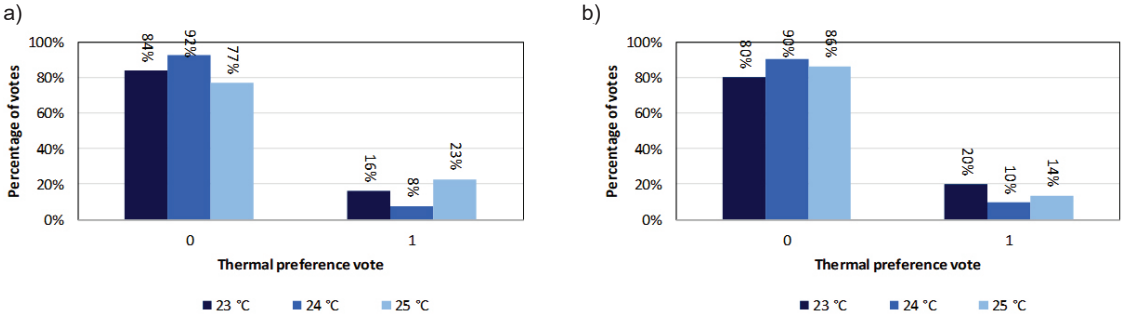


*Figure 8:*
*Thermal acceptance votes of case studies: a) Office A, b) Office B*

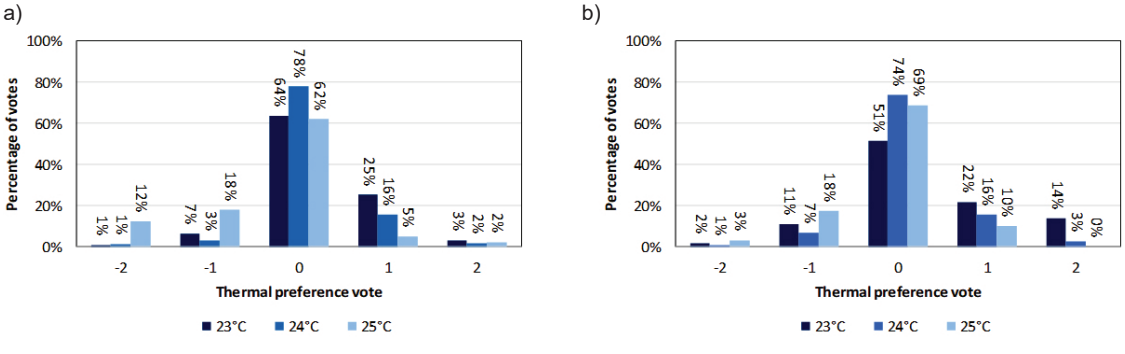


*Figure 9:*
*Thermal preference vote of case studies: a) Office A, b) Office B*

The PMV calculation was listed in Table 5. Data were derived from the questionnaire at 11:00 and 15:00 comparing with collected thermal variables. At the normal condition, most of the values were mainly below -0.5 in both cases which were 38% (Office A) and 75% (Office B). The estimation tended to be out of the recommendation zone (PMV= - 0.5 to 0.5) due to the low air temperature. The percentage of PMV fitted with the ASHRAE standard gradually increased (Office A = 57%, 62%, and 89%, respectively, Office B = 25%, 48%, and 71%, respectively). It could be concluded that in terms of PMV, the best values were in the warmest at 25°C. We also calculated a difference between PMV and TSV, it was found that PMV is different from TSV by 0.1 to 1 in Office A, and 0.1 to 0.3 in Office B. The average of the questionnaire was added into Table 6. The average PMV and TSV were quite similar on the first day, however, when changing higher temperatures, that of TSV deviated from the negative value to the positive value higher than that of PMV. TSV is more sensitive in a change in operative temperature rather than PMV.

The comfort operative temperature was derived from the Griffiths' method (Griffiths & Communities, 1991) which could be applied for several building types and climate zones including office buildings in the tropics (Humphreys, Rijal, & Nicol, 2013). The equation is $T_c = T_r$ (0 - C)/a, where $T_c$ means the comfort temperature (°C), based on T, which is temperature (°C); C is the thermal sensation vote on the scale, where 0 defines as a neutral condition; and a defines the constant rate of thermal sensation change with the room temperature. In this study, 0.5 was used as the constant value, as had been used with a seven-point thermal sensation scale by the study of Humphreys (Humphreys et al.) As the results, the average operative comfort temperature was found to be 23.6–24.8 °C in Office A, and 23.9–25.1 °C in Office B. It did not become a big gap when changing such rapid temperatures. Considering the estimation in Table 7, when we compare the measured operative temperature with the comfort temperature, it is applied that changing higher temperatures could be possibly adjusted by +2 °C. However, these cases must be carefully concerned about high relative humidity which directly affects human comfort, especially in Office B which the actual temperature was near to the comfort temperature, but people voted for discomfort up to 26%.

**Table 5**: The PMV Estimation

| Set-point (°C) | Item | PMV < -0.5 | -0.5 ≦ PMV ≦ 0 | 0 ≦ PMV ≦ 0.5 | 0.5 < PMV | Comply with ASHRAE standard 55-2017 | Does not comply with ASHRAE standard 55-2017 |
|---|---|---|---|---|---|---|---|
| **Office A** | | | | | | | |
| 23 | N | 64 | 73 | 23 | 8 | 96 | 72 |
| 24 | | 54 | 71 | 28 | 6 | 99 | 60 |
| 25 | | 8 | 70 | 54 | 8 | 124 | 16 |
| 23 | % | 38 | 43 | 14 | 5 | 57 | 43 |
| 24 | | 34 | 45 | 18 | 4 | 62 | 38 |
| 25 | | 6 | 50 | 39 | 6 | 89 | 11 |
| **Office B** | | | | | | | |
| 23 | N | 82 | 22 | 5 | 0 | 27 | 82 |
| 24 | | 44 | 32 | 23 | 16 | 55 | 60 |
| 25 | | 1 | 59 | 9 | 27 | 68 | 28 |
| 23 | % | 75 | 20 | 5 | 0 | 25 | 75 |
| 24 | | 38 | 28 | 20 | 14 | 48 | 52 |
| 25 | | 1 | 61 | 9 | 28 | 71 | 29 |

**Table 6:** Average Values of PMV and the Subjective Votes

| Set-point (°C) | Items | PMV | TSV | TCV | TAV | TPV |
|---|---|---|---|---|---|---|
| **Office A** | | | | | | |
| 23 | Mean | -0.4 | -0.6 | 0.3 | 0.2 | 0.3 |
| | SD | 0.5 | 1.1 | 1.1 | 0.4 | 0.6 |
| 24 | Mean | -0.4 | -0.3 | 0.4 | 0.1 | 0.1 |
| | SD | 0.5 | 1.0 | 1.1 | 0.3 | 0.5 |
| 25 | Mean | -0.4 | 0.6 | 0.1 | 0.2 | -0.3 |
| | SD | 0.4 | 1.4 | 1.2 | 0.4 | 0.8 |
| **Office B** | | | | | | |
| 23 | Mean | -0.7 | -1.0 | 0.1 | 0.2 | 0.3 |
| | SD | 0.6 | 1.4 | 1.0 | 0.40 | 0.9 |
| 24 | Mean | -0.3 | -0.4 | 0.4 | 0.1 | 0.1 |
| | SD | 0.8 | 0.9 | 0.9 | 0.34 | 0.6 |
| 25 | Mean | 0.1 | 0.0 | 0.2 | 0.1 | -0.1 |
| | SD | 0.4 | 0.9 | 1.1 | 0.34 | 0.6 |

**Table 7:** The Comfort Operative Temperature Estimation

| Set-point (°C) | Number | | Item | Comfort operative temperature (°C) | |
|---|---|---|---|---|---|
| | Office A | Office B | | Office A | Office B |
| 23 | 168 | 109 | Min | 17.6 | 19.0 |
| | | | Max | 29.6 | 30.0 |
| | | | Mean | 24.8 | 25.1 |
| | | | SD | 2.0 | 2.7 |
| 24 | 159 | 96 | Min | 17.7 | 17.3 |
| | | | Max | 28.0 | 28.5 |
| | | | Mean | 24.5 | 23.9 |
| | | | SD | 1.8 | 1.8 |
| 25 | 140 | 96 | Min | 18.1 | 18.7 |
| | | | Max | 29.3 | 29.4 |
| | | | Mean | 23.6 | 24.8 |
| | | | SD | 2.6 | 1.8 |
| All | 467 | 301 | Mean | 24.3 | 24.6 |
| | | | SD | 2.2 | 2.2 |

## Thermal adaptive behavior

Thermal adaptive behavior is self-adaptation of people to be comfortable in thermal environment (Nicol, Humphreys, & Olesen, 2004). Initially, a study was conducted in free-running mode buildings and later extended to cooling-mode buildings (Rijal, Humphreys, & Nicol, 2017). Some adaptive behaviors, such as changing clothes and opening a portable fan were found to be a higher rate in Southeast Asian countries (Damiati et al., 2016). The results reveal that occupants in a tropical region tolerate cooling conditions more than those in Japanese offices with a high number of warmer-than-neutral votes. Also, the study in Singapore (Chen & Chang, 2012) found that the clothing insulation was added during the day which was that of males were 0.57 clo and that of females were 0.61 clo on average. To understand air-conditioning experience of occupants, we also asked occupants what the temperature set-point that they usually set at home. There were over 50% of them setting the thermostat at 25 °C while 19% of them set the point lower than 25 °C. It is implied that most people lived at warmer temperatures at home and experienced colder temperatures in the office. People were aware of the cool condition in the office so they had to prepare themselves to stay inside the office building. This issue led to the adaptive behavior in the office that the occupants prepared some belongings to adjust themselves in the office. In this single-blind study, we did not control clothing behavior because we aimed to observe automatic responses and the impact of sudden thermal environment changes. If we informed to control the clothing rate, people would notice the change and easily gave different feedbacks or tolerated such cool temperatures. The clothing insulation changing rate of case studies were added in Table 8. Clothing insulation of occupants was checked at 9:00, 11:00, and 15:00. We did not notice a difference in the clothing rate between males and females in these cases. The percentage of belongings mostly was found to be clothing of the upper part. In Office A, the rate of people wearing suits was high because of company uniforms. In addition, the mean clothing rate slightly increased from 0.61 clo to 0.65 clo. when some occupants worn additional cloths; light jackets, sweaters, cardigans, and scarves. The increase of average on the first day was slightly higher than that on the last two days. One the first day, the average clothing rate in Office A started at 0.61 clo and inclined to 0.65 clo in the afternoon because people felt cold. When the set-point was 25 °C, the average declined from 0.61 clo 0.56 clo, nearly the expected value (0.5 clo). These results point that warmer temperatures could reduce the adjustment of cloths. Additionally, a similar trend happened in Office B when an increase of clothing was the highest on the first day from 0.53 clo to 0.59 clo and then decreased in the last two days. Occupants who wore summer clothing and stayed in the cool environment easily felt cold and preferred warmer temperatures. A similar study of clothing adaptation is mentioned in other offices in Thailand when indoor temperature became lower than 23 °C (Sikram, Ichinose, & Sasaki, 2019). Therefore, clothing change at the temperature up to 25 °C remains acceptable.

**Table 8:** The Clothing Insulation Changing Rate

| Set-point | N | Item | 9:00 | 11:00 | 15:00 |
|---|---|---|---|---|---|
| **Office A** | | | | | |
| 23 | 91 | $Clo_{av}$ | 0.61 | 0.65 | 0.65 |
| | | SD | 0.17 | 0.22 | 0.22 |
| 24 | 85 | $Clo_{av}$ | 0.58 | 0.62 | 0.60 |
| | | SD | 0.17 | 0.21 | 0.16 |
| 25 | 77 | $Clo_{av}$ | 0.61 | 0.60 | 0.56 |
| | | SD | 0.19 | 0.17 | 0.15 |
| **Office B** | | | | | |
| 23 | 58 | $Clo_{av}$ | 0.53 | 0.57 | 0.59 |
| | | SD | 0.12 | 0.10 | 0.12 |
| 24 | 59 | $Clo_{av}$ | 0.54 | 0.56 | 0.56 |
| | | SD | 0.08 | 0.07 | 0.11 |
| 25 | 57 | $Clo_{av}$ | 0.54 | 0.55 | 0.54 |
| | | SD | 0.09 | 0.10 | 0.13 |

*Note: $Clo_{av}$: average clothing value*

## CONCLUSIONS

In this study, a field investigation was conducted in two air-conditioned offices in Bangkok metropolitan, Thailand. In order to improve thermal comfort, the room temperature set-point was adjusted between 23–25 °C. Thermal performance of each day will be estimated together with the questionnaire survey. Thermal environments in office spaces of both cases were generally in the 1.0 clo comfort zone rather than 0.5 clo zone because the low-temperature point at 23 °C produced indoor thermal environment to be overcooled. When we change to higher temperatures, it was noticeable that the average temperature was changed close to the set-points. Thermal environments and occupants' characteristics in warmer temperatures were appropriated for PMV which most values shifted from a negative side to a positive side. According to TSV, at the set-point of 24 °C could enhance occupants as the highest acceptable votes of comfort, sensation, and preference, however, the votes from occupants in Office B at the set-point of 25 °C was still agreeable within 80% satisfaction. The clothing rate was found to be suitable to the 0.5 clo zone and adaptive clothing behavior reduced when changing to warmer temperatures. To apply to existing buildings, thermal environments should improve by following the estimated comfort temperature at 23.6–25.1 °C when people worn summer clothing between 0.5 clo to 0.6 clo. We notice that there were many people feeling discomfort when the operative temperature was higher than the comfort temperature. The main reason was relative humidity went higher than 60% when the temperature was set warmer. The humidification performance of this air-conditioning system must be carefully considered when temperature was increased. According to the previous study in Singapore (Chen & Chang, 2012), an effective air-conditioning performance to the new office is challenging to reduce humidity levels from outside. The development of separated

dehumidification should be more concerned when designing AC so that temperature would not be too cold and humidity is well controlled at optimum values. Nonetheless, this study does not mention energy performance, it would be more beneficial to understand the importance of an increase of set-point from different perspectives. We encourage a future study to be related to this topic.

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# An Investigation of a Modified Formula of Daylight Glare and Limiting Daylight Glare Indices in the Thai Elderly

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## ABSTRACT

Discomfort glare is perceived differently by the young and the elderly. However, the existing daylight glare formulae do not take the effects of age into account and the current limiting glare index was obtained from non-elderly subjects. To create lighting suitable for the Thai elderly, especially in terms of glare, two objectives were addressed. The first explored a modified formula of daylight glare for the Thai elderly, while the second investigated the limiting daylight glare index for the Thai elderly in particular areas of residential and public buildings. Both laboratory and field studies were undertaken. The former investigated a daylight glare formula modified for the effect of age of the Thai elderly. Experiments were carried out in a controlled chamber at Kasetsart University, Bangkok, Thailand. The latter explored the limiting daylight glare index for particular areas of residential and public buildings for the Thai elderly with studies conducted in the real environment. A modified formula was proposed to predict daylight glare for the Thai elderly. Limiting daylight glare indices for particular areas of both residential and public buildings for the Thai elderly were also proposed, and the recorded values were found to be higher than the existing limiting daylight glare indices.

***Keywords:*** *discomfort glare, daylight, glare index, Thai elderly*

## INTRODUCTION

Glare is visual noise. Discomfort glare is a phenomenon arising from high luminance contrasts or unsuitable luminance distributions in the visual field that cause discomfort (CIE, 1995). There have been many studies on glare predictions for both small-source and large-source glare. The Unified Glare Rating (UGR) (CIE, 1995), Daylight Glare Index (DGI) (Hopkinson, 1972) and Daylight Glare Probability (DGP) (Wienold & Christoffersen, 2006) are the most commonly used methods for quantifying glare predictions.

For small-source glare calculation, the Unified Glare Rating (UGR) and Illuminating Engineering Society glare index (IES-GI) systems are internationally recommended for evaluating the degree of discomfort glare from indoor lighting installations. Both UGR and IES-GI systems have been applied to small sources of glare and electric lighting installations (IES, 1967). Glare indices that are developed for electrical lighting (UGR and IES-GI) are not suitable for daylight because daylight openings have a significantly higher solid angle.

The daylight glare index (DGI) was developed many years ago, and is recognised as a well-known method to predict the amount of discomfort glare from windows or large sources (Hopkinson, 1972). Nazzal (2005) proposed a modified index called $DGI_N$ which aimed to overcome some of the limitations of the standard DGI. In this formula, sources of luminance and solid angles are modified to include the effect of the observer's position. In 2007, Tuaycharoen and Tregenza proposed DGI' as a daylight glare index modified for the effects of luminance variation (RML) and view interest (IV).

In 2006, another daylight glare prediction was proposed by Wienold and Christoffersen as the Discomfort Glare Probability (DGP). This formula showed a stronger correlation with the user's response regarding glare perception. The UGR and DGI indices, previously analysed, only focused on the contrast in the ratio between the background average luminance and the glare source luminance. However, DGP included an evaluation of the level of illuminance perceived by the observer by means of the term $E_v$. Moreover, in a subsequent study, Wienold (2007) proposed a simplified version of DGP (DGPs) where no logarithmic term depended on the local quantities (luminance and solid angle of the source seen from the observation point). Finally, in 2009, Wienold proposed the Enhanced Simplified DGP (eDGPs) for use in the case of direct sun transmission into a room.

Recently, the number of elderly people aged 65 and above has dramatically increased in Thailand. This has caused serious problems for the Thai Government who are tasked with providing appropriate infrastructure and living accommodation. Since sunlight is strong in Thailand, daylighting is one of the important factors to consider when creating a suitable environment for the Thai elderly, especially in terms of glare prevention from the window. Due to age-related changes in vision, the elderly are more sensitive to glare than younger adults (IESNA, 2016). However, none of the current daylight glare formulae in use take the effects of ageing into account. There are no different requirement between limiting glare index values for young and older people. Moreover, many recent studies have also revealed differences in visual perception in Caucasians and Asians (Bergamin et al., 1998; Van Den Berg et al., 1991). Therefore, to create lighting suitable for the Thai elderly, especially in terms of daylight glare, it is necessary to develop a modified formula to predict discomfort glare from window and limit daylight glare index values that accurately represents the particular visual features of the Thai elderly.

