POTENTIAL INFLUENCE OF COURTYARD ON INDOOR ENVIRONMENT CONDITIONS OF OFFICE BUILDINGS

FATMA HUSSIEN ABASS YOUNIS

A thesis submitted in fulfillment of the requirement for the award of the Degree of Master of Civil Engineering

Faculty of Civil and Environmental Engineering
Universiti Tun Hussein Onn Malaysia

AUGUST 2016
In the name of God, The Most Gracious, The Most Merciful
For my late father and mother, my brothers and sisters
For my friends who support me during this journey.
ACKNOWLEDGEMENT

All praise and thanks are due to Allah (Subhanahu Watale), and peace and blessing be upon his messenger. Thanks to Allah the most Gracious and Merciful, who enabled me to accomplish the research. I would like to express my deepest gratitude to my beloved family for their support and consistent encourage over the past year. Without their love and support, I would not have been able to achieve my goals. To my best friends in Sudan who stand by my side through better and worse time, I would say thanks to them for being in my life. This study is a culmination of the help, guidance and kind support of many people with whom I have been associated over the past years. I would like especially thank Associate Prof. Dr. Lokman Hakim Ismail, who contributed with his precious time, experience, and guidance to enrich the study. I would like to thank the Office for Research, Innovation, Commercialization and Consultancy Management (ORICC) University Tun Hussein Onn Malaysia for supporting this research project under GIPS Grant (U158). My sincere appreciation goes to everyone who has helped me directly or indirectly in the completion of my research.
ABSTRACT

It is recognized that the air conditioning system is a major factor that influencing energy consumption in Malaysia. In fact, residential and non-residential buildings, become a subject to significant cooling necessities due to the high intensity of heat passing from building external envelope, the rely on mechanical cooling systems to provide best indoor condition was directed to increase the energy consumption. Due to this fact, many designers highlighted the potential influence of courtyards as a natural cooling technique to enhance indoor comfort for building users and consequently minimize space-cooling conditioning. This research investigates the courtyard attributes as a natural cooling technique in tropical climates, to provide indoor thermal condition at single, double and three-story buildings; furthermore, to achieve low energy office buildings in Kuala Lumpur and Johor. The research objectives are to investigate the history of the courtyard in Malaysia, to evaluate indoor environmental conditions at office buildings and finally to assess, the effectiveness of a courtyard on conserving energy in office buildings in Malaysia. The research method is a combination of literature review, environmental measurement, post occupancy evaluation and energy consumption data. To achieve the first objective of this research previous study assessed to gain information of the courtyard at vernacular architecture, contemporary vernacular and modern architecture in Malaysia, it started before independence in 1957 and transformed through time until the dawn of the new millennium. Furthermore, several environmental aspects such as air temperatures, relative humidity, and air velocity were measured using a portable instrument (Lutron LM 8000) and thermal comfort station (BABUC A). Whereas, the post-occupancy evaluation used to assess the level of indoor thermal condition at office buildings, at least, the energy data examined through the electricity bills for the at least one-year period. According to the last findings of this
research, the influence of the courtyard on providing indoor thermal conditions achieved at single and three storey buildings, while for double storey building the indoor condition did not comply with ASHRAE-55 and ISO 7730 standards. For the term low energy office buildings, the results illustrated that single and double storey office buildings considered as low energy office buildings, while for three storey office buildings the amount of energy that used did not comply with MS 1525 standard.
ABSTRAK

setingkat dan bangunan 3 tingkat, manakala, bangunan 2 tingkat pula tidak memenuhi standard ASHRAE- 55 dan ISO 7730. Hasil menunjukkan bangunan setingkat dan bangunan 2 tingkat dikategorikan sebagai bangunan haba rendah, manakala bagi bangunan 3 tingkat, penggunaan tenaga tidak memenuhi standard MS 1525.
## CONTENTS

| TITLE | i |
| STUDENT'S DECLARATION | ii |
| DEDICATION | iii |
| ACKNOWLEDGEMENT | iv |
| ABSTRACT | v |
| ABSTRAK | vii |
| CONTENTS | ix |
| LIST OF TABLES | xiii |
| LIST OF FIGURES | xv |
| LIST OF SYMBOLS ABBREVIATION | xviii |
| LIST OF APPENDICES | xix |

### CHAPTER 1 INTRODUCTION

1.1 Research Background  
1.2 Problem Statement  
1.3 Research questions and Hypothesis  
1.4 Research objectives  
1.5 Research scope  
1.6 Significance of research  
1.7 Structure of the thesis  
1.8 Summary

### CHAPTER 2 LITERATURE REVIEW

2.1 Introduction  
2.2 History evolution of courtyard Form  
2.2.1 Ancient civilizations  
2.2.2 Classical civilizations  
2.2.3 The Middle Ages and renaissance civilizations
2.2.4 Modern civilizations

2.3 Courtyard forms and elements
  2.3.1 Orientation
  2.3.2 Wall enclosure
  2.3.3 Natural elements within a courtyard

2.4 Courtyard benefits
  2.4.1 Psycho-social benefits
  2.4.2 Cultural benefits
  2.4.3 Economic benefits
  2.4.4 Climatic benefits
  2.4.5 Architecture benefits

2.5 Courtyard disadvantages

2.6 History of courtyard in Malaysia
  2.6.1 Courtyard in vernacular building design
  2.6.2 Courtyard in vernacular contemporary building design
  2.6.3 Courtyard in contemporary building design
  2.6.4 Courtyard in non-residential building

