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SPATIAL ANALYSIS ON MALAY BUILDINGS FOR CATEGORIZATION OF MALAY HISTORIC BIM LIBRARY

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ABSTRACT

In Malaysia, Malay cultural architecture is becoming a popular topic since Malay architecture is believed to have unique characteristics, which would be beneficial if translated into Building Information Modelling (BIM) environment. However, a BIM library needs a localized system and categorization for its interface since a cultural heritage library should reflect their own original identity of architecture. From literature, it was found that the traditional design form in Malay architecture can be identified through several aspects that are inherent physical elements in the design which can be sorted into five distinct categories which are (i) Structural members (ii) Non-structural members (iii) Aesthetic and decorative elements (iv) Spatial composition and organization and (v) Material and construction technology. In order to develop a BIM library with cultural identity, this paper further the study on the characters of Malay architecture based on the spatial composition and organization aspect with respect to the theory of space and taxonomy. Spatial analysis on the layout of multiple historic Malay buildings consisting of palaces and a commoners' house were conducted where the naming of areas within the building zones was identified and presented to propose a novel categorization structure for Malay Historic BIM library. This study proposed an approach on how to address the issue of developing a BIM library based on the cultural architecture characters.

Disciplinary: Multidisciplinary (Civil Engineering, Architectural Sciences, Heritage Science).

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1. INTRODUCTION

Investment in technology has always been to improve effectiveness and increase performance in the design and build process to yield a higher return of investment at the end of the day (Mohd-Nor

and Grant, 2014). Due to the benefits of Building Information Modelling (BIM) and its huge potential of improving the Architecture, Engineering and Construction (AEC) industry, governments around the world have started to mandate the use of BIM in their own country as part of their initiatives to achieve Sustainable Development Goals (SDG) and embracing the Industrial Revolution 4. BIM is a process for creating and managing information on a construction project across the project lifecycle (National Building Specification, 2016). Among the main objectives of BIM is to support the decision-making process in a project, offer improved quality assurance and data exchange in the process. It is also meant to increase the effectiveness and efficiency of any design work because designing tasks are time-consuming. Using BIM, architects are able to virtually construct the building before physical construction begins on site. To increase design efficiency, among the approach that BIM offers to speed up the design task is with the creation of BIM library. By having a BIM database or library, it eliminates the redundancy of creating similar elements, thus reducing unnecessary workload for designers. BIM models are capable of embedding key building information into the model including materials with their physical properties.

BIM libraries are performing as online sources for building product models. It is important to have proper organisation and categorization within the database in order to effectively use it. With BIM has managed to establish itself in the designing, planning and execution stages of projects, many BIM practitioners and BIM providers embark on sharing their work on various platforms. Among platforms that are popular for these practitioners to share are RevitCity, BIMObjects, NBS National BIM Library, MYBIM library, Arcat, Smart BIM library, and BIMsmith. The contents are mostly generic BIM model which focuses on simple and contemporary design. Most designs are found to be contemporary because BIM approach is originally intended for the design process of new projects. However, according to Afsari and Eastman (2014), there are no standards or guidelines in organizing the objects systematically within the database. Apart from that, none of the libraries has a specific-theme library based on cultural architecture or designs from over the world.

While cultural architecture carries its own diversely unique identity and characters, it is always essential to appreciate diversity. Therefore, it is imperative in order to create a BIM library based on cultural architecture, and BIM practitioners should establish the library based on the culture's character and identity instead of having a generic BIM library categorization.

Among unique cultural architecture available worldwide is the Malay architecture. According to the Merriam-Webster dictionary, Malay is a member of a people of the Malay Peninsula, eastern Sumatra, parts of Borneo, and some adjacent islands. The characters of Malay architecture is unique because its characters are believed to be inherited from their legacy of an irreplaceable source of Malay lifestyle, history, and inspiration (Sim, 2010). The authors such as Said (2007) and Sim (2010) complemented that Malay has invented one of the most sophisticated and amazing houses, kenneed as traditional Malay houses. There are also researches mentioning that Malay has high skills in woodcarving and their beautiful artworks are represented in their houses and buildings (Ismail et al., 2015).

This paper's objective is to analyze the spatial arrangement from historical Malay buildings in order to propose the categorization in Malay Historic Building Information Modelling (MHBIM) library. In identifying and studying the main characters of the Malay architecture, this study reviews

and analyses on spatial arrangement because space can be considered as the basic language in architecture. Finally, the findings will act as the basis for organizing the database, to facilitate the use of the library. The main aim of this study is to address the issue of developing a BIM library based on the Malay cultural architectural characters.

2. THEORY OF SPACE IN ARCHITECTURE

Space is an important aspect of architecture. Space creates a special relationship between function and social meanings in building (Hillier and Hanson, 1984). According to them, the order of space in buildings is really about the order of relations between people.

“Architecture is not a 'social art' simply because buildings are important visual symbols of society, but also because, through the ways in which buildings, individually and collectively, create and order space, we are able to recognise society: that it exists and has a certain form.” (Quoted from *The Social Logic of Space*, Page 2.)

The theory of space in architecture proposed by Rudolph Micheal Schindler in the eighteenth century mentioned that architecture is an art that had evolved to a more sublime and abstract level by relinquishing its symbolic capacity to speak (Park, 2015). He argues that the notion of space in architecture dealt with mental processes as space was being conceived. Therefore, the form creation in architecture referred not only to the act of physical fabrication but also to the entire mental process that led from inception to completion. The theory also argues that ‘human beings could not conceive space’ but instead always conceived rooms. However, Yuan (1987) claims that Malay architecture is unique because most of the Malay accommodation is divided into areas, rather than rooms, for various social and household activities. Abidin (1981 as cited in Hoseini et al., 2014) divided the areas into four zones, *the Front Zone, Main (Middle) House Zone, Kitchen Zone and Rear Zone*.