To develop the above-mentioned formula and index, two main studies were conducted. The first study investigated a modified formula of discomfort glare from a window for the Thai elderly. This experiment was carried out in a controlled chamber at the Faculty of Architecture, Kasetsart University, Bangkok, Thailand. The second study was undertaken to establish limiting daylight glare indices for the Thai elderly in particular environments in residential and public buildings. A field survey of nine nursing homes was carried out. Finally, a modified glare formula for the Thai elderly was proposed together with limiting daylight glare indices of particular environments in residential and public buildings.

## METHODOLOGY

### Study I: Thai elderly daylight glare formula

The main objective of this study was to investigate a modified formula of discomfort glare from a window for the Thai elderly. In this study, the daylight glare

index (DGI) developed by Hopkinson (1972) was used as a reference as this formula is the most well-known method to predict discomfort glare for large sources.

## Experimental setting

Many studies have shown that there is no difference between the glare results from a simulated environment and a real daylighting condition (Iwata et al.,1992a,1992b). Since there was a need for control over many extraneous variables, this study was conducted in a simulated closed environment rather than real daylighting condition.

The first study was conducted in a controlled test chamber at the Faculty of Architecture, Kasetsart University, Bangkok, Thailand. The test chamber was located on the ground floor of the building and had no windows, consequently providing complete control over the lighting conditions. A 3.00 m wide by 3.00 m high by 3.00 m deep testing chamber was built. The ceiling of the chamber was painted matt white with reflectance ($\rho_c$) of 0.8, while the reflectance of the walls ($\rho_w$) was 0.5 and that of the floor ($\rho_f$) was 0.2, as reflectance values for standard ceiling, wall and floor.

A projector connected with a laptop was used to project image glare sources with various luminance on a wall as a simulated window. Fixation was marked at the centre of the images of the glare source. The subjects sat facing the projected wall two metres from the images and the viewing distance for each subject was constant. This maintained a constant visual size of the image (Figure 1).

## Experimental equipment and measurement

A projector was placed on one side of the subject and manipulated by one experimenter, while a cone was located on the other side of the subject to measure light levels. One experimenter stood slightly behind the subject to record the vertical illuminance to obtain the mean luminance of the glare source using a photocell with a conical mask. The experimenter also recorded the vertical illuminance to achieve the mean luminance of the background using a photocell outside the cone (Figure 2). These monitoring procedures followed the method proposed in the IEA SHC Task 21 (Christoffersen, 2001).

*Figure 1:*
*Apparatus settings used in this experiment*

*Figure 2:*
*Cone and lux meters*

At the back of the chamber, a projector cast the image of a scene onto the opposite wall creating various glare sources. These consisted of a square 50 x 50 cm area as a large glare source. To change the luminance levels of the glare source, various images containing several levels of brightness were prepared for projection. Illumination inside the testing chamber was provided by light reflecting from the projected images.

## Experimental procedure

Testing was conducted during June-July 2016. Forty-six Thai elderly subjects, aged between 61 and 76 years with no colour blindness and/or other eye problems that effects the results, participated in the experiment. This number of subjects was chosen because the same number was used in many previous glare studies (Rodriguez et al., 2017), while the number of 30 observations was devised by Bechtel (1987) as the minimum number required to obtain a statistically significant result. Half of the subjects were male and half were female. In the experiment, no significant difference was found between observers with and without contact lenses or between male and female subjects. Therefore, data were analysed without any discrimination (Kim & Koga, 2004; Kim et al., 2008).

Previous research showed that subjective assessments of glare tended to produce a wide scatter in the results. For this reason, a pretest period for controlling extraneous variables was added to the experiment. There were two periods of experiment as a pretest period followed by the real experiment.

In the pretest period, when first arriving at the test chamber, the subject was required to position himself or herself in a chair facing the wall screen. The experimenter then gave a brief explanation of the purpose of the study, during which, the subject completed the informed consent form. Each subject first completed the pre-study questionnaire, and was then given instructions containing the definition of glare, the meaning of criteria, and the trial procedure used in the real experiment. The experimenter then demonstrated her own evaluation on a test image. After, subjects performed one evaluation trial with similar procedure of the real experiment. This method was used in previous glare studies (Velds, 2002; Tuaycharoen, 2006). Then, the subject was allowed to relax for about five minutes before the real experiment was begun. This time period was for the subject to re-adapt his/her eyes in mesopic vision (Plainis et al., 2005).

In the real experiment, the subject was asked to look at the centre of each image. After 30 seconds of adaptation, the presenter asked the subjects to evaluate glare level on the questionnaire for each projected image as well as send a verbal signal by saying ‘yes’ to the two experimenters to record the light levels and change the stimuli. All image sequences were randomly assigned for each subject. Subjects participated in one session of approximately one hour in length.

## Subjective assessment of discomfort glare

In previous studies, different subjective criteria were used for assessing glare discomfort. These included Hopkinson’s multiple criterion scale, Glare Sensation Vote (GSV), Percentage Persons Dissatisfied (PPD) and Borderline Comfort Discomfort (BCD). The Glare Sensation Vote (GSV) by Wienold and Christoffersen (2006) was used as a subjective assessment in this study because this method was used in many previous glare studies (Iwata et al., 1992a, 1992b) and has been adopted as the reference standard

used in the development of current glare indexes (Fotios, 2015). The GSV was also modified as a continuous scale and was developed and linked to the time span for which the subject could withstand their sensation of discomfort to allow the subject to better understand the scale (Kent et al., 2014, Osterhaus, 1998; Rodriguez et al., 2015; Tuaycharoen, 2006; Velds, 2002). Thus, the variance of glare results was reduced. In this experiment, the definition of each point of the glare scale was described to the subject and a printed sheet of paper that included these definitions was available during the experiment. These four thresholds were described to all subjects. Also, the experimenter suggested to them to think that they have to pursue some visual tasks in the working environment while evaluating these criteria of discomfort glare. The Glare Sensation Vote (GSV) is shown as Figure 3 below.

This study aimed to modify the DGI formula according to age factor. Therefore, after obtaining all the results of GSV, the data were converted to the same scale as the DGI scale. In this study, this converted GSV data was called Glare Response Vote (GRV) following the method according to Tokura et al. (1996) (GRV was derived as follows: GRV= 4GSV+16). After that, to obtain the best fit function of the modified DGI formula ($DGI_a$), all the data, which were GRV (dependent variable, called later as $DGI_a$), DGI and Age (independent variables), were analysed using Multiple Linear Regression.

## Study II: Limiting glare indices for the Thai elderly

The main objective of the second study was to investigate limiting daylight glare indices for the Thai elderly in particular areas of residential and public buildings. There were two parts in this study. The first part aimed to investigate the limiting daylight glare indices for particular environments in residential buildings. The second study was to explore the limiting daylight glare indices for particular environments in public buildings.

### Limiting glare indices for the Thai elderly in residential building

#### Survey

In the first part, a comprehensive survey of nine nursing homes in Thailand was conducted with glare assessments of 326 residents in these homes (Figure 4). Data were gathered from seven areas with daylight condition only. The areas examined were 1) corridor, 2) active area or lounge, 3) bedroom, 4) dining room, 5) bathroom, 6) living room, and 7) main entrance.

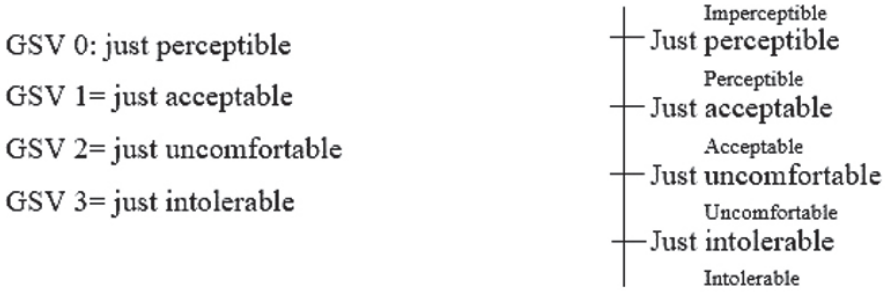



*Figure 3:*
*The Glare Sensation Vote (GSV) used in the subjective assessment of this experiment*

Ban Lopburi Older Persons House

Nakhon Pathom Residential Home

Chalerm Ratchakumaree Elders Aid Centre (Luangpoh Pern Patronage)

Tharnnukro Foundation Bangkhen Nursing Home

Chalerm Ratchakumaree Elders Aid Centre (Luangpoh Lamyai Patronage)

Watsanawet Social Welfare Development Centre for Older Persons

Ban Bang Khae Social Welfare Development Centre for Older Persons

Pathumthani Social Welfare Development Centre for Older Persons

Waiwattananiwat foundation

*Figure 4:*
*Investigated nine nursing homes*

**Experimental equipment and measurement**

In order to find the limiting glare indices for a particular area, the participants were asked to evaluate their glare sensation, and simultaneous photometric measurements of the luminous environment were recorded to calculate the daylight glare index ($DGI_a$) using the formula obtained from the first part of this study.

To measure factors relating to the $DGI_a$ formula, a digital CCD camera equipped with a fisheye lens was used to 'instantaneously' capture the luminous environment of the observer. The camera was mounted on a tripod and pointed towards the centre of the window, which was the visual fixation area for the subject. Then, nine images with different exposure values were taken for each subject evaluation to create a high-dynamic-range (HDR) image. To calculate luminance values, a Photolux software version 1.3.5 developed by the Lighting Research Group of l'Ecole Nationale des Travaux Publics de l'Etat (ENTPE) in Lyon, France was used. The software combined all the images of the same scene to create a HDR image and produced a luminance map with values of source luminance and background luminance. This method was used due to the fact that instant luminous environments have to be recorded at the same time as the subject glare evaluation and many previous glare studies use this methods (Tuaycharoen, 2006; Velds, 2002). And, in a preliminary experiment assessing the accuracy of the Photolux software under interior daylit conditions, it was found that the average error compared to

a Konica Minolta LS-100 luminance meter was found to be only 5%. To evaluate the sensation of discomfort glare from the window, a GSV scale similar to the first experiment was used.

**Experimental procedure**

Testing was conducted in nine nursing homes during November - December 2016. The nursing homes were selected because they contained similar environmental characteristics for the Thai elderly. A total of 326 Thai elderly participants were included in this experiment. All subjects were aged 61- 70 years old. Participants with colour blindness and other eye problems affecting the results were excluded from the study. Fifty percent of the subjects were male and 50% were female. In this experiment, no significant difference was found between observers with and without contact lenses or between male and female subjects. Therefore, data were analysed with no discrimination between male and female or between those with and without contact lenses.

Similar to the first experiment, there were two periods in this experiment as a pretest period and the real experiment. The pretest followed the same procedure as the first experiment. In the real experiment, each subject was required to look at a previously marked fixation in an investigated area (a normal visual task for each activity) for 30 seconds (Tuaycharoen, 2006) and evaluated the glare sensation using the GSV scale. At the same time an 'instantaneous' capture of the luminous environment of the subject was also recorded by a digital CCD camera equipped with a fisheye lens. All the areas, site visits and the time of day to be explored were randomly evaluated. All the results of GSV were then converted to GRV scale. And, after obtaining all the data of $DGI_a$ indices and GRV data, a Simple Linear Regression analysis was conducted to fit the relationship between GRV data and $DGI_a$ indices. The limiting daylight glare indices for each area were obtained from the $DGI_a$ indices at the 95$^{th}$ percentile of the GRV results with increasing or decreasing within ±5% of the values (Yonemura, 1981).

## Limiting glare indices for the Thai elderly in public building

In the second part, there were two types of public building investigated. The first type was a Thai temple and the second was a hospital. The reason for choosing these two types of the building due to the fact that these areas were most frequently used by elderly compared to other types of public buildings. For a study of glare in Thai temple, a survey of seven Thai temples was conducted with glare assessments of 142 Thai older adults during February - March 2017 (Figure 5). All subjects were aged 61-70 years old with no colour blindness and/or other eye problems that effects the results. Data were gathered from two areas with daylight condition only. These two areas were 1) temple body (hall and circulation) and 2) worship seating area. The same procedure and analysis as the part of a residential building was carried out for this part of the research.

For a study in hospital, two hospitals were explored in terms of glare by 203 Thai elderly during April-May 2017, which were Chakkarat hospital and Chokchai hospital (Figure 6). All subjects were aged 61-72 years old with no colour blindness and/or other eye

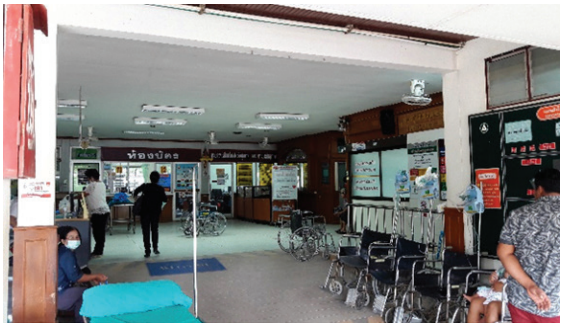
*Samian Nari Temple*

*Wat Phra Meru Rachikaram*

*Figure 5:*
*Examples of investigated Thai temples*

problems that effects the results. Glare assessments were carried out in five areas of the hospitals with daylight condition only. These areas were 1) waiting room, 2) corridor (during the day), 3) examination room (general lighting), 4) treatment room (massage and radio therapy), and 5) ward (general lighting). The similar procedure and analysis as the part of a residential building was carried out again for this part of the study.

*Chakkarat hospital*



*Chokchai hospital*

*Figure 6:*
*Two investigated hospitals*

## RESULTS

### Daylight glare formula for Thai elderly

As seen from Equation 1, Hopkinson (1972) proposed a Hopkinson-Cornell equation (DGI) to predict a large glare source as follows:

$$DGI = 10\log_{10} 0.478 \sum_{i=1}^{n} \left[ \frac{L_s^{1.6}\ \Omega^{0.8}}{L_b + 0.07\omega^{0.5} L_s} \right] \quad \ldots\ldots(1)$$

Where: $L_s$ = Luminance of the source (cd $m^{-2}$)
$L_b$ = Luminance of the background (cd $m^{-2}$)
$\omega$ = Solid angle of the source (sr)
$\Omega$ = Solid angular subtense of the glare source, modified for the effect of its position in the field of view by means of position index, *P* (sr)
*P* = Position index of the source (sr)

An empirical equation was fitted to the results to examine the relative magnitude of the age factor of Thai elderly that influenced glare discomfort using Multiple Linear Regression analysis. The author modified the Hopkinson-Cornell equation (DGI) by adding supplementary terms or correction factors. Table 1 shows the best fit equation for predicting glare from a window for the Thai elderly.

**Table 1:** Equation for predicting glare from a window for the Thai elderly

| **Equation** $DGI_a$ = C1 x DGI + C2 x Age + C3 | | | |
|---|---|---|---|
| | **Correction factor** | **Standard error** | ***p*-value** |
| C1 | 0.399 | 0.025 | 0.000** |
| C2 | 0.100 | 0.019 | 0.000** |
| C3 | 10.134 | 1.231 | 0.000** |
| R-squared ($r^2$) = 0.670* | | | |

*** Highly significant at the 0.01 level; * Significant at the 0.05 level*

The best fit daylight glare formula for the Thai elderly is shown as follows:

$$DGI_a = 0.399\,DGI + 0.100\,Age + 10.134 \quad \ldots\ldots (2)$$

Where: $DGI_a$ = Daylight glare index for the Thai elderly modified for the effect of Thai elderly's age
DGI = Daylight glare index calculated from the Hopkinson-Cornell equation
Age = Age of the Thai elderly (years)

The study also investigated if there is a significant correlation between other daylight glare metrics and the subjects' glare sensation in this study (the first study). The coefficient of determination ($r^2$) was calculated for this purpose. The coefficient of determination ($r^2$) for other daylight glare metrics and the results of the subjects' glare sensation (GRV) in this study are shown in Table 2. It was found that other daylight glare metrics as DGI, $DGI_N$ and DGP were not significantly correlated with the results of the subjects' perceptions of glare ($r^2$ = 0.330, $r^2$ = 0.251, and $r^2$ = 0.232 respectively). Table 2 is also noteworthy because none of the other daylight glare metrics calculated achieve a correlation to discomfort sensation from window of Thai elderly higher than 0.5. When compared to the result in Table 1, $DGI_a$ formula can improve a much higher correlation to the discomfort sensation from window of Thai elderly ($r^2$ = 0.670) than other existing daylight glare metrics.

**Table 2:** The coefficient of determination ($r^2$) for different daylight glare metrics and the subjective glare sensation

| **Metric** | **Subjective glare sensation** | |
|---|---|---|
| | ***r*²** | ***p*-value** |
| DGI | 0.330 | 0.082 |
| $DGI_N$ | 0.251 | 0.092 |
| DGP | 0.232 | 0.111 |

*** Correlation is significant at the 0.01 level*
** Correlation is significant at the 0.05 level*

## Limiting daylight glare indices for Thai elderly

Table 3 shows the limiting daylight glare indices for the Thai elderly in each area of residential building. Overall, results showed that the values of limiting daylight glare indices for the Thai elderly were higher than the existing limiting daylight glare index (DGI).

**Table 3:** Limiting daylight glare indices for the Thai elderly in each area of a residential building

| Area | Daylight Glare Indices from linear regression at the 95th percentile | Limiting Daylight Glare Indices for the Thai elderly ($DGI_a$) | Limiting Daylight Glare Indices (DGI)[i] |
|---|---|---|---|
| Corridor | 22.80 | 23 | 20 |
| Active area or lounge | 22.20 | 22 | 20 |
| Bedroom | 27.82 | 28 | n/a |
| Dining room | 27.76 | 28 | n/a |
| Bathroom | 27.80 | 28 | n/a |
| Living room | 24.02 | 24 | n/a |
| Main entrance | 26.04 | 26 | 20 |

*Note:* [i] *Limiting Daylight Glare Indices (DGI) are derived from limiting Unified Glare Rating (UGR) (CIBSE, 1994) and were converted by using DGI = 2/3 x (UGR+11) (Bellia et al., 2008; Cai & Chung, 2013)*

*n/a means no limiting Unified Glare Rating (UGR) proposed (CIBSE, 1994)*

Table 4 shows the limiting daylight glare indices for the Thai elderly in each area of public buildings. Overall, results showed that values of limiting daylight glare indices for the Thai elderly in each area both Thai temple and hospital were higher than the existing limiting daylight glare index (DGI). In general, the Thai elderly seem to display more tolerance on glare from a window than young Caucasian population from which DGI was originally derived (Hopkinson, 1972).