2.7 Energy conception in office building

2.8 Indoor environmental Quality in office building
  2.8.1 Human thermal comfort
  2.8.2 Basic principal of thermal comfort
  2.8.3 Predicted Mean Vote
  2.8.4 Predicted Percentage Dissatisfy

2.9 Courtyard as passive cooling techniques

2.10 Summary

CHAPTER 3 RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

3.2 Research design for evaluation courtyard building

3.3 Research method
  3.3.1 Environmental measurement
  3.3.2 Post occupants evaluation
3.3.3 Building energy consumption 53
3.4 Instruments 54
3.5 Measurement 55
3.6 Data Collection 56
3.7 Analysis techniques 59
3.9 Summary 59

CHAPTER 4 DATA ANALYSIS AND RESULTS 60
4.1 Introduction 60
4.2 Part I: Cases studies characteristic 60
4.3 Malaysia Climatic characteristics 68
4.4 Analysis courtyard design 69
  4.4.1 Discussion 72
4.5 Analysis environmental measurement 74
  4.5.1 Indoor environmental measurements 73
  4.5.2 Discussion 89
  4.5.3 Outdoor environmental measurements 90
  4.5.5 Discussion 94
4.6 User’s perception 99
  4.6.1 General questions 100
  4.6.2 The analysis of courtyard functions
      and building layout in C2 building 102
  4.6.3 Satisfaction toward the building layout 103
  4.6.4 Satisfaction toward the courtyard layout 104
  4.6.5 Satisfaction toward the courtyard as
      outdoor climatic moderator 104
  4.6.6 Satisfaction toward air temperature
      in the courtyard area 105
  4.6.7 Satisfaction toward outdoor relative
      humidity in the courtyard area 106
  4.6.8 Satisfaction toward courtyard as
      gathering area 107
  4.6.9 Satisfaction toward the courtyard
      elements 108
  4.6.10 Analysis of indoor thermal comfort in
      C2 building 109
4.6.11 Satisfaction towards indoor air temperature 110
4.6.12 Satisfaction towards indoor relative humidity 111
4.6.13 Satisfaction towards building environment 112
4.6.14 Source of discomfort inside the working space 113
4.6.15 Discussion 114
4.7 Building energy used 116
4.8 Summary and conclusion 118

CHAPTER 5 RECOMMENDATIONS 121
5.1 Introduction 121
5.2 Reviews of research objectives and questions 122
5.3 Hypothesis Review 122
5.4 Research conclusion 123
5.5 Recommendation 123

REFERENCES 125
APPENDICES 135
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>List of landscape furniture in vernacular house in Malaysia</td>
<td>25</td>
</tr>
<tr>
<td>2.2</td>
<td>Energy consumption, distribution for commercial buildings in Malaysia</td>
<td>40</td>
</tr>
<tr>
<td>2.3</td>
<td>Thermal comfort affecting variables</td>
<td>43</td>
</tr>
<tr>
<td>2.4</td>
<td>ASHRAE thermal sensation scale</td>
<td>43</td>
</tr>
<tr>
<td>3.1</td>
<td>Courtyard design checklist</td>
<td>57</td>
</tr>
<tr>
<td>3.2</td>
<td>Building architecture elements checklist</td>
<td>58</td>
</tr>
<tr>
<td>4.1</td>
<td>Description of C2 building</td>
<td>62</td>
</tr>
<tr>
<td>4.2</td>
<td>Description of MaTIC building</td>
<td>63</td>
</tr>
<tr>
<td>4.3</td>
<td>Description of Pejabat Daerah building</td>
<td>65</td>
</tr>
<tr>
<td>4.4</td>
<td>Description of C2 and ORICC buildings</td>
<td>66</td>
</tr>
<tr>
<td>4.5</td>
<td>Case studies courtyard design</td>
<td>70</td>
</tr>
<tr>
<td>4.6</td>
<td>Case studies architecture elements</td>
<td>71</td>
</tr>
<tr>
<td>4.7</td>
<td>Indoor environmental parameters of C2</td>
<td>75</td>
</tr>
<tr>
<td>4.8</td>
<td>Indoor air temperature of MaTIC and Pejabat Daerah and ORICC</td>
<td>76</td>
</tr>
<tr>
<td>4.9</td>
<td>Indoor relative humidity of MaTIC and Pejabat Daerah and ORICC</td>
<td>77</td>
</tr>
<tr>
<td>4.10</td>
<td>Indoor air velocity of MaTIC and Pejabat Daerah and ORICC</td>
<td>78</td>
</tr>
<tr>
<td>4.11</td>
<td>Indoor air temperature reading in all buildings</td>
<td>83</td>
</tr>
<tr>
<td>4.12</td>
<td>Indoor relative humidity reading in all buildings</td>
<td>84</td>
</tr>
</tbody>
</table>
4.13 Indoor air velocity reading in all buildings 85
4.14 PMV value range and PPD value based on ISO 7730 86
4.15 Comparing the value of the PMV and PPD according to ISO 7730 and ASHRAE 55 88
4.16 Comparative ranges of environmental parameters 88
4.17 Outdoor environmental parameters at C2 91
4.18 Outdoor environmental parameters of MaTIC and Pejabat Daerah and ORICC 92
4.19 Outdoor air temperature reading in all buildings 96
4.20 Outdoor relative humidity reading in all buildings 97
4.21 Outdoor air velocity reading in all buildings 98
4.18 Rating scale for evaluation elements 99
4.19 Number of participants in each building 100
4.20 Energy used in all buildings 118
LIST OF FIGURES