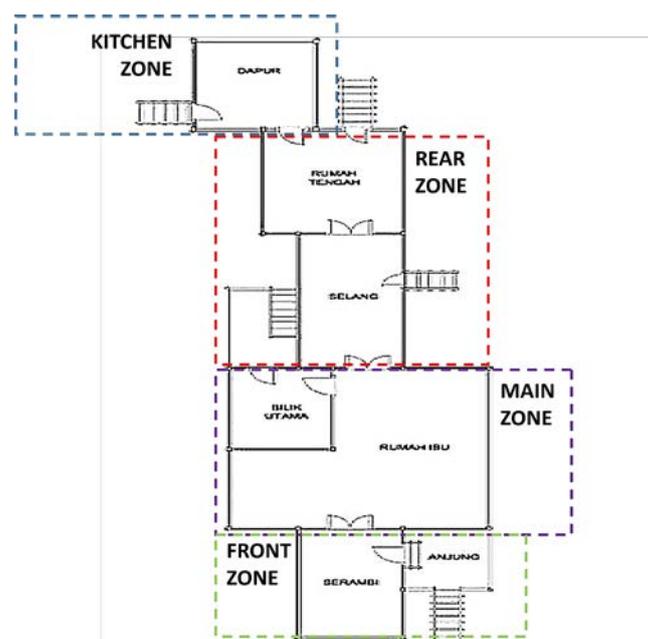


Figure 1: Typical Traditional Malay house layout (Hoseini, 2014)

2.1 MALAY ARCHITECTURE

In Malaysia, it is difficult to define Malay architecture due to the term “Malay” itself, which is not clear (Moqbel, 2014). According to the Malaysian constitution, Malay is defined as "a person who professes the Muslim religion, speaks the Malay language, and conforms to Malay customs". In the meantime, the definition of Malay cannot be limited to Malaysian only if the physical attributes of humankind are considered. Malay architecture, is a subset of South East Asian architecture, and being rooted in the Malay archipelago, its geographical reality of widely dispersed lands has made the Malay cultural region, a wide, regionally and cultural diverse entity and this diversity is also rich in terms of both physical expression and verbal expressions of its local architecture. The similarities in colour of the skins, historical background such as their previous common kingdom, civilization, religions, beliefs and DNA of the people living in the Malay Archipelago might play an important factor as observed by Alfred Wallace (cited in Van Whye, 2015):

“Two very strongly contrasted races inhabit the Archipelago—the Malays, occupying almost exclusively the larger western half of it, and the Papuans, whose headquarters are New Guinea and several of the adjacent islands.”

The architecture that reflects regional influence is known as ‘vernacular’. The term ‘vernacular’ is derived from the Latin ‘vernaculus’, meaning native, and is most widely used to denote indigenous, tribal, folk, peasant and traditional architecture. According to Chen (1998), vernacular house forms evolved according to different cultural settings and are the results of long-term modifications, adaptations, shared experiences and innovations. The terms ‘vernacular’, ‘traditional’, ‘indigenous’, and ‘regional’ are often used interchangeably (Sim, 2010). Due to the richness of cultures of the Malay within the Malay Archipelago, it is difficult to define Malay architecture unless a well-justified scope can be established. Anis et al. (2017) attempted to define the scope based on cultural influence with historical Malay palaces in Malaysia and found that there are eight influences affecting Malay architecture that can be grouped together. The influences identified are labelled as ‘Region 1 – Langkasuka Heritage, Region 2-North Straits of Malacca, Region 3- ‘The Perak,Selangor, Deli, Siak, Kampar and Langkat’ region, Region 4-Minangkabau Diaspora, Region 5- Riau Palembang diaspora, Region 6- ‘The Johor,Riau and Lingga’, Region 7- East Malaysia and West Borneo, and Region 8- ‘Makassar,Palembang, Maluku, Bulungan and Buton’ grouping (Anis et al. , 2017). Mohidiin et al. (2012) argue that the architecture of administrative buildings in Malaysia can be grouped into six (6) influences or styles namely ‘1.Traditional vernacular style 2.Dutch colonial-style 3.Neo baroque style 4.Anglo-India style 5. Modern expressionism style 6. Post-modern revivalism style’. This search for identity shows that there are various traditional and hybrid Malay house forms can be identified within the region (Yuan, 1987).

2.1.1 CHARACTERISTICS OF MALAY ARCHITECTURE AND THEIR CATEGORIZATION OF COMPONENTS

The authors such as Said (2007) and Sim (2010) complemented that Malay has invented one of the most sophisticated and amazing houses, kenneed as traditional Malay houses. The house is believed to be inherited from their legacy of an irreplaceable source of Malay lifestyle, history, and inspiration. Undeniably, the architectural design of a traditional Malay house is unique on its own. Its uniqueness in the design has reflected the identity of the owner, socioeconomic, culture and history of

the past. However, the design may look similar in nature (kindred), but the styles of Malay houses differ from state to state in Malaysia. In other words, the houses are identically in function but diverse in design. The houses generally accommodated Malaysia's tropical climate, with flexibility in the design and utilization of space.

According to Md. Nor and Isa (2015), the traditional design form in Malay architecture can be identified through several aspects that are inherent physical elements in the design. These elements can be sorted into five distinct categories.