**Table 4:** Limiting glare indices of a large source for the Thai elderly in each area of a public building

| Area | Daylight Glare Indices from linear regression at the 95th percentile | Limiting Daylight Glare Indices for the Thai elderly ($DGI_a$) | Limiting Daylight Glare Indices (DGI)[i] |
|---|---|---|---|
| **Temple** | | | |
| Temple body (hall and circulation) | 24.98 | 25 | 24 |
| Worship seating area | 25.85 | 26 | 22 |
| **Hospital** | | | |
| Waiting room | 25.86 | 26 | 22 |
| Corridor (during the day) | 27.77 | 28 | 22 |
| Examination room (general lighting) | 25.80 | 26 | 20 |
| Treatment room (massage and radio therapy) | 24.79 | 25 | 20 |
| Ward (general lighting) | 24.81 | 25 | 20 |

*Note:* [i] *Limiting Daylight Glare Indices (DGI) are derived from limiting Unified Glare Rating (UGR) (CIBSE, 1994) and were converted by using DGI = 2/3 x (UGR+11) (Bellia et al., 2008; Cai & Chung, 2013)*

## CONCLUSIONS AND DISCUSSIONS

### Theoretical implications

Based on the results, a modified glare formula for the Thai elderly was proposed, taking into account the effect of age. Limiting daylight glare indices of the Thai elderly in a particular environment in both residential and public buildings were also introduced.

Results in the first study yielded a modified glare formula for the Thai elderly ($DGI_a$) and showed a strong magnitude of the age effect. Moreover, when the correlation between other daylight glare metrics and the data sets of glare sensation of Thai elderly were made, none of the metrics had a significant correlation to discomfort sensation from window of Thai elderly. And, $DGI_a$ formula can improve a much higher correlation to the discomfort sensation from window of Thai elderly. This situation implied that the existing daylight glare formulae are a poor predictor of discomfort glare from window for the Thai elderly. This also re-emphasised the difference in glare sensitivity between the elderly and young people in the case of Thai people. Findings were consistent with research conducted in other countries by Kuhn et al. (2014) who indicated that glare may be more frequently reported by older observers (Kuhn et al., 2014).

Moreover, results in the last study showed that despite an age effect, the Thai elderly still displayed more tolerance on glare from windows of both residential and public buildings than young Caucasian. This finding was demonstrated by higher values of limiting daylight glare indices of the Thai elderly from most areas in these two types of buildings than the

existing limiting DGI (the results obtained by young Caucasian). Normally, when people getting old, their eye lens become opaque causing scatting light in their eye balls. This results in higher glare sensitivity in elderly than young people (IESNA, 2016). The results in our study seems to indicate that even though there was an age effect, in glare perception from daylight in residential and public building context, the effect of culture would still be stronger. Results in this part correlated with many studies showing different glare sensations between Asians and Caucasians. Asian people always display more tolerance to glare than Caucasians. Tuaycharoen (2013) found that when subjected to a severe degree of glare sensation, Thai people felt the same degree of discomfort glare at a higher window luminance (Tuaycharoen, 2013). Pulpitlova & Detkova (1993) established a higher tolerance to glare in Japanese than European subjects, while Akashi et al. (1996) and Cai & Chung (2013) suggested that glare sensitivity may not be consistent across cultures.

## Practical implications

The results of this study yield benefits to designers to manipulate glare from windows for the Thai elderly in residential and public buildings as follows:

1) A modified daylight glare formula for the Thai elderly ($DGI_a$) taking into account the effect of Thai elderly's age could be used to predict glare from window in living environment for the Thai elderly more accurately. An increase in discomfort glare from window was found to be related to an increase in age of the Thai elderly.

   Therefore, in the areas used by the Thai elderly, the designer needs to take more consideration in the aspects of higher glare perception, such as increasing protection against daylight by using extra curtains or lower glass transmission by the windows.

2) A high-quality lighting environment is an important aspect to maintain environments that are supportive of the ageing process, promote wellness and reduce accidents in nursing homes. Necessary light for older eyes in nursing homes can be provided by 1) substantially raising light levels, 2) balancing natural light and electric light to achieve even light levels and 3) eliminating glare as much as possible (Lizabeth & Noell-Waggoner, 2003). To maintain supportive environments in Thai nursing homes, both $DGI_a$ formula and limiting daylight glare indices identified in this study can be used as a guideline to design a suitable visual environment for older eyes in particular areas. Moreover, these $DGI_a$ formula and limiting daylight glare indices for the Thai elderly can be applied as a design guideline to other public buildings, such as Thai temple and hospital.

## Limitations of the study

There are two limitations in this study. Firstly, findings presented here are contingent on the experimental characteristics and conditions considered in this study only. Secondly, the subjects who participated in this study were Thai elderly people who represented a distinctive culture and background.

**ACKNOWLEDGEMENTS**

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# A Framework of Design Criteria for Elderly Facilities Using Maslow's Hierarchy of Needs

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## ABSTRACT

The increase in population ageing worldwide is giving rise to the design of age-friendly cities and facilities. Recognizing elderly needs is essential to promote an active life that enables continued participation in the society. However, there is no precedent that justifies the choices in the design of spaces for the elderly, so this study proposes an evaluative model of physical design that satisfies and fulfills the needs of the elderly. The Design Pyramid is based on the Theory of Maslow's Hierarchy of Needs linking the needs of the elderly with architectural attributes. The application of this model allows evaluating the spatial design and its elements and exploring improvements to promote the well-being of the elderly.

***Keywords***: *architecture, Maslow's hierarchy of needs, design, elderly, well-being*

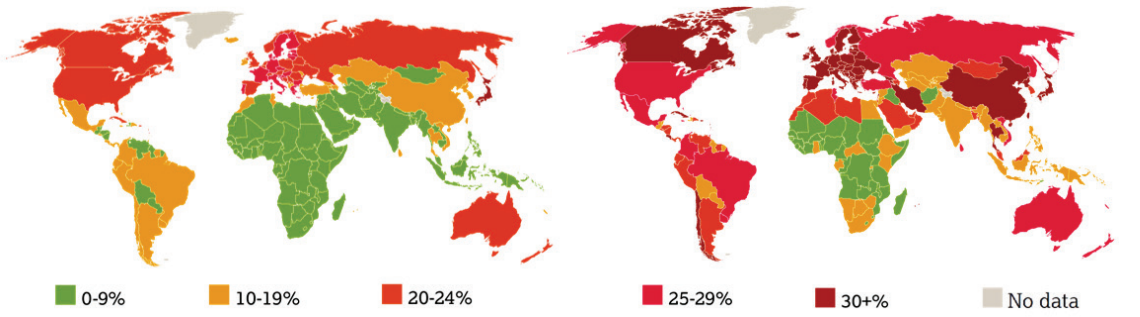



*Figure 1:*
*Proportion of population aged 60 or over in 2015 and 2050 (Source: UNDESA Population Division, World population prospects: 2015 revision, DVD Edition, 2015. Retrieved from Global AgeWatch Index Team, 2015, p. 6).*

## INTRODUCTION

The population situation around the world emphasizes the global need to provide society with age-friendly cities and environments. Globally, the population of older people is estimated to be 2,092 million by 2050. The proportion of this age group will double over the course of half a century (World Health Organization [WHO], 2014) with ageing and urbanization being the two trends that characterize this period. Many studies around the world show that the ageing population is becoming the majority group in the city (US National Institute of Aging & WHO, 2011; WHO, 2015; United Nations Population Fund [UNFPA] 2017; Huenchuan, 2018). As the city grows, its residents who are 60 years old and older are increasing, with the tendency for this population to continue living in its urban centers due to familiarity with the area and proximity to the services that they are accustomed to. For this reason, mobility and accessibility are the determining factors in choosing a place to live for the elderly, since the physical environment affects their quality of life and their future.

When distinguishing the older adult as the new and future user of urban centers, it is important to update the conventional definition established according to the chronological age of 60 years old or more (WHO, 2015). Currently, it includes aspects of psychological (experiences and circumstances faced during their lives), biological (natural changes) and social (interpersonal relationships) nature. Based on these conditions, professionals from different fields agree that designing areas to socialize, to remember and to stay active promotes positive experiences and empowers the elderly through the activities. Therefore, facilities for elderly are important buildings and landscapes that provide the elderly with opportunities and spaces to socialize and be active through different activities in their daily lives.

However, WHO (2015) notes that many elderly living in urban centers are provided with elderly facilities that were not built with their needs in mind; which limits their mobility and ability to participate in social and active lives. Hence, it is necessary to improve the elderly facilities in the urban centers to fulfill their needs for quality and active living. Unfortunately, there is no existing criteria that can be readily used to evaluate whether the existing elderly facilities satisfy the activity, social and mobility needs of the elderly.

Therefore, this study seeks to establish criteria that can be used to evaluate the existing elderly facilities and to provide design guidelines for the future development. This set of criteria would emphasize the link between the needs of the elderly and the design of the physical components in the building and landscape.

As a theoretical principle, Maslow's Hierarchy of Human Needs (Maslow, 1954) is chosen as a baseline framework on how human beings prioritize their needs. This helps establish the hierarchy of needs for the elderly to translate into the physical elements that fulfill the needs. The needs in each level of the Maslow pyramid will be fulfilled through the Kano Attributes model of satisfaction that helps establish the hierarchy of physical elements corresponding to the needs from the Maslow's Pyramid—namely the Design Pyramid. The Design Pyramid will provide the evaluative model to assess existing physical design elements provided in the elderly facilities. The conceptual derivation of the Design Pyramid is displayed in Figure 2.

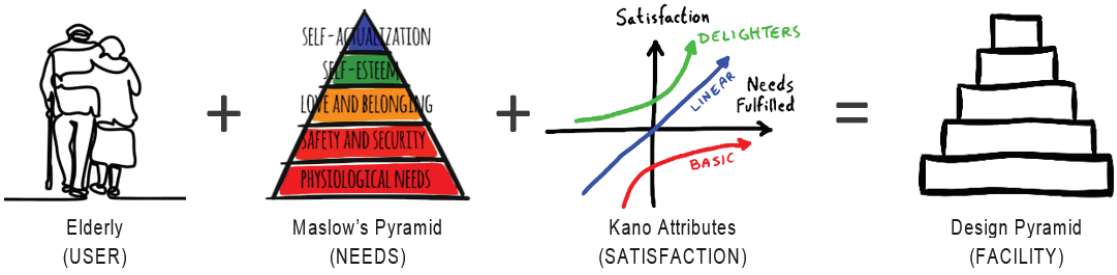



*Figure 2:*
*Theoretical framework for the design pyramid (Source: Own production)*

The Design Pyramid is validated by its application to evaluate an existing public elderly facility in the center of Lima, the capital of Peru. The evaluation results validated that the Design Pyramid can be used to assess the existing elderly facility. The evaluation results display the quality and sufficiency of the physical design characteristics that respond to the elderly needs, and finally, provide criteria for immediate improvement as well as for future development.

## FROM PSYCHOLOGY TO ARCHITECTURE

### Maslow's Hierarchy of Human Needs

First, we will address the needs according to their level of importance and motivation in the psychology literature. It is important to establish a framework that justifies the needs of the elderly in order to identify the relationship in the design of Elderly Facilities (buildings) according to their priorities. The Hierarchy of Human Needs Theory, Maslow (1943) is a model that explains that people are motivated by unmet needs. It states that as basic needs are met, humans develop greater needs and desires. This theory allows us to understand how people prioritize their needs and, therefore, how they seek to meet them. Human behavior obeys these needs, and determines decisions to act.

Maslow develops a 5-level pyramid model: the first four are known as Deficit Needs and the upper level as Growth Needs or Self-Realization. The aim is to satisfy the higher needs, which motivates the behavior; this means that the higher needs will be sought only when the basic needs have been satisfied. These needs are classified in:

1. **Physiological Needs.** They are basic in order to keep the body stable and survive. They refer to breathing, food, water, warmth, rest, eliminating body wastes and avoiding pain.

2. **Security and Protection (Safety) Needs.** Is a condition, to feel protected and safe. They are needs of physical and health security, security of resources (e.g. home, work) and housing (protection).

3. **Social (Belonging/Love) Needs.** Related to the social nature of the human being, relationships: friendship, partner, colleagues, family and social acceptance.

4. **Esteem (Recognition) Needs.** Has two types: High for one's own value (self-respect) and; Low, desire of reputation from others. Together these are called Self-Esteem, an individual's overall subjective emotional evaluation of his/her worth.

5. **Self-Realisation Needs.** The highest fulfillment is what motivates life through the development of activities.

The theory concludes that only unsatisfied needs influence human behavior, while satisfied needs do not produce action. Furthermore, that the Physiological or Basic Needs are given at birth, while the others develop as one grows (ages). And lastly, the Highest Needs do not arise if the Basic ones are not satisfied; so the Basic Needs will always influence the higher ones. This theory has been used in other fields of study such as psychology, sociology and engineering sciences (Allen, Muñoz, & Ortúzar, 2019; Asad Poor Zavei & Mohd Jusan, 2012; Salado & Nilchiani, 2013; Vanus, Koziorek, & Hercik, 2013). Thus, it is a valid tool to establish the needs of older adults.

## Architectural Attributes

In architecture, a coherent design is conceived to communicate, motivate and connect with the user. For an elderly facility, it is essential to understand the qualities and limitations of older people. The understanding help to better define the needs they face (physical or mental) in order to provide a solution that gives them some degree of satisfaction in their daily lives. Therefore, the needs will be transferred to the field of architectural design. For each level, a condition will be posed to defines an attribute (characteristic) of the spatial design. The proposals for the different attributes are detailed below:

1. **Location - Physiological Condition.** For the elderly, it relates to the condition of the immediate space that allows the maintenance of a stable state. In the design, the base of a building begins with the access; this means the physical connections (roads, paths) to get there. The location is the architectural nexus, it generates the link with the community and the amenities of the city (Nettleton, Buse, & Martin, 2018).

2. **Environment – Safety Condition.** For the elderly, living in a cohesive environment reinforces a sense of security and control. In the design, the building is seen as a refuge in relation to its surroundings. Therefore, the environment defines the utilitarian characteristics of the facade.

3. **Outdoor Space - Social Condition.** For the elderly, establishing social relationships grants mental well-being. In design, it is providing the areas to promote activity. Therefore, the configuration of the volume (building) should facilitate this relationship from the outside to the inside.

4. **Social Space - Esteem Condition.** For the elderly, it means oneself, their independence to carry out activities. In design, it is providing the facilities to move around and explore areas for socializing. Therefore, the spatial sequence must be continuous to and in social spaces.

5. **Sensory Pleasure - Self-Realization Condition.** For the elderly, it is an achievement, subordinated to their personal experiences. In design, the connection is achieved by stimulating the senses. However, the response varies, as spatial perception is subjective. Moreover, it includes all the attributes nearby, so it is not possible to establish a single basis that causes the same response, but it is possible to highlight the variable elements that add spatial value.

This approach categorized the types of attributes based on the level of priority of the elderly. The relationship to a new structure in architecture goes from the global aspect of the building to the particularities that it might involve. However, this structure does not necessarily reflect the degree of satisfaction required by the elderly. For this reason, it is adequate to search for a theory that allows for the inclusion of a satisfaction assessment in the list of design attributes.

## The Kano Model

To address the attributes of satisfaction, studies in marketing refer to the degree of satisfaction that a product or service can generate in its user. In architectural design, every intervention generates a spatial condition determined by the characteristics of the building itself. Therefore, the types of attributes can also be defined according to the degree of satisfaction they provide based on their function or service. This implies the spatial quality. Consequently, it is relevant to identify the levels of satisfaction (quality) and relate them to the design attributes of Elderly Facilities. The theory of Attractive Quality, known as the Kano Model (Allen, Muñoz, & Ortúzar, 2019; Roldán, 2017), provides the framework for organizing the attributes, which are detailed in 4 types:

1. **Basic or Expected Quality.** These are the attributes that meet the minimum requirements, so they do not serve to increase satisfaction, but their absence would produce the opposite reaction (dissatisfaction). In terms of design, the basic relationship is given by the urban context to provide access and support safety.

2. **Desired or Performance Quality.** These are essential attributes according to the user. They provide satisfaction or dissatisfaction, because their efficiency (regardless of their current level) can improve or diminish the result. In design, the relationship is given to the attributes of space itself, configuration and composition.

3. **Motivating or Exciting Quality.** These are attributes that surprise, provide an unexpected contribution but their absence does not generate

dissatisfaction. In design, it is related to details, to specific elements.

4. **Neutral or Indifferent Quality.** They are attributes that have no influence, because they do not have a direct relationship with the user. In the design, it could be considered the time of use; most buildings, when offering a service, establish an operating schedule and, unless it is modified, does not generate impact.

For this research, only some attributes may be considered, since their valuation will depend on the city context and this may vary over time. This means that some attributes would go from being excitement attributes to being basic attributes; for example, at the beginning, air conditioning or heating were supplementary elements that added satisfaction because they were not offered in all places; but over time they became basic attributes, as they were expected to be found everywhere. Also, some attributes will depend on the available technologies and levels of demand, according to the preferences of the user (elderly population), so it can be perceived differently depending on the levels of expectation and experience.

## The Design Model

Based on Maslow's Hierarchy of Human Needs and the adaptation of Kano's model, a classification is proposed for the design attributes for elderly facilities: The Design Pyramid. Based on the previous analysis, the design attributes are established considering their spatial hierarchy and formulates a relationship by levels. The attributes should follow an order of preference: (i) Functional Attributes, (ii) Dependable Attributes and, (iii) Hedonic Attributes.

i. **Functional Attributes - Environment.** These attributes are related to availability and mobility, which provide the first support and access to the design: the basic standard. In relation with the design - planning, it is the analysis of the urban environment: (1) Location refers to accessibility for the elderly and proximity to urban resources (2) Environment, in relation with the Form, the exterior appearance is the visual relationship that allows the recognition of the building in its physical surroundings.

ii. **Dependable Attributes - Service** It refers to the perception of being secure and protected; where the space supplies a sense of safety. In design, the attributes are related to the service of the facility and the built space, where the elderly develop their social skills (interpersonal relationships) and reinforce their independence. The areas of study for the elderly are the (3) Outdoor Spaces and the (4) Social Space.

iii. **Hedonic Attributes – Custom** These attributes refer to accessory aspects that the elderly will perceive positively, therefore bringing an additional (sensory) Pleasure (5). This level implies the totality of all the design elements, to create sensory pleasure in the environment, to bring comfort into the design.

