

# Alam Cipta

International Journal on Sustainable Tropical Design Research and Practice  
Volume 12 (Issue 2) December 2019 ISSN 1823-7231



Faculty of Design and Architecture  
Universiti Putra Malaysia

# A l a m C i p t a

International Journal on Sustainable Tropical Design Research and Practice  
Vol 12 (Issue 2) December 2019 ISSN 1823-7231



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### PLANNING AND DESIGN AS A BASIS FOR SUSTAINABILITY DEVELOPMENT GOAL SUHARDI MAULAN<sup>1,2</sup>

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The scope of ALAM CIPTA is about sustainability in the context of research, planning, design and practice. With the issues that we are facing now such as severe drought, flooding, desertification, loss in biodiversity and increase urban poverty level, the world needs drastic measures and actions. Since the publication of Brundtland Commission Report in 1987, many discussions had been held and several global level initiatives have been launched during United Nations (UN) Conference of Parties (COP) Summit and among the notables are Rio Earth Summit 1992, Kyoto Protocol 1997 and Copenhagen Accord 2009. The needs for sustainable development are very much a concern for the world hence in 2015, United Nations via its General Assembly launch Sustainable Development Goal (SDG). SDG is a framework or a collection of seventeen goals designed to be a blue print to achieve a better and more sustainable future for all (United Nations, 2015).

The seventeen SDG are (1) no poverty, (2) zero hunger, (3) good health and wellbeing, (4) quality education, (5) gender equality, (6) clean water and sanitation, (7) affordable and clean energy, (8) decent work and economic growth, (9) industry, innovation and infrastructure, (10) reduced inequalities, (11) sustainable cities and communities, (12) responsible consumption and production, (13) climate action, (14) life below water, (15) life on land, (16) peace, justice and strong institutions, (17) partnership for the goals. There are indeed very broad and expand the three basic tenets of sustainability which are environment, community and people.

However, it is very important to note that many of these goals cannot be achieved without strong support from creative planning and design exercise. In other words, the SDG is intertwined with planning and design. In the context of architecture, landscape architecture, urban planning and product design; sustainability is always or should always be at the back of every designers and researchers minds and creativity. What ever they do, they must

show their concern how their works will affect sustainability. For example, for architects, any building they designed, they must ask; what is the impact of their design to SDG such as affordable and clean energy. For landscape architects and planners, for every land they planned what is the consequences to SDG, for example, sustainable cities and communities. Even for industrial and product designers, how their products that they designed can affect SDG such as life on lands. For engineers, whatever they plan and design for, how it impacts SDG especially industry, innovation and infrastructure should be think about.

Eight articles have been published in this issue and two articles are brief communication on standard and measurement tools to enhance design. One article discusses on the needs to use Malaysian Standard (MS966) to boost health and safety of children and another article review building performance tools to ensure the buildings are at high quality. These two articles directly related to SDG 3: good health and wellbeing. Another two articles discussions are related to SDG 14: life below water and SDG 13: climate action when they discuss the impact of water activities to the health of waterways and influence of environmental settings towards the pedestrian's thermal comfort in tropical settings.

Meanwhile, four articles are related to SDG 3: good health and wellbeing, SDG 11: sustainable cities and communities and SDG 7: affordable and clean energy. One article discusses on the needs to international support for marine based community livelihood and another article discuss workers perception for thermal conditions of the working spaces. Motivational factors among quantity surveyors also been discussed in one of the articles to ensure they are competent in the competitive jobs' markets. Sustainable cities rely on the cities ability to preserve culture heritage and one article discuss the needs to preserve the old and heritage trees in the historic urban park.

As we see it, planning and design research and practice is a basis or perhaps the most important foundation to achieve SDG. It is a fact that whenever we design and plan, the output may have impact or change the form, shape and spatial quality of the environment surround us. It is a powerful tool and therefore, for all of us, researchers and designers in the creative field, have an important role to play for SDG and it is a very important one. Here, we are proudly saying that ALAM CIPTA is already playing their part.

ALAM CIPTA accepts articles that concern with architecture, art, and design related to the process, methods, techniques, practices, and theories in expanding our understanding to ensure sustainability. All articles in this issue provide very relevant knowledge about how can we plan and design our environment, built environment and products better. On behalf of the editors, I would like to thanks all the authors and reviewers who had work very hard. Your contribution is very valuable as it helps the advancement and dissemination of knowledge to "cipta" [create] a better world. We encourage your feedback at [alamciptaeditor@upm.edu.my](mailto:alamciptaeditor@upm.edu.my) and thank you for your continuous support of ALAM CIPTA.

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## APPLICABILITY OF MALAYSIAN STANDARDS (MS 966) IN BENEFITING HEALTH AND SAFETY OF CHILDREN IN MALAYSIA

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### ABSTRACT

*Child injuries caused by unsafe climbing equipments has become a public concern. The Malaysian Standards for playground equipment (MS 966: 2001 and MS 966: 2017) was developed and reviewed periodically by the authority of the Consumer Products, Personal Safety and Services Industry Standards Committee, Department of Standards Malaysia (DSM) and SIRIM Berhad, as a means of protecting and benefiting the health and safety of children. This paper aims to examine and critique the applicability of Malaysian Standards on standardizing design specification and safety performance of climbing equipments. The review process focuses on information gaps within the Malaysian Standards in terms of feasibility, where discussions on analytical issues in Malaysian Standards of climbing equipment was presented and recommendations on improvement were proposed. The result showed the standards focused mostly on swings and slides, whilst three analytical issues found that important design and safety standards in climbing equipments were unclear; which included free fall height, maximum height and designated age group. These three analytical issues have to be revised in order to achieve sustainable design in climbing equipment. Results from this paper could assist in revising the current standards incorporated with advanced urban recreation safety for injury control.*

**Keywords:** : Playground, Outdoor injury, Public health, Urban recreation safety, Recreation equipment

### 1. INTRODUCTION

Recently, children in Malaysia suffer from playground injuries caused by unsafe climbing equipments. It has become a public concern and topical issue where current design standards must be looked into. Public Complaints Bureau Director-General, Harjeet Singh said between 2015 and 2016, local authorities had received 11,231 complaints regarding playground injuries, while based on the injury statistics from the Ministry of Health (MOH), 530 injuries caused by falls cases were reported in public hospitals involving playground equipment between 2014 to 2016 (Jolyn N., 2018). According to Zain in 2012, 75% of playground injuries were caused specifically due to falls, and climbing equipment was accounted for causing the most injury among children. Meanwhile, through the years it was still publicly known to be one of the most popular equipment among children (Bourke & Sargisson, 2014; Mani et al., 2012; Mc Donald, 2001; Sargisson & Mc Lean, 2013).

As reported by Oh in 2014, according to a Certified Playground Safety Inspector (CPSI), Noriah Mat, although most local playgrounds do not comply with the safety and maintenance standards, they were generally MS 966: 2001 (Playground Equipment) compliant. Noriah Mat claimed that Malaysian Standards on playgrounds were not stringent and has not changed much over the past 20 years. Noriah Mat, (Sara J. M., 2016) reiterated further the need for a comprehensive nationwide study of playgrounds in Malaysia and reaffirmation of Malaysian safety standards. High fall injuries cases of children in playgrounds' were mostly caused by unsafe climbing equipments also actuated DSM to review the existing scope and requirement of MS 966: 2001 and MS 966: 2017 (Playground Equipment) Improvised

design guideline could help to promote greater and better safety awareness among those related parties including manufacturers, parks and recreational personnel in producing safer climbing equipment (Sara J. M., 2016).

Moreover, a recent study showed 90% of parents were dissatisfied with the safety level of existing climbing equipment (Ling, C.K., Azmeer, R. A., Dolah, M.S., Hasley, S., & Bolong, J., 2018). Although there was no direct injury data from MOH with regard to unsafe playground equipment, however, general data on children injuries based on per visit reported to MOH was obtained. Data showed that children nowadays always suffered from injuries involving the head (4,227 visits), followed by injuries to the elbow and forearm (2,833 visits) and injuries to the shoulder and upper arm (2,138 visits)(Refer Table 1). Results from this data were close-related to children injuries which occurred in playgrounds; therefore, design standards of climbing equipment shall be revised by focusing on reducing the top three types of children injuries.

*Table 1: Top 3 diagnosis based on number of visit in MOH hospital caused by injury among children between 3 to 12 years old, Malaysia, 2015*

	Description	Code ICD-10	Number of visit
1.	Injuries to the head	S00-S09	4,227
2.	Injuries to the elbow and forearm	S50-S59	2,833
3.	Injuries to the shoulder and upper arm	S40-S49	2,138

*Source: Patient Database from MOH hospitals, 2015 (updated in Julai 2016)  
Planning Division, Ministry of Health Malaysia (MOH)*

Nevertheless, according to Sarah in 2016, a research and policy manager from the Malaysian Association of Standards Users also encouraged collaboration and contribution from all related parties to help in providing critical reviews to construct the revision and implementation of the MS 966: 2001 and MS 966: 2017 for it to become a success.

Based on these data, it has verified the need for a critical review on Malaysian Standards regarding climbing equipments. Malaysian Standards was developed by the technical committee on playground equipment under the authority of the Consumer Products, Personal Safety and Services Industry Standards Committee. The result of the study could provide major information for technical committees on playground equipment, and also for the Department of Standards Malaysia and SIRIM Berhad that periodically

reviews the Malaysian Standard (MS 966), which was significant for allowing Malaysian children to play with safe and trustworthy climbing equipment.

### 2. METHOD

This study aims to examine and critique the applicability of Malaysian Standards on standardizing design specification and safety performance of climbing equipment. The applicability of Malaysian Standards on climbing equipment plays a crucial roles in protecting our children and it revolves around topical events of urban recreation safety. Three Malaysian Standards developed below by the technical committee on playground equipment under the authority of the Consumer Products, Personal Safety and Services Industry Standards Committee was reviewed:

- i. MS 966: Part 1: 2001 (Playground Equipment: Part 1: Specifications for Materials (first revision)
- ii. MS 966: Part 2: 2001 (Playground Equipment: Part 2: General Safety Requirements (first revision)
- iii. MS 966: 2017 (Playground Equipment – Safety Performance for Public Use – Specification (second revision)

Since this paper aims to discuss the applicability of Malaysian Standards on climbing equipment, the review will look further on information gaps and data collected which were criticized in terms of feasibility. Discussions on analytical issues within the Malaysian Standards of climbing equipment were presented and recommendations for improvements were proposed.

### 3. CRITIQUE, DISCUSSION AND RECOMMENDATION

#### 3.1 First analytical issue: Designated Age Group

According to the current standard, to ensure the general safety of users, the dimensions and degree of difficulty of the climbing equipment should be suitable for the intended users or age group. Designers should take note that equipments are designed so that the risk involved in play is apparent, obvious and foreseeable by the children. However, it was not really reliable to assume all children are mature enough to ponder over which equipment was designed for their age group. They will probably consider all pieces of equipment installed in a playground were designed and safe for them to use. It was proposed for a partition to be located in two different areas targeted for the intended age group – (5 to 12 year old) and (all ages of users).

<p><b>4. Safety requirements</b></p> <p><b>4.1 General</b></p> <p>The dimensions and degree of difficulty of the equipment should be suitable for the intended users or age group. The equipment should be designed so that the risk involved in play is apparent and foreseeable by the child.</p> <p>NOTE. For additional safety of equipment accessible to children under 36 months, specific requirements have been included for the following areas:</p> <ul style="list-style-type: none"> <li>- head entrapment (4.7.2 and MS 966 : Part 3);</li> <li>- protection against falling:</li> <li>- guardrails (4.4.3);</li> <li>- barriers (4.4.4);</li> <li>- stairs (4.9.2);</li> <li>- ramps (4.9.3).</li> </ul>
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Figure 1: Source: MS 966: Part 2: 2001 (Playground Equipment: Part 2: General Safety Requirements (first revision), pg 6.

### 3.2 Second analytical issue: Free fall height

Free fall height was always meant to be the main cause of child injuries (Zain, 2012) since it involved taking into account the possible movements of the equipment and its user. In general, the appropriate free fall height distance must be considered to lessen the risk of injury.

Table 2: Free fall height for different types of use according to MS 966: 2001

Type of use	Vertical distance from the surface of
Standing	Foot support to surface below
Sitting	Seat to surface below
Hanging	Hand support/foot support to surface below

Source: MS 966: Part 2: 2001 (Playground Equipment: Part 2: General Safety Requirements (first revision), pg 13.

According to standards in MS 966: Part 2: 2001, free fall height depended on different types of equipments, yet shall not exceed 3m. However, the term “depended on different types of equipments” in the standards caused confusion in setting the appropriate free fall height for climbing equipments. Subsequently, as for climbing equipments, free fall height was meant to be the maximum distance from foot support to surface below, yet 3m of falling distance from the highest foot support is apparently too high for climbing equipments that involved higher risks during playtime. Consequently, the

existing climbing equipment might not be safe for usage even though they were in accordance with the standards. Further study needs to be done on investigating the appropriate free fall height, specifically for climbing equipment.

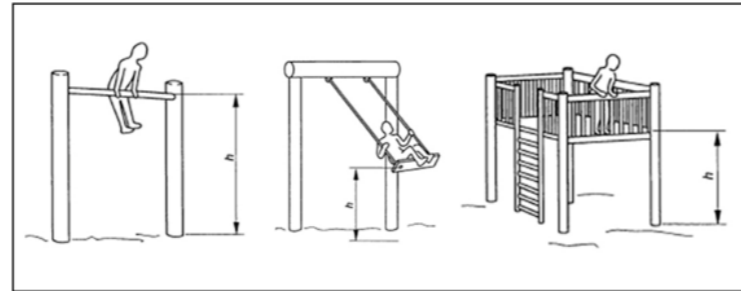


Figure 2: Example of free fall height  
Source: MS 966: Part 2: 2001 (Playground Equipment: Part 2: General Safety Requirements (1<sup>st</sup> revision), pg 37.

### 3.3 Third analytical issue: Maximum height

Rigid free standing climbing equipments usually use rigid rungs as hand support to ascent and descent climbing equipments. Rungs must be between 24.1 mm to 39.4 mm in diameter and shall not twist or rotate about its own axis. The free fall height for these equipments shall be distanced between the highest part and the protective surface below the climbing equipments. However, there was no example enclosed in the standards. Besides that, the maximum height until the protective surface was not indicated in the standards; hence the maximum height should be set in the standard as a guide in producing safer climbing equipments. Formulating the maximum height for these climbing equipments in design standards was necessary. Even though every piece of climbing equipments had its own designated play surface, some children may try to go beyond the designated play surface and climb to the highest point.

## 4. CONCLUSIONS

The result from critiques on this paper revealed that both Malaysian Standards of playground equipment (MS 966: Part 2: 2001 and MS 966: 2017) are not applicable to playground climbing equipment developers. Three analytical issues found that important design and safety standards in climbing equipment were unclear; which include free fall height, maximum height and designated age group. Malaysian parents seemed to have lost their

confidence with climbing equipments (Ling, C.K. et al., 2018) due to the high injury rate involving children. Thus, immediate action must be taken fir clarity regarding climbing equipments (Zain, 2012) that abided Malaysian Standards, immediate action has to be taken. In a nutshell, this paper also shows significance and national findings on a topical event revolved around urban recreation involving children’s safety in playgrounds.

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## A CRITICAL REVIEW ON BUILDING PERFORMANCE SIMULATION TOOLS

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### ABSTRACT

*Building Performance Simulation (BPS) is an effective tool for informed decision making and providing feedback in all stages of building lifetime due to their ability to evaluate the effects of multiple parameters per multiple evaluation criteria. The energy, exergy, economy, environment, and occupant comfort (thermal and visual) are evaluation criteria in high performance building design. The decision variables or multiple parameters include architectural parameters, building materials traits, indoor and outdoor conditions, economic and ecological indicators, the characteristics of building services. Yet state-of-the-art BPS tools still need to overcome challenges to become more user friendly, improve simulation capabilities and tool interoperability. This paper surveys BPS tools by investigating their key features and limitations to help guide experts from all domains with energy efficient building design. Tool categorization based on multiple criteria is done and key findings are summarized in tables. Future development opportunities are elaborated.*

**Keywords:** : Building energy efficiency, building energy modeling, building performance simulation, decision-support systems.

### 1. INTRODUCTION

Today, a big part of the total energy consumption worldwide stems from buildings. According to the energy consumption statistics for different sectors in International Energy Agency report, buildings are responsible for nearly 30-35% of the world's total energy consumption (during construction and operation processes), and 40% of total CO<sub>2</sub> emissions (IEA, 2018). Reducing energy consumption and green house gas emissions in buildings through energy efficiency solutions is a key goal for achieving energy and environmental goals. Towards this goal, important initiatives have been started for improving energy performance of new and existing buildings. For example, Energy Performance of Buildings Directive (EPBD) (EU, 2002) published by EU European Parliament and Council in 2002 was aimed to build standards and a common methodology for evaluation of the building energy performance, and it was later revised in an attempt to start the applications for “zero-energy building” concept (EU, 2010). Similarly, U.S. Department of Energy's (DOE) Building Technologies Office instituted some goals to decrease the energy use intensity (EUI) of buildings almost 30% until 2030, and 50% over the long term (Hong et. al., 2018).

Identification of energy efficiency improvements for buildings is a difficult process. Buildings are complex systems with their architectural, mechanical, environmental and social aspects. There is no single parameter affecting building energy performance, on the contrary, the building performance is determined as a result of simultaneous interactions of multiple parameters. Furthermore, the design team generally have to optimize a large number of conflicting criteria such as energy demand, thermal comfort, indoor environmental quality, life cycle cost and more concurrently. As a result, there is a need for decision support systems like building performance simulation (BPS) tools that support decision-making and guide the design and operation of high performance buildings.

Hence the main aim of this paper is to survey the state-of-art in BPS tools, the validation concept, key developments, applications, and also to identify the current limitations and challenges for future development of BPS tools. This paper introduces the categorization of BPS tools based on their simulation principles and interoperability issue. A group of current validated BPS tools are analyzed and compared to each other according to several uniform criteria to illustrate what simulation tools are available in building design process to help architects, engineers and other design team members for informed decision making, and also what their strengths and limitations are within the specified framework. The promising and trending issues such as enabling cloud computing, uncertainty and sensitivity analysis, parametric design and single/multi objective optimization or user customization feature of these tools are investigated to provide a base plate for the future simulation frameworks.

### 2. BUILDING PERFORMANCE SIMULATION (BPS)

Today, the most widely used methodology to performance evaluation and analysis of building in both design and retrofit phases is simulations. Simulation is an imitation of the physical behaviors of a system. Identifying a system with certain number of internal variables, boundaries and external variables ensures the idealization, measurement and simplification of system's behavior in real world and the outcome is called a physical model (De Wilde, 2004). The definition of a set of relationships among the variables of the physical model results in a mathematical model, which is usually analytical in nature but sometimes involves making numerical approximations. Building performance simulation tools were developed to reduce the complexity of the basic algorithms, the computational load, and the expected inputs from the users. Detailed simulation tools labors the development of complex mathematical models and the representation of the each possible energy flow in the building (Doyle, 2008).

Building performance simulation tools are classified according to various criteria such as calculation methods, modeling levels and usage area. Clarke (2001) separated them into two groups according to calculation methods: 1) Simplified (static), 2) Detailed (dynamic). Most of the simulation tools widely used today utilize dynamic numerical methods. The dynamic tools that have a high accuracy results use either one of the finite difference, finite elements, boundary elements methods in order to calculate building energy loads, and thermal system interactions. Dynamic tools generally calculate on an hourly basis and for each zone individually in order to take into consideration of dynamic interactions between all thermal based building elements (i.e. building envelope, HVAC system, lighting and control systems) associated with comfort and energy consumption.

Alternatively, tools can be grouped in two types: the first one is design tools such Revit, Rhino, SketchUp, and the second one is detailed simulation tools such as EnergyPlus, DOE2, and TRNSYS (Hong et. al., 2000). Additionally, there exists other software (OpenStudio, DesignBuilder, Green Building Studio) that uses the other tools' simulation engines (Han et. al., 2018). Design tools are generally static programs and are used in the early design phase of the project. These are simpler and require less input than complex programs. On the other hand, detailed performance simulation tools are usually dynamic, integrated with calculation techniques for building loads and energy calculations, and can analyze the building performance completely. Besides, detailed tools also check the design to compliance with performance-based building energy standards.

Today, there are many BPS tools available in the market (IBPSA, 2019). Some are mainly used in academia, while others are provided as commercial tools, but each one has its imperfections in terms of accuracy and ease-of-use (Zhou et. al., 2014). The wide ranges of tools are used for specific simulation purposes and are able to analyze building performance in several performance categories such as whole building energy simulation, thermal load calculations, HVAC system selection and sizing, energy conservation measures, thermal comfort analysis, indoor air quality, weather data and climate analysis, building energy auditing and monitoring, lighting and daylighting simulation, air flow simulation, solar and photovoltaic analysis, rating and certificates, acoustic analysis, and life cycle analysis. Additionally, these tools can analyze building performance for a complex combination of geometry, building components and systems.

The selection of BPS tool is also a significant issue, since each stakeholder is interested in particular aspect of the project. Some of the selection criteria are summarized below (Hong, et. al., 2000; Attia et. al., 2012; Crawley, 2015):

- The level of accuracy and detail
- Usability and information management
- Data exchange capacity
- Database support
- Interoperability with building modeling
- Integration of building design process
- Speed and cost
- Ease of use

Although BPS tools have seen significant development, there are still several challenges for using them in design process. For instance, Ostergard et.al. (2016) has identified a number of challenges preventing deployment of these tools in design process: a) interoperability pointing out data exchange between BIM/CAD models and simulation programs, b) time-consuming modeling referring to the process of modeling building geometry, zones, HVAC systems, schedules, c) stricter and contradicting requirements to meet many performance objectives such as demanding for energy, building code, sustainability with the existence of trade-offs, d) lack of simulation guidance ability indicating tool's ability to guide the designer for proper solutions, e) limited reuse of knowledge referring not reusing and sharing experience between modelers.

Most recently, Hong. et. al. (2018) has surveyed the several studies pointing out the challenging issues in BPS tools, and by summarizing and making in-depth analysis, they demonstrated key challenges for future BPS development. The main challenges that cover several existing and emerging areas of BPS are presented in ten categories: (1) finding out the performance gap between predicted building performance during design stage and actual energy performance of the building during life cycle in order to achieve performance goals, (2) Modeling and accurately simulating human-building interactions, which affect significantly both building energy use and thermal comfort level, in order to represent expected occupants behavioral interaction with buildings and their effects on simulated building energy flows in design stage, and also to ensure control schemes for building operations to optimize building energy use and occupant thermal comfort simultaneously in building operation stage, (3) Improving the modeling capabilities of the performance simulation tools to accurately represent the actual performance of the model, and decreasing the discrepancies between simulated energy using thermal model data and the actual measured data, (4) Improving the applicability of building energy simulation during building operation, control and retrofit phases to identify and evaluate the most effective energy saving solutions for the building, (5) Ensuring modeling of operational faults such as control faults, sensor offset,

equipment performance degradation (Cheung et. al., 2015), to estimate of the severity common faults and hence to provide decision making in a timely manner, (6) Supporting the design of Net-zero-energy-buildings (NZEB), modeling passive and advanced control strategies, and quantitative evaluation and optimization of design alternatives. Moreover, enabling the simulation of renewable energy generation and on-site energy generation of buildings that are able to adjust electricity demand based on grid needs, (7) Supporting the simulation of city/urban scale building energy performance to aid urban planning, and to achieve energy and environmental goals, (8) Supporting a quantitative evaluation of energy use and CO2 emissions at national and regional scales, and making future projections, (9) Modeling the adoption of building energy efficiency technologies, and ensuring decision-making for research and technology development, and identifying the impact of adoption of new building technologies, (10) Supporting decision-making process across the building life cycle by ensuring the integration of four dimensions: data, domain, simulation tool and workflow.