2.1 Different types of courtyard plans in Africa 10
2.2 Plan of House at Ur, Mesopotamia 10
2.3 Typical layout of Chinese courtyard houses and street 11
2.4 Typical layout of Japanese traditional house 11
2.5 Street view of Islamic traditional house 12
2.6 Typical courtyard dwelling during Classical Civilization 13
2.7 Courtyard house in Morocco and Baghdad during Middle ages 14
2.8 L shape courtyard house designed by Haring and Hilberseimer 15
2.9 Courtyard house in Los Angeles in 1928 - 1929 16
2.10 Different possible layouts for a single-family courtyard 17
2.11 Additional system of old Malay house 23
2.12 External envirement of Malay house 23
2.13 Malay community courtyard in different zones 26
2.14 Area distribution of vernacular contemporary courtyard in Melaka 28
2.15 Courtyard design of contemporary veracular house 29
2.16 Middle and low destiny courtyard house 31
2.17 Courtyard design at contemporary houses in Kuala Lumpur 32
2.18 Design of Menara Mesiniaga 35
2.19 Design of Wisma Shell 36
2.20 Landscape design of Putrajaya city 37
2.21 Electricity consumption by sector in Malaysia 39
2.22 Energy consumption percentage of office building 39
2.23 Body heat exchange 42
2.24 Relation between PPD and PMV 44
2.25 Evaluation scale of human thermal satisfaction 46
2.26 Different possible layouts for a single-family courtyard 31
2.27 Electricity consumption by sectors in Malaysia 37
2.28 Approximate average values of energy consumption in Office buildings in Malaysia 38
2.29 Body heat exchanges 42
2.30 Relation between PPD and PMV 44
2.31 Evaluation cycle of human thermal satisfaction 46
3.1 Research methodology 51
3.2 BABUC A thermal station 55
3.3 Lurton LM -8000 4 in 1 55
4.1 Locations of the case studies (Kuala Lumpur and Johor) 61
4.2 C2 building – Batu Pahat 63
4.3 Malaysia Tourism Center (MaTIC) – Kuala Lumpur 64
4.4 Pejabat Daerah Building - Batu Pahat 65
4.5 ORICC building-Batu Pahat 67
4.6 C2 location area and measured parameters 75
4.7 The comparison of daytime indoor temperature 76
4.8 The comparison of daytime indoor relative humidity 77
4.9 The comparison of daytime indoor air velocity 78
4.10 MaTIC location area and measured parameters 79
4.11 Pejabat Daerah location area and measured parameters 81
4.12 ORICC location area and measured parameters 82
4.13 PMV value range and PPD value in all buildings based on ASHRAE 55 87
4.14 The comparison of daytime outdoor temperature in 91
C2 building
4.15 The comparison of daytime outdoor temperature 92
4.16 The comparison of daytime outdoor relative humidity 93
4.17 The comparison of daytime outdoor air velocity 94
4.18 The comparison of daytime indoor& outdoor air temperature, relative humidity and air velocity 95
4.19 Participants percent based on gender 100
4.20 Participants rating for cloths options 101
4.21 Participants location 102
4.22 Users’ satisfaction towards courtyard and building layout in C2 building 102
4.23 The comparison of satisfaction towards building layout 103
4.24 The comparison of satisfaction towards courtyard layout 104
4.25 The comparison of satisfaction towards courtyard as climatic moderator 105
4.26 The comparison of satisfaction towards air temperature in the courtyard 106
4.27 The comparison of satisfaction towards relative humidity in courtyard 107
4.28 The comparison of satisfaction towards courtyard as gathering area 108
4.29 The comparison of satisfaction towards the courtyard elements 109
4.30 Users’ satisfaction towards indoor thermal comfort in C2 building 110
4.31 Users’ satisfaction towards indoor air temperature 111
4.32 Users’ satisfaction towards indoor relative humidity 112
4.33 Users’ satisfaction towards building productivity 113
4.34 Comparison of the source of discomfort in all buildings 114
4.35 Energy used per in buildings 118
LIST OF SYMBOLS, ABBREVIATIONS

ASHRAE  American Society of Heating, Refrigerating and
CIBSE  Chartered Institution of Building Service Engineers
EE  Energy Efficiency
EEI  Energy Efficiency Index
GBI  Green Building Index
GEO  Green Energy Office
HAVC  Heating, Ventilation and Air Conditioning
IEQ  Indoor Environmental Quality
KL  Kuala Lumpur
NGO  Non-Government Organization
MDU  Multi Dwelling Unit
LEO  Low Energy Office
POE  Post Occupancy Evaluation
PWD  Public Works Department
PMV  Predicted mean vote
PPD  Predicted Percentage of dissatisfied
RH  Relative Humidity
T_a  Air Temperature
V_a  Air Velocity
SPSS  Statistical package for Social Science
Stand.Dev.  Standard deviation
SET  Standard Effective Temperature
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Survey official letters</td>
<td>134</td>
</tr>
<tr>
<td>B</td>
<td>Case study buildings layout plans</td>
<td>139</td>
</tr>
<tr>
<td>C</td>
<td>Case studies environmental measurement reports</td>
<td>150</td>
</tr>
<tr>
<td>D</td>
<td>POE questionnaire</td>
<td>179</td>
</tr>
<tr>
<td>E</td>
<td>Electricity bills for MaTIC, Pejabt Daerah and UTHM campus</td>
<td>182</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Research Background

It is now recognized that the effectiveness of energy is becoming a vital issue, as energy has become under serious shortage in the next future (Sadeghfam et al., 2015). Thus, there is a continuous increase in energy production in an urban area, due to growing populations who appreciate the higher material prosperity and life standard (Wee et al., 2008). Many reports on the energy consumption revealed that commercial, institutional, industrial and residential building sector consumes a huge amount of energy every year, as a result the pattern of energy consumption will likely increase sharply next years. However, since the 1970s, building developers, engineers and architects are better aware towards design strategies that lower energy usage (Moghimi et al., 2011).