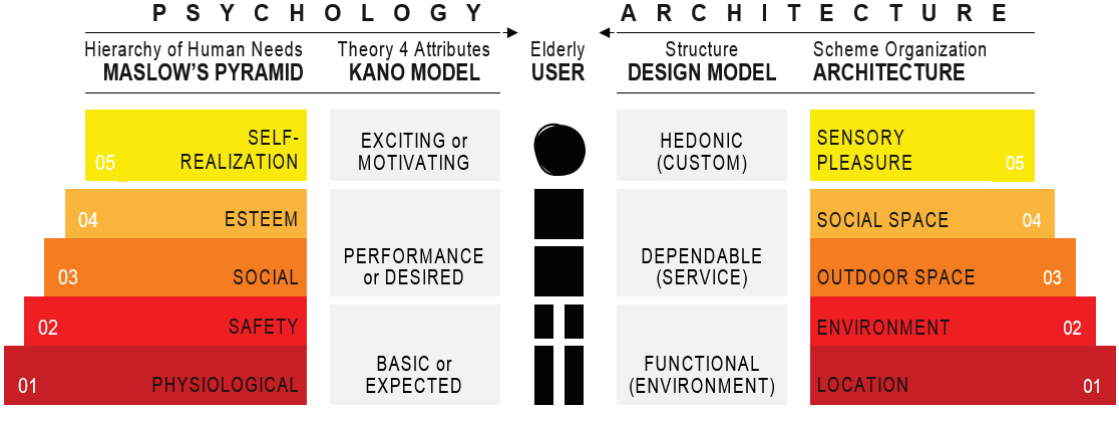



*Figure 3:*
*Theoretical sequence from Psychology to Architecture*
*(Source: Own production, based on Maslow's Hierarchy of Needs (1943) and Kano Model (1984)).*

The structure of the attributes is established under the gradual concept of needs and, in turn, are transformed under the spatial scale concept in Architecture in practical terms. The Functional Attributes are established at an urban scale as a part of the composition of the city and its organization within the existing systems. After fulfilling the basic requirements, the structure continue towards the Dependable Attributes, established at a human scale. In this sense, the perception has a role, because the definition of the spaces is based on the dimensions of the human body, taking into account whom it serves and who will inhabit it; which for this exercise is the older adult. Finally, the Interior Design of the space given by the Hedonic Attributes, which are part of a process of spatial experience.

For this study the attributes are classified according to their functional-spatial scale in the design, which is consistent with Maslow's Theory, and emphasizes the preferences of the older adult. Under this structure, the attributes are distinguished into components for each level or scale: Functional Attributes in (1) Location and (2) Environment; Dependable Attributes in (3) Outer Space and (4) Social Space; and Hedonic Attributes in (5) Sensory Pleasure. Components are expected to meet a minimum design standard to achieve satisfaction. In other words, if a building for the elderly is poorly located (e.g., difficult to access) it becomes a relevant attribute for not meeting the minimum standard. If it meets the standard, but the design of the building (e.g. the openings) do not relate to the exterior then space will become critical, so the Dependable Attributes become more important. If both are met satisfactorily, then the Hedonic Attributes, the personal experience of the older adult, will manifest. In this way, the framework for the conditions of analysis is established.

## EVALUATION METHOD

This research examines the spatial configuration properties of buildings for the elderly to prioritize design components. Three hierarchical levels of analysis were constructed.

**Functional Attributes - Urban Scale** is recognized as the first in line to establish contact with the building as a part of the city network. The first level also defines the spatial configuration of the building-environment in relation to accessibility for the elderly. The types of access are classified as follows:

1. In relation to **Location**, ease of access means:
   - The rapid or short movement of the elderly.
   - The connection to public transport networks.
   - The proximity of resources or amenities programs.

   In spatial terms, movement, connection and proximity are established in relation to the distance to be covered by the older adult. The first condition comes from the limitations of movement of the user himself, the older adult. Therefore, the analysis of displacement is established based on the medical recommendation of physical activity (daily walks) of 400m/10min intervals. This is the maximum recommended distance before the older body becomes tired. This allows for a limited radius of movement for mapping access points and area of influence. Second, the connection is established by the distance to be covered between the elderly facility and the access points of the urban network. The analysis of the satellite and radio plan are the basis for the mapping of Road Access [RA] and Pedestrian Access [PA]; these maps show the hierarchy of the streets. Thirdly, proximity is established in relation to the distance between the elderly facility and the urban services that assist the elderly. The analysis of complementary services is established on the basis of full and empty plan, and the condition of the physical space. The mapping identifies the Urban Nodes [UN] related to services for the elderly, such as medical stays, commercial and educational institutions, the built areas. But, on the other hand, complementary elements are also identified in the public space such as green areas, urban furniture and spiritual areas. These nodes are defined as Restorative Nodes [RN], as they help to rest the body at intervals. Finally, the overlap of the layers will define whether the access to the building (the street) meets the conditions of ease of access, or needs to be improved.

2. In relation to the **Form** of access, the ease of access is defined by its visual condition based on its relationship with the physical environment, it is defined in two moments:
   - When approaching
   - The Entrance

The first moment is defined by the path and arrival at the building. Ching (2012) refers to it as the distance view and classifies it as: Frontal, the path is clear and direct; Oblique, the path can be redirected to delay and prolong the sequence, and Spiral, the path prolongs the sequence and move around its perimeter. The last two are also known as indirect and are not the best option for the older adult, as they tax their physical condition by prolonging the journey and could confuse them. The second moment, Ching (2012) defines it as From Outside to Inside, is the perception of access and formally they are categorize in: Flush (maintains the continuity of the surface), Projected (forms a transitional space) and Recessed (receives a portion of the exterior space into the building). For the elderly, a projected entrance is visually more recognizable from a distance, as it stands out and announces its function to the outside.

The spatial configuration analysis is based on the shape around its environment, the schemes of the façade allow evaluating the perception of access from all reference points.

**Dependable Attributes - Human Scale**, this level relates to visual and physical contact with the building. The perception has a role; consequently, the analysis is established from the external perception towards the interior. The second level defines the configuration of the space itself, how the space is perceived in relation to its continuity. The types of spaces are classified as follows:

3. In relation to its **spatial composition**, composition is defined as the union established between two different spaces, the relationship with outdoor space. The union happens through the opening and can generate different degrees of relationships between the spaces.

   Philipe Boudon (1972) establishes three types of openings: the visual, which refers to the suppression of the limit through transparency; the physical, when between two spaces the limits are suppressed, and the transition is allowed; and the space-time involves a sequence of events, where other elements in the space guide the movement. On the other hand, the formal analysis of the Ching (2012), establishes the relationship based on the planes and their relation with the space and classifies in Enclosed, Open on One Side and Open on Both Sides.

   The analysis of the building starts as volume to disintegrate, until reaching the basic elements of relation with the exterior, from the outside the profile is the point of contact between the building and its surroundings, and its configuration articulate the interior with the exterior. The scheme analyses the transformation of the volume into two bases, the dimensional configuration and its transformation, which allow recognizing the proportion of the building and the access areas to be recognized. Then, the plane, both vertical and horizontal defines an area and establishes the visual and physical limits; its analysis is governed by the type of element (base, elevated, depressed or overhead) and the area defined by the use and its user. Finally, the space, the openings in the plane generate the visual and physical connection between the interior and the exterior (the environment), classified as open, expand and enclosure.

4. In relation to its **spatial sequence**, the design of the building is projected in relation to the service it provides and the areas established by the activities performed. The simplicity of sequences or interior paths reinforces the sense of independence and stability for the elderly. The spatial analysis is done by observing social processes during active hours. Then, collect the user sequence, from which the points are set; here is where the nodes or active points of the social areas are established. The study uses three-dimensional representation as a means of identifying spatial priorities.

**Hedonic Attributes,** area established in Interior Design, this level is related to personal preferences; the perception of social space is subjective depending on each individual.

5. Sensory Pleasure, the higher level is established as a personal interpretation, where satisfaction could be achieved due to the organization of elements that are part of the design. This is where the particularities take center stage for the user, since the perception of an element can have a different meaning for each one.

   The study can only take the added elements (fixed or movable) in its composition as references that help to increase user satisfaction, but which vary according to culture, society, among other aspects.

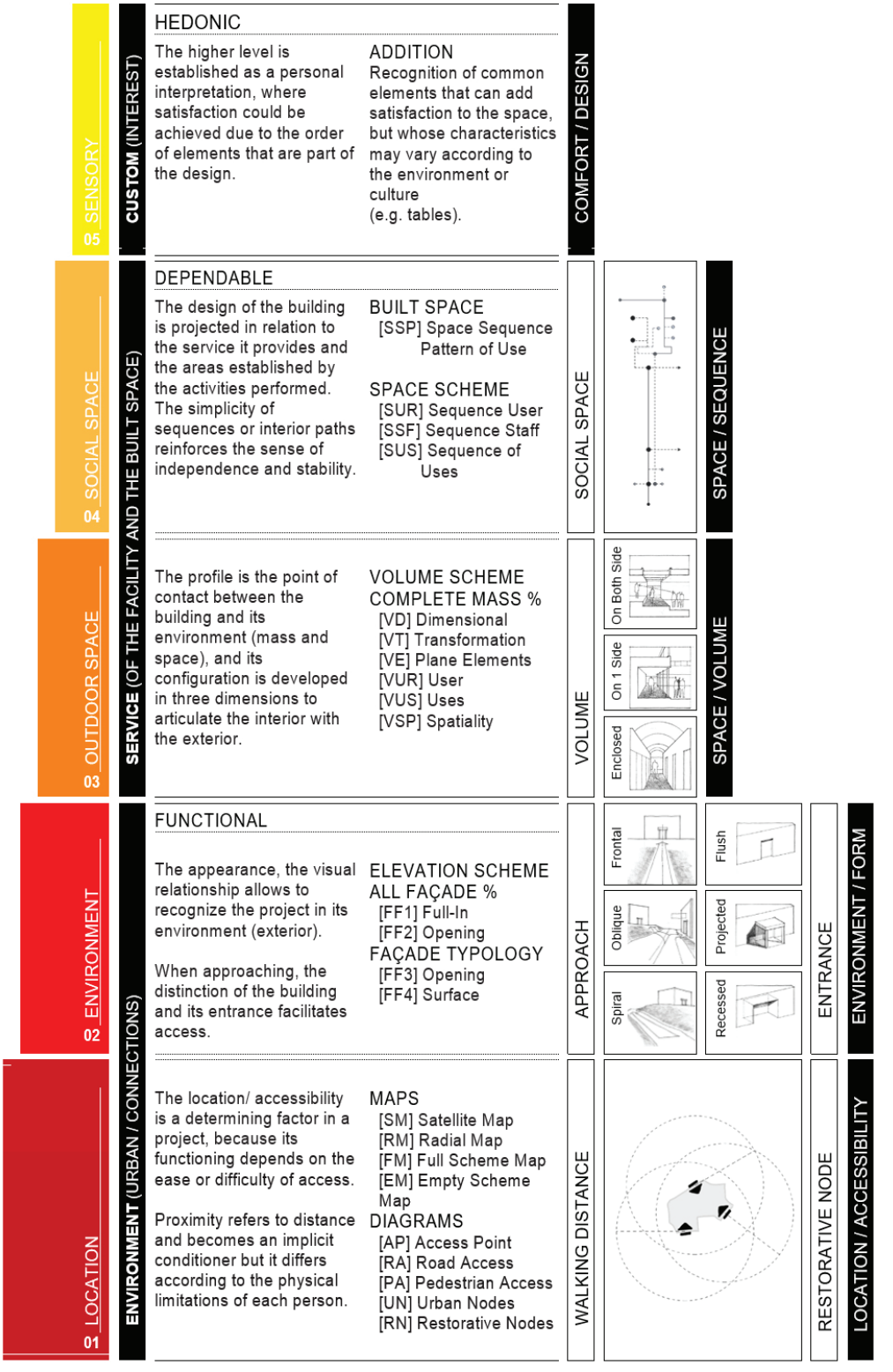



*Figure 4:*
*Organization of analysis schemes for case studies (Source: Own production)*

## CASE STUDY AND SAMPLES

In the 1950s, the Peruvian population structure was basically made up of children; for every 100 people, 42 were under 15 years old, but by 2018, 27 of every 100 inhabitants were under 15 years old. In the period of half a century, the elderly population (60 and over) proportion increased from 5.7% to 10.4%. (INEI, 2018). Attention to the elderly became a topic of discussion regarding a great variety of care for the elderly. From public facilities to private, this diversity was reflected in the architectural expression of the new buildings, mostly located in the urban environment. These new urban building typologies can range from a small scale to large projects, or adapted buildings as an option to satisfy the needs of older adults.

The State, aware of this change, generated new conditions for this population and promulgated the Law on the Elderly - No. 28803 (Ley de las personas adultas mayores, 2006). Among several issues, the law determines the creation of services for the elderly, aimed at promoting their autonomy and independence, called the Comprehensive Adult Center (CIAM – Centro Integral del Adulto Mayor). For this reason, each local government started to create new conditions for developing and updating urban plans in the cities, in order to develop public projects for the benefit of the community. In the Lima Region, the district of San Borja was one of the first places where these new policies were implemented. The district municipality was in charge of the construction of the new projects: Tambo I (2011) and Tambo II (2012). (Figure 5)

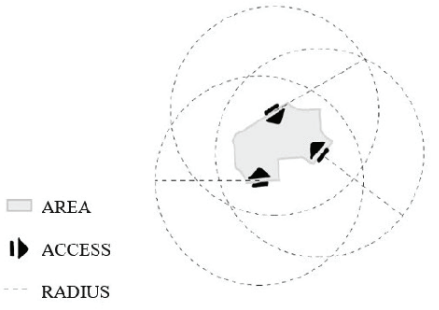

*Figure 5:*
*San Borja District. Location of the most important services (Source: Edit from Google Earth 2019).*

Tambo I was chosen for the case study, because it was the first model to be executed. Built within the facilities of the Limatambo sports center, it serves the Limatambo Residential Complex (a national housing project developed by the state in 1980). The municipality took measures to integrate it into the complex due to the increase in elderly residents in that particular sector.


**TAMBO I**
the building is located inside the Limatambo Sports Complex, shares the area with other social service programs, but works independently.

*Figure 6:*
*Location of Tambo I in Limatambo Sports Complex (Source: Edit from Google Earth 2019).*

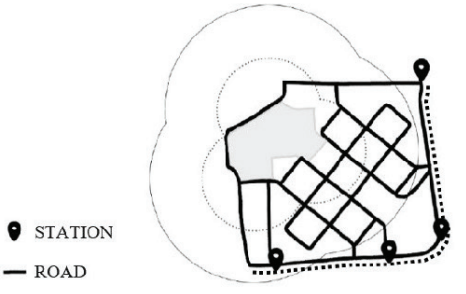
## TAMBO I: Location & Accessibility



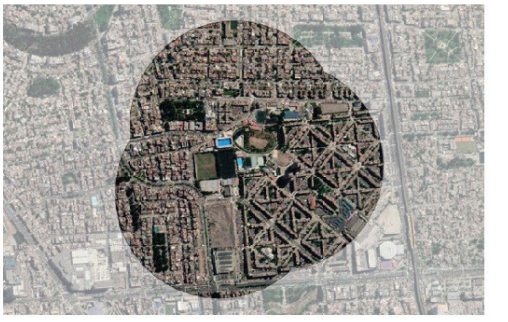

**ACCESS POINTS [AP]**
Radius of influence based on entry/exit points

The location analysis is established by the access point(s) to the building, from which the radius of influence (determined by the user) to achieve access is plotted. The elderly becomes a parameter to consider, the limited physical condition (changes in gait) is a restriction for the radius. Access is limited to 400m as the maximum distance allowed for walking from or to the entrance of the building without the need for a stop. In addition, depending on the scale of the project, an analysis of the interior system can be continued in order to establish the priority paths.

Since the building is included in another complex, it is necessary to add several radii depending on the number of accesses of the larger complex to determine the actual area of influence. In this case, the complex has three access to take as reference points (see diagram AP). Placing the project in its physical environment gives us a tool to understand its relationship with the city, the plot and network to which it belongs.

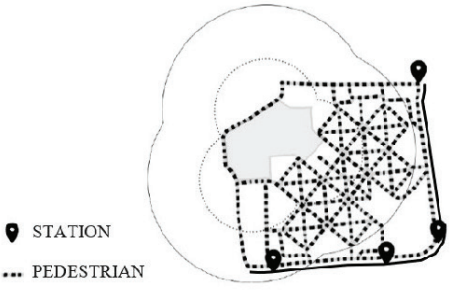



**ROAD ACCESS [RA]**
Vehicle roads in relation to the station stops.



**SATELLITE MAP [SM]**
3D terrain analytical base (volume)

[RA] The scheme is made according to the stops or stations that connect the complex at a district level. The flux and access by public transport is located at the edge of the south side corner, from there, the branches are to lower traffic roads for private vehicles. This diagram shows the first points for pedestrian access.

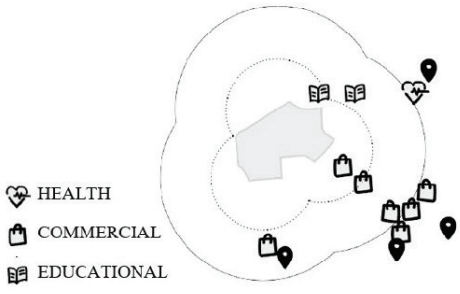



**PEDESTRIAN ACCESS [PA]**
Pedestrian roads in relation to the station stops.


**RADIAL MAP [RM]**
2D terrain analytical base (footprint)

**[PA]** The scheme is based on public transport stops. The sidewalks accompany the roads, but also branch off into secondary internal roads within the residential complex that allow a permeable framework of external and internal axes, which facilitate the mobility of pedestrians.

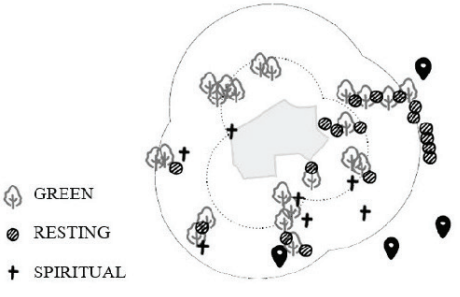
The reason for any activity of a person is their needs. Understanding this principle establishes the importance of urban amenities and their influence on the use of the street.