The defined challenges derived from literature and their mitigations with respect to building life cycle process are summarized in Table 1.

Table 1: The summary of challenges and mitigation of BPS tools

Building Life Cycle Phase	Challenges	Mitigation
Design	CAD-BPS Tool Interoperability (interoperability, time consuming modeling, rapid change of design)	Integration of models, run-time coupling, and shared schema to ensure fast and consistent modeling.
Design	Data Integration	Data from all available sources should be integrated under the Building Information Modeling (BIM)
Design	Domain integration	Multiple technical domains must be integrated
Design	Workflow Integration / limited reuse of knowledge	BPS tools should be integrated existing project workflows through some platforms such as web based tools or other web services
Design	Stricter and contradicting performance requirements	Stricter (e.g. energy, comfort, building code) and contradicting requirements (increasing cooling consumption or worsen thermal comfort) should be handled by BPS tools

Design	Lack of simulation guidance	BPS tools ability to guide the project team to favorable solutions
Design & Operation	Finding out the performance gap between predicted building performance and actual performance	BPS supports verification of the building performance goals
Design & Operation	Modeling and simulation of human-building interactions	BPS encapsulates models of occupants' behavioral interaction with buildings, which affect significantly building energy use and thermal comfort
Design & Operation	Supporting the design of Net-zero-energy-buildings (NZEB), and grid responsive buildings	BPS should support the design and optimization of NZEB buildings, and simulation of building energy loads dynamics to adjust energy demand per grid needs
Operation	Energy model calibration	Improving the modeling capabilities of the BPS tools to accurately represent the actual performance of the model
Operation & Retrofit	Improving the applicability of simulations for building operation, control and retrofit phases	BPS tools' applicability during building operation, control and retrofit phases to identify and evaluate the most effective building energy saving solutions
Operation & Retrofit	Modeling of operational faults in buildings	BPS should support the modeling of operational faults to estimate of the severity common faults for providing a timely manner decision making
Operation & Retrofit	City/urban scale modeling and simulation of building energy performance	BPS should support the modeling and simulation of city/urban scale building energy performance
Operation & Retrofit	Evaluation the energy saving potential of building technologies at national and regional scales	BPS should support decision-making for research and technology development of building energy efficiency
Operation & Retrofit	Modeling the adoption of building energy efficiency technologies	BPS should support the modeling the adoption of energy efficiency technologies, and identifying the impact of new technologies

### 3.VALIDATION OF BPS TOOLS AND MODEL CALIBRATION

In building performance simulation, validation is the process of determining if a simulation model is a good representation of real world scenario (Oberkampff and Roy, 2010). The biggest problem with validating simulation programs is the complexity of actual operational conditions such as schedules, HVAC settings (Ryan and Sanquist, 2012). In general, there are three approaches for

validation: 1) Empirical, 2) Analytical and 3) Comparative (Judkoff, 1988). Empirical validation is based on comparing real-world measurement data with simulations results. Analytical verification stems from comparing simulation results with known analytical or numerical solutions. Lastly, in comparative testing, the simulation results from different programs are compared against each other. Analytical validation approaches are inexpensive and offer robust algorithmic solutions to certain thermal problems. However, it doesn't cover all sources of error and it can only validate the numerical portion of solution. On the other hand, empirical validation is expensive and time consuming due to the detailed measurements, and it can approximate the ground truth within certain accuracy, and deal with high level of complexity. The comparative analysis is a useful technique because it does not require data from a real building, however the great disadvantage of the comparative technique is the absence of a truth model (Judkoff, 2008).

Several organizations that specialize in building energy simulations have launched standards and guidelines for the validation process of whole building energy simulation programs, such as International Energy Agency Building Energy Simulation Test and Diagnostic Method (IEA BESTEST) and ASHRAE Standard 140. BESTEST was originally developed in collaboration with The National Renewable Research Laboratory (NREL) and the main aim is to compare building energy simulation outputs of a case building and to determine the error margins. BESTEST includes several case buildings and their related test results. The results of a model generated with any simulation program are compared with the test case and if the error margin is between the limits, the program passes the test and its accuracy and reliability are ensured by this way.

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) adopted the BESTEST method with some refinements in accordance with American National Standard Institute (ANSI) procedures and formed ANSI/ASHRAE Standard 140, Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs (ASHRAE, 2004; Neymark and Judkoff, 2008). ANSI/ASHRAE Standard 140 was first published in 2001, and updated last time in 2017. It sets a standard method to evaluate the applicability of software for thermal and HVAC simulations, and identifies the differences between whole-building simulation software.

Example of works that focused the validation of simulation tools and energy models are given. As an example for the empirical validation approach, the calibration process of building energy models in DOE-2 simulation program for both hypothetical and actual office buildings was demonstrated (Reddy et. al., 2007). Similarly, an existing high-rise building in Shanghai was created



and validated by using DOE-2 (Pan et. al., 2007). Calibration of a building energy model with double skin façade created in EnergyPlus simulation tool was done by using extensive empirical data from a dedicated experimental set-up (Kim and Park, 2011). A university building energy model created and simulated in DesignBuilder/EnergyPlus was calibrated by comparing collected measured data with simulation outcomes (Mustafaraj et. al., 2014). The calibration of an EnergyPlus simulation model of a school building with displacement ventilation and radiant thermal slab was presented (Kandil and Love, 2014). Six buildings located in a university campus in US were created and validated through comparing measured data with probabilistic simulation results (Sun, 2014). A calibrated EnergyPlus simulation model of an office was performed by using long-term monitored data from an office area (Tahmasebi and Mahdavi, 2016). The simulated building model on TRNSYS building performance simulation tool was validated with the National Institute of Standards and Technology (NIST) residential test facility in Gaithersburg, USA by integrating the NIST test facility design conditions into the TRNSYS model to simulate the heating and cooling loads (Harkouss et. al., 2018). According to comparison data between measured and simulated results, the root mean square error (RMSE) and the percentage root mean square error (PRMSE) were 1.56 kWh/ym<sup>2</sup> and 4% for cooling load, and 1.26 kWh/ym<sup>2</sup> and 6% for heating load. Hence the NIST experimental measures are good fit with TRNSYS simulation results and the validated building energy model was used for passive design optimization process. Similarly, an existing school building energy model was created with EnergyPlus simulation tool, and then by using the actual monthly utility data, the validation of the building energy model was done according to two indicators from ASHRAE Guideline 14: CV\_RMSE and NMBE were determined as 12.81% and 3.26%, respectively, and the base case energy model developed was considered acceptable (Senel Solmaz et. al., 2018).

As for the analytical validation, a mathematical model was developed to simulate the effect of the contraction of the HVAC system air duct insulation on the zone heat gain, supply air temperature (Kumar et. al., 2018). The model

was validated by comparing the amount of total heat gain between simulation and measured data (5 kW vs. 5.21 kW). Similarly, an analytical optimization methodology based on degree-days and life cycle cost analysis was used for optimization of building wall insulation material thermal properties (Kumar et. al., 2019), and the optimum insulation thickness were calculated based on energy savings, payback periods and CO<sub>2</sub> emission rates of buildings (Kucuktopcu and Cemek, 2018). As for the comparative validation, a thermal model of building was generated with EnergyPlus, and the model was validated according to ANSI/ASHRAE Standard 140- Case 600 (Rad et. al., 2019). According to results, the difference between ANSI/ASHRAE Standard 140 for modeling of case 600 by EnergyPlus and created thermal model are 3.24% for annual heating, and 0.67% for annual cooling.

As mentioned before in the main challenges of BPS, the significant discrepancies between simulated energy consumption data and actual data plays a key role for relying on model predictions, hence limiting the adoption of building performance simulation tools during building life cycle. So, building energy models should be improved to represent the building performance as closely as the actual performance of modeled buildings. This can be achieved through model calibration: the tuning of various simulation inputs to match predicted and observed energy usage (Reddy, 2006). While the simulation accuracy of building energy models is determined by thousands of parameters, there are usually limited measured data available as calibration inputs. Although, the simulation accuracy of the building energy models is determined based on a huge number of parameters, there are generally limited numbers of measured data available as calibration inputs. Therefore calibration becomes an over-parameterized problem with no unique solution where matching can be obtained in many different ways (Coakley et. al., 2014). Presently, according to ASHRAE Guideline 14 (ASHRAE, 2014), the standard for model calibration is defined, although it does not consider the uncertainty of simulation inputs or the accuracy of BPS tool. The main approaches to model calibration are categorized as manual and automated. Manual calibration approaches rely on iterative trial and error process driven

by users, a very time-consuming process due to the nature of trial-error process, and having no form of automation. On the other hand, automated calibration approaches based on mathematical/statistical techniques, and a number of automated calibration methods ranging from optimization techniques such as Bayesian calibration, object penalty function to other modeling techniques like artificial neural networks (ANN), meta-modeling have been developed in this area (Coakley et. al., 2014).

#### 4.COMPARISON OF BPS TOOLS

So far, the general overview of BPSs and various requirements and challenges has been presented. In this section, features and limitations of current validated and dynamic BPS tools are assessed. A reduced set of simulation tools has been selected for further investigation and comparison per several criteria (e.g. validation/accuracy).

The 9 selected tools are: DesignBuilder, EDSL-TAS, EnergyPlus, ESP-r, eQUEST, Green Building Studio (GBS), IES-Virtual Environment (IES-VE), OpenStudio and TRNSYS. The reviews and comparisons of the tools are made according to:

- The general properties of tools (i.e. major capabilities, expertise required, users, programming language/platform, license, developer/company)
- Tool integrated design stage, geometric modeling unit (design tool, GUI), simulation engine, interoperability/data exchange, user customization, performance criteria, applications/functions
- Main strengths and limitations, input and output file formats, weather data and validation

##### 4.1.Comparison of BPS tools per general properties




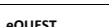
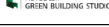

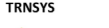

The comparison of the tools in terms of general properties including major capabilities (indicating the tool's main performance analysis), expertise

required, users (tool primarily intended for), programming language/platform, tool's license (open source or not), developer/company information is presented in Table 2. More specifically, the tools are mainly capable of making different performance analysis not for only energy criterion. For instance, some tools can perform an airflow analysis, parametric analysis and even single/multi-criteria optimization. The primary users of tools could be from multiple domains with or without deep understanding of building systems and technology. From an "expertise required" perspective, almost all the tools have similar requirements such as having information or good understanding about building physics and environmental systems, or having an experience with 3D geometry modeling with CAD/BIM systems, in order to use them and understand the simulation process and results adequately.

##### 4.2.Comparison of BPS tools per integrated design stage, GUI, simulation engine, interoperability, customization, performance criteria and applications

Since the categorization made in Table 2 is general, and there is a need for further investigation about the details of tool interoperability indicating how BPS tools integrate/connect to CAD/BIM environment. The detailed information for fulfilling this need is given in Table 3. The detailed descriptions of the categorization are as follows:

Table 2: Comparison of selected building performance simulation (BPS) tools with respect to general properties

BPS Tools	Major Capabilities	Expertise Required	Users	Language/ Platform	License	Company/ Country	Ref
 DesignBuilder	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>Load calculations</li> <li>HVAC system selection and sizing</li> <li>Parametric and optimization</li> <li>Air flow simulation</li> <li>Ratings and certificates</li> <li>Code compliance checking</li> </ul>	<ul style="list-style-type: none"> <li>No steep learning curve</li> </ul>	<ul style="list-style-type: none"> <li>Architects</li> <li>Engineers</li> <li>Building designers</li> <li>Building scientist</li> <li>Academic research and teaching</li> </ul>	<ul style="list-style-type: none"> <li>Linux</li> <li>Windows</li> </ul>	License is required, free to try	DesignBuilder software Ltd./UK	(DesignBuilder, 2019)
 EDSL-TAS	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>HVAC system selection and sizing</li> <li>Parametric and optimization</li> <li>Lighting simulation</li> <li>Airflow simulation</li> <li>Code compliance checking</li> <li>Detailed cost analysis</li> </ul>	<ul style="list-style-type: none"> <li>Qualified engineer and architect</li> <li>Training courses are not necessary</li> <li>Includes comprehensive tutorials</li> </ul>	<ul style="list-style-type: none"> <li>Architects</li> <li>Building services engineers</li> <li>Consulting engineers</li> </ul>	<ul style="list-style-type: none"> <li>Windows</li> </ul>	Free for non-commercial & academic use, free to try	Environmental Design Solutions Limited (EDSL)/UK	(EDSL, 2019)
 EnergyPlus	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>Load calculations</li> <li>HVAC system selection and sizing</li> <li>Lighting simulation</li> <li>Air flow simulation</li> <li>Code compliance checking</li> </ul>	<ul style="list-style-type: none"> <li>Background in building physics and mechanical engineering is helpful</li> </ul>	<ul style="list-style-type: none"> <li>Architects</li> <li>Engineers (mechanical, energy, control)</li> <li>Building auditors and operators</li> <li>Energy-efficiency policy analysts</li> <li>Researchers</li> </ul>	<ul style="list-style-type: none"> <li>Linux</li> <li>Windows</li> <li>Mac OS X</li> </ul>	Free/Open source license	US Department of Energy (DOE) & National Renewable Energy Laboratory (NREL)/US	(DOE and NREL, 2019)
 ESP-r	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>Complex buildings and systems</li> </ul>	<ul style="list-style-type: none"> <li>Researchers and building designers having good understanding of building physics, environmental systems and controls is necessary</li> </ul>	<ul style="list-style-type: none"> <li>Building designers</li> <li>Engineers</li> <li>Energy consultants</li> <li>Researchers</li> <li>Multi-disciplinary design firms</li> </ul>	<ul style="list-style-type: none"> <li>Linux</li> <li>Windows</li> <li>Mac OS X</li> </ul>	Free/Open source license	University of Strathclyde Energy Systems Research Unit (ESRU)/UK	(ESRU, 2019)
 eQUEST	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> </ul>	<ul style="list-style-type: none"> <li>Experience with energy analysis is necessary</li> <li>Knowledge of building technologies is required</li> </ul>	<ul style="list-style-type: none"> <li>Building designers</li> <li>Operators</li> <li>Owners</li> <li>Energy/LEED consultants</li> </ul>	<ul style="list-style-type: none"> <li>Windows</li> </ul>	Free/Open source license	James J. Hirsch & Associates/US	(James J. Hirsch & Associates, 2019)
 Green Building Studio (GBS)	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>Parametric and optimization</li> <li>Energy conservation measures</li> </ul>	<ul style="list-style-type: none"> <li>No expertise is required to use Green Building Studio</li> <li>3D-CAD/BIM experience is required for geometry modeling</li> </ul>	<ul style="list-style-type: none"> <li>Architects</li> <li>Engineers</li> <li>Construction managers</li> </ul>	<ul style="list-style-type: none"> <li>Web/SaaS</li> </ul>	Free for non-commercial & academic use, free to try	Autodesk Inc./US	(Autodesk Inc, 2019)
 IES-Virtual Environment (IES-VE)	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>Load calculations</li> <li>HVAC system selection and sizing</li> <li>Lighting simulation</li> <li>Code compliance checking</li> </ul>	<ul style="list-style-type: none"> <li>Software knowledge is required but includes documentation for learning</li> </ul>	<ul style="list-style-type: none"> <li>Architects</li> <li>Engineers</li> <li>Sustainability and Energy Consultants</li> <li>Building Owners</li> <li>Facilities Managers</li> <li>Contractors</li> </ul>	<ul style="list-style-type: none"> <li>Windows</li> <li>Mac OS X</li> </ul>	License is required, free to try	Integrated Environmental Solutions (IES)/UK	(IES, 2019)
 OpenStudio	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>Energy conservation measures</li> <li>Lighting simulation</li> </ul>	<ul style="list-style-type: none"> <li>Building physics and mechanical engineering background is helpful</li> </ul>	<ul style="list-style-type: none"> <li>Architects</li> <li>Engineers (mechanical, energy)</li> <li>Energy-efficiency policy analysts</li> <li>Researchers</li> <li>Students, educators</li> <li>Software developers</li> </ul>	<ul style="list-style-type: none"> <li>Linux</li> <li>Windows</li> <li>Mac OS X</li> <li>Web/SaaS</li> </ul>	Free/Open source license	National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy	(NREL, 2019)
TRNSYS	<ul style="list-style-type: none"> <li>Whole building energy simulations</li> <li>Parametric and optimization</li> <li>Detailed component simulation</li> </ul>	<ul style="list-style-type: none"> <li>No need an expertise for standard package use</li> <li>Fortran knowledge is helpful for generating new components</li> </ul>	<ul style="list-style-type: none"> <li>Architects</li> <li>Engineers</li> <li>Researchers</li> <li>Consulting firms</li> </ul>	<ul style="list-style-type: none"> <li>Windows</li> </ul>	Reduced for non-commercial & academic use	Thermal Energy System Specialists, LLC/US	(Thermal Energy System Specialists, 2019)

*Plugins for design tools to use external simulation engines:* These are plugins for different design tools (i.e. SketchUp, Revit) in order to couple with external simulation engines to perform specific simulations. Among the selected tools, OpenStudio and Green Building Studio (GBS) are in this group (Table 3). OpenStudio (NREL, 2019) is an open-source software development kit (SDK) that accompanies Sketch-up and takes care of constructions, schedules, HVAC systems of the energy model while Sketch-up is used for 3D geometry. It is originally developed for EnergyPlus simulation engine and now also supports ESP-r, Radiance for advanced lighting analysis, CONTAM airflow engine, CEN/ISO 13790, and the code compliance engine CBECC-Com. OpenStudio SDK can also be customized using Ruby and Python programming languages. A cloud-based service GBS (Autodesk Inc, 2019) is Autodesk's core whole building energy simulation tool that enables energy analysis for Autodesk Revit, Autodesk Insight 360 and Autodesk FormIt 360. It uses DOE-2.2 simulation engine for energy analysis, and creates accurate input files for EnergyPlus for interoperability at the same time. It provides decision making for design team by performing an entire building energy analysis, energy consumption optimization and the other sustainability criteria such as carbon data, water use, renewable energy, natural ventilation especially in the early design stage. GBS creates the energy model by automatically reading building information and geometry from Revit and 3D-CAD program.

*Graphical User Interface (GUI) without an external simulation engine:* This category includes the tools with a GUI and are being developed based on existing simulation engines such as EnergyPlus, DOE 2. Among selected tools, DesignBuilder and eQUEST are in this group (Table 3). DesignBuilder (DesignBuilder, 2019) is a comprehensive interface and visual modeling tool based on the EnergyPlus dynamic simulation engine for building performance evaluation. The program has its own modeling window, and includes a total of 11 modules: 3D-modeler, simulation, visualization, certification, daylighting, HVAC, cost, LEED, scripting, optimization, and CFD. It has several types of building templates, which have large amount of building information data regarding construction materials, schedules, occupancy, lighting, HVAC and more. When the specific building template is chosen, the corresponding building information data is brought automatically from the database and the users can modify these default settings according to their input data, and develop their own building energy model. DesignBuilder allows both inner creation of building geometry and import from other files such as dxf, gbxml file formats (IBPSA, 2019). eQUEST (James J. Hirsch & Associates, 2019) is a whole building energy performance design tool based on the DOE 2.2 dynamic simulation engine. It provides the design team assessment and detailed analysis of building energy performance throughout the entire design process from the conceptual stages to final stage with its detailed interface

and two design wizards (schematic design wizard and design development wizard). It provides users to import building geometry from CAD tool with (.dwg) and gbxml file formats.

*Tools with own GUI and simulation engine:* Among selected tools, IES-VE, EDSL-Tas, ESP-r, TRNSYS are in this group (Table 3). IES-Virtual Environment (IES-VE) (IES, 2019) building simulation tool was developed by Integrated Environmental Solutions (IES). IES-VE has its own simulation engine for energy simulation and RadianceIES for daylighting analysis, and encapsulates two packages: VE for architects and VE for engineers. It has its own visual 3D modeling block, providing users to create a building energy model directly in the tool, and also IES developed plug-ins for Revit and Sketch-up that ensures tool interoperability and interconnection between BIM and CAD tools in order to simplify modeling process. Therefore, IES-VE can also be categorized under the first group. EDSL-Tas (EDSL, 2019) is a dynamic whole BPS tool, and has its own simulation engine and user interface. It has a modular characteristic, with committed programs serving a specific application such as Tas 3D modeler for creation of building geometry; Tas building simulator and viewer for building information modeling, simulation, and viewing and exporting simulation results both 2D and 3D formats; Tas system for HVAC modeling and simulation; Tas ambiens 2D is for a modeling airflow in buildings and CFD analysis. Tas 3D modeller allows users to import data files such as dwg, gbxml, EnergyPlus input file (.idf), DOE2/eQUEST input file (.inp). ESP-r (ESRU, 2019) is a whole building energy simulation program with its own simulation engine and GUI for integrated modeling of building energy performance, and definition of building systems and equipment. Particularly, it allows users to define detailed HVAC and renewable energy systems. It is capable of simulating innovative technologies such as combined heat and electrical power generation, PV facades, 3D transient CFD, multi-gridding, and control systems. Transient System Simulation Program (TRNSYS) (Thermal Energy System Specialists, 2019) is a whole building simulation tool having modular system characteristics including its own graphical interface (Simulation Studio), a dynamic simulation engine and detailed component library ranging from variety of building models and standard HVAC systems to renewable energy systems. It enables users to create their new components. It is capable of simulating building energy and thermal comfort performance, sizing HVAC systems and their analysis, multi-zone airflow analysis, solar design and electric power simulation and more. TRNSYS is capable of interfacing with other simulation packages/software such as Excel, FLUENT, GenOpt and Matlab.