The movement focused towards finding effective passive strategies to bring down the energy demands of buildings, and encourage further awareness of energy-conscious invention. The outcome of this step that the designers became more aware of old strategies that depend on non-mechanical methods, in order to improve the comfortable atmosphere. For an example in hot-dry and warm, humid zones cooling is a priority than heating, for this demand many elements support natural techniques applied in these buildings for many decades, such as courtyards, mashrabiyya, wind towers and ventilation tunnel (Noble, 2007). Noble in his study focus on the cooling techniques around the world, he found that in hot, dry and humid regions, vernacular design techniques involved elements in providing a cooling environment such as (high opening window, building orientation, shading device), while in the United State of America, ventilation tunnel is popular in the region. In Middle Eastern countries mashrabiyya and
ventilation through water elements used in a humid area, whereas in the dry area they used wind tower and courtyard.

This research will focus on the courtyard as an element that provides the cooling to the building. The significant role that played by the courtyard in building design of many regions, shown during warm weather (Muhasilen, 2006). The elements of the courtyard have unique advantages in hot and humid climates as passive cooling systems, which has ability to cooling the building and offers the thermal comfort for users’ (Sadafi et al., 2008). After many attempts of examining this tool, designers started to introduce the benefit of the courtyard on the first stage of building design, especially in green building and offer the best techniques that compatible with the building elements to gain significant impact of the courtyard.

However, during the construction or building refurnished, the elements of the courtyard as landscaping and water features could add to the building environment without change the structure of the existing building. Various efforts conducted field measurement or computer simulation, in order to improve energy efficiency in the buildings by incorporating courtyards as passive cooling technique.

1.2 Problem statement

Nowadays, most governments have made repetitive requests for preservation energy as well as global warning after the Kyoto protocol of 1997 was singed (Sadeghifam et al., 2015), and one of these countries is Malaysia. The traditional Malay buildings were designed according to the local needs and respects for nature; therefore, it is not surprising to find that the traditional house in the Peninsula can adapted natural strategies in ventilation, lighting and cooling (Ismail, 2007).

After Independence in 1957, Malaysia has developed in the economy, which in recent years, has successfully transformed from an exporter of raw materials into a diversified economy, this makes the country perceived speed development in all aspects, especially in construction. The desire to outline the architectural image of new nation leads to adapt the international style for the architecture of non-residential and residential buildings (Ju & Omar, 2011), according to Bakar et al., (2015), the increase in the number of modern buildings in Malaysia has an effect of the energy demand.
Another essential point is the climate characteristics of Malaysia, which caused the general temperature during daytime between 20°C to 32°C, while during night it reduced to 21°C to 27°C, with relative humidity around 75% to 90% and never went under 60%. Therefore, residential and non-residential buildings are subject to significant cooling necessities due to the high intensity of heat passing from building external envelope, the rely on mechanical cooling systems to gain indoor thermal comfort was directed to increase energy consumption. In fact, the percentage of electricity growth reached to 30% after 1st June 2006 (Puteh, 2007).

From the above points, this research focuses on reducing energy consumption in buildings by finding natural cooling techniques, in this research is to study the potential influence of courtyard in tropical climate in order to provide indoor thermal conditions and achieve low energy office.

1.3 Research questions and Hypothesis

This part deals with the research questions and the hypothesis that will address the objectives of this research, as listed follows:

Q1. Does the effectiveness of courtyard area will succeed to provide a comfortable indoor environment in an office building?

- **Hypothesis 1**: An Office building with a courtyard has a better indoor environmental condition as required by standards.

Q2. Does the introduction of courtyard area in an office building will be effective to reduce the total of energy usage?

- **Hypothesis 2**: The potential of the courtyard to lower energy consumption will efficiently reveal at single storey office building with full shade courtyard.


1.4 Research objectives

The aim of this research is to study the potential influence of a courtyard building, whichever as natural cooling technique, or as a micro-climatic regulator in hot-humid climates. The objectives of this research are as follows:

i. To investigate the courtyard history in Malaysia, through vernacular, contemporary vernacular and contemporary building design.

ii. To evaluate indoor thermal conditions of single, double, and three-storey conventional office buildings.

iii. To assess, the effectiveness of a courtyard on conserving energy at office buildings in Malaysia.

1.5 Research scope

The main motivation of this research is to offer indoor thermal conditions by using architectural and natural cooling strategies to reduce the indoor air temperature; also, it focused on lower energy consumption particularly on elements that related to mechanical cooling system. Conventional office buildings with single, double and three storeys that located in Kuala Lumpur and Johor were selected for the field measurement, the selected buildings had to be similar in the form of the courtyard, the total build area, the external envelope and the construction materials. Moreover, the number of persons accommodated in an office had to be similar. At last, the electricity in each building used in lighting, cooling systems beside office equipment’s (desk computer, photocopy and printers).