**URBAN NODES [UN]**
Amenities that support the daily life of older adults, such as medical stays, business or educational institutions.

**FULL SCHEME MAP [FM]**
Built map showing the construct environment in relation with the radius of influence.

**[UN]** The scheme relates the support amenities around the Elderly Facility, which influence their daily life, with the built space. The Full-scheme map [FM], graphically explains the type of space and accessibility in the urban context, that relates to the use of it. Therefore, it allows the recognition of preferred routes based on proximity and use of services. This scheme establishes the main axes of movement for the next support factor, the restorative areas.

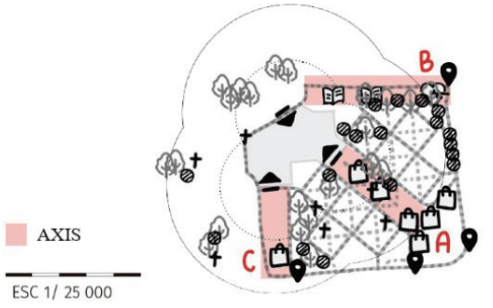



**RESTORATIVE NODES [RN]**
**Public Areas that support the daily life of older adults, such as green areas, resting areas and spiritual areas.**

**EMPTY SCHEME MAP [EM]**
**Empty map showing the public space within the radius of influence.**

**[RN] The scheme is also related to support spaces for the elderly, open and public areas for both physical and mental rest. These areas are related to the Empty Scheme Map [EM], which graphically explains the type of surface and accessibility. The nodes are elements in between, it might not be the end for an activity but it allows to get closer to fulfilling it.**

*Figures 7:*
*[SM] - Satellite Map with the influence radius from the access points (Source: Edit from Google Earth 2019).*
*[RM] - Radial Map with the influence radius from the access points (Source: Edit from Google Maps 2019).*
*[AP], [RA], [PA] - Graphic diagrams of accessibility (Source: Own production).*




**OVERLAYING ACCESIBILITY**

The urban-scale complex is visible for its user from the access points to the stations, it has three connection axes marked by urban and restorative nodes. These influence the choice of the route to follow since the older adult must take rest intervals in order to prevent mistreating their condition and physical health. The axis scheme is configured in three sectors: A is generated as a commercial corridor by the urban nodes that form it, while B acts as a green corridor, buffer at the edge of the complex. C presents a limited quantity of elements, making it the least attractive alternative, but the shortest access.

## TAMBO I: Location & Accessibility

Comparative sequence of the interior roads of the complex towards the Tambo I. The measured distance must comply with the pre-established criteria of 400m or otherwise provide the restorative spaces for the use of the older adult.

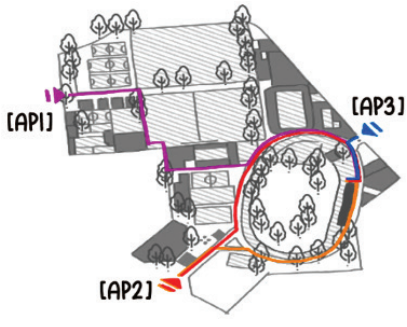

**[AP1]**
PRINCIPAL - EAST GATE


**[AP2]**
RESIDENTIAL - SOUTH GATE


**[AP3]**
ZONE - NORTH GATE

*Figure 8 :*
*Interior accessibility [AP1] - Principal Gate (Vehicle Access) is the inter-district connection, the entry has a parking area and bicycle park zone; [AP2] - Residential Gate (Pedestrian and Cycling Access) is the direct connection with the residential complex, its axis borders the Huaca before reaching the facility; and [AP3] - Zone Gate (Pedestrian Access & Services) is the back connection, auxiliary access (Source: Own Production).*


*Figure 9:*
*Aerial view, Limatambo Sports Center. Re-elaborated image from photographic bases (Source: San Borja Municipality, 2019. Retrieved from http://www.msb.gob.pe/externas/DeportesV2/polideportivo-limatambo.html).*




**OVERLAYING ACCESIBILITY**

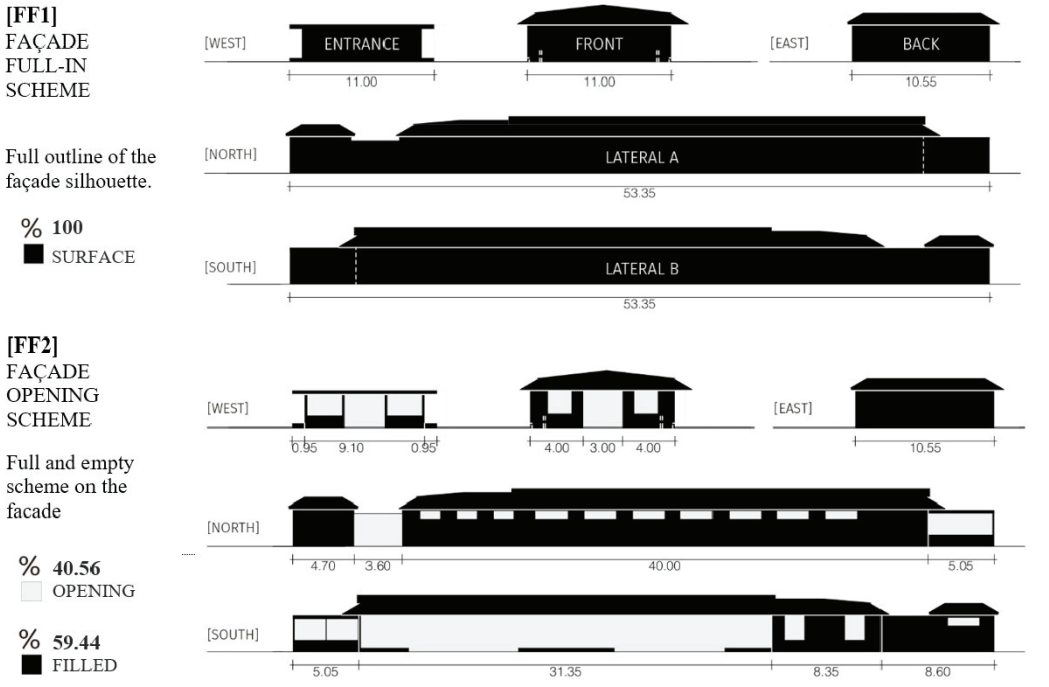
The complex has its own network of connections between its services facilities and sports fields. The interior analysis is given by the Access points of the Complex [AP1], [AP2] and [AP3], from these points the walking path is measured to the entrance of the facility (organized from the longest to the shortest route). Although distance is a factor that conditions the user, the visual relationship becomes a more relevant factor when approaching the project. The pedestrian walkway allows having an open view to the conservation zone (Huaca) which is the most attractive feature for the elderly, since they tend to sit and talk surrounding this space.

## TAMBO I: ENVIRONMENT & FORM


*Figure 10:*
*Exterior views [EE1] Pedestrian Approach, [EE2] Entrance, West Façade, [LB1] Lateral Side, South View Façade, and [LB2] Lateral Side, South View Façade. (Credits: Silvana Vasquez)*

The Form and its proportions relative to the environment are a utilitarian condition that allows a good management of lighting and ventilation, but will always be conditioned by their location. Tambo I has the advantage of being located within a complex in an open green area without party walls. It was built under the influence of this space network, where the Huaca takes the leading role, so its location is closely related to the natural archaeological zone. Due to this, it has the advantage of presenting the four facades: North (Lateral A), South (Lateral B), East (Back) and West (Entrance). In addition, it has an intermediate facade Front, a rest area.

The visual analysis of the shape is based on the Full-in [FF1] and Opening [FF2] schemes of the facade. From the first, the geometric ratio 1,2,4 is obtained as the spatial dimensional relationship, while the second shows the dimension of the openings with the environment

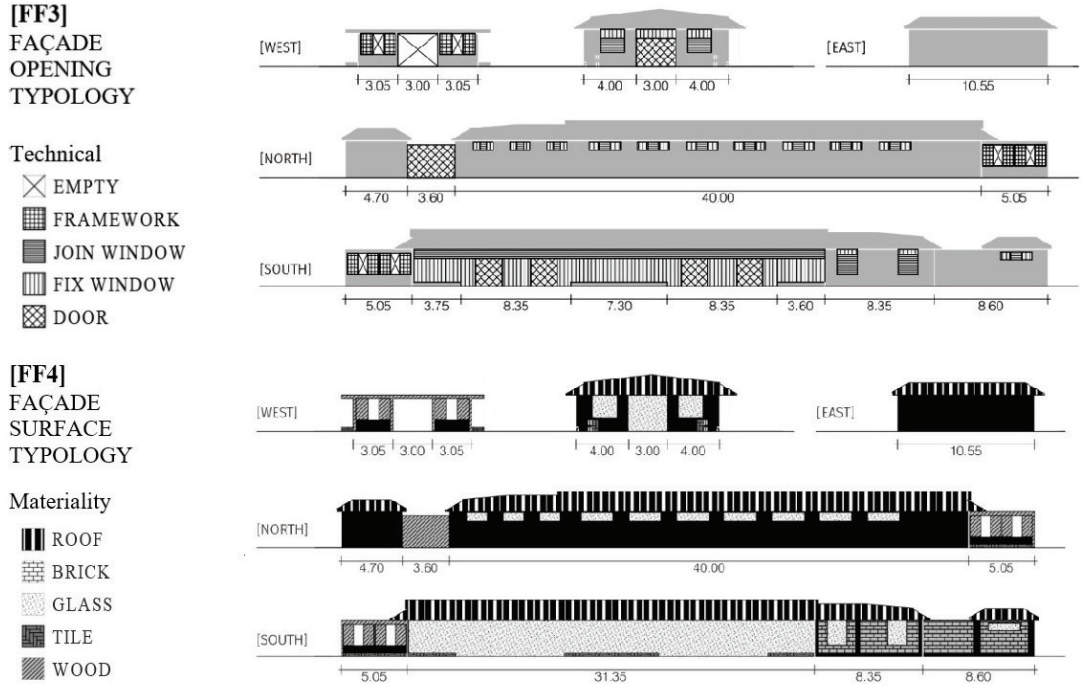


## TAMBO I: ENVIRONMENT & FORM


*Figure 11:*
*Exterior views [LB3] Lateral South Façade. [BB1] Back Side, East Façade, [LA1] Lateral Side, North View Façade, and [FF1] Front Intermediate. (Credits: Silvana Vasquez)*

In the southern hemisphere, the most appropriate orientation for the openings is related to the northern facade, however, the user ends up defining the relationship with the context.

The view and natural lighting are additional factors to consider. The Opening Typology Scheme [FF3] and the Surface Typology Scheme [FF4] of the facade shows how a visual connection to natural space is prioritized, without forgetting to protect the user. The application of different openings (in size and materials) helps guarantee a controlled interior environment and at the same time provides a restorative view for the elderly.
Furthermore, most of the north facade is closed with high openings, while the south facade opens directly to the Huaca. While this relationship is not ideal, it provides indirect light that is recommended for older adults, since drastic or direct light changes can hurt your eyesight.



## TAMBO I: SPACE & VOLUME

The profile is the point of contact between mass and space, the configuration occurs in two dimensions to articulate the interior with the context (exterior).

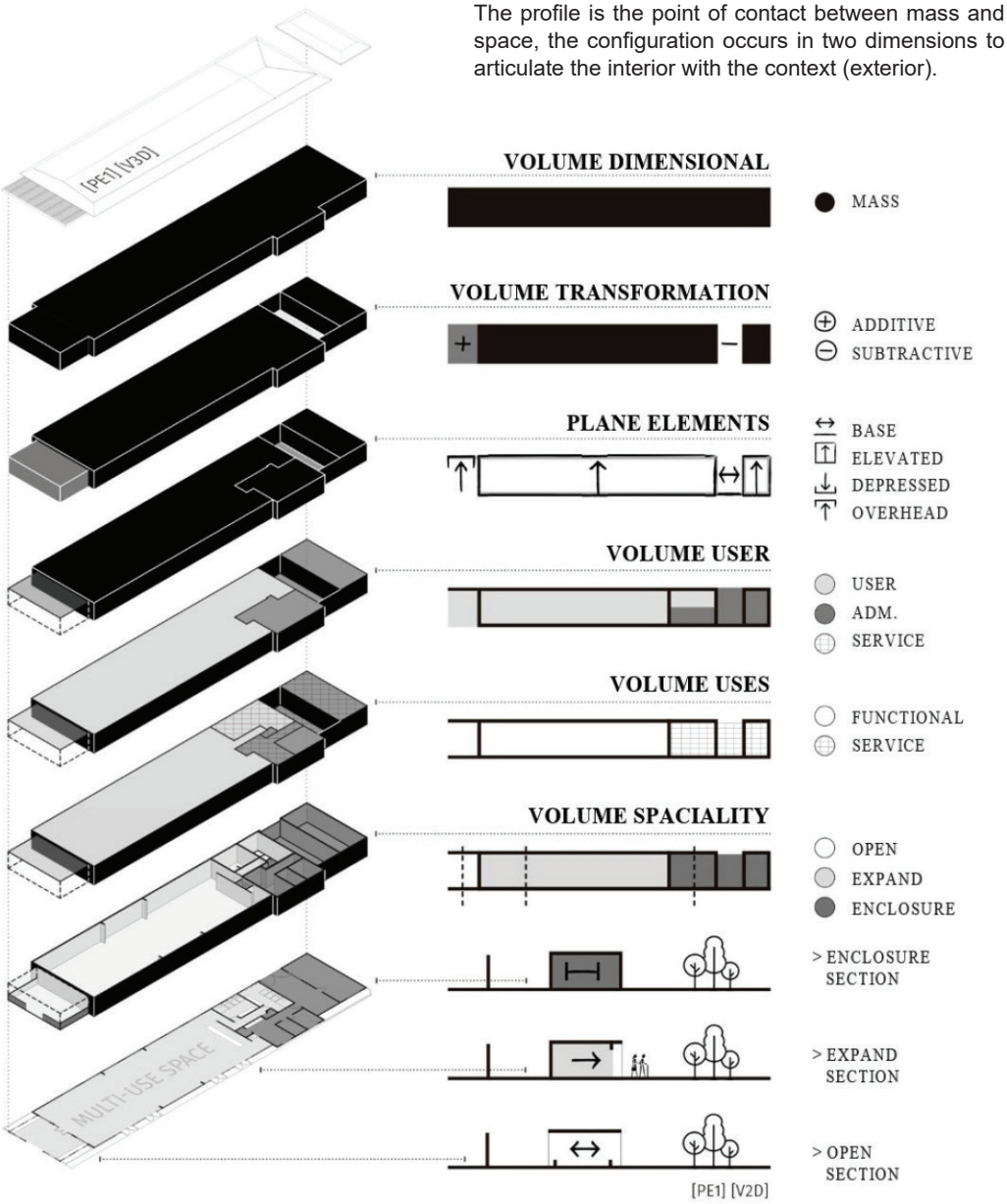
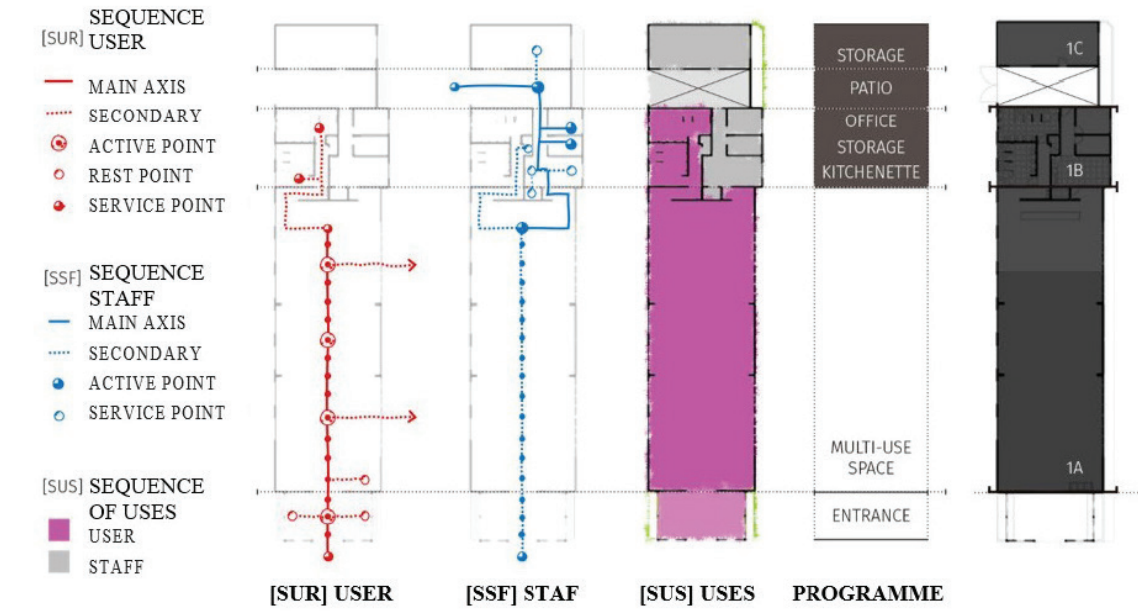
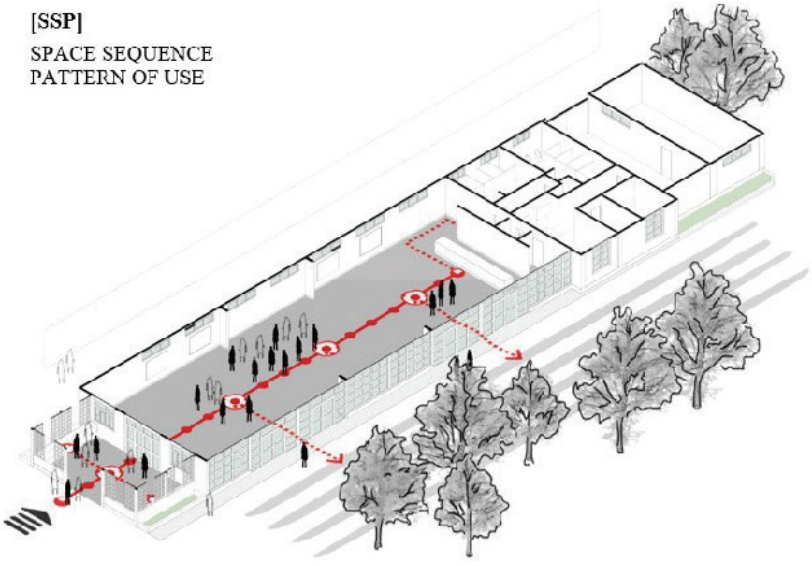



*Figure 12:*
*[V3D] Volume Scheme, shows the transformation of the mass in a tridimensional perspective. [V2D] Plane Scheme, shows the transformation of the space as a surface (sections) in two dimensions. (Source: Own Production)*

The transformation scheme provides a way to understand the organization of the individual components that characterize a building. The perception of the mass changes as one approaches. The entrance is differentiated as an adherent, permeable and elevated element, easy to recognize for the user. Also, it allows an intermission before going into the main volume. On the other hand, the linear organization is related to the context, the form that encloses the Huaca (natural area), therefore the path configuration passes through the spaces. Then, the form of circulation may vary to determine the activities and their use.