*Simulation Engine without having own GUI for geometry design:* This is the last group of tools, which were developed originally as a simulation engine

Table 3: Comparison of selected BPS tools in terms of integrated design stage, GUI, simulation engine, interoperability, customization, performance criteria and applications

BPS Tools	Integrated Design Stages					Design Tool/GUI	Simulation Engine	Interoperability/ Data Exchange	User Customization	Performance Criteria										Applications					
	Pre-design	Conceptual design	Design development	Detailed design	Operation & Management & Retrofit					Energy	Thermal	Daylighting	Environmental Emission	Life Cycle Analysis (LCA)	Energy Cost/Life Cycle Cost (ECC)	CFD Analysis	Code/Certification Compliance	Renewable System Analysis	Cloud Computing	Uncertainty/Sensitivity Analysis	Parametric analysis	Optimization			
Design Builder	✓			✓		Self	EnergyPlus/Radiance	File exchange	EMS, FMU, C#, Python scripting tool	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓				
EDSL-Tas			✓	✓		Self	Self	Standalone	TasGenOpt	✓	✓	✓	✓		✓	✓					✓	✓			
Energy Plus				✓		DesignBuilder/OpenStudio	Self	Standalone (IFC, gbxml)	EMS, FMI, External Interface	✓	✓		✓												
ESP-r				✓		Self	Self	Standalone	N/A	✓	✓		✓												
eQuest	✓	✓		✓		Self	DOE 2.2	Standalone	N/A	✓					✓										
Green Building Studio (GBS)	✓	✓				Revit	DOE 2.2 & Energy Plus	File exchange	N/A	✓		✓	✓					✓							
IES-VE	✓		✓	✓	✓	Self/Revit/SketchUp	Self & Radiance IES	File exchange	“Hone”, “Parametric tool” Python scripting	✓	✓	✓	✓	✓	✓							✓	✓		
Open Studio	✓		✓	✓	✓	SketchUp	EnergyPlus/Radiance	File exchange	API modification by Ruby, Python, C#, JavaScript	✓	✓	✓	✓					✓		✓	✓				
TRNSYS			✓	✓		Self/TRNSYS3D for SketchUp/TRNLizard	Self	Standalone	N/A	✓	✓				✓			✓							

without no 3D geometry design GUI. Among the selected tools, EnergyPlus simulation engine is the only one in this group (Table 3). EnergyPlus (DOE and NREL, 2019) dynamic simulation tool was designed with its own calculation algorithms, implements ASHRAE Heat Balance method for zone thermal modeling, and has the capability to build with a wide variety of system configurations and conditions. EnergyPlus is an advanced simulation engine that combines best features of DOE-2 and BLAST. Input file (IDF) is text based and created in IDF Editor, and its advanced simulation engine is used by multiple tools with GUI such as DesignBuilder, OpenStudio, Sefaira. The other comparison criterion in Table 3 is “integrated design stage”, indicating the design stage(s) the tool is specifically/typically used in. Generally, the building design process is separated into five stages: pre-design, conceptual design, design development, detailed design, and operation-management- retrofit. Most of the simulation tools are widely used in the later design stages such as detailed design, and their use in both early design and retrofit stages is limited. However, the design decisions being made in the early phases have a significant impact on final performance of building and project costs and the integration of the building simulations in early design stages should be increased. Similarly, the use of BPS tools in the operation, management and retrofit of existing buildings should be improved.

“Interoperability/Data exchange” criterion in Table 3 indicates the different ways that ensure the connection between CAD/BIM design tools/models and BPS tools. In the literature, there are four different methods of linking CAD and BPS models: integrated method referring to the situation that numerical calculations are integrated into CAD environment; run-time interoperability method indicating the links between CAD tools and analytical models constituted by plugins or application programming interface (API); file exchange method based on common file exchange format that is readable and also sometimes writable from CAD and BPS tools (i.e. Industry Foundation Classes (IFC), XML, gbXML, dwg); standalone method defining that the data is interpreted by users (Ostergard et al. 2016). So, most of the tool interoperability is based on the file exchange or standalone.

“User customization” in Table 3 points out if the simulation program allows users to customize via scripting, programming, or any advanced system. For example, EnergyPlus provides users to customize with Energy Management System (EMS), and enables co-simulation with other engines through Functional Mockup Interface (FMI). In addition, OpenStudio API can be scripted via programming languages such as Ruby, Python, C#, JavaScript in order to extend, customize and automate the design applications.

“Performance criteria” in Table 3 presents the significant independent performance criteria/objectives/categories for high performance buildings.

Each of these tools can be used for specific simulation purposes, and while some of them are able to analyze building performance for several performance criteria ranging from energy to CFD analysis, others are capable of making assessment only in limited categories, or specialize in very specific performance objectives. Therefore, application of interest determines the selection of simulation program. Among the selected tools, IES-VE dynamic performance simulation software has high capacity to assess building performance according to many criteria (e.g. energy, thermal comfort, daylighting, CFD).

“Applications” criteria in Table 3, encapsulates significant applications/functions that BPS tools have to support design team through an iterative process, giving feedback for making rapid design changes during the design process and ensuring informed decision-making. These applications are: ability of tools to make a parametric analysis, to perform uncertainty analysis (UA)/sensitivity analysis (SA), to perform a single/multi objective optimization, and to enable to cloud computing. DesignBuilder has a parametric analysis block inside the tool that can analyze the influence of design parameters on building performance, and identify trade-off relationships between parameters (DesignBuilder, 2019). IES-VE has a standalone Parametric Tool that enables users to create and automatically run the simulation of multiple design scenarios without the need to manual interference (IES, 2019). The Parametric Tool is completely customizable and during parametric analysis, the VE can still be used. Similarly, OpenStudio plugin has an independent package named Parametric Analysis Tool (PAT) for parametric analysis and UA/SA applications, which can be realized by coupling these two units. This feature extends the tool’s capabilities by enabling to simulate and compare multiple design options (Macumber et al., 2014). As for the optimization function, Design Builder has an optimization module that can optimize multiple variables and find the optimum set of solution per objective functions. IES-VE has a standalone “Hone” optimization tool that enables users to discover the optimal building design parameters that achieve the defined objective criteria. The “Hone” is capable of optimizing multiple design variables such as thermal comfort, total energy, and carbon emission simultaneously. Similarly, TasGenOpt is a utility, and a result of combining EDSL-Tas engineering simulation program and GenOpt optimization package developed by LBNL, for performing parametric simulation and optimization. TasGenOpt allows users to change aspect of energy models dynamically using C# programming language (EDSL, 2019). Beside built-in optimization modules, there are many independent optimization software such as GenOpt, BEOpt, jEPlus, MOBO, which can be coupled with several BPS such as EnergyPlus, TRNSYS, DOE2 to solve single/multi-objective optimization problems. However, they are not easy to use because they require users to

understand optimization theory and have computer programming skills. Therefore, building performance optimization unit like DesignBuilder and IES-VE may be more suitable especially for architects due to the user-friendly interface and easy-to-learn operation process. Lastly, finding an optimal design solution within a huge design space requires exploring thousands of detailed simulations. Cloud computing can help with such time-consuming process to increase the usability of building performance simulation/optimization tools in design process. There is a growing interest for it in building simulation field. For example, DesignBuilder, Green Building Studio and OpenStudio all enable cloud computing to ensure considerable time saving on simulation runs, and quickly measure and analyze key building performance data.

#### 4.3. Comparison of BPS tools per strengths/limitations, input/output files, and validation

Lastly, the comparison of selected BPS tools in terms of main strengths and limitations, input and output file formats, weather data and validation are presented in Table 4. The input file formats indicate original input file formats and other file formats that ensure data exchange and interoperability with the other programs. Similarly, while there is some variation on the weather files that the tools use, most of the tools utilize the common weather files such as International Weather for Energy Calculations (IWEC), Typical Meteorological Year (TMY) and TMY-2. As for the validation, most tools are validated based on the ANSI/ASHRAE Standard 140 and ASHRAE 90.1-2007 for several years. Other tools have other validation test results, e.g. EDSL-Tas has a several validations according to EN ISO13791: 2012/ EN ISO13792: 2012/ EN ISO15255: 2007/ EN ISO15265: 2007, CIE 171:2006 (for daylighting calculations), and CFD validation based several criteria. In Table 4, the general and specific limitations for each tool are determined as a result of detailed literature survey. Examples to common limitations are if the tool offers modelling capabilities of human-building interaction, supports city/urban scale building energy modelling and analysis, support an evaluation of the building stock's energy use and CO2 emissions, or support building codes/certification compliance checking.

## 5. CONCLUSION

This study provided a critical overview of the recent developments in BPS tools, evaluated their effectiveness in design process. A group of validated and accurate BPS tools were investigated, categorized and compared based on general properties, validation, interoperability, user customization, application/functions, strengths and limitations. As a result, the most significant research issues/limitations were considered and development challenges lying ahead in

both academia and software industry were summarized in order to propose a simulation framework that covers and addresses all of these important issues in BPS tools.





The main limitations to be addressed and future directions of BPS tools are: In terms of integration of the tools during process, most tools are used during the detailed design stage. Therefore, the applicability of these tools during not only early design stages, but also building operation, management and retrofit phases should be improved to make the most effective decisions for building energy and environmental performance.

Most tools are capable of evaluating the building performance in common domains such as energy, thermal comfort, and environmental emissions. They should add support for assessment of other crucial analyses like CFD, code compliance and renewable energy systems, and the simulation of renewable energy generation and on-site energy generation of buildings in order to adjust electricity demand of buildings. Supporting users for modeling and simulating human-building interactions in order to develop advanced interactive control strategies and improve building energy efficiency and thermal comfort could be a valuable addition. Moreover, it is crucial to expand the modeling capabilities to include design and modeling of building stocks and simulation of urban scale building energy performance and environmental emissions to ensure decision making for urban planning strategies and achieve energy and environmental goals in regional/national scale. Lastly, the tools should support the development of new building technologies in terms of research and technology development, and identification the impact of these brand new technologies on building energy efficiency.

The interoperability issue addressing the data exchange between BIM/CAD programs/models, and simulation tools by different ways is significant development area, and yet it is still not fully solved. Besides continuity and interdisciplinary collaboration issues, the interoperability is mostly addressing the time-consuming modelling problem during geometry design and simulation phases due to the missing or defective data transfer among the tools. Users are sometimes forced to create the building geometry from scratch while transferring the building model among the tools. A wide range of plugins have been developed to ensure run-time coupling between CAD software and analytical models for fast feedback and parametric analysis such as OpenStudio, TRNSYS3D for SketchUp design tool, and DesignBuilder and OpenStudio for EnergyPlus.

Expansion of the BPS tool functionality to support the design team by giving immediate feedback for rapid design changes, and enable exploration of the

Table 4: Strengths, limitations, file formats and validation of building performance simulation (BPS) tools

BPS Tools	Strengths	Input File	Output File	Weather Data	Validation	Limitations
 Design Builder	<ul style="list-style-type: none"> <li>User-friendly interface</li> <li>Ability to simulate building model using different engines (EnergyPlus, Radiance, CFD)</li> <li>Ability to automatically create a base-line model with its HVAC system per ASHRAE 90.1, and to calculate that model's LEED credits for energy efficiency and daylighting.</li> <li>Ability to perform sensitivity analysis</li> <li>Ability to analyze for both naturally ventilated and air-conditioned buildings</li> <li>Ability to customize for specific problems using Energy Management System (EMS) Runtime, C#, Python scripting tools</li> <li>Ability to provide compliance with building codes/certification (i.e. LEED, Energy Star, BREEAM)</li> </ul>	<ul style="list-style-type: none"> <li>Building geometry can be imported from 3D BIM tools (Revit, Microstation, ArchiCAD and SketchUp) using gbXML such as</li> <li>2D floor plans, and even freehand drawings can be imported</li> </ul>	<ul style="list-style-type: none"> <li>Files can be exported in: <ul style="list-style-type: none"> <li>EnergyPlus input file (.IDF)</li> <li>gbXML and 3-D DXF formats</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>ASHRAE weather data sets, and EnergyPlus hourly weather data such as International Weather for Energy Calculations (IWEC), Typical Meteorological Year (TMY), and EnergyPlus Weather File (EPW)</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2017 (DesignBuilder v6.1 with EnergyPlus v8.9)</li> <li>ASHRAE 90.1-2007</li> <li>ANSI/ASHRAE/AC CA Standard 183-2007 (DesignBuilder v5)</li> <li>DesignBuilder CFD validation tested against Phoenics</li> </ul>	<ul style="list-style-type: none"> <li>File export limitations to EnergyPlus input file (.IDF) for HVAC systems.</li> <li>Does not offer modelling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modelling and analysis</li> <li>Does not support evaluation of a building stock's energy use and CO<sub>2</sub> emissions</li> </ul>
 EDSL-Tas	<ul style="list-style-type: none"> <li>Ability to create model by importing files from CAD drawings, gbXML etc. (EDSL-Tas 3D Modeler)</li> <li>Ability to model large and complex buildings</li> <li>Ability to display results in different formats such as tabular, graphical or 3D</li> <li>Ability to model building plant and systems (EDSL-Tas System)</li> <li>Ability to perform 2D CFD analysis (EDSL-Tas Ambiens)</li> <li>Ability to perform parametric analysis and optimization (TasGenOpt)</li> </ul>	<ul style="list-style-type: none"> <li>TAS input file (.TBD)</li> <li>Building geometry can be imported from REVIT TM (gbXML), EnergyPlus (.IDF), and DOE-2eQUEST (.INP) files</li> <li>Geometric data from CAD programs (.DWG)</li> </ul>	<ul style="list-style-type: none"> <li>TAS output file (.TSD)</li> <li>TAS can export output data readable by EnergyPlus based tools</li> <li>Simulation data can be exported to Microsoft Excel, Word, Adobe, Publisher</li> </ul>	<ul style="list-style-type: none"> <li>Tas Weather Database (TWD), CIBSE Test Reference Year (TRY) weather datasets (in .twd format)</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2014 (TAS v9.4.1, 9.4.2, and 9.4.3)</li> <li>ASHRAE 90.1-2007</li> <li>EN ISO13791: 2012/ EN ISO13792: 2012/ EN ISO15255: 2007/ EN ISO15265: 2007</li> <li>CIE 171:2006 (for daylighting calculations)</li> <li>CFD validation based on several criteria (experimental validation, time accuracy verification, jet nozzle comparison etc.)</li> </ul>	<ul style="list-style-type: none"> <li>Requires knowledge on building energy simulation area.</li> <li>Does not offer modelling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modeling and analysis</li> <li>Does not support evaluation of a building stock's energy use and CO<sub>2</sub> emissions</li> </ul>
 EnergyPlus	<ul style="list-style-type: none"> <li>Ability to perform detailed algorithms for heat transfer</li> <li>Ability to provide dynamic interaction between thermal zones and HVAC systems in time series</li> <li>Ability to provide combined heat and mass transfer model that ensures air movement between thermal zones</li> <li>Ability to define both standard and novel HVAC system configurations via Component based HVAC system feature.</li> <li>Ability to provide heat balance-based solutions including combined effect of radiation and convection heat transfer to have an accurate surface temperatures for thermal comfort and condensation calculations</li> <li>Ability to provide numerous built-in HVAC and lighting control strategies, and also scripting system for providing user-defined control.</li> <li>Ability to provide detailed calculations for visual comfort and lighting control</li> <li>Ability to customize programs for specific problems using Energy Management System (EMS)</li> <li>Ability to provide Functional Mockup Interface (FMI) for co-simulation with other engines</li> <li>Having committed support from DOE.</li> </ul>	<ul style="list-style-type: none"> <li>EnergyPlus input file (.IDF)</li> <li>Can take the inputs as structured ASCII text file</li> </ul>	<ul style="list-style-type: none"> <li>CSV, HTML, and SQLite</li> </ul>	<ul style="list-style-type: none"> <li>EnergyPlus Weather File (EPW) format, IWEC, TMY, TMY-2, Comma separated values (CSV) file, Weather Year for Energy Calculation 2 (WYEC2), FMT (DOE-2 format), CLM (ESP-R ASCII format), ASC (BLAST ASCII format), Hourly or sub-hourly</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2014 (EnergyPlus v9.0.1)</li> <li>ASHRAE 90.1-2007</li> </ul>	<ul style="list-style-type: none"> <li>Requires good knowledge on building thermodynamic concepts</li> <li>Text based model generation and input definition compared to the graphical interfaces</li> <li>Does not provide model viewing during performance analysis</li> <li>Potentially long run time for detailed models</li> <li>Convergence issue for complex system configurations</li> <li>Does not offer modelling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modeling and analysis</li> <li>Does not support an evaluation of the building stock's energy use and CO<sub>2</sub> emissions</li> </ul>
 ESP-r	<ul style="list-style-type: none"> <li>Ability to model all plant and control systems located within the building for thermodynamic interactions between building and plant</li> <li>Ability to provide multi-volume representation of plant components (condensing boiler, hot-water store, solar thermal collector, PV array)</li> <li>Ability to include internal features that create thermal mass and longwave-shortwave radiation for thermal load calculations</li> <li>Ability to provide imposition of CFD models on a thermal zones to support thermal comfort/air quality</li> <li>Ability to integrate measured data such as weather, air flow, internal gains on the simulation</li> <li>Ability to provide detailed lighting control analysis with Radiance</li> <li>Ability to provide occupant behavior representation regarding IT usage and heating system control</li> <li>Ability to include PV component model linking to local network to support grid interaction</li> </ul>	<ul style="list-style-type: none"> <li>Building geometry can be defined via CAD programs</li> </ul>	<ul style="list-style-type: none"> <li>Models can be exported to other simulation tools such as Energy Plus, Radiance or VRML</li> </ul>	<ul style="list-style-type: none"> <li>ESP-r Climate Formatted File (CLM), ESP-r-text format, Test Reference Year (TRY) weather data, Typical Meteorological Year (TMY), TMY-2</li> </ul>	<ul style="list-style-type: none"> <li>IEA ECBCS Annex 1</li> <li>IEA ECBCS Annex 4</li> <li>IEA SHC Task 8</li> <li>IEA ECBCS Annex 10</li> <li>IEA SHC Task 12 (Envelope BESTEST and Empirical)</li> <li>IEA SHC Task 22 (HVAC BESTEST Volume 1-2, Furnace BESTEST and RADTEST)</li> <li>BEPAC Conduction Tests</li> <li>CIBSE TM33</li> <li>ISO 13791</li> </ul>	<ul style="list-style-type: none"> <li>Requires knowledge of the particular subject and good understanding of building physics, thermophysical processes in the buildings, environmental systems and controls, electrical, microtoxin and CFD assessment</li> <li>Does not support building codes/certification compliance checking</li> <li>Does not offer modelling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modeling and analysis</li> <li>Does not support an evaluation of the building stock's energy use and CO<sub>2</sub> emissions</li> </ul>

*TTable 4: Strengths, limitations, file formats and validation of building performance simulation (BPS) tools (continued)*

BPS Tools	Strengths	Input File	Output File	Weather Data	Validation	Limitations
eQUEST	<ul style="list-style-type: none"> <li>Detailed (DOE-2) interface that supports detailed analysis from construction documents to post-occupancy phases.</li> <li>Ability to evaluate whole-building energy performance throughout the entire design process.</li> <li>Ability to provide schematic design wizard, design development wizard and detailed interface that enable design team to explore the energy performance of design concepts from early design stage.</li> <li>Ability to perform many evaluations of large models and hold interactions between building systems by its execution speed.</li> <li>Having rule-based processor that ensure automated quality control checks of simulation inputs and results.</li> </ul>	<ul style="list-style-type: none"> <li>All building geometry data from gbXML file format generated by BIM or 3D-CAD</li> </ul>	<ul style="list-style-type: none"> <li>gbXML for Trane TRACE 700 and other tools</li> <li>DOE 2.2 file for eQuest</li> <li>Energy Plus IDF file</li> <li>VRML file</li> <li>Design Review file</li> <li>US EPA ENERGY STAR</li> <li>Water preliminary analysis for LEED</li> <li>Customizable charts</li> <li>Weather file (Binary (BIN) and CSV)</li> <li>Weather data summary</li> </ul>	<ul style="list-style-type: none"> <li>The Autodesk Climate Server provides to access a large weather database and file formats like TMY, TMY2, DOE-2 Binary file,</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2014</li> <li>ASHRAE 90.1-2007</li> </ul>	<ul style="list-style-type: none"> <li>Requires extensive knowledge on building technology</li> <li>Program's defaults and automated compliance analysis have been done only with California Title 24, no support for ASHRAE 90.1 yet.</li> <li>Only supports IP units (not SI units).</li> <li>Daylighting analysis can only be applied in a convex space configuration.</li> <li>Limitation for custom code development in eQUEST.</li> <li>Does not offer modelling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modelling and analysis</li> <li>Does not support an evaluation of the building stock's energy use and CO<sub>2</sub> emissions</li> </ul>
Green Building Studio (GBS)	<ul style="list-style-type: none"> <li>Ability to provide energy analysis for Autodesk Insight 360, Autodesk Revit and Autodesk FormIt 360</li> <li>Ability to provide cloud-based service feature to quickly find the effective energy efficiency measures</li> <li>Ability to run building performance simulations to optimize energy-efficiency, carbon emissions in the early design stage</li> <li>Ability to provide default settings based on the ASHRAE 90.1, ASHRAE 90.2, ASHRAE 62.1 and CBECs data.</li> <li>Ability to synchronize historical weather data and utility billing data for existing building retrofit</li> <li>Ability to provide optimization based on parameterization</li> <li>Ability to create geometrically accurate input files for EnergyPlus (IDF)</li> <li>Ability to calculate the building model's credits based on EnergyStar and LEED daylighting</li> </ul>	<ul style="list-style-type: none"> <li>All building geometry data from CAD/BIM systems</li> <li>Can import gbXML, IFC, and DXF files</li> </ul>	<ul style="list-style-type: none"> <li>gbXML for Trane TRACE 700 and other tools</li> <li>DOE 2.2 file for eQuest</li> <li>Energy Plus IDF file</li> <li>VRML file</li> <li>Design Review file</li> <li>US EPA ENERGY STAR</li> <li>Water preliminary analysis for LEED</li> <li>Customizable charts</li> <li>Weather file (Binary (BIN) and CSV)</li> <li>Weather data summary</li> </ul>	<ul style="list-style-type: none"> <li>The Autodesk Climate Server provides to access a large weather database and file formats like TMY, TMY2, DOE-2 Binary file,</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2007, 2004, 2011</li> <li>ASHRAE 90.1-2001</li> <li>Regression testing (for internal analytical results)</li> </ul> <p>Note: GBS uses DOE-2.2 simulation engine for energy analysis. DOE-2.2 is validated by Lawrence Berkeley National Laboratory and the Los Alamos National Laboratory.</p>	<ul style="list-style-type: none"> <li>Requires good knowledge of Revit including gbXML export feature</li> <li>Limited for architectural design, and able to generate complex building models. Contrarily, it is not suited for control purposes.</li> <li>Only supports Imperial (IP) units (not SI units) (EMIN/MISIN)</li> <li>Requires internet connection due to being a web-based tool</li> <li>Does not ensure model viewing during performance analysis, so the project settings can not be checked after sending model for analysis</li> <li>Does not offer modeling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modeling and analysis</li> <li>Does not support an evaluation of the building stock's energy use and CO<sub>2</sub> emissions</li> </ul>
IES-Virtual Environment (IES VE)	<ul style="list-style-type: none"> <li>Ability to analyze different design alternatives for best energy efficiency solutions, low carbon and renewable energy technologies, energy use, CO<sub>2</sub> emissions, occupant comfort.</li> <li>Ability to provide comprehensive building performance analysis with wide range of performance metrics</li> <li>Ability to provide integrated central data model that makes the design changes immediately updated for other modules such as HVAC system modeling, natural ventilation modeling, CFD analysis, daylight control, solar shading analysis, cost analysis</li> <li>Interoperability with other CAD/BIM tools</li> <li>Ability to increase productivity and simulation time using cloud-based services, and parallel execution.</li> </ul>	<ul style="list-style-type: none"> <li>Geometrical building data from CAD/BIM systems</li> <li>Can import gbXML, IFC, and DXF files</li> </ul>	<ul style="list-style-type: none"> <li>Analysis results in wide range of formats (e.g. tabular, graphical, video, 3D geometric)</li> </ul>	<ul style="list-style-type: none"> <li>IES VE can read the weather file formats like (.twt) (AVE proprietary format), EnergyPlus</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2014</li> <li>ASHRAE 90.1-2004, 2007, 2010, 2013 - Performance Rating Method</li> </ul>	<ul style="list-style-type: none"> <li>Does not support building codes/certification compliance checking</li> <li>Does not offer modeling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modelling and analysis</li> </ul>
OpenStudio	<ul style="list-style-type: none"> <li>Having an Application Programming Interface (API) feature-accessible via a several scripting languages such as Ruby, Python, C#, JavaScript- allows it to be customized and extended easily.</li> <li>Ability to execute scripts written in these languages.</li> <li>Ability to create a 3D geometry and energy model in SketchUp.</li> <li>Ability to provide OpenStudio scripts library and component content in the public Building Component Library database that allows these elements to be approved by and shared with a community.</li> <li>Having committed support from DOE.</li> </ul>	<ul style="list-style-type: none"> <li>Only content types like constructions and schedules can be imported from .idf file</li> <li>gbXML and IFC files</li> </ul>	<ul style="list-style-type: none"> <li>OpenStudio file (.osm)</li> <li>EnergyPlus (.idf) file</li> </ul>	<ul style="list-style-type: none"> <li>International Weather for Energy Calculations (IWEC), Typical Meteorological Year (TMY), TMY-2, Weather Year for Energy Calculations (WYEC)</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2014</li> <li>ASHRAE 90.1-2010, 2013 - Energy Cost Budget Method (Chapter 11)</li> <li>ASHRAE 90.1-2016 (Fixed Baseline) / ASHRAE 90.1-2013</li> <li>NECB in Canada</li> <li>Title 24 in California</li> </ul>	<ul style="list-style-type: none"> <li>Requires good knowledge of building technology and scripting</li> <li>Does not support building codes/certification compliance checking</li> <li>Does not offer modelling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modelling and analysis</li> <li>Does not support an evaluation of the building stock's energy use and CO<sub>2</sub> emissions</li> </ul>
TRNSYS	<ul style="list-style-type: none"> <li>Ability to simulate behavior of transient systems focusing on the performance of thermal and electrical energy systems.</li> <li>Ability to execute several applications ranging from central plant modeling, building simulation, solar thermal processes, coupled multi-zone thermal/airflow modeling to wind and PV systems, data and simulation calibration, optimization.</li> <li>Ability to model a variety of energy systems in different complexities using its modularity</li> <li>Ability to easily modify existing components or write their own</li> <li>Ability to provide extensive documentation on component routines (e.g. explanation, typical uses, supplied time step, starting and stopping period)</li> <li>Graphical interface named SimulationStudio</li> <li>Ability to integrate with several programs such as COMIS, CONTAM, EES, FLUENT, GenOpt and Matlab</li> </ul>	<ul style="list-style-type: none"> <li>Standard TRNSYS input file known as deck file (.dck)</li> <li>TRNSYS Project File (.tpr)</li> <li>ASCII text file</li> <li>EnergyPlus input file (.idf) by TRNSYS3D</li> </ul>	<ul style="list-style-type: none"> <li>TRNSYS basic output format is ASCII</li> <li>TRNBuild can generate Radiance files (.rad), (.dtd)</li> </ul>	<ul style="list-style-type: none"> <li>Any user-specified format, Monthly average data, EnergyPlus Weather file (.epw), ESP-r Climate Formatted File (CLM), European Test Reference Year (TRY), Typical Meteorological Year (TMY), TMY-2, Japan Automated Meteorological Data Acquisition System (AMeDAS) weather data</li> </ul>	<ul style="list-style-type: none"> <li>ANSI/ASHRAE Standard 140-2014</li> <li>ASHRAE 90.1-2007</li> </ul>	<ul style="list-style-type: none"> <li>Requires detailed knowledge about the building and HVAC system in order to create a building energy model.</li> <li>Does not support building codes/certification compliance checking</li> <li>Does not offer modelling capabilities of human-building interaction</li> <li>Does not support city/urban scale building energy modelling and analysis</li> <li>Does not support an evaluation of the building stock's energy use and CO<sub>2</sub> emissions</li> </ul>