This research is carried out using observation of a courtyard configuration and building layout, field measurement and (POE) questionnaire to evaluate the users’ perception towards indoor thermal conditions, thus; to audit energy consumption in each building using electricity bills. Furthermore, a review of common research that conducted the courtyard as natural cooling methods and the tool that selected discussed in the following chapter.
1.6 Significance of research

Minimize heat gained is an important concept of building design of many regions; it is a serious economical aspect in terms of the first cost and operating cost. Over various methods to provide indoor thermal condition of buildings directed by using the courtyard area, several authors demonstrated that the air temperature in courtyard building is lower than the outer atmosphere.

The significance of this research appears through the reflection of courtyard area on providing comfort conditions, which could cause a positive impact on the occupants’ health and productivity, besides lowering the building operating cost by minimizing the total energy that used to offer indoor comfort.

1.7 Structure of the thesis

The research organized into five chapters and eleven appendices.

i. Chapter 1 Introduction: Described motivations, problem statement and objectives for this study.

ii. Chapter 2 Literature Review: Includes background on the courtyard types in different parts of the world, their historical evolution, and the basic forms along with the benefits. Furthermore, an overview of courtyard building types in Malaysia over three buildings type was added as a part of research objective. Furthermore, two parts of this study were investigated (energy consumption in office buildings and human thermal comfort). The chapter reports previous studies that conducted the effect of the courtyard as passive cooling strategies.

iii. Chapter 3 Research Design and Methodology: It is the descriptive part of the research. It describes the procedure or the methodology that adapted, and the characteristic of selected buildings. Moreover, the criteria that used for evaluation the environmental measurement and post-occupancy evaluation (POE).

iv. Chapter 4 Data Analysis and Results: This chapter presents the main research work detailing the research analyzing the measurement process and the questionnaire. The chapter provides the results and the validation of assessment the courtyard area and building layout; the result of environmental measurement, the result of POE questionnaire and the results of evaluate the energy consumption.
v. **Chapter 5 Conclusion and Recommendation:** Conclusion and recommendations are providing for consideration in future research of courtyard area at an office building.

vi. **The appendices** include case studies layouts, the environmental measurement, the questionnaire and table of electrical bills.

### 1.8 Summary

Nowadays the scientists around the world focused on the adapting methods that conserve the energy, this is mainly due to a probable future energy shortage as well as global warming. On the building sectors, engineers attempted to afford energy saving and sustainable strategies by adopting old passive cooling techniques. Ultimately, the courtyard is one of the traditional architectural that used to enhance natural cooling inside buildings, which it leads to offer indoor thermal comfort and conserving energy. Thus, courtyards in this research are under investigation in contemporary office buildings with single, double and three storeys.

The next chapter presents the literature review of the historical background of the courtyard. Thus, it deals with the courtyard type’s identification in different parts of the world, their historical evolution, the basic courtyard forms, and the benefits and liabilities associated with these forms. Thus, it illustrates a review of energy consumption in an office building and indoor environmental quality in office building. In addition, it reports earlier studies conducted at courtyard building as passive cooling strategies in different climates.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Courtyards are enclosed outdoor spaces but are normally open to the elements at their top; another definition of a courtyard according to Oxford dictionary is “An unroofed area that is completely or partly enclosed by walls or buildings, typically one forming part of a castle or large house.” A courtyard is a common design feature, which has applied for thousands of years in different regions of the world, mainly in houses. Courtyard used in basic as a gathering place for house users’, and for daily particular purposes in another area, it is used as encode (Edwards, 2006). Edwards revealed that the courtyards did not belong to specific period of history; it seems that it had always been around, the idea of the courtyards as a plan configuration goes back thousands of years to Neolithic settlements.

To the deep understanding of the court in all guises, it is useful to introduce the difference, between interior courtyard house and exterior terraced house. The courtyard house is a sign of urban pattern through the time, especially in the hot regions, the Middle East and North of African as an example, which provide an exclusive private part of the house. A terraced (or row) house always lies in road faces in it and is directly accessible to it from the outside. Andre Bazzana, mentioned the different characteristic of interior court and exterior to the economic status, the interior court was used by the sedentary farmer and the exterior court used by nomadic (Petruccioli, 2006).

The courtyard had the same form around the countries and different climatic regions; the basic design form of the courtyard is a center open area circling by wall enclosure. Generally, this design familiar in the arid climate of the Middle East,
gradually courtyards transformed over the time, so the activities that once took place outdoors begin to take place indoors.

### 2.2 History evolution of courtyard Form

Courtyard housing is known as the oldest form of residence. The historical evolution of courtyard configuration across the world showed in ancient civilization from excavated at Kahun in Egypt, which back to 5000 years old to the Chaldean City of Ur before 2000 B.C. (Oliver, 2003). The characteristics of courtyard housing depend on the environment and the culture of a group of the specific region; for an example, courtyard may use as an inner garden, or there is may function as the focal point in the house. Through thousands of years different planning of courtyard housing was demonstrated, Sumer and Pharaonic Egypt recorded as the oldest culture of the Middle East, which hold the oldest example of the courtyard (Ayhan & Neslihan, 2011).

At 700B.C, in Italy a new courtyard design, which refer as atrium house, was developed from the old form, the purpose of this type is to provide private outdoor space. While, atrium house met up with the Greek pre-style, the atrium design showed small courtyard enclosed by columns (Das, 2006). On the other hand, in the Middle East courtyard house is an architecture tool, that are common in hot and dry climates, it was held in many ancient cities and attempts to generate private area for introversion (Al-Azzawi, 1994).