## TAMBO I: SPACE & SEQUENCE




**SERVICE [1B] [1C]**
Support areas for Staff and services for the user. It has independent access through the patio from the side end.

**SPACE IN USE [1A]**
Support areas for Staff and services for the user. It has independent access through the patio from the side end.

*Figure 13:*
*3D Interior Model of the Space Organization in relation with the environment (Source: Own Production)*

People move through a sequence of spaces, the organization of it results in different forms of circulation. The analysis in the facility explores the social area (in Sector 1A), where the elderly develop most of their activities or classes at the same time. The linear condition allows using the space by sectors. Within a large space, it is "open on one side" with complete windows that provide visual and spatial continuity with the natural environment.

# TAMBO I: DESIGN PYRAMID

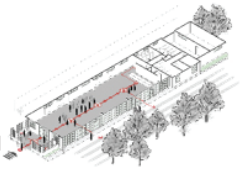
**05 SENSORY** — CUSTOM (INTEREST) — COMFORT / DESIGN

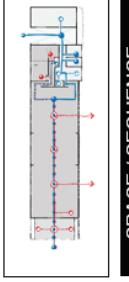
The additional elements that always remain in space are the pictures. Old black and white photographs showing the most representative areas of the district.
This provides additional excitement for older adults, for the memories it evokes in them, especially as they are residents of the district.

**04 SOCIAL REALM** — SERVICE (OF THE FACILITY AND THE BUILT SPACE) — SOCIAL SPACE — SPACE / SEQUENCE

The elderly develops most of their activities or classes at the same time, the linear condition allows to use the space by sectors.

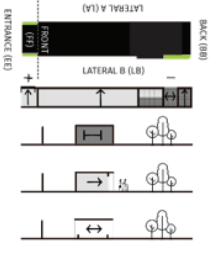
Within a large space, it is "open on one side" with complete windows that provide visual and spatial continuity with the natural environment.

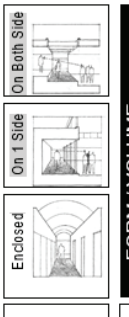




**03 OUTDOOR SPACES** — VOLUME — FORM / VOLUME

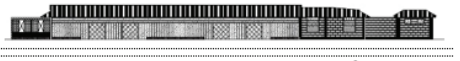
The form volume develops in one dimension (one level), with additive and subtractive spaces that provide the hierarchy for the spatial sequence.
From the volume spatiality, the view to the natural environment is prioritized.

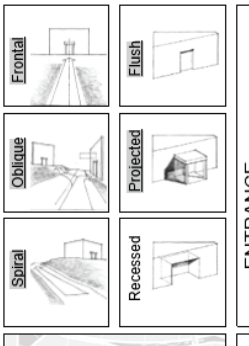



**02 PHYSICAL ENVIRONMENT** — ENVIRONMENT (URBAN / CONNECTIONS) — APPROACH — ENTRANCE — FORM / FACADE

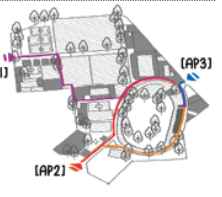
For the approach inside the complex:
AP1 and AP2 show a Spiral and longer way than AP3, an Oblique approach. However, the sequence goes around a natural environment (la Huaca) which makes it an attractive and restorative way for the elderly to get into the facility.
On the other hand, the entrance for the user is Projected to prevent any kind of confusion and to be easy to see from any access point, while the staff entrance is Flush on a side, which helps prevent any kind of confusion.

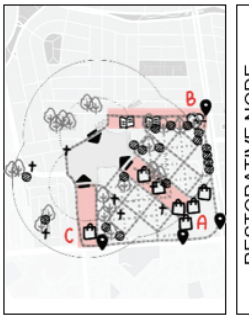





**01 LOCATION ACCESIBILITY** — WALKING DISTANCE — RESTORATIVE NODE — LOCATION / ACCESS

In the urban scale,
3 sectors are configured:
*A [Frontal Approach] as a commercial corridor by the urban nodes of the housing complex;
*B [Oblique Approach] as a green corridor, buffer at the edge of the complex;
*C presents a limited quantity of elements, making it the least attractive alternative, but the shortest access and the one that should be improved with more resting areas (restorative nodes) for the elderly.



## CONCLUSIONS AND RECOMMENDATIONS

This study proposes a Design Pyramid, establishing the link between the needs of the elderly and the physical space where they live. It begins with the premise that the physical environment affects the quality of life of people and their future development, so there should be a psychological theory that provides information on basic needs regarding the design of spaces and how to assign their importance. Maslow's Hierarchy of Needs is chosen (Maslow, 1943, 1954), since it provides a clear framework on how human beings establish their needs. This allows systematic links to be made between the architectural attributes of the building and the user's motivation factors, which are fundamental pieces for the design.

As a case study, the model is applied in a building for older adults in an urban center, where data collection and the analysis of the results confirm the existence of a hierarchy of design attributes. The results show the importance that is given to the design of social areas, prioritizing the benefit for the user according to their immediate environment. From the Tambo I Case Analysis, the design of the social space is complemented by the proximity to a natural environment (La Huaca). The access to this green, open area supports the physical and mental restoration of the elderly residents by promoting a positive experience.

Since there is an urgent need to establish usable data on the preferred attributes for the design process, Maslow's hierarchy of needs is useful for organizing an appropriate scale to achieve person-environment balance, so this model serves as the basis for exploring some improvements in the spatial quality of elderly facilities that promote their well-being.

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# Housing Conditions and Improvement Guidelines for the Elderly Living in Urban Areas:
## Case Studies of Four Bangkok's Districts

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## ABSTRACT

The demographic structure of the Thai population has shifted to an ageing society with an increasing number of elderly people living in urban areas. This research, therefore, is aimed to study and analyze the housing conditions of the elderly as well as relevant behaviors and issues, and provide recommendations for improvement. This research employs interviews and onsite-surveys for data collection. Findings showed that the current conditions are inappropriate; bedroom furniture should be less high; handrails should be installed in bathrooms; stair risers should be shortened, and a common area e.g. a gazebo, should be provided for the elderly to spend time outside together.

***Keywords**: housing condition, living inside a dwelling, elderly people, urban area*

## INTRODUCTION

According to the United Nations' (2017) estimate of the world's older population, year 2001 to 2100 has been designated the century of the elderly; when the population aged 60 or over exceeds 10% of the world population. In 2017, the number of the older population reached 12.7%, which was the first time in world history that the number surpassed that of the children. The number of those of extreme old age is likely to surpass that of the past century. These growing numbers means that there will be a smaller proportion of the working-age population which will lead to the reduction of labor production, as well as savings. The implication also includes a greater government budget must be allocated to social welfare and medical expense to support the ageing population. Therefore, resource management studies and preparation are crucial for economic and social stability.

Thailand shares the trend of an ageing population with the world. From the estimate of the Thai population projection from 2010 – 2040 (Office of the National Economics and Social Development Council, 2013), Thailand will have an increased number of elderly dependents. This is in line with the data from the National Statistical Office (2014) showing that Thailand has become an aged society since 2005, having an old-age population of 10.4%. It is also expected that numbers will be increase to 20% which makes Thailand become a complete aged society in 2021, and turn to be a super-aged society in 2035 when an old-age population reach to 28% of country population.

From studies about older people living in Bangkok by the College of Population Studies, Chulalongkorn University, and Department of Older Persons, the post-implementation report of the National Plan for Older Persons No. 2 during 2002 – 2021 and Phase 3 during 2012 – 2016, it was found that in Bangkok, only 7.3% of the houses were in suitable condition for the living of older persons. As urbanization is driving higher prices of land and houses, it also shifts housing design from horizontal to vertical development. All of which have created barriers for the older persons' living. It is pertinent to study and find the proper housing conditions for older people living in the urban environment.

Therefore, this research set out to investigate the housing conditions of older persons living in Bangkok areas; including the 4 districts of Phasi Charoen (Khlong Lat Phachi, Sirin & Friends, and Rasi Tham Communities) (Rattanapaisal, 2018), Pra Nakorn (Praeng Puthorn and Praeng Nara Communities) (Laksameewattana, 2018), Wang Thonglang (Sub Sin Mai Community) (Thupoltab, 2017), and Din Daeng (Din Daeng Community Restoration Project) (Buapradit, 2018). It includes the analysis of conditions, relevant behaviors and housing issues. Consequently, the research arrives at housing improvement recommendations and guideline, which could lead to future design prototypes suitable for the living of the elderly.

## HISTORY AND BACKGROUND

This research was conducted in the 4 urban districts of Phasi Charoen, Pra Nakorn, Wang Thonglang, and Din Daeng. Each has its own history and background given different context of location, environment, and key events in history. Details are as follows:

### Phasi Charoen District (Khlong Lat Phachi, Sirin & Friends, and Rasi Tham Communities)

Phasi Charoen District's Ban Man Kong Community is a housing project accommodating those inflicted by gentrification in the past. As consequence of aggressive land development in Bangkok, those without the land ownership were forced to leave as the owner wished to realize its financial potential. Ban Man Kong Housing Development Project was initiated to solve the issues by providing affordable accommodation to those affected.

### Pra Nakorn (Praeng Puthorn and Praeng Nara Communities)

Pra Nakorn District is located on the Rattanakosin Island. From the city plan[1], the area is in reserved for promotion of Thai cultural identity. Buildings in the

[1] Principle City Plan of Bangkok by Department of City Planning

conservation zone typically have limited space and with steeper stairways, which are not friendly to older people. The area, under the ownership of Bureau of the Crown Property, went through the Restoration Project which consisted of 6 sub-projects; including the 114 and 123-year-old commercial buildings of Praeng Puthon and Praeng Nara. Currently, the two buildings are registered as historical sites and, though not yet improved by the owner, were included in the plan. Key highlights of this study area were 1) its buildings' long history dating back to the reign of King Rama I, registered to the Fine Arts Department as historical sites 2) its reputable, long-established local restaurants 3) its current local occupants who who adopted and would pass on the lifestyle to the next generation.

## Wang Thonglang (Sub Sin Mai Community)

The community in Wang Thonglang district, also under the Bureau of the Crown Property's patronage, was developed as the model for Older People's Living Quality Improvement Program. It has the distinction of being the urban community with over-30-year family relations as its foundation. Older people lived in the area including locals and migrants; some of which moved in for jobs from other parts of the country. This group also includes the elderlies who moved into the city to look after their grandchildren; as the parents worked away from home. The migration directly impacted the living of these older persons.

## Din Daeng (Din Daeng Community Restoration Project)

Previously, the area of National Housing Authority's Din Daeng Housing Project[2] was allotted for the City's dump site. Later, it was occupied by the poor and became a slum. The government, therefore, assigned the Public Welfare Department to build a flat for the low-income tenants. It was named Din Daeng Flat. Currently, the 50-year-old flat is in a deteriorated state, and might not be considered as healthy for living. The National Housing Authority, accordingly, resolved to pass the Din Daeng Community Restoration Master Plan (2016 - 2024), of which included the 28-story Residential Building G. The G Building was completed, and ready for move-in on July 2018. The majority of its occupants were from the old Din Daeng Flat. The Building G was designed by considering its older residents. The 8th and 9th floors were specifically dedicated to the senior tenants. The building was, therefore, an interesting case studying as it offers a look into 1) the housing conditions of the building designed to meet the needs of the elderly and 2) limitations to the older people living in a high-rise building.

# RELEVANT CONCEPTS AND THEORIES

This research concerns housing conditions of older people. Important ideas and theories pertinent to this research are Age-friendly City, Ageing In Place and Accessible City.

## Age-friendly City

An age-friendly city refers to a city responsive to living of older people. The United Nations has laid out 8 key areas for a framework for development including "1) Outdoor spaces and buildings 2) Transportation 3) Housing 4) Social participation 5) Respect and social inclusion 6) Civic participation and employment 7) Communication and information and 8) Community support and health services," which need support from each and all units. Among these, the areas pertinent to physical environments are 1), 2), and 3), which directly determine people's living quality in terms of convenience and efficiency of their daily routine.

Most of all those keys would be used from the beginning of this research. The key number 3 (Housing) would be concerned in the analyzing part to summarize the housing improvement guideline with the key number 4 (Social participation) and 5 (Respect and social inclusion) which describes the participation of the community and the elderly participants who live in all 4 districts area. All sample

[2] Phaen Maebot Khrong Kan Fuenfu Mueang Chumchon Dindaeng 2559-2567 BE [Din Daeng Community Restoration Master Plan (2016 - 2024)].

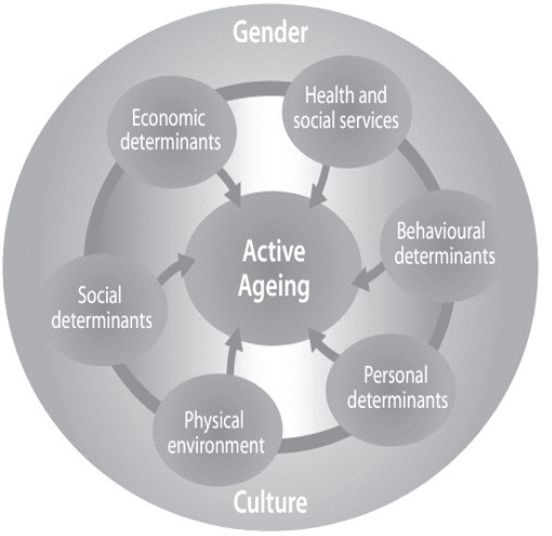



*Figure 1:*
*Determinants of Active Ageing*
*(Source: Global Age-friendly Cities: A Guide 2007)*

respondents and also other people living in those communities would receive all data and information they should understand before and while the research continuing as refer to the key number 7 (Communication and information).

## Ageing in Place

In Thai culture, the most common family structure is the large family consisting of all family members living together as an extended family. The Thai Population Situation Report 2015 by UNFPA Thailand shows that a three-generation family has the largest number as 33.6% of the total number of families in country. The number is increasing due to the fact that the elderly is living longer, and the family need to save costs related to economic matters. Ageing people are increasingly staying in their place living with their family.

The concept of ageing in place pertains to providing health services. It entertains the idea of encouraging retirees to continue to live in their homes, where health services and supports will be made readily available, when needed. In general, older persons will need to move into other place such as health centers or hospitals to obtain health and medical services. However, in fact, more than 90% of the older people wish to stay at their own houses in their community, as it feels at home and comfortable, which could help them to experience a faster physical health recovery.

The concept of ageing in place is for integrated development aiming to optimize happiness and satisfaction for the elderly, which ultimately refers to the ability to continue to live in their community. The society and people in the community should support and enable older persons to live with others normally. This could be obtained by providing facilities and housing improvement to meet the older people's needs. Key principles of this concept are to create awareness and shift the mind-set regarding the design of housing, as well as social and community environment, to that of Design for All.

This research supports the idea of ageing in place by searching for the better living guideline to maintain desirable environment which the most suitable for the elderly's happiness.

## Accessible City

In the city scale, key concepts of environmental design for older persons consists of 1) environmental management for the elderly 2) environmental model for the elderly's healthy living and 3) usage of public spaces, which covers quality living development for older people in all aspects of physical environment, including public spaces, as well as social areas, with an aim for the wellbeing of residents. (Bureau of Environmental Health, 2015)

In addition to issues concerning housing condition, this research also cover the area of social contexts in four districts. The idea of Accessible City would be used as the supportive theory to find the solution for more suitable living condition of the elderly in case of the connection of housing area and public area.

Although set forth by different organizations, the three theories commonly focus on the importance of well-being of the elderly, whether at the city level, district level, community level or home level. All of those are used to determine the direction of this research to conduct the guideline for the better path forward.

## RESEARCH OBJECTIVES

This research aims to study housing conditions of the elderly in environmental, economic, and social contexts of four Bangkok districts; Phasi Charoen, Pra Nakorn, Wang Thonglang, and Din Daeng district, and analyze the housing conditions, behaviors, and relevant issues found at the houses of the older people living in that area and continue to make a recommendation for housing improvement guideline related to those issues and relevant theories to encourage the elderly to stay living in their homes or their areas in accordance with the Ageing in Place theory. Besides, this research would support the old people to live in more suitable environment including private and public areas according to the theory of Accessible City.

## SCOPE OF THIS RESEARCH

This research is focused on the living conditions of the elderly under the social and economic context, activities, and behaviors in four districts; Phasi Charoen district (Khlong Lat Phachi, Sirin & Friends, and Rasi Tham Communities), Pra Nakorn district (Praeng Puthorn Community and Praeng Nara Community), Wang Thonglang district (Sub Sin Mai Community), and Din Daeng district (Din Daeng Community Restoration Project). The study does not cover any other areas in Bangkok.

The population samples in this research are limited to older people aged 60 and over, living in the studies areas. From the secondary source of information and site surveys, the sampled population can be categorized as shown in Table 1 below. The first group is those allowing for interviews. The second is the rest who allow for volunteered visit and survey with the recommendation of being good samples, specifically selected by distinction. (Table 1)

## LIMITATIONS

This research has the timeframe to limit period of selecting samples, about 8 - 12 months per each district for all research processes. As it took time to get familiarized by the elderly before they allowed the interviews or house surveys, some sites were not yet allowed for visits and information obtaining.

Some of the populations were older people with sight impairment or illiterate that they could not read; making them unqualified as samples.