1. Structural members.
2. Non-structural members
3. Aesthetic and decorative elements.
4. Spatial composition and organization.
5. Material and construction technology

2.1.2 STRUCTURAL, NON-STRUCTURAL, AESTHETIC AND DECORATIVE ELEMENTS, MATERIAL AND CONSTRUCTION TECHNOLOGY

Structural members of a building are the components such as beam and columns which primarily carry the load of the building. Non-structural components include doors, windows, railing, decorations, and roof. According to Yaaman & Azrin (2013), Roszalan (2014) and Raktim (2016), a typical traditional Malay house consists of plinth, column, and beam as their structural members; roof, wall, floor and openings such as door and windows as non-structural members, and decorations of motifs as their aesthetic elements. The traditional Malay houses are a functional product of human-made architecture (Yuan, 1987), for a total consideration of design values, which is embedded many conceptions, notion, and ideology in one unit which the experience of the entire house is achieved through the sensory factors. The materials used are normally from high strength grade timber such as Cengal for the structural members while a softer grade timber such as Meranti, Jati or Merbau are used for the non-structural and decorative components. Among the characters of Malay house is because of the 'tanggap' or mortice and tenon technique used, where the house was constructed without using nails. The technology used is environmental-friendly and considered as unique workmanship in the construction field.

2.1.3 SPATIAL COMPOSITION AND ORGANIZATION

Among other characters of Malay buildings' architecture is the spatial composition and organization. The architecture from the Malay race is unique because most of the Malay dwellings are divided into areas, rather than rooms, for various social and household activities (Moqbel, 2014). The typical plan layout of a Malay house is normally discussed according to zones, the inhabitants' interactions through daily activities (functional components), domains that are gender-related, age-related and guest-related. Abidin (1981 cited in Ghaffarian Hoseini et al., 2014) divided the zones into four, the Front Zone, Main (Middle) House Zone, Kitchen Zone, and Rear Zone. Many other works of literature, on the other hand, zoned the interior spaces into public and private spaces or in accordance with functional elements. In Malay history, the palaces and aristocratic houses are exaggerated or scaled up according to certain proportion from houses due to its main construction arising from timber (Wong, 2011; Anis et al., 2017). Therefore, it is believed that there must be

standard conventions that link smaller scale typologies such as houses with complex typologies such as palaces. Anis et al. (2017) stated the 'rumah ibu' could be referred to the main lobby of a palace. The main lobby is assumed to have a 'tiang seri' which normally is positioned in the centre of 'rumah ibu'. *Rumah ibu*, as the core space of the house, which may refer to two things: the volume of the main house and space inside to serve as living room in the daytime and bedroom at night. Chen et al. (2008) suggested that the main area of Malay building is quite distinctive for having the largest volume and the highest roof. They claimed that there are three main spaces that form a quite rigid layout relationship in Malay house which are the *Serambi*, *rumah ibu* and *kitchen*. *Serambi* functions as the reception area, dining room or bedroom for the guests, and the floor can be sat or slept on. *The kitchen* basically is the space for cooking and eating (Chen, 1998). This similarity of components application within the spatial organizations give Malay architecture a sense of their own cultural character. In addition, Lim (1987) also observed that the main building of a Malay house can be considered the prototype for all of its associated buildings, and can be considered as the pivot from which various ways of expansion are developed into different house types in different areas in terms of spatial organization and construction method. He claimed that there would be more diversified spatial and formal transformations through the input of some foreign construction language such as *verandah* or balcony, which refers to the front area of the building, similar to *serambi*.

2.2 BIM LIBRARY

A BIM library is a database consisting of BIM objects where the contents can be downloaded, edited and utilized for the benefits of design utilization. BIM libraries simplify the process of finding appropriate objects for a design (NBS, 2018). The objective of creating a BIM library is to capture information that will be beneficial to solve the customers' issues, pains, and goals. Ultimately, the library becomes the foundation for building decision-making tools that are capable of measuring cost reductions, cost avoidances and values added. Building a high-quality value inventory or database takes time and effort, but the payback comes tenfold. The main aim of having a database is to improve the sharing of information between different professionals within a project, to solve the interferences between them, avoiding the creation of mistakes, decreasing costs, obtaining good results. Among the main benefits of having a BIM library are:

2.2.1 IT ENHANCED COLLABORATION AND TRANSPARENCY

Using BIM library, it helps to enhance the collaboration between project stakeholders where the information is embedded inside the BIM objects. It has standardized information which referred to as a one-stop centre for information resources. By having standardized information embedded which can be easily accessed, it increases working transparency and reduces the risk of ambiguity in executing construction project. With BIM, all parties are encouraged to work collaboratively and share information with each other, where the library provides act as a better platform to share information efficiently.

2.2.2 KNOWLEDGE IS EASILY TRANSFERRED

With all stakeholders referring to and using the same model, significant time is saved, and the transfer of knowledge within teams and between different parties is streamlined. Automation and customisation features can also help in reducing the time spent communicating and adding new information. Through the library, it provides a reliable and sustainable way to transfer information

about data such as measurements, materials, description and maintenance instructions.

2.2.3 THE BIM MODEL IS AVAILABLE FROM ANYWHERE, AT ANY TIME

Most of the BIM library is cloud-based web services, which means the objects and data are accessible with the connection of the internet.

2.2.4 BIM LIBRARY AS DECISION SUPPORT SYSTEM FOR CULTURAL HERITAGE MANAGEMENT

By having BIM library, it enables a more efficient way of working, with consequent time and cost-saving (Giudice and Osello,2013). The availability of BIM objects suitable for industrial elements and modern architecture can be usefully applied to heritage documentation and management of the data on conservation practices. The availability of BIM library can help in supporting preventive conservation, information sharing and knowledge dissemination of heritage, for professionals, public institutions and experts involved in any decision making process.