design space and guide the design rather than just evaluate the performance of design. Main functionalities are parametric analysis for creating geometry and automatically making rapid design changes for the geometry, statistical analysis such as sensitivity/uncertainty analysis for identifying the most influential design parameters on performance criteria within a wide range of parameter set, single/multi-objective optimization for automatically searching an optimal set of design solution within a large solution space in order to optimize the performance criteria, and lastly cloud computing for helping to overcome time consuming process of performance based design to increase the usability of BPS in design process. Through the review of selected BPS tools, it is deduced that only a very limited number of these tools have aforementioned functions. It is believed that this limitation leads software industry to focus more on developing different types of applications such as plugins, GUIs by third-party developers to encapsulate this challenge.

Lastly, model customization during evaluation of the building performance allows expanding the design limits and propose suitable solutions according to the project requirements. Among selected tools, some of them (e.g. DesignBuilder, EnergyPlus, IES-VE) allow users to customize the model via several ways such as scripting. Therefore, customization of BPS tool is a good feature to add for the future in order to extend, customize and automate the design applications.

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## THE IMPORTANCE OF INSTITUTIONAL SUPPORT TO SUSTAIN COMMUNITIES' LIVELIHOODS IN MARINE PROTECTED AREA: TUN SAKARAN MARINE PARK, SABAH, MALAYSIA

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### ABSTRACT

*This study was conducted in the first and the only marine protected area in Malaysia to include private land and recognize native customary rights (NCR) especially in matters regarding land. This exploration is especially timely for the communities in Tun Sakaran Marine Park (TSMP), where some are entitled to native rights and some have been given usufruct rights by native rights holders, and yet they are living in a gazetted park under Sabah Parks administration, a statutory body under Sabah's Ministry of Tourism, Culture and Environment. Therefore, it is crucial to examine the livelihoods impacts of park establishment on communities living within the park and the strategies to cope with the impacts. A sustainable livelihoods (SL) approach was adopted as a framework to analyse the relationships among the institutional entitlement, which is the NCR, livelihood strategies and livelihood outcomes. In-depth household surveys and stakeholder interviews were undertaken during the fieldwork. Although co-management and ecotourism were planned to be implemented in TSMP, it was found that the local communities are not involved in management and benefited from any tourism activities. Therefore, institutional arrangement should be strengthened to support the design of more appropriate livelihoods strategies for communities in TSMP.*

**Keywords:** : Native customary rights, communities' well-being, institutional arrangement, livelihood sustainability

### 1. INTRODUCTION

Often the issues and problems in a MPA, such as resources exploitation, resources users' conflicts, and ecosystem deterioration, are caused by social, economic, institutional or political failures (Saarikoski et al, 2018). Previous analysis on sustainable governance of common resources suggested that institutions play a key role in governing the commons e.g. marine resources (National Research Council, 2002). Furthermore, Muradian and Rival (2012) and Primmer et al. (2015) suggested that multi-level participatory governance processes that focuses on both internal and external institutions is more likely to produce better outcomes in common pool resources management.

Understanding the situations of people and how property rights and institutions are influenced by social, cultural and historical situations will lead to comprehension of how people connect with marine resources institution. McCay (2002) supported this in his discussion of 'the emergence of institutions for the common' that emphasizes individual rational choice in particular situations that are placed firmly in the context of history, political dynamics, social structure, culture and ecology. As rules, laws and governance are commonly recognized as major institutions that shape human behavior, Muradian and Rival (2012) further acknowledged that institutions for the commons should also include new and changed patterns of behavior, norms and values.

In Sabah, Malaysia, native customary rights (NCR) are a significant social, cultural, historical and political factor to be considered in understanding their influence on community involvement in shaping institutions that eventually result in a community's well-being. Native rights to land were introduced in Sabah during the colonial era, 1885-1913. It was only during

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the second governorship (1889) of Charles Creagh that the native rights to land were implemented seriously. However, native claims had to wait until the introduction of Land Laws in 1913 that established natives with state-recognized title (Doolittle, 2005). The objective was to protect native rights to land and to protect them from increasing foreign land concessions during that colonial era.

Under Malaysian law, native title has been described as a *sui generis*, i.e. it is based in statute, common law, and native laws and customs. In order to determine the nature of the right, judiciaries must refer to all the bodies of laws, to give practical importance to what the courts have called a 'complementary right' (Phoa, 2009). At present, NCR is a right given to the natives of Sabah that have been living and working on public land for their livelihoods for three consecutive years and is subject to section 65, 13-16 and 88 of the Land Ordinance (Sabah Cap 68).

## 2. SUSTAINABLE LIVELIHOODS APPROACH

A sustainable livelihoods approach is one of the community development approaches that has been adopted especially to reduce poverty by putting people and their needs as the priority for development (Morse et. al, 2018; DFID, 1999). Livelihood thinking requires initial understanding of what a livelihood is, and in what shape, form or state that livelihood is sustainable? This study cites the most well-known and most-cited definition of sustainable livelihoods by Chambers and Conway (1992, pp. 6) that stated: A livelihood comprises the capabilities, assets (store, resources, claim and access) and activities required for a means of living. *A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets and provide sustainable livelihood opportunities for the next generation.*

For the purpose of this research, empirical work focused on a marine protected area (MPA). An MPA has been defined as 'an area designated to protect marine ecosystems, processes, habitats and species, including the essentials of marine biodiversity and which can contribute to the restoration and replenishment of resources for social, economic and cultural enrichment' (WWF, 2008). This research focuses on an MPA that not only protects natural areas but also includes social, economic, and cultural interests.

<sup>1</sup>Section 65. "Customary tenure" means lawful possession of land by natives either by continuous occupation or cultivation for three or more consecutive years or by title under this Part or under the Poll Tax Ordinance, or Part IV of the Land Ordinance, 1913.

Commonly inhabited by rural communities who live in poverty and surrounded by agricultural land in the case of terrestrial PAs and marine resources for MPAs, often the establishment of protected areas has had unfavorable effects through a reduction in food security and a loss of livelihoods for local people (Karki, 2013). Hence, numerous incentive-based programs (IBPs) have been advocated, such as community-based conservation (CBC), community-based tourism and integrated conservation and development projects (ICDP), to reduce the adverse social effects for local communities (Karki, 2013; Garnett et al., 2007). Some research studies have highlighted the failure and negative impacts of such programs, including lack of attention to social differences, wishful expectations without meeting targets, and an unequal distribution of benefits (Naughton-Treves et al., 2005; West et al., 2006). In addition, one significant limitation for the evaluation of IBPs is lack of information on the impacts of protected areas and conservation incentives at individual or household levels. This means that the overall impacts of IBPs remain uncertain, especially how impacts vary in different contexts because of the highly complex and heterogeneous characteristics of communities and the settings in which they operate (Lai and Nepal, 2006). Moreover, ICDP conceptual frameworks seldom adequately address issues of legality, laws, governance and policy that will ultimately influence the success of the projects and other initiatives i.e. these things have only been considered as aspects of social capital rather than as influences on all capital assets and, therefore, requiring consideration in all other asset components (Morse et. al, 2018).

Therefore, the concept of Sustainable Livelihoods (SL) is used in this study to bridge the gaps that have been highlighted in Incentive-Based Programs studies concerning the impacts of MPAs on communities' livelihoods. Given a primary interest in the well-being of local people and the precarious nature of their means of sustenance, the prevalence of poverty in the developing world and the considerable evidence that local lifestyles are disrupted by PA establishment, it is appropriate to adopt a SL framework to explore local livelihood issues.

### Sustainable Livelihoods Framework (SLF)

The advantage of adopting a SL approach is the strengths of the framework that is used to draw in conventional analyses (economic, environmental, social, and institutional) to understand the complexity of livelihoods, the influences on poverty, people's options regarding sustaining their livelihoods and to identify where interventions can best be made (Figure 1) (Morse et. al, 2018). An analysis of assets is fundamental to understanding the options that are accessible to households and communities, and to the recognition of the assets that people possess and how they change over time. Five capital assets (assets pentagon) are identified in the framework: human, physical,

social, natural, and financial. Moreover, social differences are recognized in the analysis of the accessibility to and control over assets. Options are further determined by policies, institutions and processes (such as the role of government and the private sector, institutional and traditional culture, gender etc.) with which people engage (Morse et. al, 2018).

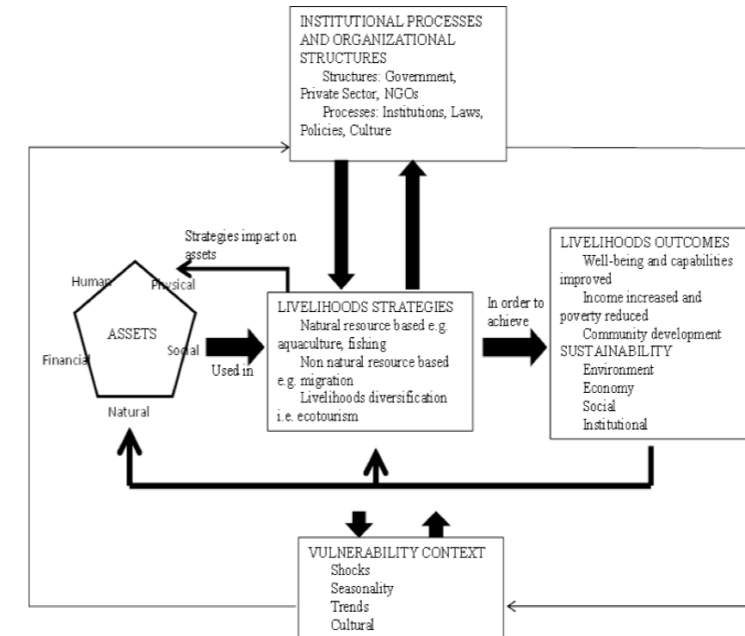


Figure 1: Sustainable Livelihoods Framework (SLF) (adapted from Scoones, 1998; Cahn, 2002)

An analysis of outcomes focuses on achievements, indicators and progress that eventually provide an understanding of what contributes to the well-being of people (Cahn, 2002). Furthermore, it is important to understand the diverse and dynamic livelihoods strategies to identify the best time to intervene. An analysis of livelihoods strategies provides important information on how people negotiate on appropriate processes and structures to implement the strategies. Finally, an analysis of the vulnerability context helps one to understand how people adapt and cope with events that are beyond their control. In the proposed study, vulnerability will be addressed through a focus on the establishment of marine parks and how it influences the overall livelihoods system. In addition, the analysis should examine the role of institutional processes and structures required to handle and reduce vulnerabilities and how the vulnerabilities influence processes and structures.

However, for the purpose of this study, the analysis using SLF will focus only on the institutional processes and structures, livelihoods strategies, livelihoods outcomes and their possible relationships between the key research components.

## 3. METHODS

A priority is given to qualitative methods as the research involved an ethnographic case study to observe and to collect data, especially in regards to the issues of institutional structures and processes, the social and cultural attributes of marine communities, livelihoods and native rights issues that are easier to describe through qualitative analysis and more comprehensible through qualitative interpretation. Although qualitative approaches dominate the research design, quantitative measures are also used. Methods such as content analysis and analysis of secondary data incorporate statistical techniques using SPSS. Similarly, questions requiring quantitative responses, such as demographic information on household size and ethnicity, were asked on the household survey as a means of gathering data for statistical analysis. Quantitative analysis of survey data is important, especially when needed to complement the qualitative results and to analyze diverse opinions.

### Fieldwork

The fieldwork was conducted for three months in Tun Sakaran Marine Park, which is located within Semporna district, Sabah. TSMP is situated at the entrance of Darvel Bay in Semporna, off the southeast coast of Sabah, Malaysia (Figure 2).



Figure 2: Location of the Tun Sakaran Marine Park in Malaysia

Three ethnic groups live in TSMP: Bajau, Bajau Laut and Suluk. Although Bajau and Bajau Laut speak the same Sama language (perhaps with different dialects) and are believed to be from the same origins, they are different in terms of the places they lived in, the livelihoods strategies they choose, their perceptions of their lives and the institutional structures that shape their livelihoods. At the same time, Suluk people are distinctively different from Bajau and Bajau Laut, especially in terms of language and livelihood activities. In addition, the three ethnic groups live in the islands only among their own people, with the Bajau community living permanently in Selakan, the Bajau Laut scattered around Maiga, Bodgaya, Boheydulang and Sibuan, and the Suluk people found especially in Sebangkat (the great majority live on the reef-top settlement), and some villages in Bodgaya and Boheydulang. Different islands also support different livelihood activities: Sebangkat and Selakan are significant for seaweed farming, and Bodgaya and Boheydulang possess better soil for gardening. With this in mind, it was necessary to devise a sampling method to represent each ethnic group and island.

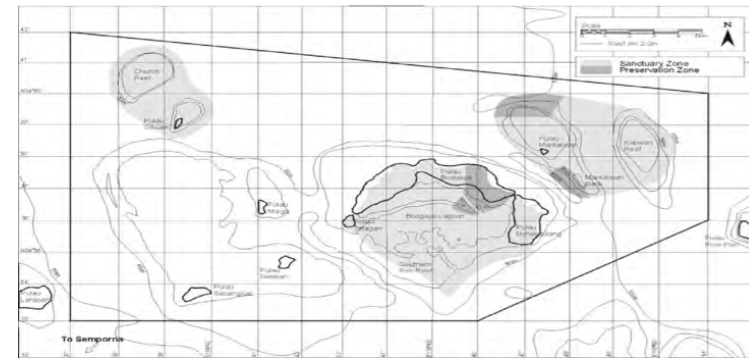


Figure 3: Map showing the eight islands and associated reefs (SIP Management Plan, 2001)

Proportionate stratified random sampling was chosen to ensure representation of the three ethnic groups in all of the six inhabited islands. 79 households were interviewed i.e. approaching half of all households in the park (total household =184). From the interviews, it was found that 28 respondents of Bajau ethnicity represent 179 Bajau population, the 20 Bajau Laut respondents represent 145 Bajau Laut population, and the 31 Suluk households represent 209 Suluk population. The household survey was designed to obtain information about respondents' livelihood practices (before and after park establishment), demographic characteristics, institutional issues especially regarding local participation in park management and the relationship with native customary rights, and respondents' perceptions of ecotourism.

Therefore, the interview questions were divided into four groups: demography; livelihoods; institutional structures and processes, and ecotourism. The four themes were each addressed through both closed and open-ended questions. Open-ended questions allow the researcher to hear respondents' opinions in their own words and minimize external influences from the interviewer or from the research instrument itself.

#### 4. RESULTS

##### *Native customary rights (NCR) entitlement*

NCR entitlement is an important variable to consider in this study area and is among the rationale for site selection. There are important relationships between NCR and institutions that promote livelihoods strategies, community participation, and property entitlement, which will need to be examined. Hence it is very crucial in this study to investigate how NCR influences community's participation in institutional arrangements and livelihoods.

Table 1 shows that 100% of Bajau respondents said they are entitled to NCR status, and 100% of Suluk and Bajau Laut respondents said they are not entitled to it. In the household survey, it was discovered that the majority of the Bajau Laut and Suluk lived in TSMP islands with the permission of the owners/heirs of the island who was entitled to NCR or based on the usufruct rights. Some of the owners/heirs lived in Selakan island and many had moved to live in Semporna town and other parts of Sabah and Malaysia. However, although they are entitled to NCR, not many of them actually owned land officially or possessed permanent accommodation (Table 2).

Table 1: NCR entitlement according to ethnicity

	Entitlement		
	Yes	No	Total
Bajau	28	0	28
Bajau Laut	0	20	20
Suluk	0	31	31
Total	28	51	79

Table 2: Land or property owned by respondents

	Entitlement		
	Yes	No	Total
Bajau	28	0	28
Bajau Laut	0	20	20
Suluk	0	31	31
Total	28	51	79

All twenty-eight native Bajau respondents in Selakan island are entitled to NCR but, in most cases, the grants for houses or land they occupy belonged to their parents or grandparents who had already died. According to the interviews with most of the related respondents, lack of knowledge of how to transfer the name on the grants to the heir's name is one factor that contributes to the current situation. Furthermore, the process of transferring ownership to a new owner requires all potential owners/heirs to come to a mutual agreement as to whose name should be given e.g. if the father died, the mother and all children must come to an agreement as to who should administer the property (Act 98, 2006) and, usually, the responsibility is given to the eldest brother in the family (Subject #024, 2013). This is a complicated process where lack of knowledge and awareness among family members hinders the process of changing ownership. Therefore, the properties are considered hereditary with rights to the land in TSMP and rights to permit others to settle on the land provided the park authorities are informed. It can be concluded that NCR plays an important role in the rights of TSMP communities to stay in TSMP, and gives an absolute right to the Bajau community and usufruct rights to Bajau Laut and Suluk communities to stay in the park and get involved in park activities since Bajau community have land rights.

##### *Current livelihoods activities and community settlements*

Twenty eight respondents from the Bajau community that were interviewed in this study lived permanently in Selakan island. Selakan is the only island inhabited by the native people that are recognized by the state's Native Laws. Twenty Bajau Laut respondents were interviewed during the fieldwork. The Bajau Laut people adhere to their traditional nomadic lifestyle and they move to find a better place when things are not good for them. Thirty one respondents from Suluk community were interviewed. Particularly in TSMP, Suluk people were initially brought in by the seaweed company to work in their farm. Based on interviews and observations, it is concluded that Suluk people are gifted with farming skills on both land or on the sea. This is why the seaweed farming company hires many Suluk people as their farmers. Based on Table 5, Suluk communities show the highest percentage of all ethnic groups for seaweed farming and gardening, i.e. 56.4% and 66.7% respectively. Their settlements are largely on Sebangkat-Selakan reef-top settlement (for seaweed farming) and Bodgaya island (for fruit and vegetable gardening).

Based on Table 3, Table 4 and Table 5, the proportion involved in fishing for Bajau community is relatively low in comparison with the Bajau Laut (23% compared to 45%) as many people in Selakan have stopped fishing as their main livelihood since park establishment. Similarly, the proportion involved in seaweed farming is low compared to the Suluk (23% compared to 56%). One of the reasons for this situation is that people in Selakan, as recognized citizens, have many livelihood options. Although there are not yet any alternative livelihoods provided by park management, being natives and recognized as citizens provide local people in Selakan with the opportunity for them to take their own initiatives. The Department of Fisheries (DoF), a government department responsible for enhancing fishermen's livelihood status, is the most important stakeholder in Selakan for fishing and seaweed farming. The department has its own station in Selakan with one permanent officer (a local Selakan man). A variety of fisheries projects have been offered to the Selakan community to raise their living standard, including boat and engine subsidies and mariculture projects such as seaweed and fish farming (Interviewees, 2013). Moreover, a successful seaweed-farming project in collaboration with Universiti Malaysia Sabah (UMS) provides another alternative, especially for younger generations in Selakan island (Subject SH07, 2013). In addition, running tuck shops, craft production and migration are other sources of livelihood. From interviews with local people and other stakeholders, it was found that apart from two respondents, there also some people in Selakan work with government agencies such as Sabah Parks, DoF and the District Office. The fact of having legal citizenship status distinguishes the Bajau from the Bajau Laut and Suluk communities in terms of opportunities and entitlements.