**Table 1:** Population and samples in the 4 studied areas

| Studied areas | Phasi Charoen | Pra Nakorn | Wang Thonglang | Din Daeng |
|---|---|---|---|---|
| **Population** | **108 people** (Those with names in Civil Registration of Phasi Charoen District Office) | **65 people** (All of the older people living in the Community) | **358 people** (Those living with families or in the area no less than 2 years) | **156 people** (Those moved from the old Din Daeng Flat to G Building) |
| **Sample Group 1:** Older persons allowing for interviews[3] | **16 people** | **22 people** | **38 people** (Those live in Sub Sin Mai Community) | **86 people** (Those who actually live there and are willing to give information) |
| **Sample Group 2:** Older persons allowing for visit and survey. | **16 people** (same people as in Group 1) | **22 people** (same people as in Group 1) | **3 people** (Specifically selected) | **9 people** (3 live in the units designed for the elderly and 6 living in those of typical design) |

[3] For smaller sample group, should represent at least 30% of the population; with reference to Jamornman, U. (1993).

## DATA COLLECTION

The research is based on 2 types of data including primary data and secondary data as followings:

Primary data are collected from site surveys, interviews with community leaders or the locals who knew the targeted older persons well (to help introduce the team, and make appointment with the older persons), and the targeted older persons.

Secondary data are collected from printed documents and statistics relevant to the target group of older people and the studied areas e.g. the elderly information, basic information of each district, ownership, pattern of buildings, etc. books and materials of the relevant concepts, theories, and researches and also an information of the elderly in the Chula ARi[4] Project to be selected as samples for this research.

## METHODOLOGIES

As mentioned earlier, the population samples of this research are the elderly who are 60 years old and over, most of whom have vision problems that might affect reading ability. Some seniors are low-income people who did not have enough access to good education so that they were unable to read, and therefore, they were unqualified as samples. The rest who were selected to be samples also had less issues with senility, so they were viable candidates. To avoid errors and misunderstanding from respondents, this research uses the direct unstructured interview method. Researchers and assistants collected information at the sites by reading and explaining each question to those elderly in the first sample groups, then noted the response. The interview would cover the 4 areas of basic information: personal data, occupation and income, daily routine, and condition of the house.

In Addison to collecting information from the interviews, researchers and assistants did non-participant observation on site to observed activities and how the spaces are utilized by the elderly. Afterwards, we continued with using participant observation method by attending in community activities such as yoga and morning aerobics to build familiarity with both the elder people and their routine.

After collecting all the data, we analyzed and identified the current living condition of the elderly in the area, then summarized the brief recommendations for the physical improvement which would be more suitable with their daily lives. Later, referring to the Age-friendly city theory with 8 key areas, research team ran a focus group with the respondents for better data by listening to their opinions, adjusting to find the pleasant options for all people. Those are in accordance of the key number 4 (Social participation), 5 (Respect and social inclusion) and 7 (Communication and information). Then, the sample group 2 would be selected from some of the sample group 1 to conduct volunteered detailed surveys of their houses and specific living conditions for final improvements guideline.

Onsite surveys, taking photos and in-depth interviews were subsequently used in the final part of this research, including measured the sites. All data were analyzed and consulted with the architect team to finalize the improvement guidelines for the elderly living in urban areas.

## FINDINGS

From the 4 studied areas, findings are divided into 3 parts: 1) Social and economic context and housing conditions 2) Patterns and issues relevant to the housing conditions 3) Recommendations/ guidelines for improvement. Details are as follows:

### 1) Social and economic context and housing conditions

**General information and social status:** From the information gathered from the 4 districts, despite their different background as described earlier in “History and background”, older residents shared many characteristics. It was found that the majority of the older people were female, an average of 71%, most of which were married. Lesser portions were of single or widowed status, which varied across the districts.

[4] Chulalongkorn University Platform for Ageing Research Innovation (Chula ARi)

**Table 2:** Genders of the sampled older persons by district

| Gender | District | | | | | | | | Total (n=162) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Phasi Charoen (n=16) | | Pra Nakorn (n=22) | | Wang Thonglang (n=38) | | Din Daeng (n=86) | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Female | 11 | 68.75 | 15 | 68.00 | 31 | 81.60 | 58 | 67.40 | 115 | 71.00 |
| Male | 5 | 31.25 | 7 | 32.00 | 7 | 18.40 | 28 | 32.60 | 47 | 29.00 |
| Total | 16 | 100.00 | 22 | 100.00 | 38 | 100.00 | 86 | 100.00 | 162 | 100.00 |

**Table 3:** Marital status of the sampled older persons by district

| Marital status | District | | | | | | | | Total (n=162) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Phasi Charoen (n=16) | | Pra Nakorn (n=22) | | Wang Thonglang (n=38) | | Din Daeng (n=86) | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Married | 6 | 37.50 | 13 | 59.00 | 20 | 52.60 | 51 | 59.30 | 90 | 55.56 |
| Widowed | 3 | 18.75 | 3 | 14.00 | 12 | 31.60 | 18 | 20.90 | 36 | 22.22 |
| Single | 4 | 25.00 | 6 | 27.00 | 2 | 5.30 | 12 | 14.00 | 24 | 14.81 |
| Divorced | 1 | 6.25 | - | - | 1 | 2.60 | 3 | 3.50 | 5 | 3.09 |
| Others | 2 | 12.50 | - | - | 3 | 7.90 | 2 | 2.30 | 7 | 4.32 |
| Total | 16 | 100.00 | 22 | 100.00 | 38 | 100.00 | 86 | 100.00 | 162 | 100.00 |

**Economic status:** Most of the older people were unemployed, approximately 62%. As for the employed group, its majority worked as low-skill laborers and sellers. Primary source of income for most of the older people was from their children.

**Table 4:** Occupations of the sampled older persons by district

| Occupation | District | | | | | | | | Total (n=162) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Phasi Charoen (n=16) | | Pra Nakorn (n=22) | | Wang Thonglang (n=38) | | Din Daeng (n=86) | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| Unemployed | 6 | 37.50 | 11 | 50.00 | 20 | 52.63 | 63 | 73.26 | 100 | 61.73 |
| Laborer | 7 | 43.75 | 2 | 9.09 | 7 | 18.42 | 12 | 13.95 | 28 | 17.28 |
| Seller | 1 | 6.25 | 2 | 9.09 | 10 | 26.32 | 7 | 8.14 | 20 | 12.35 |
| Food seller | - | 0.00 | 7 | 31.82 | - | 0.00 | - | 0.00 | 7 | 4.32 |
| Officer worker | 2 | 12.50 | - | 0.00 | - | 0.00 | - | 0.00 | 2 | 1.23 |
| Others | - | 0.00 | - | 0.00 | 1 | 2.63 | 4 | 4.65 | 5 | 3.09 |
| Total | 16 | 100.00 | 22 | 100.00 | 38 | 100.00 | 86 | 100.00 | 162 | 100.00 |

**Health conditions:** About 80% of the elderly had health issues. The most prevalent was hypertension. Others found were gastritis, diabetes, etc. However, from the observation, the older persons looked well and strong with minor complications e.g. aches, stammered speech, which were not preventing them from living normally with friends, families, and others in the community.

**Table 5:** Health conditions of the sampled older persons by district

| Health condition | District | | | | | | | | Total (n=162) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Phasi Charoen (n=16) | | Pra Nakorn (n=22) | | Wang Thong-lang (n=38) | | Din Daeng (n=86) | | | |
| | No. | % | No. | % | No. | % | No. | % | No. | % |
| With issues | 11 | 68.75 | 20 | 90.90 | 28 | 73.70 | 71 | 82.60 | 130 | 80.25 |
| Without issues | 5 | 31.25 | 2 | 9.10 | 10 | 26.30 | 15 | 17.40 | 32 | 19.75 |
| Total | 16 | 100.00 | 22 | 100.00 | 38 | 100.00 | 86 | 100.00 | 162 | 100.00 |

**Housing conditions:** Buildings of each district had different characteristics as shown in Table 6 below. However, utilization of spaces was similar i.e. how the interior and surrounding spaces of the residence were used, as behaviors and lifestyle of groups of older persons were similar across the districts.

**Table 6:** Housing conditions in the 4 studied districts

| District | Phasi Charoen | Pra Nakorn | Wang Thonglang | Din Daeng |
|---|---|---|---|---|
| Housing conditions |  2-story houses with the design of Ban Man Kong Housing Development Project. The older persons only lived on the first floor of the houses. |  2-story commercial buildings located in the conservation zone. The older persons lived on the first and second floor. |  2-story houses, found old and new across each community due to different times of construction. The older persons lived on the first and second floor. |  28-story building with 2 dedicated floors for older residents (8th – 9th floor). However, older residents were found living on many other floors across the building. |

## 2) Patterns and issues relevant to the housing conditions

From in-depth interviews and site surveys in the 4 districts, it was found that living patterns were similar across the districts i.e. living spaces were divided into the common area (interior space), sleeping area, bathroom, and kitchen/ washing area. In Phasi Charoen, Pra Nakorn, and Wang Thonglang, stairways were found in the houses. As for Din Daeng district, the building was that of a hi-rise condo without any stairway within the unit. The main access was through passenger elevators.

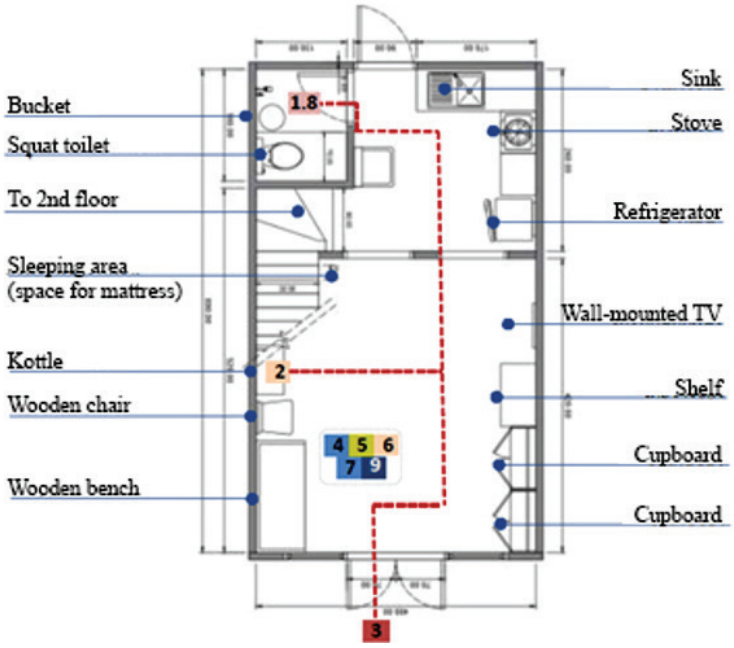



*Figure 2.:*
*House plan of the residence in Phasi Charoen*

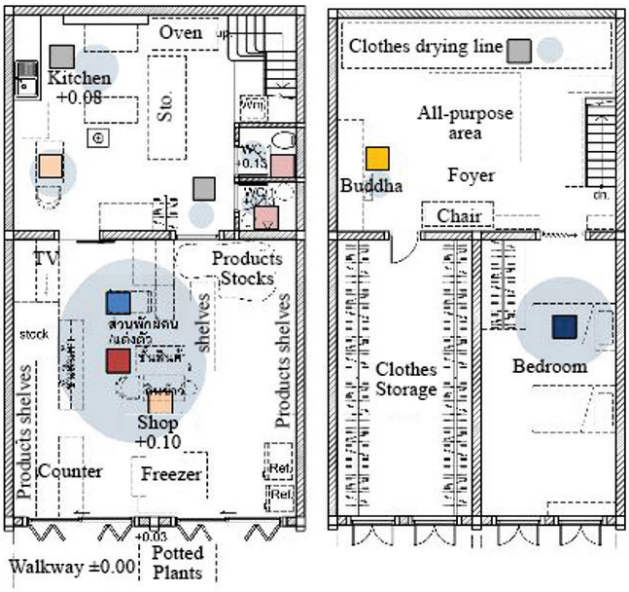



*Figure 3:*
*House plan of the residence in Pra Nakorn*

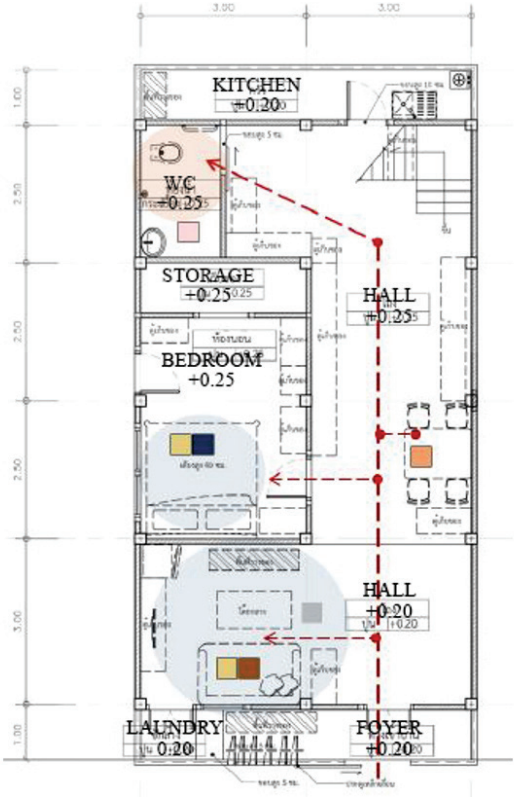



*Figure 4:*
*House plan of the residence in Wang Thonglang*

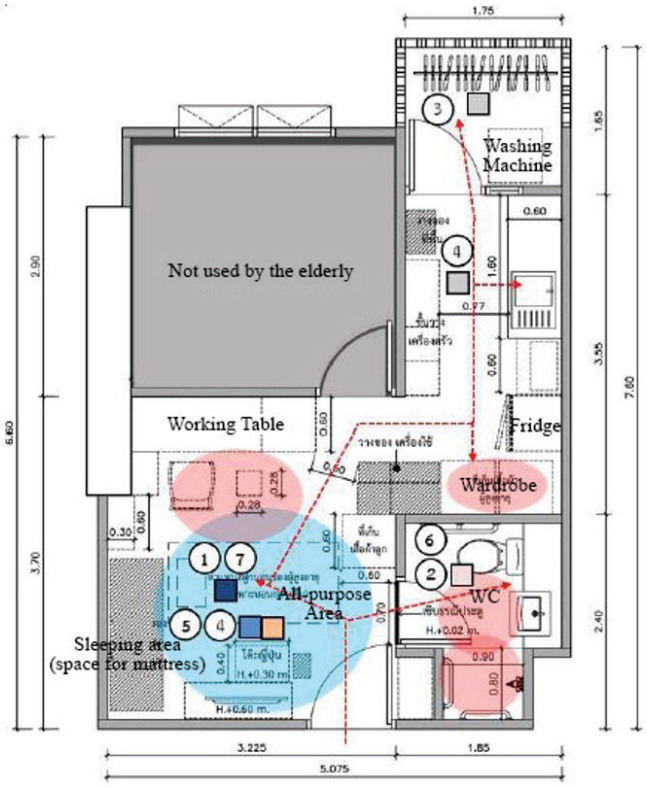



*Figure 5:*
*House plan of the residence in Din Daeng*

Across the 4 districts, the survey found issues both similar and different, which were categorized by space utilization i.e. all-purpose area (interior space), sleeping area, bathroom/ toilet, kitchen/ washing area, and stairway.

The condition of the all-purpose areas have deteriorated. The furniture was inappropriate for elderly people to use since tables and chairs are either too high or too short. Owing to the selection of wall color as a solid color, the atmosphere of the area was covered by a dark haze and gloom. In Phra Nakhon District, slip-prone floor material such as ceramic tiles were found mostly in use. In Wang Thonglang District, generally, there are stairs at the entrance of all-purpose area. Even if there are not many steps, most of them were steep stairs without handrails that caused difficulties to older persons. Besides, the all-purpose area and other areas floor levels were uneven or even had door curbs as borders in Phra Nakhon and Din Daeng causing increased risk to the elderly for tripping and falling.

For sleeping areas, it is found that the majority of elder people were using thin sheets or mattresses on the floor without a bed which made it inconvenient to get up in the morning. In the case of having beds, the elderly mostly placed their beds next to the wall with no space left which caused inaccessibilities. In Phasi Charoen District, sleeping area was usually arranged on the ground floor of the house, so it was suitable to use. However, in some districts, sleeping area was arranged on the second floor of the house which could possibly cause risk of falling from stairs.

Most bathrooms do not have handrails installed for the elderly that might lead to risk of slipping accidents except in Din Daeng district where rooms were intentionally designed for the elderly, so additional handrails have been installed. Despite that, the handrails installation was not proper. The position was too high and still not suitable for practical use. Moreover, in areas other than Din Daeng district, there were issues and problems with

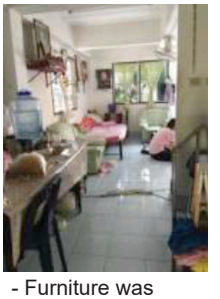
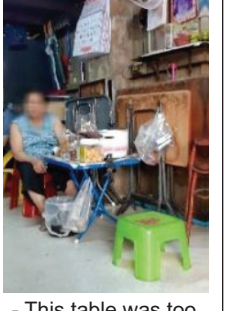
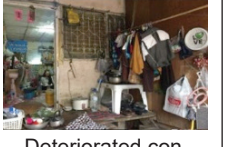
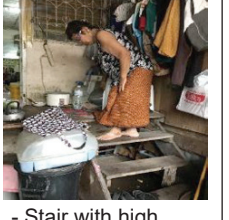
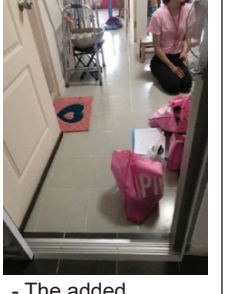
other inappropriate designs, such as the bathroom area being too small, and the installed position of sanitary wares make them difficult to use. The location of the bathroom was on a different floor with the bedroom. In the toilet or bathroom area, water on the floor drained slowly causing the wet and slip-prone floor, etc.

Kitchen or washing issues were encountered in all districts, mainly due to unsuitable furniture size and forms. Kitchen counters were found mostly without open space under the counters which was not convenient for participants who needed to sit in a wheelchair or had a walking stick to support walking. Also, the height of counters was too high and not consistent with the physiology of users. In Phasicharoen District, it was found that the gas tank and gas stove locations are not suitable for usage. In the area of Wang Thonglang, floor materials in the kitchen looks oily that increased risk of slipping. In Pra Nakorn district, most kitchen or washing areas were dilapidated.