3. METHODOLOGY

In studying the architecture of Malay, there are many buildings typologies such as the palaces, aristocrats' houses, commoners' houses, mosques, and administration buildings. For this paper, researchers will study on the commoners' house and Malay palaces only because it is believed that palaces are the exaggeration of scales from commoners houses (Wong, 2011 and Tengku Anis et al. 2017). Multiple case studies technique is applied where six (6) Malay palaces and two (2) commoners house in Peninsular Malaysia are selected, and their building layouts are retrieved. The buildings are Istana Balai Besar Alor Setar (Kedah), Istana Balai Besar Kota Bharu (Kelantan), Istana Seri Menanti (Negeri Sembilan), Istana Tengku Long (Terengganu), Istana Gahara (Perak), Istana Leban Tunggal (Pahang), Rumah Pak Ali (Selangor) and Rumah Haji Akil (Johor). This study uses historical research strategies as its methodology due to its focus on 'a setting or circumstances from the past' in attempts to provide the meaning of human actions conducted from encounters with the subject of investigation or derived from 'textual-archival or artefactual sources' and fieldwork (Groat & Wang, 2013). Historical research depends on a constructed logic of interpretation, but that interpretation is based on documents and artefactual evidence, and typically entails a narrative structure. Therefore, data are collected through literature review and variety sources of Malay building documentation such as measured drawing reports and CAD documentation to explore the enquiry of this paper.

4. ANALYSIS

4.1 TAXONOMICAL CATEGORIZATION OF AREAS IN MALAY BUILDINGS

Based on the buildings' layout, researchers study their spatial arrangement by identifying the zoning within the layout and extracted the naming of areas given in the layouts. Buildings' layout was collected from International Islamic University Malaysia's Kuliyyah of Architecture and Environmental Design Heritage Laboratory and Universiti Teknologi Mara (UTM) Center for the Study of Built Environment in the Malay World (KALAM). The marking for boundaries of the zoning starts from the front entrance and the ending boundaries for the zoning is considered when there is a change of function within areas (Gullberg, 2016). For example, the front zone ends when the

area of *rumah ibu* starts. The analysis is shown in Figures 2, 3 and 4, whereas the outputs are tabulated in Tables 1 and 2.

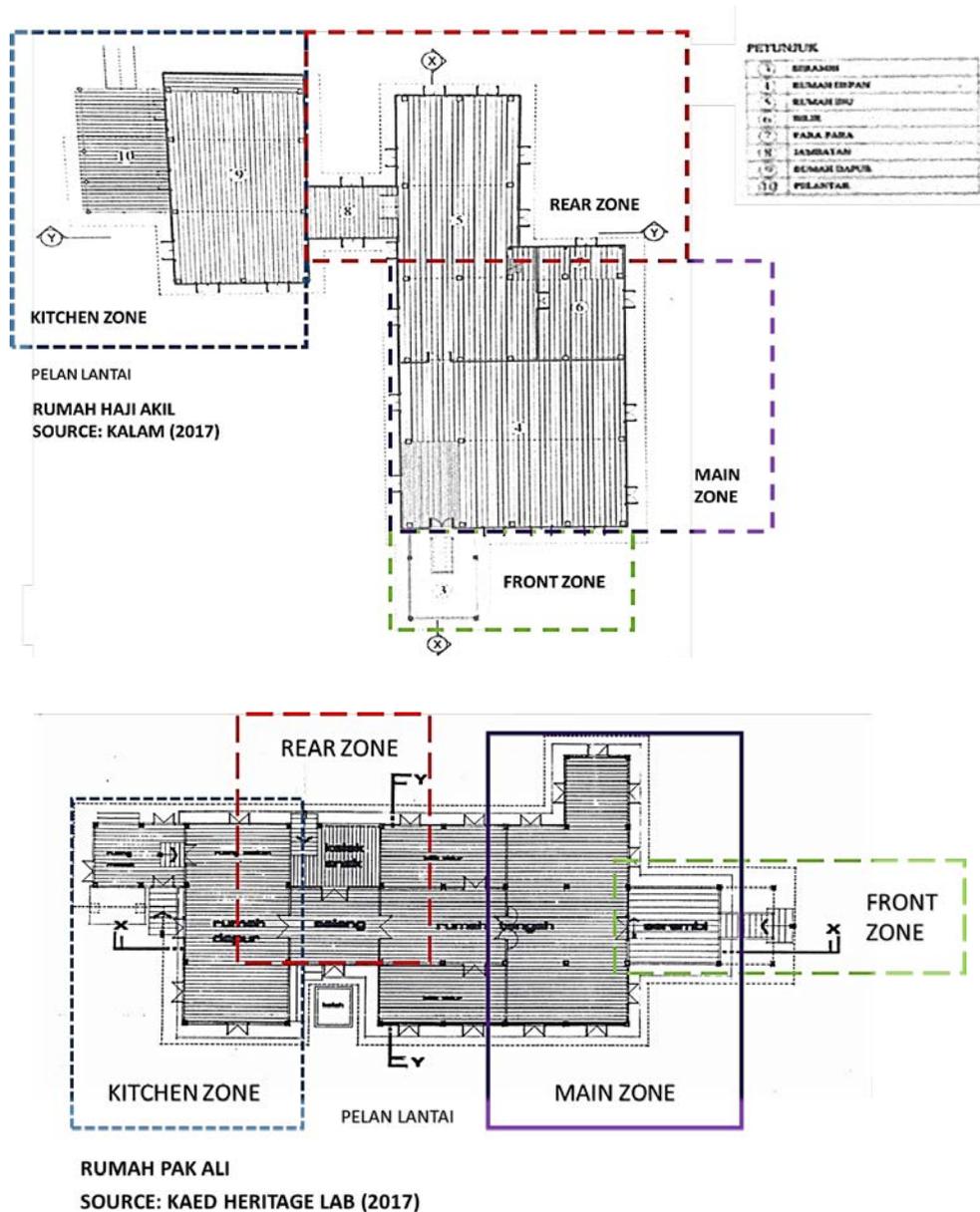


Figure 2: Spatial analysis of commoners' house layout.