Table 3: Livelihoods activities of Bajau respondents

Livelihoods activities	Frequency (N=28)	Percent	Percent of total (of all ethnics)
Fishing	9	32	23
Seaweed Farming	9	32	23
Gardening	1	4	8
Operating tuckshop	2	7	40
Housewife	11	39	85
Craftsman	4	14	100.0
Others (work in nearby town)	3	11	33
Total	39	100	



Table 4: Livelihoods activities of Bajau Laut respondents and their settlements

Livelihoods activities	Frequency (Total N=20)	% of total (of all ethnics)	Islands						
			i	ii	iii	iv	v	vi	vii
Fishing	18	45	0	0	6	1	7	4	0
Seaweed Farming	8	21.5	0	0	1	0	7	0	0
Gardening	3	25	0	0	3	0	0	0	0
Tuck shops	3	60	0	0	1	0	1	1	0
Others	3	33.3	0	0	1	0	1	1	0

i= Selakan; ii= Sebangkat; iii= Bodgaya; iv= Boheydulang; v= Maiga; vi= Sibuan; vii= Sebangkat-Selakan reef top settlement

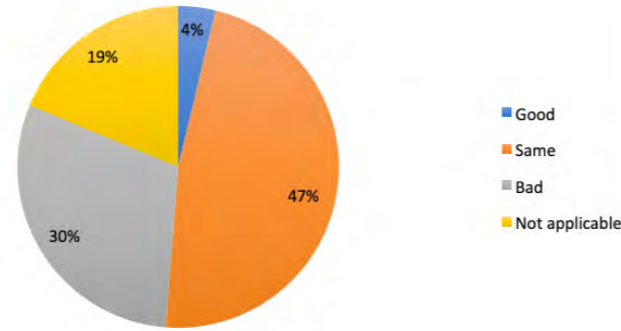


Figure 4: Status of existing livelihoods activities

Table 5: Livelihoods activities of Suluk respondents

Livelihoods activities	Frequency (Total N=31)	%of all ethnics	Islands						
			i	ii	iii	iv	v	vi	vii
Fishing	13	32.5	0	2	4	1	1	0	5
Seaweed Farming	22	56.4	0	2	0	0	6	0	14
Gardening	8	66.7	0	0	5	3	0	0	0
Housewife	2	15.4	0	0	0	1	0	0	1
Others	3	33.3	0	1	1	0	0	0	1

i= Selakan; ii= Sebangkat; iii= Bodgaya; iv= Boheydulang; v= Maiga; vi= Sibuan; vii= Sebangkat-Selakan reef top settlement

Figure 5 indicates that approaching a half (43%, n=34) believed that there had been few changes in their circumstances in the preceding ten years, whereas 37% (n=29) perceived negative changes and 20% (n=16) said there had been positive changes. Again, the negative evaluations reflect livelihood deterioration due to fish bombing, poor seawater conditions, adverse effects of zoning and reduced accessibility to the fishing area, and unequal distribution of benefits.

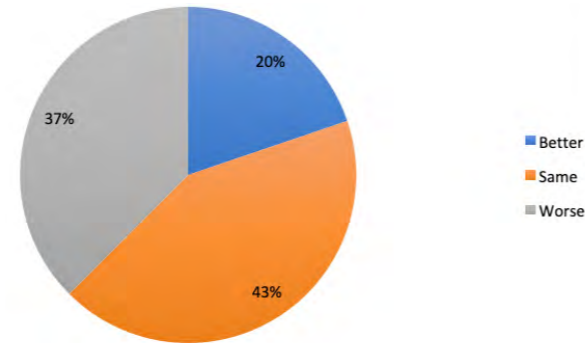


Figure 5: Changes perceived in the past 10 years

#### Livelihoods status and changes before and after park establishment

Based on Figure 4, almost half (47%, n=37) indicated that their livelihood activities had not changed in any way, although 30% said that their livelihoods activities and income had decreased substantially. One tenth (9%, n=7) suggested that the question was not applicable to them as they were mostly women who were basically housewives. For Bajau and Bajau Laut, men are the head of the family and are expected to be the breadwinner. In the Suluk community, women also help in seaweed and gardening activities. Only 4% (n=3) said that their livelihood was currently good and they engage in alternative livelihood activities, such as running a small business, fish farming or operating their own seaweed farm.

Further analyses were undertaken in search of possible difference between the ethnic groups. According to one-way ANOVA and the post hoc test (Table 6 and Table 7), significant differences were found in association with ethnicity: Bajau respondents were more vocal in expressing opinions/perceptions than Bajau Laut and Suluk who were more reserved in their responses. Again, most of Bajau Laut and Suluk respondents answered 'I don't know', 'nothing', or 'the same' when asked for their opinions in Likert-type questions. Interviews and open-ended questions resulted in more revealing responses. For example, Bajau Laut and Suluk respondents expressed their views as follows:

*'I never agreed with the park establishment. But we are Bajau Laut. We have no rights to say no because we have not acquired a legal document. We are afraid of being displaced. At the end of the day, we do not care anymore about the park.'* (Subject #050)

*'Our lives have always been difficult. Before, after (park establishment), the same. Nothing more we can do except to go on.'* (Subject #026)

*'We were thankful to the Malaysian government for accepting us here. We do not want to go back to the (southern) Philippines. Life is even worse there: you can get killed easily. We feel safe here.'* (Subject #072)

Bajau people with NCR were more vocal in expressing their opinions than the socially marginalized Bajau Laut with no entitlements. The Suluk were once recognized as a superior group in the Sulu-Sulawesi Sea, but their status as immigrants, both legal and illegal, undermined their right and willingness to express their feelings.

Table 6: One-way ANOVA test showing differences with ethnicity

		Sum of Squares	df	Mean Square	F	Sig.
Better	Between Groups	.761	2	.380	2.538	.086
	Within Groups	11.391	76	.150		
	Total	12.152	78			
Same	Between Groups	.033	2	.016	.064	.938
	Within Groups	19.335	76	.254		
	Total	19.367	78			
Worse	Between Groups	4.590	2	2.295	11.804	.000
	Within Groups	14.777	76	.194		
	Total	19.367	78			

\*The mean difference is significant at the p<0.05.

Table 7: Post-hoc test to determine which group is significantly different from the others

Dependent Variable	(I) Ethnic_3	(J) Ethnic_3	Mean Difference (I-J)	Std. Error	Sig.
Better	Bajau	Bajau Laut	.221	.113	.131
		Suluk	.192	.101	.144
	Bajau Laut	Bajau	-.221	.113	.131
		Suluk	-.029	.111	.963
	Suluk	Bajau	-.192	.101	.144
		Bajau Laut	.029	.111	.963
Same	Bajau	Bajau Laut	-.029	.148	.980
		Suluk	.023	.132	.983
	Bajau Laut	Bajau	.029	.148	.980
		Suluk	.052	.145	.932
	Suluk	Bajau	-.023	.132	.983
		Bajau Laut	-.052	.145	.932
Worse	Bajau	Bajau Laut	.543*	.129	.000
		Suluk	.474*	.115	.000
	Bajau Laut	Bajau	-.543*	.129	.000
		Suluk	-.069	.126	.848
	Suluk	Bajau	-.474*	.115	.000
		Bajau Laut	.069	.126	.848

\*The mean difference is significant at the p<0.05. Tukey HSD test.

#### Institutional arrangement of TSMP

Currently, the Sabah Parks Board of Trustees, also known as Sabah Parks, a government agency under Sabah's Ministry of Tourism, Culture and Environment, manages TSMP. Sabah Parks was established in 1964 and has now gazetted eight parks in Sabah with a total area of 317, 654 hectares. The headquarters of Sabah Parks is located in Kota Kinabalu on the west coast of Sabah, and has branch offices located at each gazetted park. TSMP was gazetted after an intense study called The Semporna Island Project (SIP) led by the Marine Conservation Society (MCS) (UK) and Sabah Parks. The initial management objectives of the park gave significant priority to benefits for local people and the environment. The conservation framework was properly designed in the interest of all users, especially the TSMP community. Co-management was proposed to manage the park. However, unfortunately, until now, after nine years of establishment, Sabah Parks is still hesitating to implement the framework and has doubts about the co-management regime due to conflict with the park's communities (Subject #SH09, 2013).

According to the interviews with a park official, only a few staff and rangers are originally from Semporna and only one of them is from Selakan island in TSMP. As a result, many officers that were interviewed suggested that they possessed little knowledge regarding the historical, cultural and social contexts of the park. However, officers exhibited more knowledge regarding environmental issues. When asked about the community, many of the officers answered with comments that showed lack of knowledge about the community and lack of involvement of the community in the park's activities:

*"I am not sure how many of them there are now. The last time we conducted a survey was in 2010 and I believe the number has changed since then. I don't have the exact figure now."* (Subject SH09)

*"It is hard to determine the number since the Bajau Laut people come and go at any time."* (Subject SH04)

*"We have a communication problem with the TSMP community. It is hard to develop the park, especially when we have unsettled land issues."* (Subject SH05)

When asked about co-management, the Acting Manager responded that the idea of appointing people as park rangers from TSMP communities had been discussed at the park level; however, since the park is under state administration, all appointees must be approved by the state's leaders and supported by Sabah Parks' Board of Trustees. This process is cumbersome since most of the top-level decision makers do not understand the problems that exist on the ground (interviewee SH16, 2013). It is commonplace in Sabah that government employees are reluctant to honor local stewardship or respect local knowledge (Subject# SH16, 2013; Doolittle, 2005).

In the interviews with park rangers, they complained that the existing staff were not sufficient to safeguard the 35,000 ha park. The organization chart that the researcher obtained from the Sabah Parks office in Semporna showed that 15 rangers / officers were located at three substations in the islands. However, Sabah Parks only placed a total of six rangers at three substations in Boheydulang island, Sibuan island and Mantabuan island. Furthermore, they were not on duty at the same time, thus reducing the capabilities of the staff to patrol the ocean and deal with the multiple tasks, such as identifying legal permits for visitors and, importantly, dealing with the prevalent fish bombing incidents. Significantly, the staff and park rangers agreed that the park is in need of local rangers and that cooperation from villagers, especially from Selakan island, has resulted in positive outcomes in terms of protecting their village and waters from intruders. The situation reflects the willingness of

local communities to co-manage TSMP, especially in terms of safeguarding the surrounding waters.

#### *Community involvement in TSMP management*

Co-management that would involve communities and other stakeholders in park management is yet to be implemented. The in-depth household survey revealed that 43% of respondents had been involved in planning, the decision-making process, or had received information or education, only once or twice before the park was officially gazetted. Almost half (49%) of the respondents said that they were never called to participate in any consultation or meeting with the park authority. Interviews with other important stakeholders i.e. the district (municipal) office, the Department of Fisheries and tourism operators, also revealed that most of them were not official members of the park management team. Representatives from the district office and the Department of Fisheries agreed that they were involved in consultation and any development projects in TSMP but that the final decisions always depended on Sabah Parks alone. Interviews with tourism/dive operators revealed that they were not involved officially in planning and developing tourism in TSMP and they literally visited Sabah Parks to register tourists who would be going to TSMP and Sipadan Island.

## **5. DISCUSSION**

#### *Native customary rights (NCR) and institutional arrangement for sustainable livelihoods*

Customary laws are a very important factor that should protect a community's rights to land and other property on that particular land. Indirectly, when a community has their rights recognized by law, it should also ensure that they could never be sidelined in park decision-making processes. Based on the findings of the study, NCR is marginally recognized as an influence in TSMP institutional arrangements. The park management plan indicates that co-management will be introduced, hence the foundation of a Local Community Forum (LCF) to represent those in the community with NCR. Unfortunately, engagement with LCF only occurred before and a few times after park establishment. A very important member of LCF indicated in an interview his disappointment that Sabah Parks had stop consulting them prior to making decisions about the park. He added that prior to the park's official establishment, they were given priority treatment in every discussion and decision-making process. They filed ten pledges to be fulfilled if Sabah Parks wanted the community to give consent to the proposed TSMP. Sabah Parks only agreed to six of the pledges. Nonetheless, LCF proceeded to give their

consent because of the promises made by Sabah Parks i.e. co-management, ecotourism and a hatchery project. At the time of interview in 2012, the respondents stated that it had been five years since they had been last invited to Sabah Parks meetings.

The park authority's failure to consult with local communities on park management and development are detrimental to relationships among stakeholders and the management of the park. Hostility between the park authority and local people is fostered, as well as negative perceptions towards conservation and ideas about sustainable resource use. Disempowerment of the community further marginalizes poor people. These negatives consequences could be reduced if the park authority would give extra attention to educating and involving local people in park management. The participatory events organized by the researcher and survey results revealed widespread negative perceptions towards the park authorities.

The most significant consequence of the failure to recognize those with NCR is that pending development plans are thwarted due to long-standing problems of ignorance and, in consequence, local resistance. For example, in an interview with a Sabah Parks officer, it was discovered that some projects have been cancelled or postponed because of disapproval from the community. The officer argued that many of those who disagreed with a project did not justify their action with claims of legal entitlement to native land, and gave no proof of a grant or other evidence of belonging. From the perspectives of Sabah Parks, communication and consultation with the local community will only complicate matters. As a result, they adopt a controller role as the state's government agency rather than acting as a facilitator to involve relevant stakeholders in developing and managing the park. On the other hand, from the community's perspective, the argument has been made that they inherited the land and the sea from their ancestors. This can be seen from their gardens, their ancestors' graves and the seaweed farms that they ran for many years before park establishment. Some who did not possess valid grant or native title argued that they claimed the land under NCR long before park establishment and suspected that their application was still pending due to the gazetting of the park.

The two different perspectives can only be resolved through a meaningful and ongoing discussion, consultation and sharing of information between the park and people. NCR entitlement means that holders have the right not only to stay in TSMP, but also to be involved in managing it, i.e. determining access and control over resource use. They should benefit from whatever opportunities the park has to offer. For example, there was strong support for the introduction of ecotourism development in TSMP if it is locally managed. Some respondents

especially the Bajau and Suluk communities expressed interest in homestays, boat rentals, cruises and other sea-venture activities but most emphasized that they would only agree to such activities if the power and benefits are equally shared. Surprisingly, most of the the Bajau Laut community agreed to follow (ikut saja) whatever their fellow Bajau community is doing. This shows that the community was well aware of what was happening around them, but they were not sufficiently well informed and well educated to devise their own means of influencing the institutional arrangements and management actions effectively.

#### *The importance of institutional change for the livelihoods system*

An SL approach is promoted in an attempt to eradicate poverty among rural, often marginalized, communities by putting people's priorities first, linking sectors both vertically and horizontally and from local to higher levels, building capacity and recognizing ownership of land or other properties, thereby moving the system in the direction of sustainability (Keely, 2001). In accordance with this, the institutional process, including customary laws, and the organizational structure (park management arrangements) have been studied in order to investigate how they can be used to influence the livelihoods system. Based on previous discussions, if NCR is truly recognized, it could be used to stimulate the acquisition of local feedback, thereby changing how institutions work, eventually contributing to organizational change (institutional arrangements). For instance, representatives from the people with NCR entitlement could be incorporated into the organizational structure of park management, allowing them to participate actively and meaningfully in information sharing and the decision-making process. Community participation is necessary to inform the management team about the situation on the ground and also for the community to be well informed on what is happening outside of their jurisdiction. Through information sharing and education, understanding and trust could be created, possibly resulting in mutual accommodation among stakeholders. Management efficiency could be increased through provision of a more productive environment, especially in terms of livelihoods and marine conservation in TSMP.

The objectives of the organization in managing TSMP should be to improve the well-being of communities and to conserve the ecosystems and natural resources of the park. Once all stakeholders are in unison to work on these objectives, feedback would inform the institution to change management strategies accordingly. Furthermore, the dynamic nature and complexity of the marine environment will influence the feedback process and the movement towards sustainable livelihoods through institutional change.

## 6. CONCLUSION

In summary, through combining interactive appropriate research methods with a sustainable livelihoods framework, the researcher found that institutional inefficiencies have contributed substantially to the many negative impacts of park establishment, such as livelihood depression and the associated hostility towards Sabah Parks. The case of TSMP involves residents with NCR rights and, thus, sustaining their livelihoods should have been a priority in order to obtain their cooperation and willingness to engage in the co-management of the park. It shows that even where legal rights exist, they can be ignored. The entitlement should influence their involvement in the institutional arrangements that should be created to address issues and problems. Therefore, empowering communities is a vital strategy in any attempt to reduce over-exploitation of marine resources, especially when they have strong legitimacy to participate in co-management because they have the most to lose if the resources that they control are degraded (Mozumder et. al, 2018). Eventually, relevant stakeholders that will guide the management of the park should represent the park organization through such an institutional arrangement. Through the legal empowerment of the community, they could influence the decision-making process, especially related to park resources management and livelihoods issues.

## ACKNOWLEDGEMENT

The research team is grateful to the TSMP's communities, their hospitality, care, and kindness made this study possible. We are greatly indebted to our local research assistants, Sakkah Jauhali and Jalil Mapait, whose knowledge, wisdom, and tremendous help had made the impossible possible. This research was financially supported by the Ministry of Higher Education Malaysia, the University of Waterloo Graduate Studies Office (UW-GSO), and the UW's Faculty of Environment Graduate Scholarship Award.

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## SUSTAINING THE MOTIVATION OF QUANTITY SURVEYORS IN FACING THE COMPETITIVE ENVIRONMENT

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### ABSTRACT

*The construction industry is complex and is frequently associated with occupational stress. Following this, the employees' motivation is important as it affects job performance. Motivated employees tend to be better at their jobs as they find and create initiatives to achieve their goals. In the construction industry, quantity surveyors are highly involved in the contractual and financial management of projects. The increasingly challenging environment has changed their work method, causing various significant impacts on performance. This paper explored the impact and effectiveness of motivation on quantity surveyors from three types of organisations in Malaysia; government agencies, private consultancy firms, and private contracting firms. A mixed-methodology was adapted, which included questionnaire surveys and a semi-structured interview with quantity surveyors registered with the Board of Quantity Surveyors Malaysia (BQSM). The findings demonstrated that 'good relations amongst staff and management team' sparked motivation the most, reflecting that it is the most effective motivational practice in many organisations.*

**Keywords:** : Malaysian Construction Industry; Industrial Revolution 4.0; Motivation; Quantity Surveyors.

### 1. INTRODUCTION

The major feature of construction processes is that they are infamous for their complexity (Construction Industry Master Plan for Malaysia [CIMP], 2005). This naturally creates occupational stress on the employees (Gunning and Cooke, 2007). In addition, the industry relies on the ability of individuals, the people-reliant nature of the industry (Smithers and Walker, 2010) causing the industry to be known as a stressful environment (The Chartered Institute of Building [CIOB], 2013). These significantly affect performance. In the construction industry, it is typical that construction employees with different skill sets work together in a project (Dainty *et al.*, 2007). Malaysia has its own new emphasis on sustainability in design practise and construction, creating new and unprecedented responsibilities on quantity surveyors' profession. On top of their traditional job scopes, quantity surveyors are currently required to offer new services such as analysing and advising on the benefits of life cycle costing management and cost-effective sustainable strategies. Due to its competitive nature, there has been a shortage of qualified workers in the Malaysian construction industry (Hee and Ling, 2011). This situation threatens the long term survival of the profession (Frei, 2010), creating additional pressure in assuring the flexibility of employment and working arrangements (Ofori and Toor, 2009). Following these observations, this research investigated the alternatives for individuals to endure the challenges in this competitive industry to improve job performance based on the motivation aspect.

There are many motivational practices that can influence job satisfaction and overcome performance problems due to occupational stress (Machungwa

and Schmitt, 1983). Nevertheless, there is a lack of knowledge on the same matter for those who work in the construction industry (Smithers and Walker, 2010). An in-depth understanding of motivational practices may improve the mechanisms for enhancing performance within the sector, in addition to providing possible insights into the types of people that the industry currently attracts and employs (Asad and Dainty, 2005) including quantity surveyor professionals. Smithers and Walker (2010), Oyedele (2010), and Ruthankoon and Ogunlana (2003) are among the researchers whose studies focus on the motivation of construction professionals. Despite their efforts, there is a lack of knowledge on the impact and effectiveness of motivational practices on construction professionals (Herman, 2017). Therefore, this paper seeks to identify the impact and effectiveness of motivational practices on quantity surveyor professionals in the Malaysian construction industry.

Moreover, motivation theories such as needs theories: Maslow's Hierarchy of Needs Theory (1943), Herzberg's Two-Factor Theory (1959), McClelland's Need for Achievement Theory (1961), and Alderfer's Existence-Relatedness-Growth (ERG) Theory (1972) describe the components necessary for human behaviour to occur. These theories are concerned with the factor that energises, directs, and shapes behaviour (Hellrigel *et al.*, 1995). Meanwhile, process theories are other motivation theories that are concerned with the analysis and description of the impact of personal factors such as cognitive processes determine people's motivation. Some of the process theories include Vroom's Expectancy Theory (1964), Adam's Equity Theory (1963), Porter and Lawler's Expectancy Theory (1968), and Latham and Locke's Goal-Setting Theory (1979) (Bowen *et al.*, 2008).

Moreover, motivation themes are derived from motivation theories and consisted of motivation factors that have similar nature or characteristics. Job characteristics, work nature, intrinsic rewards, and extrinsic rewards are among the examples of motivation themes. Among the many authors studying motivation themes – Brian (2014), Lim and Ling (2012), Oyedele (2010), Leung *et al.* (2008), Bowen *et al.* (2008), Steers (1987), and Machungwa and Schmitt (1983) – the themes discussed by Machungwa and Schmitt (1983) was used as a basis for this paper since it is the most comprehensive evaluation of motivation themes (Herman, 2017). The themes include growth and advancement opportunity, nature and characteristics of the works, material and physical provisions, relations with others, and fairness in organisational practices.

The first theme of growth and advancement opportunity include the possibility for promotion, opportunity to learn more about the job, receive further training, receive trust, confidence shown by superiors and co-workers,

placement in a job with regards to one's skills, and placement in a job with regards to previous training. In the context of this research, quantity surveyors are motivated with work or assignment that they enjoy or understand better. The strength of the employees (in terms of skills) has an important moderating effect (Lim and Ling 2012). Therefore, when quantity surveyors are sent to training, they have a tendency to become experts in their job scope since their confidence level of success is higher.