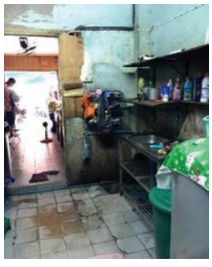
The main physical problem found was that stair risers were higher than standard heights which was dangerous to use. Even though we found this similar physical problems in most areas, each area had different usage conditions. In Phasi Charoen district, most areas for the elderly are located on the ground floor of the house, so improper staircases were not problem. In Phra Nakhon district, the buildings were old and some located in conservation areas which were not possible to be improved. Stairs found in that areas were all dangerous with too high risers and too narrow treads yet elderly people still used them regularly. In Wang Thonglang District, the stairs were built based on standard width with handrails, but those handrails were not suitable for elderly use. In the Din Daeng area, since it was a tall building, the elderly accessed their units by using the passenger elevators. Therefore, there were no major challenges with the use of stairs. The studies found that form and size of the elevators were suitable for use.

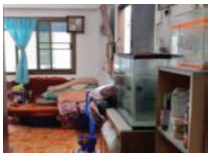
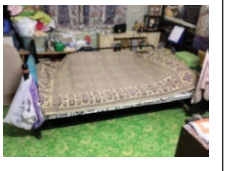
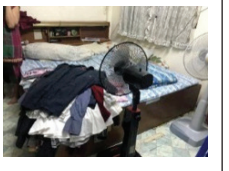
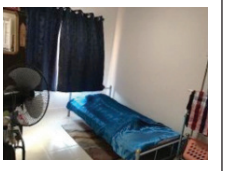
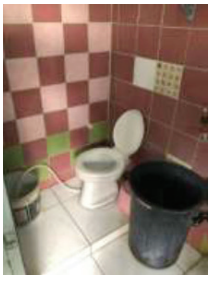
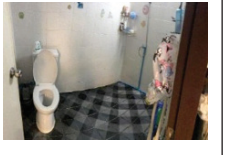
All issues found could be summarized as shown in Table 7.

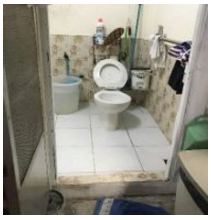
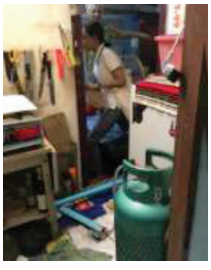
**Table 7:** Patterns and physical issues relevant to the housing conditions of the elderly in the 4 districts[5]

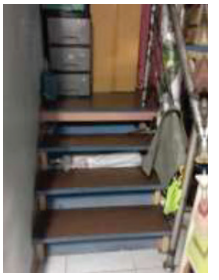
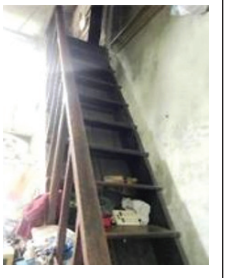
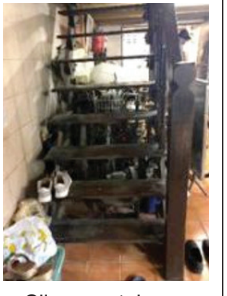
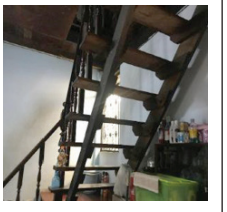
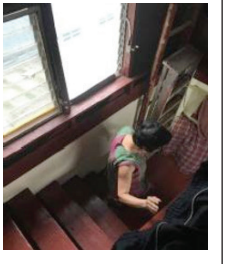
| District | Phasi Charoen | Pra Nakorn | Wang Thonglang | Din Daeng |
|---|---|---|---|---|
| **Interior all-purpose area** |  - Furniture was improperly high. |  - This table was too short. |  - Deteriorated condition and not safe.  - Stair with high risers and without handrails |  - The added threshold to protect against dust and insects, which created uneven ground. |

[5] Each picture was taken by the research team.

| District | Phasi Charoen | Pra Nakorn | Wang Thonglang | Din Daeng |
|---|---|---|---|---|
| **Interior all-purpose area (continue)** | |  <br>- The stool was too small and short. The couch was too soft making it difficult to get up.<br>  <br>- The deteriorated floor could cause accidents such as stumbling or slipping.<br>  <br>- Dark color of the walls gave a gloomy atmosphere.<br>  <br>- Uneven floor between rooms (also found thresholds) | | |

| District | Phasi Charoen | Pra Nakorn | Wang Thonglang | Din Daeng |
|---|---|---|---|---|
| **Sleeping area** |  <br>- Using mattress on the floor could be difficult getting up.<br>  <br>- It was proper for the elderly to live on the first floor. |  <br>- Using mattress on the floor could be difficult getting up.<br>  <br>- The bed was usually pushed to one corner; no surrounding space.<br>  <br>- Some of the older persons slept on the second floor, exposed to risks of using the stairs. |  <br>- Using mattress on the floor could be difficult getting up.<br>  <br>- The bed was usually pushed to one corner; no surrounding space. |  <br>- The bed was usually pushed against one side of the walls. |
| **Bathroom/ toilet** |  <br>- No handrails installed for the elderly. |  <br>- No handrails installed for the elderly.<br>- Far distance from the bed room<br>- No toilet on the second floor, inconvenient for those sleeping on the second floor. |  <br>- Slippery floor as water was not properly drained.<br>  <br>- Too small without any space for a care taker. |  <br>- The handrail was too high. |

| District | Phasi Charoen | Pra Nakorn | Wang Thonglang | Din Daeng |
|---|---|---|---|---|
| **Bathroom/ toilet (continue)** |  <br>- The toilet was away from the walls and too far to reach for when trying to stand up. | |  <br>- A toilet with a threshold. | |
| **Kitchen/ washing area** |  <br>- LPG tank was further away from the stove that the LPG tube was made long and left hanging across the floor, which could cause an accident from tripping. |  <br>- Space under the counter was not closed and too high.<br>  <br>- The seat was too short or the person had to squat sitting; difficult for older people.<br>  <br>- Kitchen floor was deteriorated and uneven. |  <br>- Entrance to the kitchen was made with slippery material. |  <br>- The counter was not transparent and too high. |

| District | Phasi Charoen | Pra Nakorn | Wang Thonglang | Din Daeng |
|---|---|---|---|---|
| **Stairs** |  - The house had 2 stories but was not the issue as the older persons lived on the first floor. |  - Too-high risers and too-narrow threads.  - Slippery stairs. |  - Too-high risers.  - Only one side of the handrail. |  - As a high rise building, elevators were normally used. The design and size were proper. |

## 3) Recommendations/ guidelines for improvement

The found physical conditions and issues led to some recommended guidelines for housing design and improvement for the residences in the 4 districts, which could be divided into interior all-purpose area, sleeping area, bathroom/ toilet, kitchen/ washing area, and stairs.

### All-purpose area

The floor was of ceramic tiles or polished cement in bad condition that could cause slipping. This could be improved by using floor materials of rougher texture. In case of the conserved buildings, which did not allow renovation, vinyl floor tiles could be used on top after fixing the old floor as shown in figure 6.

*Figure 6:*
*Floor materials found at sites (left) and an example of using vinyl floor tiles (right)*
*(Sources: Photos taken by research team (Left), Tarkett Company (Right))*

*Figure 7:*
*Uneven floor (left) and an example of a ramp (right)*
*(Sources: Photos taken by research team (Left), Harmar Threshold Ramp - justwalkers.com (Right))*

In addition, there was the issue of uneven floor and threshold, which caused difficulties or even accidents from tripping and falling to older persons. Therefore, it was recommended that each joint should be replaced with a ramp; a built, a ready-to-use, or a moveable one as shown in figure 7 for more convenience of the older residents

## Sleeping area

Foldable sleeping mattresses were inappropriate for older people due to the difficulty of getting up. A replacement with a bed is recommended. In case of space constraint, a foldable bed could be put to use as shown in figure 8. Bedroom or sleeping areas for

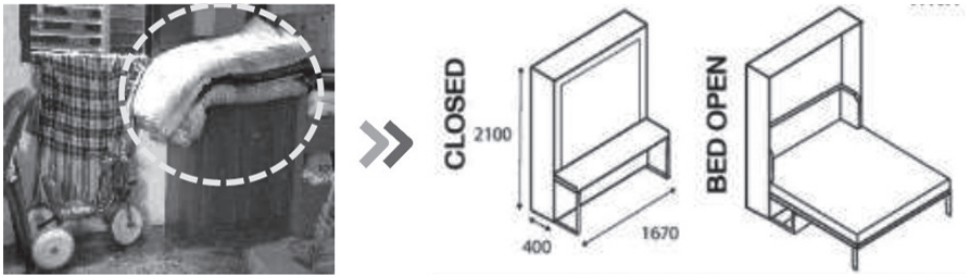



*Figure 8:*
*A foldable mattress from the survey (left) and a foldable bed (right)*
*(Sources: Photos taken by research team (Left), domoreliving.com (Right))*

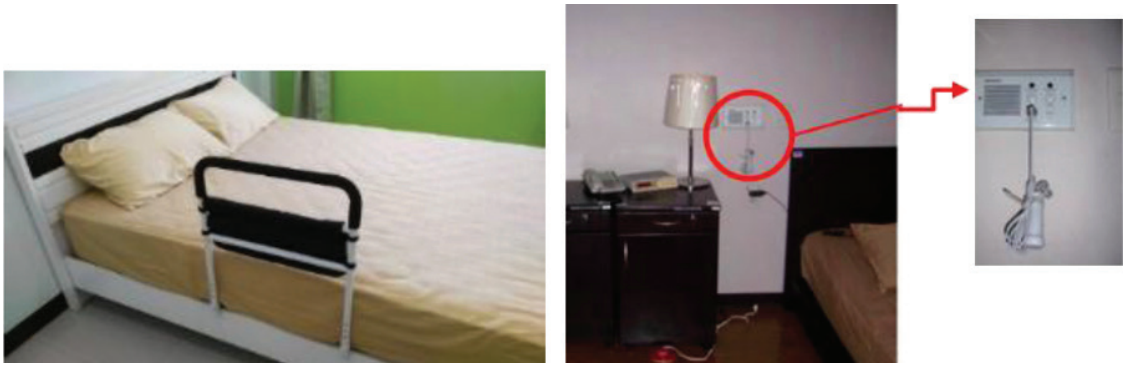


*Figure 9:*
*Example of the bed with safety rail and emergency alarm*
*(Source: okwheelchair)*

the elderly are on the second floor, which needed to be access via stairway and could cause accidents. It is recommended that the sleeping area for the older persons should be moved to the first floor. Safety rails should be installed at the side of the bed as well as an emergency alarm for the older persons to call for assistance conveniently.

## Toilet

The toilet is the area the older people are most likely to have accidents and should be improved to meet the safety standard e.g. by installing a handrail on one side of the wall within a reaching range from the toilet bowl. In the case that the toilet bowl was not near either side of the walls, the toilet rail innovation[6] could be used as shown in figure 10. The handrails available in the market could be costly. A cheaper alternative of PVC pipe could also be considered to save cost and still could reduce the risk of the older persons having accident in the toilet.

## Kitchen/ washing area

Kitchen counters should be of the height for the use by the elderly, which is 0.75 meter by the standard. However, the number could be adjusted following the height and usage of the individual. Under the counter should be an open space, which was accessible for wheelchairs as shown in figure 11.

As for the case found in Phasi Charoen district, a long tube between the LPG tank and the stove was left on the floor and could cause accidents from tripping. A replacement with a set of stove tops with LPG tank housing is recommended as shown in figure 12, for more safety and convenience.

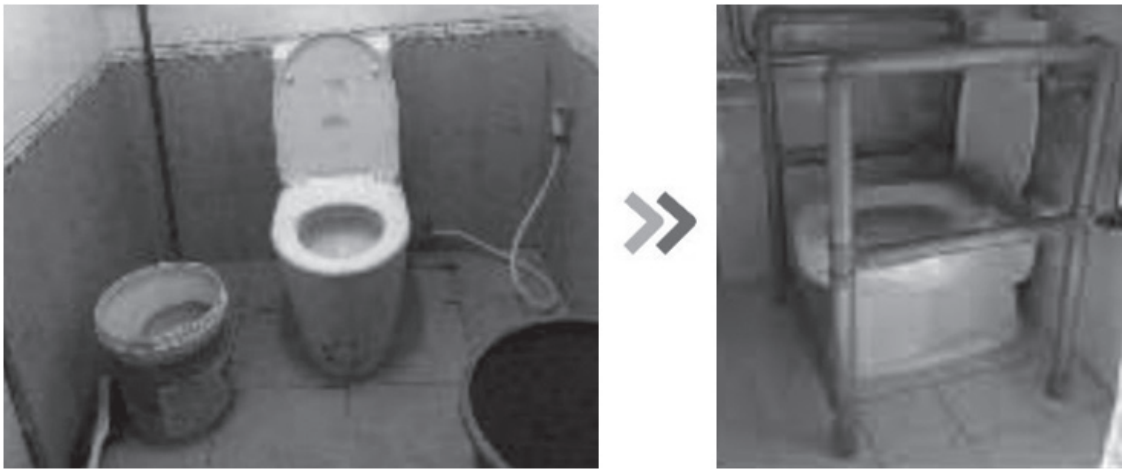


*Figure 10:*
*The toilet without a handrail of one of the samples (left) and an example use of the toilet rail innovation (right) (Sources: Photos taken by research team (Left), Faculty of Medicine Siriraj Hospital (Right))*



[6] The Toilet Rail innovation was awarded an outstanding innovation in 2015 by the Top Star Project, Faculty of Medicine Siriraj Hospital, Mahidol University.


*Figure 11:*
*Example of a kitchen counter appropriate for the elderly*
*(Source: kitchenmagic.com)*

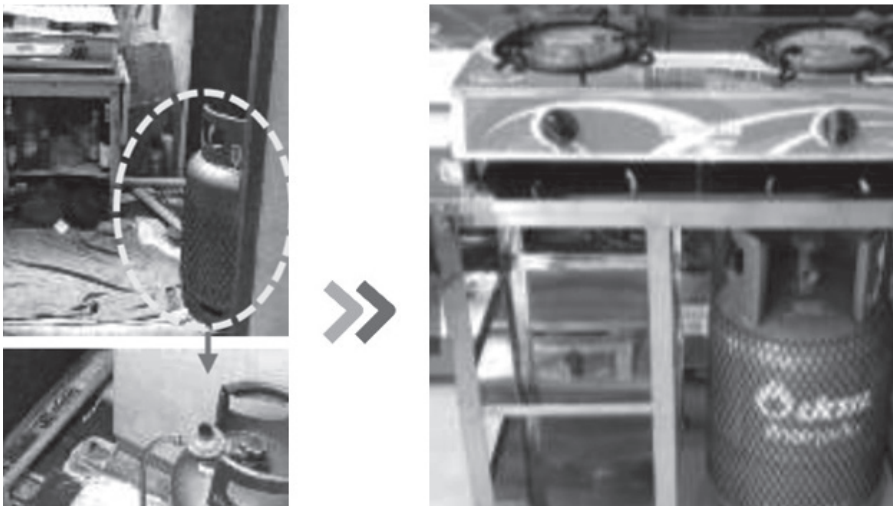


*Figure 12:*
*The kitchen with safety issue (left) and an example of the improvement (right)*
*(Sources: Photos taken by research team (Left), muangnongas.com (Right))*

**Stairs**

Stairways in some studied communities were found with higher risers and narrow treads as shown in figure 13. It was recommended to rebuild the stairs to meet the minimum standard size for safer use by older persons. The risers and treads should also be distinguished with different colors. Anti-slippery tape should also be added on for more safety as shown in figure 14.

*Figure 13. Inappropriate stairways found at the studied sites. (Sources: Photos taken by research team)*

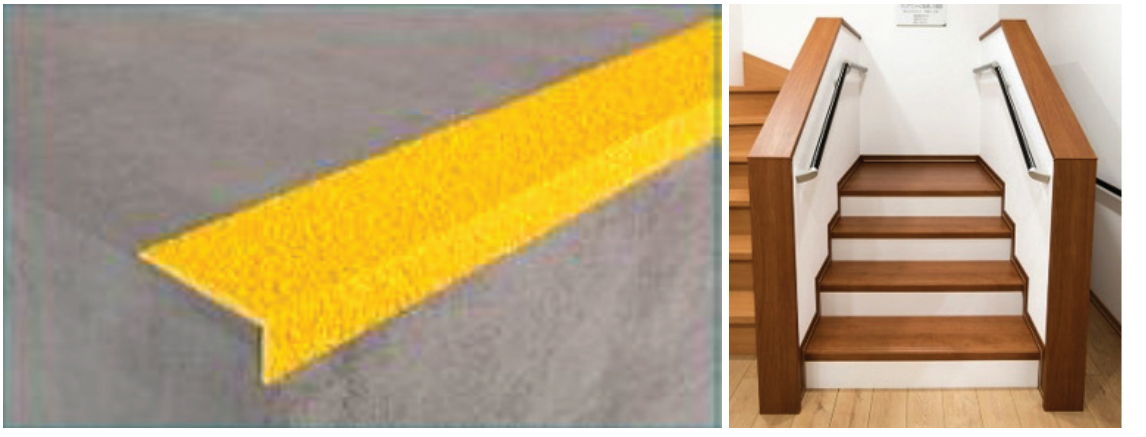


*Figure 14. Example use of anti-slippery tape (left) and the stairs with distinguished colors of risers and threads (right) (Source: www.marketingoops.com/news/brand-move/aging-society)*

## CONCLUSION

The older people living in the 4 districts of Phasi Charoen, Pra Nakorn, Wang Thonglang, and Din Daeng are those who have lived in the area for a long time as well as new arrivals coming to live in the City with family or financial reasons. Development of the residences for the elderly living in Bangkok was limited by space constraints and the City Plan, in some cases. From the information gathered from the 4 districts, it was found that despite of the different housing conditions (e.g. low rise versus high rise building), older people shared quite a similar lifestyle and daily routine. The space usage and the relevant issues were also found to be similar. Considering their usage, the residential areas could be divided into an interior multi-purpose, a sleeping area, a toilet, a kitchen/ washing area, and a stairway. From the interviews and site surveys, it is appropriate to conclude and recommend as described above. Each of the recommendations aims to resolve physical issues and improve efficiency of space utilization. These recommendations could also be used as a guideline for future projects to help enable older people to live in their own homes and communities with good health, both physical and mental.

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