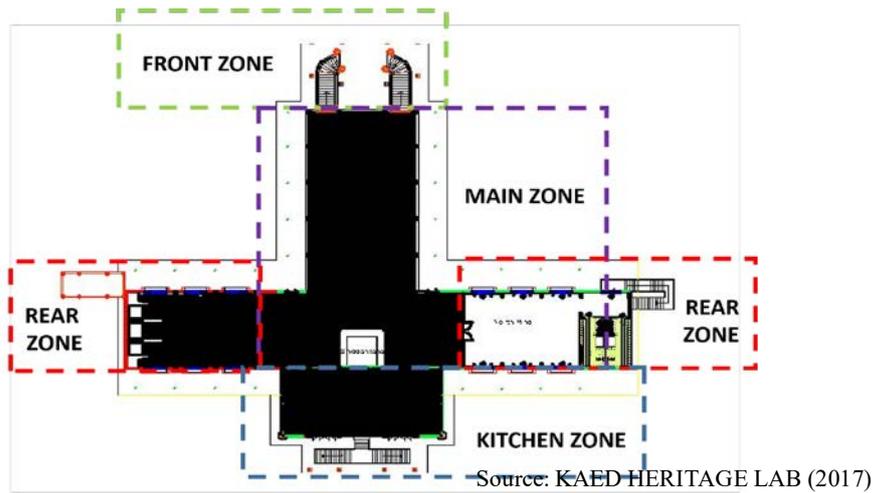
4.1.1 TRADITIONAL MALAY HOUSE

From the commoner's house layout, areas are found as given in Table 1.

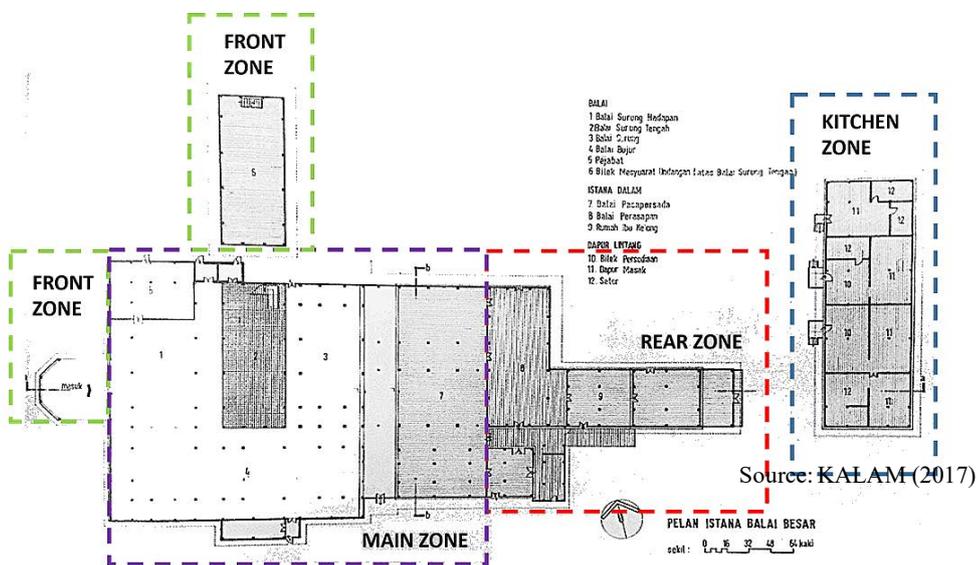
Table 1: Areas found in commoner's house layout

No	Rumah Pak Ali	Rumah Haji Akil Source: KALAM (2017)
1	Rumah Tengah	Serambi
2	Ruang Makan	Pelantar
3	Rumah dapur	Rumah dapur
4	Selang	Rumah Ibu
5	Rumah Masuk	Rumah Depan
6	Bilik tidur	Bilik
7	Bilik Setor	Para-para (anjung)
8	Serambi	Jambatan (Selang)

Source: Authors' work



ISTANA BALAI BESAR ALOR STAR
SOURCE: KAED HERITAGE LAB (2017)



ISTANA BALAI BESAR
SOURCE: KALAM (2017)

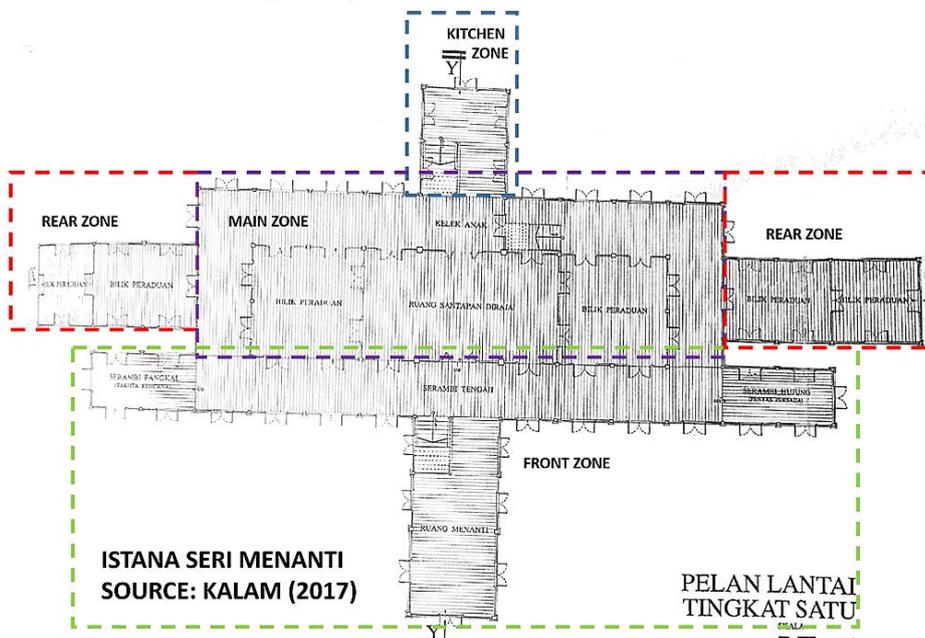


Figure 3: Spatial analysis of Malay palaces' layout.