#### 2.2.1 Ancient civilizations

From north of Africa particularly in Southern Tunisia a troglodyte village in Matmatas found, it was the most primeval society, which built houses with courtyard (Taleghani et al., 2012), the first prototype of the courtyard introduced in many regions in south, west and north Africa, also in Morocco (Das, 2006), figure 2.1 shows the different types of the courtyard plans in Africa.

Another example that reveals in the archeological survey found at Ur on the Euphrates River in Mesopotamia in 2000 B.C as shows in figure 2.2, the plan showed a square courtyard that surrounded by rooms on the ground floor, and the second floor of
the house is open to the courtyard (Al-Dawoud, 2006). In China, primary houses have significantly influenced by religion and the philosophy of Yin and Yan; moreover, the courtyard used for privacy and meditation (Das, 2006). Even the form had another attribute from the first example of Ur, instead of surrounded by rooms, the Chinese courtyard surrounded by an individual, which belong to different people. Garden and water features were two signs for the courtyard, thus they are used as a cooling tool in a warm climate in the Southern area (Bridson, 2012), figure 2.3 illustrates the typical layout of Chinese dwelling and courtyard houses, while, figure 2.4 presents the typical layout of the Japanese traditional house. Another religion philosophy of courtyard house found in Islamic civilization, the court area used normally by family members, the courtyard have been surrounding by the house itself or high wall and is an “open to sky” area that used as living extension area for the house members. Most of time guest is welcome to use this area but with separation genders, the courtyard area of Islamic house is organized well to ensure no mix between genders (Edwards, 2006), figure 2.5 illustrates traditional courtyard with street view of courtyard with high level wall.
Figure 2.1: Different types of courtyard plans in Africa
(Schoenauer & Seeman, 1962)

Figure 2.2: Plan of House at Ur, Mesopotamia
(AI-Dawoud, 2006)
Figure 2.3: Typical layout of Chinese courtyard houses and street
(Schoenauer & Seeman, 1962)

Figure 2.4: Typical layout of Japanese traditional house
(Schoenauer & Seeman, 1962)
2.2.2 Classical civilizations

In Italy, the development of the courtyard took another kind of design in 700 B.C that named as the atrium house. The atrium house design had a small courtyard surrounded by rooms, with a container in the center of the courtyard to gathering rainwater to drink. The main purpose of this design, which is an open to the sky is to provide a private outdoor space. Another era of the courtyard house appeared around 275 B.C. when the Roman architecture became a mix feature, which inherited from the Etruscans and the Greek after occupied of Southern Italy by Romans (Al-Dawoud, 2006).

Furthermore, the atrium house was met up with Greek pre-style (court enclosed two columns), when people started to build a big house contained two styles (atrium and pre-style). Any one of these styles had their location in design, atrium near to street and pre-style in the back of the house, figure 2.6 presents both classical era of the courtyard house and atrium.
2.2.3 The Middle Ages and Renaissance civilizations

Das (2006), emphasize that after the fall of Roman Empire by A.D. 476, the courtyard type dwelling suffered relapses and found in Italian Cortile and monastic cloisters. During Christian architecture era, the atrium style became familiar in early churches, which it used as a meeting place. In the center of the colonnaded open court, there was a fountain or well that used by worshiper to wash their hands before entering the church.

In some Islamic countries at the Middle and East North Africa, a courtyard house or which known as “Dar” follows the philosophy “privacy and seclusion with a minimal display of the occupant’s social status to the outside world”, private courtyard offers isolated space for women to relax with sheltered courtyard trees, a pool, and outdoor furniture. Another element of the design of courtyard (serdab), appeared in Mesopotamian region, this room used as a retreat cool air to the house figure 2.7 shows courtyard house design in Morocco and Baghdad at that era (Das, 2006). According to
Das, there are two Courtyards in northern area around the Mediterranean Sea. Particularly in Spain, that influenced by the Roman atrium, the design of the courtyard in the north of Spain is more solid than the Southern, which used the court for more outdoor activities that help the evolution of the courtyard dwelling type.

Figure 2.7: Courtyard houses in Morocco and Baghdad during Middle ages
(Bloom, 2009; Edwards, 2006)
2.2.4 Modern civilizations

In Europe, a single storey courtyard houses became widespread when this type of house design requested by low-income class, the first detached courtyard built in the South by Hugo Haring in 1929 (Jones, 1999). The design of the house like today mobile house with thin and narrow structure, by 1931 (L shape) plan modified by Hilberseimer who recreate new design that separate living room from bedrooms’ area, which became popular in England and Germany until the 1960s. Figure 2.8 presents L shape courtyard house designed by Haring and the new design by Hilberseimer.

In United States, the courtyard entered to the West Coast of North America and revealed in the Southern California due to the influence of Spanish colonial, whereas another opinion mentioned that, the reason of the different building’s style of Los Angles influenced by the movie set and film industry. Stefanos et al., (1996), observed that the tourists who settled down in California between 1880 and 1930 created need to high accommodation that, changed the form of courtyard houses in that region. During 1920s building designer included the several architectural elements of classical era of French and Italian renaissance besides vernacular form of rural Spain to develop new courtyard house (Polyzoides et al., 1992), which mixed between variant forms figure 2.9 illustrates courtyard house in Los Angles in 1928 and 1929.