The second set of themes relates to the nature and characteristics of the works. This includes the amount or difficulty level of the work assigned (a lot of work, sufficient or more but not too much), jobs with short deadline, interesting and challenging assignments; work perceived as important and offering variety, and work that allows a sense of achievement and opportunity to prove oneself (Hytti *et al.*, 2013). Based on these themes, achieving target or goal, interesting work, and work-life balance are among the motivations of construction professionals including quantity surveyors (Holmes, 2012). Meanwhile, Bowen *et al.* (2008) identify that a variety of works, non-repetitive work, and having social interaction motivate quantity surveyors. This factor reflects that quantity surveyors will be more work-motivated if they enjoy the work rather than having to tailor their lives to their work.

Furthermore, the third group of items related to the amount of material and physical provisions present in the job situation. The components of the motivation under this theme are financial incentives, job security, and fringe benefits. Quantity surveyors are also affected by the mentioned motivation factors (Bowen *et al.*, 2008; Holmes, 2012), in addition to the quality of the work environment (Clark, 2000). Imagine a situation; traditional method requires frequent reference to drawings, therefore, an adequate work station (i.e. a table with the wide surface) will make the drawing reading and referencing more convenient to the quantity surveyors. Other than that, office facilities such as a personal computer with sufficient software will increase efficiency, particularly in preparing tender and contract documents.

Next, the fourth set of items is concerned with the relations of an individual with others. This includes: recognition or praise from superiors, co-workers, or subordinates, consultative and participative supervision, good interpersonal relations, supportive family and friends, and the concerns on the employees' problems shown by the company (Machungwa and Schmitt, 1983).

In addition, the fifth category of the themes pertains to the degree of fairness perceived in organisational practices. Machungwa and Schmitt (1983) identified two divisions for this cluster: (1) perceived fairness in promotion decisions; pay rises, work assignments, and other personnel practices and

decisions, and (2) keeping promises made to employees. This is in line with Adam's Equity Theory (1963). Nonetheless, Holmes (2012) and Bowen et al. (2008) argue that quantity surveyors are not affected by the degree of fairness in organisational practices.

Motivation affects how and to what extent the employees will utilise their skills and abilities. The organisation is defined as a social entity that is goal-oriented, deliberately structured with coordinated activity systems, and is linked to the external environment (Daft, 2007). An organisation is made of people and their relationships with one another. Nevertheless, there is no single theory of motivation that can claim to embrace the entire range of organisational and personal circumstances that exist. The difference of knowledge amongst the motivational theories requires managers to think contingently and to understand the work attitudes of each employee. Only then they can deal with the employees differently according to the strongest motivational drive identified in each employee. Consequently, employers will face challenges in implementing suitable motivational practices in the organisation that will be effective in causing a positive impact on the employees.

In the last decade, the roles of the quantity surveyor have undergone significant changes and challenges that threaten its existence (Frei, 2010). This can be seen from the statement of several major industrial researchers, reviewed by Cheung et al. (2010). His study identified that the construction industry must improve its efficiency. As stated by Adros *et al.* (2011), globalisation forces the construction industry to be more competitive amongst other firms to secure projects.

The quantity surveying profession began with core services from the seventeenth century. More services have continuously evolved throughout the nineteenth century. For the past fifty-five years, the roles of quantity surveyors have changed quite dramatically – from being a cost consultant to being a project solution provider (RISM, 2011). The change in the quantity surveyor's role reflects that this profession is being recognised in the industry and is increasingly becoming more important in Malaysia. The development of the quantity surveyors' roles are due to the competitiveness of the construction industry such as the increase in competition both from other practices and from firms attempting to replace their role (Jenning and Betts, 1996), and clients become more complex and demanding (Abidin *et al.*, 2011). To sustain the profession in today's competitive construction industry, it is necessary for the quantity surveyors to transform their work method to increase efficiency (Frei, 2010). This is in line with the latest demands required by clients and the construction industry (Abidin *et al.*, 2011).

## 2. RESEARCH METHODOLOGY

This study employed surveys and archival reviews as its research strategies. In addition, questionnaire surveys and face-to-face semi-structured interviews were used to collect the data other than document reviews. A total of 71 out of 200 distributed questionnaires were received and 22 quantity surveyors were interviewed. The respondents were quantity surveyors from the government agencies, private consultancy firms, and private contracting firms. Furthermore, the questionnaire surveys were analysed using descriptive analysis and statistical tests. Meanwhile, the semi-structured interviews were analysed using the content analysis method.

## 3. ANALYSIS AND DISCUSSION

By using the Kruskal-Wallis test, the results showed that the respondents' length of working period in the quantity surveying profession in the Malaysian construction industry (QS experience) and respondents' length of working period in the current organisation (experience in current organisation) did not affect both the level of impact and the effectiveness of current motivational practices for all the items of motivational practices. This contradicted Lim and Ling (2012) who emphasised that the experience of quantity surveyor impacted their performance. In addition, the gender of respondents did not affect the level of impact and the effectiveness of current motivational practices for all items of motivational practices.

With regards to the impact of current motivational practices employed, the results showed that three out of five motivational practices were statistically significant with types of organisation. The motivational practices were *receive growth and advancement opportunity* (item 14-1), *prepare appropriate nature of work* (item 14-2), and *receive material and physical provisions* (item 14-3). Meanwhile, two out of five motivational practices' influences on the individuals were statistically significant in terms of their job title, which included *receive growth and advancement opportunity* (item 14-1), and *prepare appropriate nature of work* (item 14-2).

Apart from that, the results from the semi-structured interviews showed that *having good relations with colleagues and management team* were also important to most quantity surveyors. Nineteen interviewees agreed that being in a caring and friendly environment brings them joy and that they wanted to stay longer to expand the organisation. Most of them agreed that this particular motivational practice contributed significantly to their work motivation.

In addition, job title and types of respondents' organisation were also statistically significant on the effectiveness of current motivational practices on individuals. The motivational practices were *receive growth and advancement opportunity* (item 15-1), and *receive material and physical provisions* (item 15-3), respectively. On top of that, the gender of the respondents was statistically significant to two of the motivational practices items, namely *prepare appropriate nature of work* (item 15-2), and *receive fairness in organisational practices* (item 15-5).

From the interviews, 19 out of 22 interviewees stated that *having good relations amongst staff and management team* contributed to high effectiveness. The interviewees agreed that having a good relationship with colleagues and employers made them feel like they were a part of a big family and made them feel comfortable to work in the organisation. Nonetheless, one interviewee commented that his organisation did not provide him with this incentive, and it was the staffs that initiated similar incentives by themselves.

From the discussions above, it can be concluded that many of the impacts and effectiveness of the motivational practices on individuals were not affected by the demographics of the respondents (Table 1).

The highest impact and the highest effectiveness of motivational practice (item 14-4 and 15-4) in organisations suggest that the perceived quality of team support and the quality of relationship with colleagues and management team are important and valued by the individual quantity surveyors (Table 2). The qualitative analysis also supports the results from the quantitative analysis as almost all the interviewees responded positively to this particular motivational practice as being effective. This is in line with the study done by Anderfuhren-Biget et al. (2010) who concluded that the quality of team support – recognition by and relationship with superior and teammates – positively impact work motivation. The results also mirrored the conclusion from Bowen *et al.* (2008), who mentioned that the participation in a team and having a good relationship with co-worker were among the factors that motivate the quantity surveyors. This result also supports all the theory of needs (the Third Level of Maslow's Hierarchy Theory, the Hygiene Factor of Herzberg's Two Factor Theory, the Need for Affiliation of McClelland's Need for Achievement Theory, and the Relatedness Needs of Alderfer's ERG Theory) which state that there is the element of social needs and awareness in each individual (Herman and Sharom, 2017).

Table 1: Kruskal-Wallis analysis on the effect of demography on motivational practices

Questions	Item ID	Motivational practices	Job title	QS experience	Experience in current organisation	Gender	Types of organisation
To investigate the level of impact of current motivational practices on individual quantity surveyors.	14-1	Receive growth and advancement opportunity	.001* *	.753	.707	.775	.008**
	14-2	Prepare appropriate nature of work	.016*	.863	.688	.129	.029*
	14-3	Receive material and physical provisions	.078	.417	.865	.184	.005**
	14-4	Have good relation amongst staff and management team	.134	.636	.920	.155	.084
	14-5	Receive fairness in organisational practices	.130	.333	.749	.083	.169
To investigate the level of effectiveness of current motivational practices on individual quantity surveyors.	15-1	Receive growth and advancement opportunity	.023*	.157	.874	.405	.128
	15-2	Prepare appropriate nature of work	.168	.685	.796	.001**	.102
	15-3	Receive material and physical provisions	.620	.513	.943	.072	.009**
	15-4	Have good relation amongst staff and management team	.162	.505	.958	.052	.071
	15-5	Receive fairness in organisational practices	.759	.622	.739	.045*	.621

\*Result is statistically significant at  $q < 0.05$ .

\*\*Result is statistically significant at  $q < 0.01$ .

Table 2: Summary of findings of the impact and effectiveness of current motivational practices employed by organisations in motivating quantity surveyors

Questions	Item ID		Overall mean score	Kruskal-Wallis test	Thematic analysis (no. of sources)
To investigate the level of impact of current motivational practices on quantity surveyors.	14-1	Growth and advancement opportunities	2.24	Significant	16
	14-2	Appropriate nature of work	2.25	Significant	20
	14-3	Material and physical provisions	2.41	Significant	20
	14-4	Good relations amongst staff and management team	2.42	Not significant	19
	14-5	Fairness in organisational practices	2.28	Not significant	16
To investigate the level of effectiveness of current motivational practices on individual quantity surveyors.	15-1	Growth and advancement opportunities	2.29	Not significant	18
	15-2	Appropriate nature of work	2.36	Not significant	20
	15-3	Material and physical provisions	2.32	Significant	17
	15-4	Good relations amongst staff and management team	2.51	Significant	19
	15-5	Fairness in organisational practices	2.30	Not significant	17

#### 4. CONCLUSION

This research investigated the impact and effectiveness of motivation practices on quantity surveyors in the organisations. The results demonstrated that the highest impact of motivational practices, as well as the most effective motivational practices on individual quantity surveyors is good relations amongst staff and management team. New quantity surveyors should consider the driving forces of the green environment to have high motivation level. Malaysia is in the era of industrial revolution 4.0 and the construction industry is moving towards it, encouraging various technologies to replace the traditional method. Quantity surveying organisations are pertinent in supporting the change by preparing the quantity surveyors to adapt and embrace the new revolution. Quantity surveyors should be motivated in preparing themselves for the competitive environment of the industrial revolution 4.0 (BQSM, 2018).

#### ACKNOWLEDGEMENT

This research may contribute to the job performance of individual quantity surveyors, other construction professionals, construction organisations, academicians, and professional bodies such as the Board of Quantity Surveyors Malaysia (BQSM) and The Royal Institution of Surveyors Malaysia (RISM).

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## THE SIGNIFICANCE OF HERITAGE TREES CONSERVATION FOR URBAN DEVELOPMENT IN TAIPING LAKE GARDEN, MALAYSIA

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### ABSTRACT

*Lack of awareness on the environmental benefits and services offered by urban heritage trees among the decision makers and society has endangered these urban heritage trees, thus they are not recognized as an important asset. Heritage trees are important in giving historical identity and cultural symbolic to the landscape of the cities. Rapid development of urban areas in Malaysia has changed the land use of natural environment to into built environment. This situation causes a lot of urban heritage trees to be felled to make way for urban development. The main objective of this paper is to identify and analyze the benefits of heritage trees in Taiping Lake Garden based on tourists respond. This research has applied a contingent valuation survey questionnaire in collecting the data. A total of 400 tourists were randomly interviewed in Taiping Lake Garden. The study was also focused on the importance of preserving the non-use value and inducing public awareness on conservation of heritage trees as part of landscape roles to create culture and historical value in cities. Analyzing benefits of heritage tree through a participatory process that involves the tourists could help to promote the sustainability of the Urban Heritage Trees conservation efforts in Taiping Lake Garden.*

**Keywords:** : Natural environment; Non-use value; Public awareness; Trees conservation

### 1. INTRODUCTION

Historically, trees generally have their own space relatively in gardens and parks, a luxury that is becoming increasingly difficult to justify in sub-division mentality of the modern planning environment. As larger plots are redeveloped into smaller units, trees and people are being squeezed together, creating conflicts that were never an issue in the past. Above ground, dense crowns close to buildings and recreational areas can reduce light to intolerable levels. Large, spreading crowns can interfere with buildings and access, creating hazards and obstructions. Below ground, roots can disrupt services, foundations and surfacing, causing serious damage and inconvenience. The closer trees get to people, the more problems there seem to be, with one inevitable conclusion. In a straight fight, trees lose every time. The traditional approach of trees having their own space is no longer realistic and certainly not working in our modern world.

Conservation of heritage trees is a concern worldwide. Therefore, many countries have taken the initiative to raise awareness to the public about the importance of heritage trees and enact laws or declared policies to authorize the conservation of heritage trees as part of the culture of the city. Heritage tree might look the same as ordinary tree that provides benefits and aesthetic value to the urban community. In fact, it has the same ecological-landscaping roles such as the interception of rainfall and reducing water pressure into surface, reducing air pollution and increasing property values in an area. Though, in Malaysia's context heritage tree is considered as a new term.

The conservation efforts towards this valuable heritage protection are deeply needed in law or policies and public awareness. Heritage trees can adapt in urban stress environment while others are sensitive to various ecosystems.

Due to population increase most urban trees including which having the potential to be gazetted as heritage trees, are felled or neglected to give way to development resulting in the decrease in carbon sink. The deforestation of urban trees has significant impacts to the ecology causing environmental problems such as flash flood and increased carbon emitted due to the increase of fuel and energy consumption for transportation, buildings component such as the Heating, Ventilating and Air Conditioning System (HV AC System) which induces the Urban Heat Island (UID) phenomenon. Moreover, the value of urban trees are undervalued by the decision makers and society, thus very little consideration is given to the urban trees.

Normally, community will relate to heritage trees as bestowed by their religion, spiritual or other symbolic values (Read, 2000). A century ago, *Pterocarpus indicus* (angsana) was recorded as the earliest urban tree in Malaysia. It was planted in 1778 in Malacca (Koenig, 1894) and in Penang (Burkill, 1966). Because of the impact of its wide diameter of canopy and fast in germination, *Pterocarpus indicus* had been chosen as a popular tree for urban planting and remained in Malaysia and Singapore in 1990s (Philip, 1999). However, in 1935 these trees were reported to be affected by unknown plant disease that spread rapidly in Malacca, Penang and Singapore (Furtado, 1935). In order of prevent the disease from spreading to all trees, certain affected trees were removed by cutting down the trees. This situation could have been avoided if it was put through a regular tree inspection and correct maintenance technique. The Malaysia's management of urban heritage trees protection was poor, lacking of knowledge about the maintenance, with the aspect of public security being underestimated (Sreetheran, Philip, Adnan & Siti Zakiah, 2006). Therefore, the protection of heritage planting becomes worst because there is no action to handle the problem (Zamil, 2012).

### 2. LITERATURE REVIEWS

There are several studies in the literature about the importance of protecting the heritage trees due to its special characteristics. The studies by Loeb (1992) showed that many trees in urban cities have declined and died prematurely due to urban stress ecosystem. It is unusual to find old trees that manage to soldier on despite the heavy odds. These heritage trees are treasured by the community. Special attention and care has been given to this heritage tree because it is showing a status of cultural heritage. According to Cloke and Pawson (2008), trees can be marked as histories of the lives that lived around

them and also be marked by the changing of cultural settings in histories. Operational Guidelines for the Implementation of the World Heritage Convention has been use since 1992. Any significant interactions between people and the natural environment are recognized as cultural landscapes and considered as "natural heritage" (UNESCO, 2013). Heritage commonly refers as 'something' that has been passing on to the generations of people on the present day. Various dimensions of heritage have been looked and discussed either by local or foreign countries and this includes inheritance, tradition and culture, legacy and beliefs. Basically, three key entities consolidated and was referred to heritage; material culture, natural environment and built environment (Nur Hijrah et al., 2015).

#### 2.1 Urban Heritage Tree

Trees that have lived for a long time or are associated with culture are often highly valued in different societies. As the pride of local communities, they are commonly included in tourist guides (Lai et al, 2019). Urban heritage trees can be the backbone of the cultural landscape and society because they have particular natural or cultural characteristics and, therefore, demand an effective protection policy (Mid, 2012). The urban heritage tree can be recognized and qualified by the following criteria; 1) large size in relation to biological potential dimension of the species, 2) outstanding tree form, 3) unusual or rare species, 4) aged preferably over 100 years and 5) have cultural, historical, commemorative or ecological significance (Jim & Zhang, 2013). Urban Heritage trees are also variously labeled as ancient, beautiful, big, champion, elite, exceptional, famous, heritage, historic, landmark, old, outstanding, remarkable, specimen, veteran trees, ancient, and old-valuable (Read, 2000; Browne, 2001; Meyer, 2001; Jim, 2005; Jim & Zhang, 2013). In the cities they are characterized as significant natural-cum-cultural resources of cities that give broad expanse of biological, historical and cultural values to the urban community (Fay, 2002; Green, 2002, Jim and Zhang, 2013). According to Oregon municipal, age, size, species, quality, landmark importance, and its retention not unreasonably interfering with the use of the property upon which it is located are the criteria that should be viewed to be classified as a heritage tree. Moreover, the criteria such as public access, tree health and historic element play important roles in whether or not a tree or grove qualifies. Among the criteria to qualify a tree to be entitled as a Heritage tree include: a girth of more than 5 meters, unique species and historical significance as proposed by National Parks for Singapore Botanical Garden in the Heritage Trees Scheme. Many studies of heritage trees in Asia focused in compact cities such as Guangzhou (Jim, 2004), Bangkok (Thaiutsa et al., 2008) and Hong Kong (Jim & Zhang, 2013). The old, heritage or valuable trees are concentrated in temple grounds, roadsides and urban parks with different modes of urban development and fabric (Lai et al., 2019).

## 2.2 Heritage trees enforcement

Local Planning Authorities in Malaysia was given the order that each construction must follow the rules of Tree Preservation Order (TPO) that is legally enforceable to protect trees impunity to be cut down to preserve cultural value and historical elements in the interests of public amenity. In 1995, Tree Preservation Order (TPOs) was introduced in Malaysia in an amendment to Town and Country Planning Act (Act 172) that inserted Part VA in respect of TPOs into the act (Akta Perancangan Bandar dan Desa (Pindaan) Akta 1995). Section 5A beginning Subsection 35A to 35H Act 172 Akta Perancangan Bandar dan Desa (Pindaan) Akta 1995 relates the whole provision about tree preservation. Section 35A stated that local authority has a power to give out a tree preservation order to control regarding the felling of trees that is endangered or with special value (Table 1) while in Section 35H it is stated that all matured trees with diameter of 0.8 meters will get a special protection not to be felled unless given permission by the local authority.

Table 1: User trees to be preserved and protected

	The threat of extinction Custom	
Trees that have special value	Custom Value	Species that have natural beauty or the local value or aesthetic contribution to the landscape, or as an adverse opinion or the future development and historical value.
	Value Of History	Tree species planted more than 30 years ago and has to do with the history of the area where it is planted.
	Eminent Crops	The trees planted by the leaders and dignitaries during a ceremony of national interest.
Trees that are threatened with extinction	Rare	Rare tree species. However, the number is still much more to be categorized into the group threatened.
	Endemic	Tree species that only grows in certain places that have the appropriate climate, local ecology, the earth and the composition of suitable land with trees.
	Endangered	Rare tree species and the numbers a bit and if not protected, chances are the trees of this species will become extinct.

(Source: Department of Town & Regional Planning, 2005)

## 2.3 Benefits of Heritage Tree

The multiple benefits of trees in enhancing the livability of cities have been well documented (Roy, Byrne, & Pickering, 2012), but they face acute growth challenges especially in compact cities. Few urban trees can continue to thrive in the urban fabric for over a century (Zhang, Lai & Jim, 2017). The notable remnant trees are often respected as heritage trees, which have been referred to as ancient, champion, historical, legacy, old, precious, outstanding, valuable, or veteran trees (Jim, 2005a). Heritage trees play

pertinent ecological-landscaping roles in cities, yet only a few known studies are mainly descriptive or have resource inventories (Jim, 2005b). Trees can have a high amenity value and can make an important contribution to social benefits such as improvements in building energy conservation, air and water quality, cooler air temperatures, and reductions in ultraviolet radiation (Jim, 2004). Heritage trees have lasting values that teach us about our culture by providing a context for community identity, growth, and contrast in our modern world. Trees, like buildings, are an essential part of the fabric of where we live, making a significant contribution to the health and wellbeing of our communities and the wider environment (Ali et al, 2016; Historic Preservation Guidelines City of Elberton, 2009). Heritage trees also reflect the patterns and processes that have shaped our natural and urban environments over time. Heritage trees may represent the last vestiges of former natural or cultural landscapes – symbols of our environmental, social and economic histories (Godefroid, 2001).

Different cultures have cultivated urban trees for their multiple benefits and functions and city greeneries often reflect the history of urban development and associated environmental changes. They form a heterogeneous group, including spontaneous or cultivated tree and native or exotic species. These outstanding remnant specimens are widely respected as landmarks or heritage trees by urban dwellers (Jim, 2004). Heritage trees are non-renewable and irreplaceable living heritage, with great preservation value in the urban city (Meyer, 2001). Trees that hold significance for their notable and historic heritage contribute to the community's well-being and environment in many ways. These resources also provide continuity between the past, present and the future. Godefroid (2001) stated that significant trees are inextricably linked to the quality and identity of a 'place'. Heritage trees can be symbols of great spiritual power. Heritage trees may have associations with individual and communities or tell stories of other times and places or the historic development of a place.

## 2.4 Conservation of Heritage Trees

In developed economies, the government and people are or they should be more aware of their historic legacy, and they are more willing to devote resources for its conservation. Like many historical buildings, heritage trees have matured alongside the community to link the past with the present (Lai et al., 2019). Heritage tree offer a common strand to construct an important part of the society's collective memory. It is appalling that 100-year heritage buildings were conserved while 100-year heritage trees were just ignored. For heritage trees conservation, it is very important to do the survey, inventory and analysis of heritage trees condition and value before the decision for

treatment or cutting down is made. Thus, heritage trees are not simply cut down without the reasons. Heritage trees are an integral and valuable part of our natural and cultural landscape and are often among the oldest living objects in the country. They are found in our native woodlands, historic parklands and estates, in association with human settlement, along roadsides and in hedgerows, agricultural fields and occasionally as isolated specimens in the middle of housing estates or development sites. Heritage trees are often all that remains as a legacy of some of our most historic landscapes (Society of Irish Foresters, 2014). They survive today because of their historical connections, aesthetic appeal, their ecological or botanical significance or simply because they are hidden away. The valuable heritage trees demand protection and preservation for the future generations. Unfortunately, threats from natural hazards, human activities, disease, pest and parasitic plants are continually damaging these living treasures. Fortunately, most of the threats could be avoided or minimized by better tree monitoring and care, such as regular tree inspection, setting up protective regulations and enhancing public education. Well-protected and managed urban trees could increase the number, species and distribution of heritage trees over the city after decades of effective efforts (Zhang, Lai & Jim, 2017).