4.1.2 MALAY ROYAL PALACES

From the Malay Royal Palaces' layout, areas are found as given in Table 2.

Table 2: Areas found in Malay palaces layout

No	Istana Tengku Long Source: KALAM (2017)	Istana Balai Besar Kota Bharu	Istana Seri Menanti
1	Surung	Surung hadapan	Serambi Pangkal
2	Balai	Surung tengah	Serambi Hujung
3	Dapur	Surung	Serambi Tengah
4	Rumah padi (storage)	Balai Bujur	Ruang santapan
5	Pelantar	Pejabat	Ruang menanti
6	Serambi	Rumah ibu kelong	Kelek anak
7	Ruang Mengadap	Balai pacaparsida	Bilik Peraduan
8	Bilik santapan	Balai perasapan	Lompang
9	Ruang tengah	Dapur	Langkan
10	Ruang khas	Bilik Mesyuarat	Ruang Keluarga diraja
11	Bilik peraduan	Setor	
12	Bilik Bersiram		
No	Istana Balai Besar Alor Setar	Istana Leban Tunggal	Istana Gahara
1	Grand Staircase (Porch)	Porch	Verandah (serambi)
2	Dewan Balai Lepau	Guest living room	Office
3	Serambi Kanan	Office	Living area
4	Serambi kiri	Dining area	Entrance hall
5	Singgahsana	Master bedroom	Dining area
6	Bilik Siak	Toilet	Bedroom
7	North Wing	Passage (selang)	bathroom
8	South Wing	Storage	Kitchen
9		Kitchen	Servant's room
10		Family area	Hallway (Selang)
11		Verandah	Family area

5. RESULT AND DISCUSSION

The output confirms that the layouts of Malay historic buildings can be categorized into *the Front Zone, Main (Middle) House Zone, Kitchen Zone and Rear Zone* as according to zonings proposed by Abidin (1981). This also confirms the claim by Wong (2011) and Tengku Anis et al. (2017) that the palaces and aristocratic houses in Malay history are an exaggeration from houses. It can be deduced that the conceptually, the space between the typical house, palaces and aristocrat house have a similar 'social logic of space'. It is observed that the number of areas within the zone increases as the typology of the buildings changes from houses to palaces. The increase in the number of areas is due to the need for space's function. A normal house not necessarily has to accommodate visitors as often as, and the royalty might have to. According to Sim (2010), areas in Malay house normally started with 'rumah ibu' and will be expanded to other areas to accommodate the owner's roles in society.

One of the famous mantras in architecture is "form follows function" as famously said by Louis Sullivan (Guimera and Pardo, 2018), which Sullivan credited the rule was actually originated from the ancient Roman architecture. From the analysis, it can be deduced that Malay architecture also adhered to the rule. As space plays an important role in society, the Malay community is observed to be adaptive in nature since they practice the concept of incremental housing. Incremental housing is an additional system of a building that grows with the needs and means of the owner (Yuan, 1987).

The system being practice requires only a small initial capital investment and grows when the owner has the reason to expand their building. Normally, the incremental housing concept for traditional Malay house starts with *rumah ibu* and will be followed by other areas. This also can be deduced that among unique characters of Malay buildings is that they are flexible to changes. This is mostly possible since the materials are mainly made from timber. Figure 5 shows the common addition sequence as previously suggested by Yuan (1987).

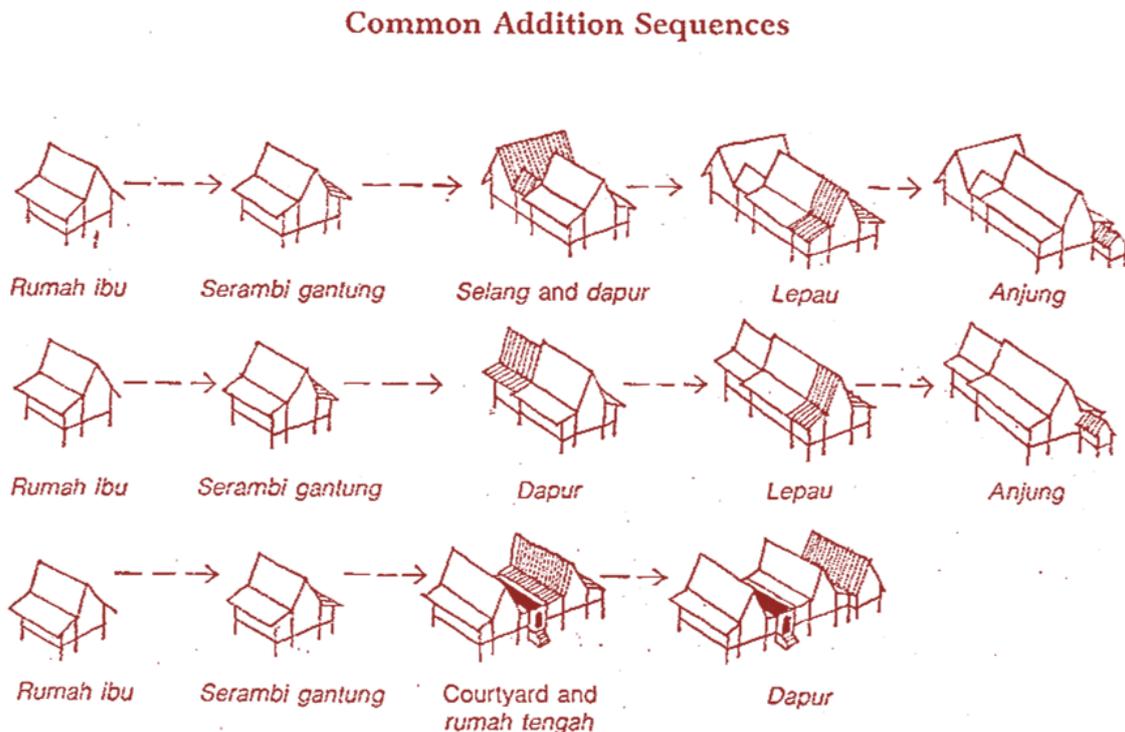


Figure 5: Common addition sequences as suggested by Yuan (1987).