![Hugo Haring single aspect house and Hilberseimer courtyard](image_url)

Figure 2.8: L shape Courtyard houses designed by Haring and Hilberseimer
(Morton, 1990)
2.3 Courtyard forms and elements

The courtyard does not have a specific plan, the first design of courtyard housing is usually rectangular, square and circle. These forms have been converting to accomplish ecological aspects such as site limitation, topography, building orientation and function to produce new forms [U shape, L shape, T shape, V shape, H shape or Y shape]. Figure 2.10 shows different possible forms for a single-family courtyard with one storey and two storeys. The scale and size of the courtyard can be adjusted from very close to expand the space, based on history evolution of courtyard house, it may say that the
courtyard area can be fully or semi-enclosed or surrendered by only two walls (Meir et al., 1995).

Different studies carried out to examine critically the performance of courtyard layout and the elements at both urban and architecture levels, to define the shortcoming, difficulties and the potential of future design development of courtyard layout. The rectangular layout of a courtyard studied by Tablada et al., (2005); the study recommended this form to protect the building from solar radiation and dusty wind. Furthermore, another study cited that three sides courtyard created preferable climate condition, especially when the orientation and ventilation sought during the design process (Meir et al., 1995).

Muhaisen (2006), investigated rectangular form proposition to gain the extreme effect in summer and winter in different four climates, while Rajapaksha et al., (2003) developed ecological condition through natural ventilation in high-rise residential buildings by used internal courtyard. Orientation, wall enclosure and natural elements of the courtyard were investigated as an essential architectural element that played significant role on the building climatic and the social aspect.

Figure 2.10: Different possible layouts for a single-family courtyard
(Edwards, 2006)
2.3.1 Orientation

Building layout is playing an important role in the courtyard orientation, thus the sun location, shading performance, solar gain and wind direction are an elements that could affect the courtyard microclimate condition (Bagneid, 2006). According to Meir et al., (1995) the correct orientation of the courtyard helps to develop indoor thermal comfort, the study also mentioned that unsuitable applied of solar angle and wind direction may cause thermal discomfort for building users’.

2.3.2 Wall enclosure

The term wall enclosure refers to the elements, which have a vital role on microclimate condition such as walls, windows, and doors, these components define the form of a courtyard with the building. Furthermore, designers during design stage can manipulate these elements to gain the positive impact of the courtyard.

Almhafdy et al., (2013a), investigated different functions of wall enclosure on the thermal performance. While, the effectiveness of the courtyard building with variant design condition such glazing type and window to wall ratio conducted by (Aldawoud, 2008). At last, color, materials, shading device and wall enclosure material studied as another option to develop the environment condition (Almhafdy et al., 2013b).

2.3.3 Natural elements in the courtyard

The natural elements within the courtyard found that increased the comfort condition, also have potential to reproduction environment benefits, as an example, shrubs, trees and flower plant used to shade areas. Thus, used water body, water spray and tent was found that the internal courtyard and surrounding area be cooler especially during the sunny hours (Almhafdy et al., 2013a).
2.4 Courtyard benefits

Over the time, scholars cited many advantages of the courtyard in order to define courtyard social and ecological functions. These benefits are psychosocial benefits, cultural benefits, religious benefits, economic benefits, climatic benefits and architectural benefits.

2.4.1 Psycho-social benefits

The base of the courtyard profits is finding by it is inner form, which offers a sense of confidentiality and enclosure to the house (Sthapak & Bandyopadhyay, 2014). However many theories’ set the court acts as:

- Space for interaction for all family members, and encourage the family to act as a group.
- Visual privacy, when the court visually secluded, by screening or walled entrances.
- Sleeping area during the night when the climate is conducive to outdoor activity.
- Acoustical privacy, enclosure elements works as a noise barrier between the courthouse and outside area.

According to Rust (2010), the courtyard can play a role in healing procedure, shaded trees, water, and flowers are an example of these features, also wind tower, pavement, and materials colors all these could provide positive effects towards the five senses of human body. Study at Hong Kong university campus by Lau & Yang, (2009), shown that the garden within a courtyard that located normally at the entrance, and the meditation garden that found near to library has specific purposes and should have a differentiate pattern and landscape design. The meditation garden is better for study environment while the garden within a courtyard supports public social interaction. Toone (2008), evaluated the effect of healing gardens in order to reduce stress in children medical center in Austin, the finding revealed that the stress level is lower when patient sitting at healing garden more than the indoor area.
2.4.2 Cultural benefits

Use more than one courtyard is normally in traditional design; this is usually to segregate the public and private spaces within the house. The public space is mainly for guest and generally used by male (especially in an Islamic countries), whereas, the inner court is more restricted to the female members, generally it use as an outdoor area for activities (Das, 2006).

2.4.3 Economic benefits

The design of courtyard house shown it is efficiency in land use, when adjoining courtyard houses share walls, generally the courtyard form is flexible interior spaces. Moreover, in a courtyard house each room can modify into serving multiple purposes (Sthapak & Bandyopadhyay, 2014).

2.4.4 Climatic benefits

With the right position of the house and suitable material, the courtyard could help to reduce the heat gain; this will act efficiency with the properties of self-shading and thermal lag. Finally, another benefit of the courtyard that it could act like a cool air reservoir especially in hot-arid climates (Sthapak & Bandyopadhyay, 2014).

2.4.5 Architectural benefits

The significant of the courtyard shown by it is position in the central of the house enclosed by various courtyard and trees elements, which promoted our social and working life (Meir, 2000). Moreover, the courtyard fulfills visual and acoustic protection to the building, for a reason the geometry of the courtyard and the properties of the finishing materials should take priority during the design stage to afford a high level of thermal comfort.
2.5 Courtyard disadvantages

Despite the many benefits of the traditional courthouse, many scholars also highlighted certain disadvantages of this form. Das (2006), cited that the typical structure of the courtyard house, (low storey open -to- sky) may be susceptible to burglary, the design of the continuous roof and shared wall may help burglars to climb easily and find access to the courtyard. Moreover, the open court brings nature to the atmosphere, which means different insects can come easily into the house, also if the courtyard had a water spring or a fountain, it can be easy to breed mosquito. Therefore, care should take to dry water and prevent the occupants from discomfort and ill. In addition, the outdoor space had an inclination for collecting dust; therefore, the courtyard area needs to repeatedly clean and maintained.