## 3. METHODOLOGY

This study applied single case study as a research approach. Taiping Lake Garden has been chosen as a case study because it has heritage trees that aged more than 130 years planted during the British ruling in Malaysia. One set of questionnaire was designed for tourists in Taiping Lake Garden to identify and analyzes the benefits of heritage trees based on tourists respond. In context of this research, stakeholders groups (tourist) were considered as the main stakeholders in heritage tourism and heritage value assessment (Nicholas et al., 2009). A total of 400 tourists (domestic and foreign) who have paid a visit to Taiping Lake Garden were randomly selected as respondents. The respondents were at least 18 years old. The questionnaires were developed based on the contingent valuation methodology to elicit the benefits of heritage trees of the individual respondent (Khee et al., 2009) to urban heritage trees conservation. The structured contingent valuation questionnaire aided by photo images was applied in this survey. Photos of heritage trees in a pleasant and poor state were taken for use in show cards to summarize the idea of the valuation scenario (imaginary situation) delivered to the respondents.

## 3.1 Case Study: Taiping Lake Gardens.

The name Taiping is made up of two Chinese characters (tai – 'great') and (ping – 'peace'). Taiping town is located in Larut, Matang and Selama District, Perak, Malaysia. Taiping also receives some limelight for being the wettest town in Peninsular Malaysia. The average annual rainfall is about 4,000mm in Taiping while the peninsula's average is 2,000mm - 2,500mm. Its unusual rainfall has also led to a fertile collection of flora and century-old rain trees in the Taiping Lake Gardens. The British made Taiping the administrative center for the state of Perak in 1875. The town served this function until 1937 when the state capital was moved to Ipoh. Before the arrival of the British, the district (known in its earlier days as the The Larut Settlement) was governed by the Minister of Larut, Dato' Long Jaafar (and later by his son Ngah Ibrahim) who was empowered by the Sultan of Perak at that time, to govern that territory. Due to the booming tin-mining industry in the 19th century and its previous position as capital of Perak, Taiping is the pioneer in many fields achieving many 'firsts' in the country. The list given by Taiping Municipal Council records a total of 40 firsts in the country under Taiping's belt. Dated as early as 1844, these firsts are either in monuments or events.

During the British ruling in Malaysia, Taiping Lake Gardens was established as the first public garden in 1880 that is originally a mining ground. The garden area is 64 hectares and located near Bukit Larut. Colonel Robert Sandilands Frowd Walker gave the idea and Charles Compton Reade developed the garden (1880 -1933). There are ten scenic lakes and ponds, which give emphasized value to the gardens. The focus of this study was more to Rain Tree, Samanea saman because it was the first planted tree in Taiping Lake Garden during the era of Mr. R. Denny, the officer in charge of Government park in 1898. Samanea saman, lining the streets of Taiping Lake Garden with branches stretching from one end of the road into the waters across, has become an icon of Taiping. Map 1 shows the boundaries of study area and the orange lines are location of Samanea saman trees in Taiping Lake Garden. The total quantity of urban heritage trees in Taiping Lake Garden was 118 trees. Six species of trees were found including Samanea saman (91), Adenanthera pavonina (20), Vitex pubescens (3), Artocarpus elasticus (1), Bertholletia excels (1), and Pterocarpus indicus (1).





Figure 1: Location of Samanea saman trees in Taiping Lake Garden (Source: JPBD, Majlis Perbandaran Taiping)

#### 4. FINDINGS AND DISCUSSION

There were 400 respondents who participated in the interview. The interview was sampled on the tourists (domestic and foreign) in Taiping Lake Garden. This sampling size represents 10% of the overall sample data collection.

Table 2: Tourists Demographic in Taiping Lake Garden

Demographic	Variable	Percentages (%)
Gender	Male	39.3
	Female	60.8
Age	18-20	23.8
	21-30	33.0
	31-40	22.5
	41-50	9.8
	51-60	8.8
	>60	2.3
Race	Malay	92.0
	Chinese	3.5
	Indian	4.0
	Others	.5
Religion	Islam	92.5
	Buddhism	3.3
	Hinduism	3.5
	Christianity	.5
	Other	.3
	Education level	No Formal Education
UPSR		1.5
SRP/PMR		5.3
SPM		46.0
Diploma Degree		23.8
Bachelor Degree		16.8
Other		3.0
Monthly income	No Income	28.8
	< RM500	2.5
	RM501-RM1000	10.8
	RM1001-RM1500	11.5
	RM1501-RM2000	19.3
	RM2001-RM3000	8.8
	RM3001-RM4000	11.3
	RM4001-RM5000	1.0
	RM5001-RM6000	3.5
	>RM6001	2.0
Other	.8	
Occupation	Civil Servant	23.0
	Non-Government Employee	22.0
	Businessmen	9.8
	Student	21.3
	Others	24.0
Malaysia Tourist	Johor	.8
	Kedah	10.0
	Kelantan	3.0
	Kuala Lumpur	.8
	Melaka	.3
	Pahang	2.3
	Perak	77.0
	Pulau Pinang	4.8
	Sabah	.5
	Selangor	.3
Foreigner Tourist	Indonesia	.5

Table 2 shows that Female (60.8%) dominated the interview of respondents consisting of visitors in Taiping Lake Garden. The highest range of age is 21 – 30 (33%). Most of the respondents are Malays (92%). The highest education level is SPM (46%). Most of the respondents monthly income are ‘no income’ (28.8%) like housewife or student. Second highest respondents income is RM1501-RM2000 (19.3%) as an average salary. The highest number of Malaysian tourist was from Perak (77%) because visitors surrounding Perak can reach Taiping Lake Garden easily distance wise. Meanwhile, only foreign tourists coming from Indonesia was found.

Table 3: Attitude of Tourists towards the heritage tree conservation and its benefits on Taiping

Attitude towards the heritage tree conservation and its benefits on Taiping	Strongly disagree	Disagree	Partially agree	Agree	Strongly agree	Mean
	%					
1 The Heritage Tree in Taiping Lake Garden as an identity and landmark of Taiping	.8	2.0	10.5	41.5	45.3	4.29
2 The Heritage Tree in Taiping Lake Garden as a link to Taiping history	0	2.5	9.0	44.5	44.0	4.30
3 The Heritage Tree in Taiping Lake Garden provided habitat and food sources for urban wildlife	1.0	5.3	25.8	39.8	28.3	3.89
4 The Heritage Tree in Taiping Lake Garden has improved the economic performance of Taiping by increasing the attractiveness of business and tourism	.5	2.3	17.3	42.5	37.5	4.14
5 The Heritage Tree in Taiping Lake Garden has improved aesthetic value of Taiping	0	3.0	16.8	45.3	35.0	4.12
6 The Heritage Tree in Taiping Lake Garden has created a feeling of relaxation and well-being	0	.8	10.8	33.0	55.5	4.43

From table 3, the analysis of item 1 (The Heritage Tree in Taiping Lake Garden as an identity and landmark of Taiping) shows that most of the tourists strongly agreed (45.3%) followed by agreed (41.5%) and partially agreed (10.5%) that they recognized the benefits of heritage trees as an identity and landmark of Taiping. Most of the tourists can identify this heritage trees because the trees were lined straight along the corridor of the road approaching the lake that becomes an icon of Taiping in signage and handout to promote tourism in Taiping (Figure 2). Only 2.8 % of the tourists disagreed (2%) and strongly disagreed (0.8%) that heritage trees in Taiping Lake Garden is an identity and landmark of Taiping.



Figure 2: Trees were lined straight along the corridor of the road approaching the lake that becomes an icon, identity and landmark of Taiping. Sources: Author, 2017

The analysis on item 2 (The Heritage Tree in Taiping Lake Garden as a link to Taiping history) found that most of the tourists agreed (44.5%) followed by strongly agreed (44%) and partially agreed (9%) that they recognized the benefits of heritage trees as a link to Taiping history. They know the fact that the heritage trees in Taiping Lake Garden were planted during the British era. According to Taiping Municipal Council, the first planted tree in Taiping Lake Garden was the Rain Tree or Samanea saman in 1898 (Figure 3). The visitors can expect the age of this heritage trees from the physical size of the branches and canopy and physical appearance of the trees. Only 2.5 % of the tourists disagreed that heritage trees in Taiping Lake Garden is a link to Taiping history.



Figure 3: The first planted tree in Taiping Lake Garden was the Rain Tree or Samanea saman in 1898 during the British era as a link to Taiping history. Sources: Author, 2017

Analysis on item 3 (The Heritage Tree in Taiping Lake Garden provided habitat and food sources for urban wildlife) shows that most of the tourists agreed (39.8%) followed by strongly agreed (28.3%) and partially agreed (25.8%) that heritage trees have increased the environmental benefit of urban wildlife because they can find a few species of bird and squirrel in Taiping Lake Garden (Figure 4). Only 6.3 % of the tourists disagreed (5.3%) and strongly disagreed (1%) that heritage trees in Taiping Lake Garden provided habitat and food sources for urban wildlife.



Figure 4: Spread over 64 hectares, the lake is surrounded with birds, insects and wildlife. Sources: Nur Hijrah et al., 2015.

The analysis on item 4 (The Heritage Tree in Taiping Lake Garden has improved the economic performance of Taiping by increasing the attractiveness of business and tourism) found that most of the tourists agreed (42.5%) followed by strongly agreed (37.5%) and partially agreed (17.3%) that the benefits of heritage trees have improved the economic performance of Taiping by increasing the attractiveness of business and tourism. This finding shows that tourists were very interested with the aesthetically pleasing environment created by the heritage tree in Taiping Lake Garden (Figure 5). Many tourists from different districts of Perak and states of Malaysia came to visit Taiping Lake Garden to feel the environment. Only 2.8 % of the tourists disagreed (2.3%) and strongly disagreed (0.5%) that heritage trees in Taiping Lake Garden has improved the economic performance of Taiping by increasing the attractiveness of business and tourism.

For item 5 (The Heritage Tree in Taiping Lake Garden has improved aesthetic value of Taiping) it was found that most of the tourists agreed (42.5%) followed by strongly agreed (37.5%) and partially agreed (17.3%) that heritage trees have improved the aesthetic value of Taiping. The form of heritage tree that gives unique and aesthetic value to the Taiping Lake Garden has attracted tourists to pay a visit (Figure 6). Only 3 % of the tourists disagreed that heritage trees in Taiping Lake Garden has improved the aesthetic value of Taiping.



Figure 5: Tourists were very interested with the aesthetically pleasing environment created by the heritage tree in Taiping Lake Garden has improved the economic performance of Taiping. Sources: Author, 2017.



Figure 6: The unique form of heritage tree in Taiping Lake Garden has improved aesthetic value of Taiping. Sources: Author, 2017

The analysis on item 6 (The Heritage Tree in Taiping Lake Garden has created a feeling of relaxation and well-being) found that most of the tourists strongly agreed (55.5%) followed by agreed (33%) and partially agreed (10.8%) that they recognized the environmental benefit contributing to health, relaxation and well-being of humans by creating a peaceful, aesthetically pleasing environment into urban settings. This result seems to indicate that many tourists came to Taiping lake garden to enjoy the environment and take pictures with the background of heritage tree for outdoor wedding photo-shoot, family gathering and leisure time with friends that would create memorable memories (Figure 7). Only 0.8 % of the tourists disagreed that heritage trees in Taiping Lake Garden has created a feeling of relaxation and well-being.



Figure 7: The environment in Taiping Lake Garden has created a feeling of relaxation and well-being to tourists. Sources: Author, 2017.

As shown in Table 3, the highest mean score of benefits of heritage tree is that the heritage tree in Taiping Lake Garden has created a feeling of relaxation and well-being (4.43). This shows that the visitors like to come to Taiping Lake Garden because they like to enjoy the peacefulness and aesthetically pleasing environment created by heritage trees. Meanwhile, the lowest mean score of benefits of heritage tree is that the heritage tree in Taiping Lake Garden provided habitat and food sources for urban wildlife (3.89).

## 5. CONCLUSIONS

In conclusion, urban heritage trees protection in Malaysia still needs to be improved by the law and policies implementation. The issues and challenges of urban heritage trees in Malaysia need solutions to upkeep appropriately in maintaining the overall setting of heritage site value. Due to the new development in cities, many heritage trees are unprotected. The knowledge about benefits offered by heritage trees is important on giving awareness to tourists to join and volunteer for the management and conservation of Taiping Heritage Tree Conservation. The willingness-to-pay value of Urban Heritage Trees in Taiping Lake Garden is a initiative for preservation, protection and conservation purpose in future formulation of state or federal policy. By conserving Urban Heritage Trees, the Federal Government of Malaysia together with the State Government of Taiping and also Local Authorities would be able promote sustainable development on urban areas without neglecting the environment which aligns with Malaysia's policy on Sustainable Development enunciated in the 7th Malaysian Plan (GOM 1996). Hence, by assigning the willingness-to-pay value on the trees, it would promote awareness to the decision makers and tourist to consider protecting our green assets in order to promote sustainable development in urban setting. The influences of the colonial era has a great impact to the planting scheme

in Malaysia where a significant planting scheme could clearly be noticed from Taiping Lake Garden together with Malacca, Singapore and Penang. Furthermore the public awareness protecting urban heritage trees need to be increased by actively promoting it through education and promotional programmes, greater public understanding and appreciation of heritage trees and an importance of protecting them.

## ACKNOWLEDGEMENT

This research was made possible by financial support from Universiti Putra Malaysia (GP-IPM/2016/9501200).

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## LOCAL RESIDENTS AND TOURISTS' OPINION ON THE EFFECTS OF BOATING ACTIVITY TOWARDS KILIM WATERWAYS

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### 1. INTRODUCTION

Malaysia is very fortunate to have a valued environment and resources of tropical rainforests. The State Forestry Policy outlines the importance of conservation and conservation of forests in the country (National Forestry Policy 1977). This policy is seen in parallel with the National Biodiversity Policy, which focuses on the importance of preserving the diversity of biodiversity found in Malaysia (National Policy on Biological Diversity 2016 – 2025). In this regard, it is desirable to ensure the best ways and means to safeguard, retain and conserve these assets. Since most natural resources are limited and non-renewable, every tourism activity introduced in one area needs to be holistic so that the concept of sustainable development can be achieved.

It cannot be denied that tourism is one of the vital contributions to the economy in Malaysia, even with the increasing demands for ecotourism and nature-based tourism in recent years have created more impacts on the natural environment in ways that it put pressures on the carrying capacity of the environment (Wong, 2004; Muhanna, 2006). Globally, vehicles meant for travelling has contributed to the increasing causes of greenhouse gas emissions, habitat loss, and degradation of various types of environments, such as coastal, wilderness, rural areas and small islands. Those environmental changes affecting land, air, and water (Wong, 2004). It is suggested that the environmental impacts of tourism spread in line with the increasing awareness of environmental issues in 1970's. It is the combination of creating tourism as a form of economic development and simultaneously bring conservation issues together (Cole and Scott, 2004). According to Holden (2000), research on the environmental impacts of tourism is still “relatively immature and true multidisciplinary approach to investigation has yet to be developed” (p.250). The opinion of

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### ABSTRACT

*Heritage sites within Kilim Karst Geoforest Park consist of geology, archaeology, ecology, history and culture. Therefore, both tourism and resource conservation should be integrated in order to benefit human and natural resources. This paper presents research that identifies the opinion of tourists and local residents on the effects of boating activities towards natural resource conservation in Kilim Karst Geoforest Park, Langkawi. 320 structured questionnaires were distributed to tourists, local residents in Kilim and staffs who are in charged in the tourism operation of Kilim Karst Geoforest Park including staff of Langkawi Development Authority (LADA), Koperasi Kampung Kilim Langkawi Berhad (KKKLK) and Komuniti Pengurusan Sumber Perikanan (KPSP). The study managed to gather 93% with response rate (n=299) that consist tourists (65), local residents of Kilim (145) and staff (89). Based on the analyses conducted, it was found that boating activities contributed to the pollutions along Kilim waterways in many ways for instance, oil spills and waste disposals. Majority of the respondents agreed that high boats speed increased strong waves, which lead to depletion of mangrove trees and affecting aquatic life. Kilim has become one of the preferred destinations for nature lovers since the area has been given the Geopark and has received countless of tourist arrivals. Nevertheless, this situation had also affected natural resources of the area. Thus, people who involved in tourism activities and the management of Kilim Karst Geoforest Park should concern and possessed adequate knowledge on natural resource conservation so that the area can be experienced by the future generations.*

**Keywords:** Kilim Karst Geoforest Park, Boating Activities, Effects; Natural resource; Conservation

Holden is justified, as the environmental impacts of tourism must be explored by all parties that involved in tourism activities. Professionals in the built environment such as Landscape Architects and Planners have argued that, with effective design and management, the existence of “symbiosis” between tourism and the environment is possible to reach (Cole and Scott, 2004).

Various steps have been taken in conserving the natural resource from being extremely destructed by countless developments comprising of tourism activities. One of the efforts is the growth of sustainable tourism which is derived from sustainable development. The exertion is meant to sustain the environment for future generations. Natural resource conservation issues arose after public concern of environmental degradation began in the mid-nineteenth. However, this did not become a major concern for most people until in the late of twentieth century (Bowler et al., 2010). Consequently, there has been an explosion of awareness around the world in issues of sustainable development, ecological restoration, and resource management. All those issues were destined to reach the aim for natural resource conservation. As a vicegerent on earth, men have responsibility to protect, control and manage the natural resources accordingly. Natural resources are significant for the whole ecosystem stabilization as every creature live in symbiosis. Therefore, in order to retain the natural environment for future generations, conservation efforts need to be continued and increased.

The term “ecotourism” was first used in the mid of 1980s. Those terms and concepts are created to suggest a symbiotic relationship between tourist and the natural environment. It is not only possible but perhaps it also the utmost step in balancing tourism and conserving the natural resources. It is because, both tourism and natural resources are significant to the economic growth and human well-being. The tourism activities contribute revenues to the country and inspire human to appreciate the natural environment. While, the natural resources contribute to the economy and support the cycle of the natural ecosystem. Balancing tourism and resource conservation are essential to support the economic growth and to sustain the natural environment. Therefore, knowledge on the effect of tourism activities towards natural resource is imperative in sustaining the environment.

## 2. THE EFFECTS OF TOURISM ACTIVITIES

Tourism in the world’s largest industry and ecotourism is one of the fastest growing trends among other types of tourism industry. Even though tourism industry contributes positive impact towards the economy, excessive tourism activities in extensive period of time could harm the condition of the natural environment. Massive tourism activities would affect nature in many ways.

Ecotourism by its definition entails commitment by various parties which include establishing, marketing, maintaining, enforcing regulation and funding the tourism sites’ land management and community development (Muhanna, 2006). It is one of the ways to promote sustainable tourism development. However, it is a fact also that it is a form of industrial development to which somehow bring environmental impacts upon the natural resources of a place.

Tourism industry brings impact upon the physical environment in many ways (Mowforth & Munt, 2015). Reviews of literature suggests that among the significant impacts of tourism development in many places of the world are: depletion of natural resources that put pressures on water supply, energy and food resources degradation of scenic landscapes, loss of wildlife habitats, disturbance and erosion such as clearing forested land to make ways for tourism facilities and frequently the pollution from transportation, solid waste and littering due to tourism activities (Fauzi et al., 2017; Tyler, 2014; Muhanna, 2006).

### 2.1 The Effects Of Boating Activities In Kilim

Based on these literatures, the research identifies the effects of tourism activities, focusing on transportation effects from boating activities towards the natural resource conservation in Kilim Karst Geoforest Park, Langkawi. Kilim Karst Geoforest Park is one of the three world heritage sites in Langkawi Island that recognized by UNESCO since 2007 (UNESCO Global Geopark, 2007). It is one of the three Langkawi’s Geoparks in the northeast corner of Langkawi Island. The main attractions of this heritage site are the nature-based activities to the coastal tropical landscape, kayaking down the mangrove forest and river, visiting the karst landscape and cave, fish farm, fish feeding, and eagle and wildlife watching (Sapari et al., 2013; Nazaruddin et al., 2017).

Transportation service and other activities concerning tourism cause countless negative impacts to the environment. However, Page (2006) acknowledges the importance of transportation in recreational activities. The increased in number of transportations, caused the travelling expenses to become more competitive and indirectly would increase the tourism activities. Nonetheless, environmental impacts might occur due to excessive gas, smoke and oil emission released by massive transportations that supported the tourism industry (Gossling et al., 2007). The effect of transportation services due to tourism activities can also be seen in the area of Kilim Karst Geoforest Park.

The influx of tourists to the site has increased the demand for facilities and services within the ecotourism site. Since the site is largely covered by water,

the main mode of tourism transportation is boating activities to experience the scenery and to get to many places of interest within the site. Due to the high development of the park, there is a decline of the quality of the environment and the experience of high carrying capacity of visitors. Fauzi et al. (2017) identified three main issues faced in the Geopark due to tourism development: (i) erosion of river banks of Sungai Kilim and erosion of the karst, (ii) water and noise pollution from construction of facilities and boating activities, and (iii) disruption of the mangrove reserved area and the overall landscape due to propagating waves from boat. Hence, the transportation services, in particular the increasing numbers of boat tour in the park in many ways have caused degradation to the natural resources and habitat of the site. For example, the unregulated speed of tour boats causes erosion of riverbanks, water and noise pollution (Sapari et al, 2013; Tajan & Kamal, 2013; Fauzi et al., 2017). There is a continuous increase of visitors per day, which then has caused the boat tours rushing and increasing the speed of their boat in order to be punctual to servicing other passengers. Furthermore, the boats’ engines leave a film of oily scum on the river’s surface, which then clings to the roots of the mangroves, affecting their survival (Tyler, 2014). A study by Ayob and co-authors (2009) have also implied in their study that there is a need to undertake measures to prevent irreversible danger to nature and provision for minimal disturbances towards wildlife. This is because the environmental management factor contributed only about 14.5% towards tourists’ satisfaction. Furthermore, further improvement is needed on efforts to prevent damage to the environment, garbage management, and waste management of the site (Ayob et al., 2009).

Numerous studies have found that there are two natural resources that are undergone depletion process, which are the mangrove areas along Kilim River and wildlife habitat such as dolphins and eagles. On February 12, the National Hydraulic Research Institute of Malaysia (NAHRIM), found that the boats speed that were measured along Kilim waterways were from 16 to 29 knot (1 knot = one nautical mile/1.852 km per hour), which can be considered as high (Fauzi et al., 2017). As a result, the wake current from boat activity triggered erosion to riverbank along Kilim waterways. The increasing of tourism development and activities highly affected the mangrove ecology of Kilim River. It should be noted that 176.83 out of 2153.07 hectares of mangrove area were destructed in Kilim River due to human activities such as mangrove clearing (38%), development (40%) and wake current from boating activities (6%) (Shahbudin et al., 2012, p.185). Further, Mokhtar et al. (2005, p.402) mentioned that the water quality in Kilim River is not in a good condition and need to undergo conventional treatments for sensitive aquatic life. Hence, the study identifies the effects of tourism activities focusing on transportation service on the site, which is the boating activity through the perception of

various groups including tourists, local residents in Kilim and staffs who are in charged in the tourism operation of Kilim Karst Geoforest Park. Review of literature with regards to tourism activities on the heritage site has pointed out that boat services are the main transportation service for tourism activities. In addition, the activity contributes to water and environmental problems within the mangrove ecosystem, (e.g. Sapari et al, 2013; Tajan & Kamal, 2013; Fauzi et al., 2017). Thus, the boat service for tourism activity is found to affect nature and wildlife habitat in the area, in particular to the water quality, mangrove ecosystem and aquatic life.