From this study's analysis and Yuan's (1987) observation, it is observed that in Malay cultural architecture, the owner's status is among the determining factor on how the layout of their buildings will look. In short, as their status and ranking in society increases, they also change the type of house they reside in. It is also a show of power within society. Due to this societal behavior, researchers are aware that the list of areas identified within the zones might be innumerable as they may grow through evolution. In order to establish a universal categorization system for Malay historic BIM, it is important to identify the areas that should be considered according to the zonings system discussed. From the observation of the case studies conducted, the summary of the result is tabulated.

5.1 SUMMARY OF AREAS IN THE ZONINGS

Based on the literature review and analysis carried out, a system for categorization of the Malay Historic BIM library is proposed. It is found that the basic character of Malay architecture in terms of spatial composition and organization (Md. Nor and Isa, 2015) consists of private and public space, which can be further broken down as front zone, main zone, rear zone and kitchen zone (Abidin, 1981) whereas the categorization for Malay building components can be categorised as 1) non-structural (architectural) 2) structural and 3) decorations (Md. Nor and Isa, 2015). In furthering the study on the zonings, the namings of areas are also identified and presented in Table 3.

Table 3: Areas according to zones

Front zone	Main Zone	Rear zone	Kitchen zone
1. Serambi	1. Rumah Ibu	1. Rumah Tengah	1. Rumah Dapur
2. Anjung	2. Bilik	2. Selang/Jambatan/Hallway	2. Pelantar
3. Porch	Utama/Tidur/Bilik	3. Ruang Makan	3. Storage/Rumah Padi
4. Verandah	Peraduan	4. Rumah Depan	4. Bilik Bersiram
5. Ruang Menghadap	3. Rumah Tengah	5. Bedroom	5. Bilik Persediaan
6. Ruang Menanti	4. Balai Rong Seri	6. Servant's Room	6. Servant Room
7. Foyer	5. Surung	7. Balai Pacaparsada	7. Washing Area
	6. Office	8. Balai Perasapan	8. Bilik Siak
	7. Living Area	9. Kelek Anak	
	8. Bilik	10. Yard	
	Santapan/Ruang Santapan Diraja	11. Bilik Mandi	
	9. Balai	12. Serambi	
	10. Galeri	13. Ruang Rehat	
	11. Dewan		

Source: Authors' work

There is an on-going debate on the use of terms for certain areas in Malay building since the analysis shows the same issue. The 'Serambi' is widely translated as 'verandah' (Zin, Ibrahim, Zain and Jamil, 2012), however according to Shireen et al. (2018), 'serambi' denotes more of an outdoor room, a completely public area where people can congregate yet they are unable to enter beyond a certain boundary in the Malay house. This is a semantic issue, where certain meanings cannot be adequately captured if they are directly translated. However, for the purpose of this paper, the authors agreed that the usage of terms is beyond the current scope and the issue needs to be properly discussed by language experts. As for now, the system proposed for MHBIM will use the current term found in case studies.

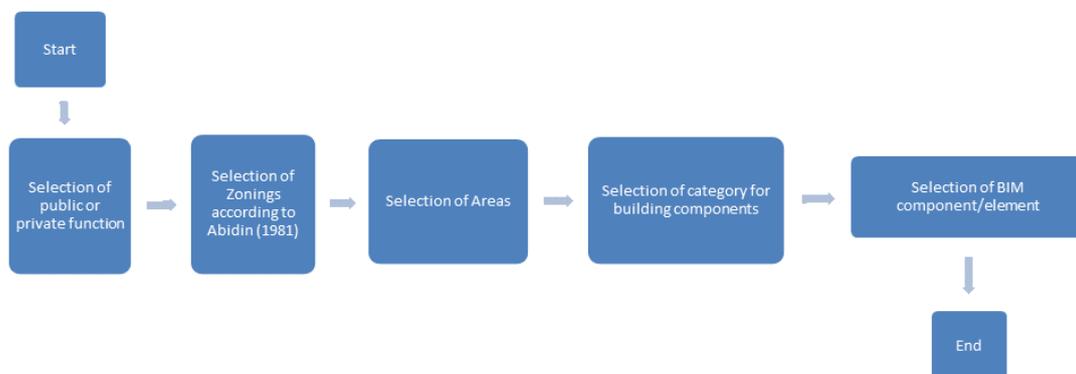


Figure 6: Process of using the proposed library (Source: Authors' work).

The structure of the system starts with the selection of public or private functions before moving on to the selection of zones. Inside the selected zones, there will be areas that commonly can be found within the selected zone. The areas within the zoning method can be expanded if there are more areas found to be relevant to the zones. Next, once an area is selected, the breakdown of components which can be normally found in the area is presented. From the categories, there will be various selections of BIM elements and components from the specified area for users to choose from. The system for the Malay BIM library is expected to help designers in their design and BIM practitioners with their practice. The flowchart in Figure 6 explains the process of how to use the system proposed, whereas Figure 7 shows the work breakdown system for the proposed library categorization.