On the other hand, the inner courtyard draws private and insolate family activities, especially for the children, it may seclude them from the other neighbors’ children this could create negative effect on their social behavior with the outside community. There is a stereotype among low-income people, who clarified that the courtyard form is a sign of poverty for low-income people, for this reason there is a movement of linking this form of low construction methods with modern concepts, like mechanical ventilation to improve the performance of natural ventilation.

In spite of the disadvantages of the courtyard resulting from the appropriate design or the material and construction techniques, the basic advantages of the courtyard still overcome the barriers.

2.6 History of courtyard in Malaysia

The history of the courtyard in Malaysia goes back to the era of an indigenous design of Traditional Malay house, the inner courtyard at Malay house was inspired from the traditional Chinese houses (GhaffarianHoseini et al., 2014). The next paragraphs will focus on investigating the history of the courtyard in pensuila Malaysia to achieve the objective number one “To investigate the courtyard history in Malaysia”. The review of the courtyard building covered particularly on three era of building designs in Malaysia vernacular, contemporary vernacular and contemporary building design. The assessment
started before the independence in 1957 and transformed through time until the dawn of the new millennium.

2.6.1 Courtyard in vernacular building design

The term “vernacular” originates from Latin vernacular, that meaning native, commonly it used to indicate tribal, indigenous, peasant, folk and traditional architecture (Sim, 2010). According to Chen (1998), vernacular house forms developed due to different culture settings, thus, it was a result of the continuing adjustment, shared experiences, innovation, and adaptation. However, the design concept of Malay vernacular house was studying through the time from many scholars, to gain knowledge of traditional design techniques such as building form and physics, bioclimatic factors, thermal comfort, natural resource and tourist attraction.

The integration of courtyard concepts in the vernacular Malay house has been transmitted from generation to another, Malay in the past had design skill that presented the role of courtyard elements. On the other hand, house with surrounding courtyard imitates the simplicity of the society according to their beliefs and philosophy (Ismail, 2002). Thus, there is a link between the residences activities and the elements in the courtyard; in general, the Malay courtyard developed in vernacular house was to accomplish harmony with the environment. Zakaria et al., (2013), mentioned that early Malay has had strong awareness about involving every element in the court to compatible their daily life needs with the environment.

According to Sim (2010), the courtyard was introduced from urban Chinese design and linked to the elements of vernacular Malay houses. Figure 2.11 reveals an additional system in traditional Malay house the highlighted figure shows the developed of Malay house, as per the highlighted part illustrated the introduction of courtyard area in the building design (Yuan, 1984), while figure 2.12 shows the design of an old Malays house surrounding by landscaping elements.
Figure 2.11: Additional system of old Malay House
(Yuan, 1984)

Figure 2.12: External environment of Malay house
(Yuan, 1991)
The Malay courtyard had two main components, soft elements (vegetative materials) and hard elements (which known as courtyard furniture). Ahmadi (2004), investigated on the types of soft elements that usually find in Malay courtyard, he arranged the plants to three categories fruit plants, ornamental plants and food and medicine (herbs) plants. Furthermore, there are varying types of plant normally found in Malay house such as Canangium odoratum (Cananga), Cocos nucifera (Coconut), Vallaris glabra (Kesidang), Jasminum sambac (Jasmine), Areca catechu (Areca nut), Cymbopogon nardus (Lemongrass), Languas galanga (Galangal), Zingiber (Ginger), Lawsonia inermis (Henna) and Curcuma domestica (Turmeric) (Zakaria et al., 2014).

The hard elements normally refer as the man-made elements; it reflects the individuality of the region, table 2.1 illustrated a list of courtyard furniture in the vernacular house in Malaysia as mentioned by Zakaria et al., (2014). Generally, the cultures, the geographic distribution, have played a significant role in the design and arrangement of the courtyard in Malay Community, and the movement of ethnic groups from place to another.

The arrangement of Malay courtyard depends on the area compound, the old Malay house divided into three areas (front compound, side compound, and rear compound). The front compound is an area, which situated in a front courtyard as a play area for children, also to entertain guest. Side compound is located on the left and right side of a house, it has two functions first as the road to connect between rear and front compound and play area. While, rear compound is a space that connects the kitchen activities (cooking, washing and bathing); moreover, it used by women during gathering activities.

The settlement of soft and hard elements based on the function of each area. However, the arrangement of the elements is different from zone to another in Peninsular Malaysia; according to a geographic area, Malaysia could divide into four zones; figure 2.13 referees community courtyard according to each zone (the northern zone, middle zone, the southern zone and the eastern zone). In addition, there was another type of courtyard house in Malacca, that brought by the Chinese traders when they settled in Melaka (shop houses and town houses).


Azuan, Z. M., & Ismail, L. H. (2012). Natural Ventilation Approached on Circular Courtyard. The International Conference on Civil and Environmental


Tariq, M. (2011). Campus planning and design: exploring the programmatic elements involved in creating residential campus courtyards. (Master of Landscape Architecture), Mississippi State University, Mississippi.