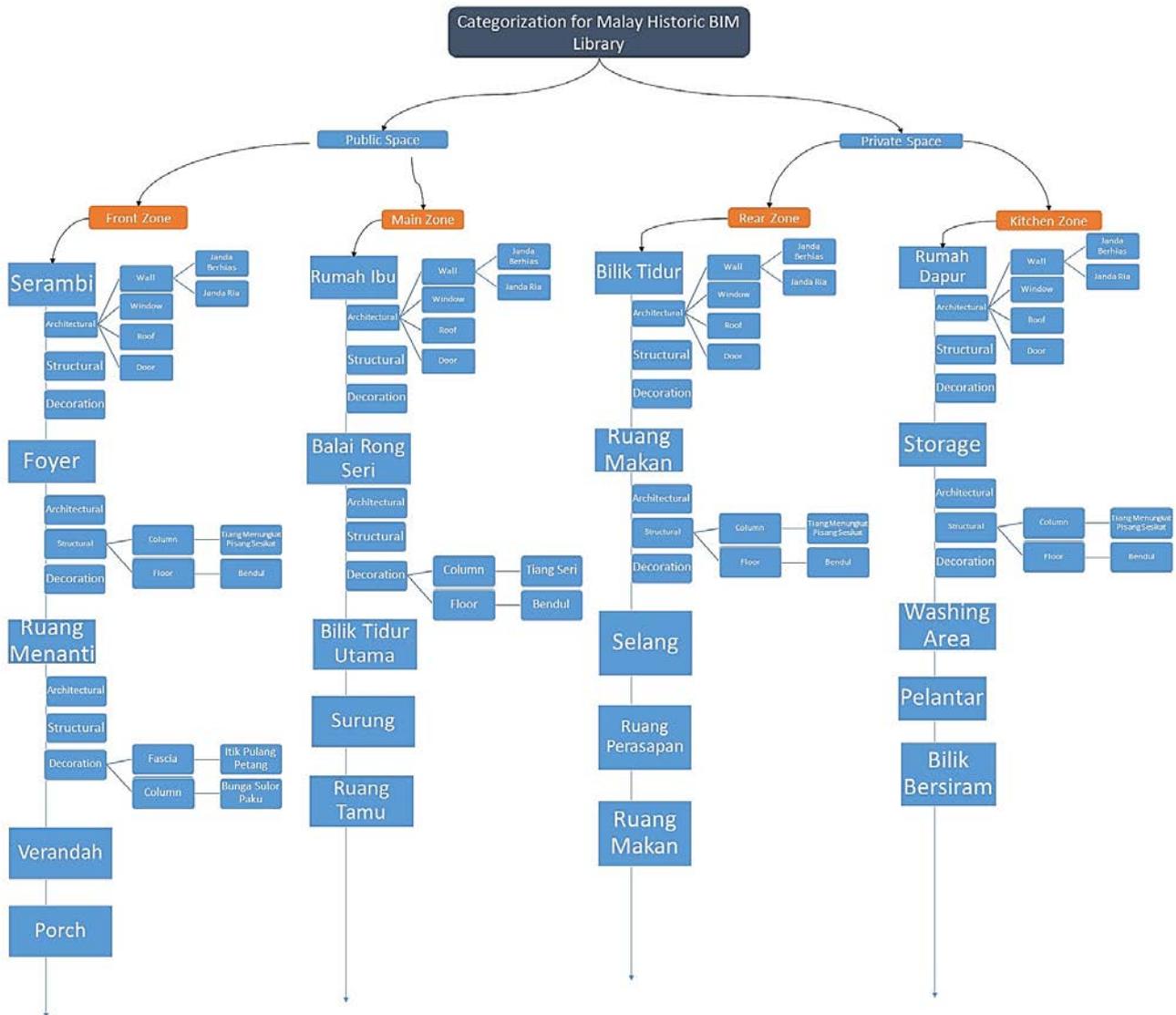


Figure 7: Breakdown of the categorization process for Malay Historic BIM library (Source: Authors)

Since Malay buildings are rich with unique components - such as ‘Tiang seri’ which normally located at ‘Rumah Ibu’ area within the Main Zone. Therefore, a coding scheme in locating the components within a Malay building is proposed to enrich the semantic of this cultural heritage BIM library. The main purpose of this enrichment is to set a guidance rule for designers so that the correct components can be placed at the correct location within a building. Hopefully, with this enrichment, the ‘Tiang Seri’ column which normally found at ‘rumah ibu’ area will not be located in other areas such as the kitchen area (serambi). This is important to protect the authenticity of the architectural character of the specific culture. Figure 8 shows the diagram of the proposed coding scheme.

PROPOSED CODING SCHEME

• Example :

- 1st tier (Zone) – **Main Zone (M)**
- 2nd tier (Space) – **Rumah Ibu(RI)**
- 3rd Tier (Category of component) – **Structural (S)**
- 4th tier (Type of component) – **Column(C)**
- 5th tier (Origin of component) – **Istana Balai Besar**
- 6th Tier (Name of component) – **Tiang Seri**
- Hence : **MRISC_Tiang Seri or Main_RumIbu_Struc_Col_balaibesar_tiangseri**



Figure 8: Proposed coding scheme to enrich the cultural heritage BIM library’s semantic (Source: Authors’ work).

6. CONCLUSION

Malay society is rich in values and practice moderation within their lifestyle. Their architecture symbolizes harmony in the design and their logic of space as they only expand their houses when there is a need. In embracing Industrial Revolution 4.0, the utilization of tools such as BIM is encouraged by the government of Malaysia when they mandated that starting 2020, construction projects must be BIM-operated. Therefore, it is important to create a system that is universal and expandable that reflects the character of Malay building, to ensure the continued relevance of the proposed BIM library. By having this kind of library, it will increase the productivity of the industry and prepare the players to be more competitive in a good way. The library will provide access to industry players to consider components with Malay identity in their design. Apart from that, by utilizing BIM approach, the government's aspiration to contribute to the world's sustainable goal development also can be addressed.

7. AVAILABILITY OF DATA AND MATERIAL

Data can be made available by contacting the corresponding authors

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