## 3. METHODS

Structured questionnaires were distributed to tourists and local residents in Kilim as well as staffs who involved in tourism activities in Kilim Karst Geoforest Park, Langkawi. The survey data were then analysed using Statistical Packages for the Social Sciences (SPSS version 21.0) software. A good questionnaire is designed according to the research aim as well as research objectives and answering the research questions (Ahmad and Usop, 2011). The questionnaire survey was structured into four sections. Section 1: Respondents’ demographic information. Questions regarding age, gender, qualifications and employment status of respondents were included in this section. The aim of this information was to recognize whether there was a relationship between the biographic data of respondents and their intentions of operating, managing and performing the tourism activities in Kilim. Section 2: To identify whether boating activities caused water pollution. This section aims to get respondents opinion on the water quality along Kilim waterways. Section 3: To identify whether tourism boating activities depleted mangrove area. This section is to discover the main reason of mangrove depletion as the effect of tourism activities in Kilim Karst Geoforest Park. Section 4: To identify whether tourism boating activities polluted Kilim waterways and threaten aquatic habitat. It should be noted that pilot testing of the questionnaire surveys was conducted before the content and format of each questionnaire was finalized. Initially there were 7 items listed under Section 3 and five items under Section 4, however several items were dropped considering the questions were redundant and misleading. After pilot study was conducted, there were 4 items for both Section 3 and Section 4. Pilot test for this study was conducted on 30 respondents. 10 respondents were selected for each targeted groups (local residents of Kilim, tourists and staff). Those respondents were first briefed by the researchers on the purpose of the study before they answered the questions. According to Ahmad and Usop (2011), there are a lot of factors that could affect the reliability of the research instrument such as the words applied and layout setting of the questionnaire, condition of the surrounding study area as well as attitude of respondents.

Therefore, in order to enhance the reliability of the questionnaire of the study, questions were constructed based on selected related reference, briefing were given to the respondents and conducive places were chosen as to make them feel comfortable while answering those questions. The content validity of this questionnaire was referred from the literature review as it supports the information needed from aim, objectives and questions of the study. The validity of the standard questionnaire is validated using eigenvalue equal to or greater than 1 (eigenvalue  $\geq 1$ ) and confirmatory factor analysis (CFA) with the value of each variance is greater than 51% (CFA  $\geq 51\%$ ) for each question item. The reliability test was conducted and indicated that a Cronbach's alpha coefficient of 0.720 from the written items of the survey's content. Therefore, it can be concluded that the validity of the survey contents has high internal consistency since the reliability coefficient of 0.70 or higher is considered acceptable in most social science research situation as stated by Pallant (2005). Sample size is an important feature of any empirical study in which the goal is to make inferences about a population from a sample (Zaki et al., 2012). The population size for this research area is 1300. Thus, the research decided to use standard formulae to determine the sample size using Krejcie and Morgan (1970) method in determining sample size for research activities. Estimation of sample size using the method used the following formula to determine sampling size.

$$\text{POPULATION SIZE KNOWN:}$$

$$\text{SIZE} = \frac{X^2 NP (1-P)}{d^2 (N-1) + X^2 P (1-P)}$$

$X^2$  = table value of Chi-Square @  $d.f. = 1$  for desired confidence level  
 $.10 = 2.71$   $.05 = 3.84$   $.01 = 6.64$   $.001 = 10.83$   
 $N$  = population size  
 $P$  = population proportion (assumed to be .50)  
 $d$  = degree of accuracy (expressed as a proportion)

Local residents in Kilim area are the main study population. They constitute of the local residents in Kilim and staffs of Kilim Karst Geoforest Park. The study considered a respondent as 'local resident' based on the following categories; 1) Malaysian citizen, 2) Own or rent a house in Kulim and 3) Has been living in the area of Kulim for more than 5 years. Thus, the sample size needed for the study is 297. Respondents that are tourists were included to complement the result from the local population. The study used convenient sampling (also known as availability sampling) to select respondents. It was conducted by stopping random individual at the study area and asked them to participate

in answering the questionnaire survey. The study prepared more samples for the consequences of the Outlier Data. Therefore, 320 questionnaires were distributed to respondents. After clearing the Outliers Data, only 299 samples were valid to be proceeded for the data analysis process. For this research, one-way ANOVA was applied for questions in Section 2, 3 and 4. All sections were aimed to gain information from respondents about their opinion on the effects of tourism activities towards natural resource conservation in Kilim. Other than that, descriptive statistics were used to describe basic features of data in order to provide simple summaries about the samples and measures of the study.

#### 4. RESULTS

To obtain data, 320 questionnaires were distributed to three categories of respondents. They are local residents of Kilim (140), tourists (70) and staff (110) who are in charged in the tourism operation of Kilim Karst Geoforest Park including staff of (Langkawi Development Authority (LADA), Koperasi Kampung Kilim Langkawi Berhad (KKKLB) and Komuniti Pengurusan Sumber Perikanan (KPSP). Nevertheless, after data cleaning process using SPSS, 51 questionnaires were rejected. 299 questionnaires were used for the analysis that make up of residents of Kilim (145), tourists (65) and staff (89). The highest sample were taken from the local residents as they were considered as the most people that witnessed the development of Kilim from the beginning until now. Whereas, staff was the second highest as they have knowledge about Kilim and witnessed the tourism activities in Kilim. Meanwhile, tourist was the least sample taken as they may infrequently spend time and witnessed the changes of natural environment in Kilim.

Out of 299 samples 48.83% (n=146) are female and 51.17% (n=153) are male respondents. The numbers are slightly similar, but the male targeted group were more responsive, therefore they were slightly higher than female respondents. Nevertheless, as this study is focusing on conservation in tourism area therefore, gender of respondents would not affect much to the findings. The 20's age group are among the highest sample received from respondents with 144 (48.16%). Second highest samples are among age 30's, which are 94 (31.44%). Then, followed by respondents among age 40's, which are 26 (8.70%). Whereas, the second lowest samples received from respondents are among age 50's that are 19 (6.35%) and the lowest sample of respondents are among the teenagers which are 16 (5.35%). Therefore, young adults between the age of 20's and 30's is the highest number of samples as they are very responsive, and their opinion can be accepted for this research. The age level can be considered as matured and might have some experience concerning the issue of tourism activities and conservation in Kilim Karst

Geoforest Park. Majority of respondents (40.8%) obtained SPM, followed by 17.06% with degree and 3.33% is a PhD holder (n=1). Based on the survey conducted, educational qualification is considered as not significant and does not associate with respondents' category. Although in general, educational level is important, respondents' experiences and observations of Kilim are much more significant for this research. The study needs a genuine answer as it focuses on tourism activities and natural condition of Kilim Karst Geoforest Park as a whole.

#### a) Boating activities caused water pollution along Kilim waterways

According to water quality test conducted by Shamshiry et.al (2011) at Kilim Jetty, the water condition was identified not in good condition and should undergone conventional treatments for sensitive aquatic life. This issue was subjected to high numbers and frequency of boats at Kilim Jetty. A one-way ANOVA was conducted to compare the opinion from three categories of respondents (local residents, tourists, staff) pertaining to the effect of tourism activities on oil spills, whether increased pollution or decreased pollution along Kilim waterways.

Table 1: Boating activities caused oil spills according to category of respondents (local residents, tourists, staff)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	89.458	2	44.729	12.748	.000
Within Groups	1038.576	296	3.509		
Total	1128.033	298			

Based on the result obtained in Table 1, it was found that the opinion that boating activities cause water pollution were significant with the  $p < .05$  level for the three conditions [F (2, 296) = 12.748,  $p = 0.000$ ].

Table 2: Post hoc comparison using the Tukey HSD test to survey whether boating activities caused oil spills according to category of respondents

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
Local Residents	145	3.39	1.784	.148	3.09	3.68	1	6
tourist	65	4.34	1.492	.185	3.97	4.71	2	6
staff	89	4.08	1.687	.179	3.72	4.43	1	6
Total	299	3.80	1.740	.101	3.60	4.00	1	6

Further, a Post hoc comparisons using the Tukey HSD test indicated that the mean score for local residents of Kilim opinion (M = 3.08, SD = 1.98), tourist opinion (M = 4.43, SD = 1.24) and staff opinion (M = 3.83, SD = 2.07) were also considered as statistically significant. The result shown in Table 2 suggested that local residents of Kilim, tourists and staff agree that tourism activities in Kilim increased the amount of oil spill along Kilim waterways. Nevertheless, the mean score for the local residents was inclining towards 'mostly agree' that boating activities affected the water quality in Kilim waterways. Their opinion must have been influenced by their experience in dealing with Kilim River as most of them are fisherman. Thus, the study believes that developments and tourism activities must have affected the water quality and indirectly affect the aquatic life and catches of the fisherman.

#### b) Boating activities cause mangrove depletion in Kilim waterways

Mangrove area in Kilim Karst Geoforest Park has undergone depletion process from excessive and high-speed boat activities since the area was recognized as Geopark Status and open for tourists' destination in 2007 (Sapari et al, 2013; Tajan & Kamal, 2013; Fauzi et al., 2017). The following data were obtained to identify whether 'wake current from tourism boat depleted mangrove forest in Kilim'. A one-way ANOVA was conducted to compare the opinion from three categories of respondents (local residents, tourists, staff) regarding the effect of tourism boat on mangrove depletion, whether increased depletion or decreased depletion of mangrove forest along Kilim waterways.

Table 3: Identifying tourism activities that affected nature and wildlife habitat according to categories of respondents (local residents, tourists, staff)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.908	2	2.454	.701	.497
Within Groups	1036.062	296	3.500		
Total	1040.970	298			

Based on the result obtained in Table 3, it shows that there is a significant effect on the number of tourism boat contributed to the increased of mangrove depletion along Kilim waterways, according to the opinion of the three categories of respondents [F (2, 296) = 0.701,  $p = 0.497$ ].

Table 4: Post hoc comparisons using the Tukey HSD test to identify tourism activities that affected nature and wildlife habitat by category of respondents

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
					Local Residents	145		
Tourist	65	4.06	1.590	.197	3.67	4.46	1	6
Staff	89	3.84	1.888	.200	3.44	4.24	1	6
Total	299	3.84	1.869	.108	3.62	4.05	1	6

Further, a Post hoc comparisons using the Tukey HSD test indicated that the mean score for local residents of Kilim opinion (M = 3.73, SD = 1.97) tourist opinion (M = 4.06, SD = 1.59) and staff opinion (M = 3.84, SD = 1.89) were not significant. Table 4 shows that majority of the respondents extremely agreed with the question pertaining to the said issue. However, the lowest score mean is from the local resident group (M= 3.73, SD=1.973) followed by staff (M=3.84, SD=1.888) and finally tourist (M=4.06, SD=1.590). The result shows that majority of the local residents agree that tourism boat depleted mangrove forest along Kilim waterways, followed by tourist and staff. The study believes the Kilim River has become wider due to the effect of mangrove depletion and erosion from massive tourism boats with high speed.

### c) Boating activities affected aquatic life in Kilim

The following data was obtained in order to identify whether aquatic life in Kilim is decreasing since tourism boats were swiftly operated. A one-way ANOVA was conducted to compare the opinion from three categories of respondents (local residents, tourists, staff) pertaining to the effect of tourism boat towards aquatic life in Kilim, whether increased or decreased aquatic life in Kilim.

Table 5: Identifying whether tourism activities affect aquatic life according to categories of respondents (local residents, tourists, staff)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20.117	2	10.059	3.296	.038
Within Groups	903.395	296	3.052		
Total	923.512	298			

Based on the result obtained in Table 5, it shows that there was significant effect on the number of aquatic life in Kilim waterways according to the opinion of the three categories of respondents [F (2, 296) = 3.296, p = 0.038].

Table 6: Post hoc comparisons using the Tukey HSD test to identify whether tourism activities affect aquatic life by category of respondents

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
					Local Residents	145		
Tourist	65	4.29	1.444	.179	3.93	4.65	1	6
Staff	89	3.60	1.964	.208	3.18	4.01	1	6
Total	299	3.81	1.760	.102	3.61	4.01	1	6

Further, a Post hoc comparisons using the Tukey HSD test indicated that the mean score for local residents of Kilim opinion (M = 3.73, SD = 1.73) tourist opinion (M = 4.29, SD = 1.44) and staff opinion (M = 3.60, SD = 1.964) were significant as shown in Table 6. Staff has the lowest mean scores with 3.60, which define that they are mostly agree with the statement. Then, followed by local resident with 3.73 slightly difference figure. Finally, the least mean score is from the tourist group with 4.29. This could be because they did not have a chance to always observed the situation of the area, as they only come as a tourist in a short period of time. Conversely, a high mean score with significant data from the local resident group proved that aquatic life along Kilim waterways are affected by tourism boats. In most tourism activities situations, local residents can't be neglected as among the valuable witnessed of the development in Kilim. Besides, their answer correspondingly can be categorised as genuine.

## 5. DISCUSSION

With rapid development of facilities and amenities, Kilim received more tourist arrivals yearly since after its' endorsement as Geopark status (Sapari et al., 2013; Mat Yunus et al., 2016; Fauzi et al., 2017). Based on the data gained from Koperasi Kampung Kilim Langkawi Berhad (KKKLB) and Komuniti Pengurusan Sumber Perikanan (KPSP) on tourist arrivals and boat trip in Kilim waterways, it can be concluded that there is an increment in both activities after Langkawi received an international endorsement from UNESCO as Langkawi Geopark in Jun 2007. The result which was obtained through questionnaire surveys in Table 3 indicates users' opinion is parallel

with the research conducted by the National Hydraulic Research Institute of Malaysia (NAHRIM). In the study, 82% of the respondents agreed that wake current from tourism boat depleted mangrove forest. Increasing number of boat trips in Kilim had led to erosion of the riverbank, depletion of mangrove trees and in long term could affect the whole ecosystem of the Geoforest park. Similar with Fauzi et al. (2017) and Sapari et al (2013), it was found that high boat speed had caused depletion towards mangrove forest along Kilim waterways. Therefore, the study believes that one of the alternatives to control mangrove depletion along Kilim waterways is to limit number of tourism boat trip per day and replantation of mangrove trees at the affected area. The other suggestion is to ensure boat operators to observe speed limit in order to slow down wake current effects along Kilim waterways. It is understandable that the boat operators increased speed in order to catch their next boat trip and to avoid tourists for waiting too long. It should be noted that (Langkawi Development Authority-LADA) has repeatedly reminded boat operators to reduce boat speed but unsuccessful. Therefore, the effort taken by LADA management to process a drafting law pertaining to boat speeding along Kilim waterways is highly praised.

The other issue is regarding water quality in Kilim waterways affecting aquatic life caused by wastes and oil spills from tourism boats. As indicated earlier, previous research (e.g. Shamshiry et.al, 2011) found that the water condition in Kilim River was not in good state and should undergo conventional treatments for sensitive aquatic life. This situation was caused by large number of tourism boats operating at Kilim Jetty. In addition, the result shows in Table 2, which were obtained through questionnaire survey stated 74% of the respondents agreed that oil spilled from tourism boat had affected the water quality in Kilim waterways. Although wastes in Kilim waterways usually come from unknown places as they were drifted by the water flow, minor oil spills from boating activities were ignored by the community from taking this issue seriously. However, the effect of oil spills cannot be noticed through naked eyes but mixtures of muddy from clay and alluvium soil from nearby mangrove forest make the river water cloudy. Besides questionnaire survey, informal interview with few of the local residents confirmed that nowadays dolphins can hardly be seen in Kilim waterways probably due to habitat changes as they can easily migrate to any other suitable places. Majority of the respondents agreed that the emergence of bottlenose dolphin in Kilim waterways is reducing. Therefore, since dolphin has been an icon for tourist attraction in Langkawi, effort must be carried out to create habitat that can attract the unique mammals back to Langkawi especially in Kilim waterways. Thus, in order to support the conservation effort in Kilim, tourist arrivals at the area must be limited according to appropriate carrying capacity. Quality of the place should be prioritized than the quantity of tourist arrivals.

For tourism boat activities in Kilim, the study found that there is no limitation of boat trips. In fact, the boat operators increased boats speed in order to get more passenger for the next trip. In a positive sight, they work hard to gain good income but indirectly the high-speed boat harms the surrounding nature. As expressed by Tyler (2014), speeding boats trigger strong wakes, which cause severe erosion to the sides of the waterway, and cause mangrove trees to destabilise and topple over. Boat is a device that is controlled by human. Thus, in order to control this situation, awareness and knowledge of human handling the boat operation needs to be set. Therefore, boat operators need to be educated accordingly on short- and long-term effect of excessive boating activities. On-site class can be carried out by showing them the natural resources that have been affected by excessive boating activities. They shall also be explained on the future effects of such act, if the activities are not being controlled from now.

## 6. CONCLUSIONS

The paper presents local residents and tourists' opinion on the effects of boating activities towards Kilim river. The respondents feel that high number of boating activities with high speed along Kilim waterways affected the natural resources and habitat by the strong boat wakes as well as the oil spills. The affected natural resource from strong boat wakes is mangrove trees along Kilim waterways, while, the affected habitat recorded was Bottlenose Dolphins. Thus, boat speed as well as number of boating activities should be reduced in order to sustain the natural resources and habitat for a longer period. Reduction number of boat activities can be suggested to be reduced slowly as tourism boat operators are among the fisherman from residents. Tourism boats are the alternative income for them. Reducing number of tourism boat drastically may affect their household income harshly. However, perhaps fee for each destination can be increased in order to recover their income for the boat trip limit. Indirectly, higher fee also may position the natural trip in Kilim Karst Geoforest Park to a more exclusive trip with limitations. In opposition, if the conservation effort is neglected, the quality of the natural resources in Kilim may degrade easily. This situation could affect the Geopark status and simultaneously may reduce trust among tourist to the area. Therefore, individuals in charge of each agency involved have a great responsibility to ensure that these natural treasures are well maintained and administered so that future generations can enjoy it. In this regard, organizations involved in environmental management should strive to embrace high integrity and instil awareness and love of nature to all their employees. The high integrity nature of the environment can provide returns to an organization it represents. This is because, every decision taken by an employee in charge or administration in an organization is towards the retention, conservation and administration of

good natural resources. If our level of awareness of the environment is high, then the country will be more resilient and capable of forming a better future generation.

## ACKNOWLEDGEMENT

This research is supported under the Research Initiative Grant Scheme (PUBLICATION) (P-RIGS18-054-0054)

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# IMPACT OF BUILT ENVIRONMENT ON THERMAL PERCEPTIONS AMONG OFFICE WORKERS IN TROPICAL LOW CARBON CITY: A PHYSICAL INACTIVITY AWARENESS ASSESSMENT

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## ABSTRACT

Majority of city dwellers do not engage in regular physical activities due to their built environments that are designed to favour travel by motor vehicles. Data from the Ministry of Health, Malaysia revealed 73% of the total deaths recorded were due to Non-Communicable Diseases (NCDs), of which, approximately 35% included Malaysians belonging to the working population (< 60 years). The first objective of this study was to investigate the physical inactivity among office workers through their perceived thermal hindrances on exposure to transient thermal conditions at three different building sites in Putrajaya. The second objective was to assess the awareness level of respondents regarding their physically inactive lifestyles. Respondents suffering from NCD were identified and their level of awareness in pursuing an active lifestyle was assessed. Perceived thermal hindrances that led to physical inactivity were measured by asking participants to rate their thermal sensation and thermal comfort votes at three different times of the working weekdays, namely, commuting from home to work (morning), lunch break (afternoon), and commuting from work to home (late afternoon). The results suggested that around 85% of respondents in Putrajaya were vehicle dependant that is they used private cars and motorbikes to and from work. Most of the respondents were willing to improve their health by walking more but expressed that the midday heat and natural humidity of the tropical weather coupled with the lack of shaded paths were partially reasons for them to opt for motor vehicles as their mode of transportation in Putrajaya.

**Keywords:** : physical inactivity; warm weather; office workers; thermal sensation; thermal comfort; non communicable diseases

## 1. INTRODUCTION

According to the World Health Organization (2018a), government's lack of investment in building built environments that promote physical activities may contribute to further negative impacts on the community well-being and trigger Non-Communicable Diseases (NCDs). The main types of NCDs include cardiovascular diseases, cancers, chronic respiratory diseases, and diabetes (WHO, 2018b). In Malaysia, 73% of the total deaths recorded were caused by NCDs with an estimated 35% deaths among working population Malaysians (aged < 60 years) (IPH, 2015). Rapid development of the built environment in cities suggests a positive association with most types of NCDs, as compared to that in rural areas, partly due to the decrease in physical activities (Angkurawaranon, Jiraporncharoen, Chenthanakij, Doyle, & Nitsch, 2014; Koch, 2017). Furthermore, sedentary office workers are considered the most affected population to suffer from obesity due to their lack of physical activities during working and break hours (Addo, Nyarko, Sackey, Akweongo, & Sarfo, 2015; Cheng, 2016; Heinen & Darling, 2009).

In an effort to improve societal well-being in terms of green technology adopted in the tropical built environment and health, the Malaysian government proposed The Low Carbon City Framework (LCCF) under the National Development Policy (2013). LCCF covers low carbon impact issues in four main areas, namely, urban environment, urban transport, urban infrastructure, and buildings. In relation to the National Green Technology Policy, four initiatives on sustainable development in Malaysia have been divided into five aspects: growth of energy consumption, enhancing green technology industry's contribution to the national economy, enhancing Malaysia's green technology competitiveness in the global arena, enhancing public awareness of green technology, and ensuring sustainable development through the conservation of the environment (KeTTHA, 2011). However, despite being designed to promote walking and cycling activities, residents of

a Tropical Low Carbon City (TLCC), such as Putrajaya are hesitant to adopt the aforementioned mode of transportation (Abas, 2018; Siti Fatimah Hashim, Habsah Hasihm, & Shuib, 2017; Wan Omar, Patterson, & Pegg, 2011). Physical inactivity in cities have been linked with the occupants' perception of their outdoor thermal conditions, particularly with respect to walking in tropical places (Böcker, Dijst, & Faber, 2016; Chan & Ryan, 2009; Kim, Park, & Lee, 2014; Makaremi, Salleh, Jaafar, & GhaffarianHoseini, 2012; Makoto, 2009; Nasir, Ahmad, Zain-Ahmed, & Ibrahim, 2015; Pilcher, 2002; Song & Jeong, 2016).

To understand TLCC residents' hindrance towards walking or using the available pedestrian facilities, this study assumes that the respondents' walking preferences may be influenced by their thermal perceptions and the surrounding built environment of their workplace. This approach relies on testing in accordance with the following study objectives:

- 1) To investigate the physical inactivity among office workers in Putrajaya with respect to their thermal sensation and thermal comfort votes when walking within their workplace vicinity.
- 2) To assess the awareness level between the physical inactive lifestyle and its association with NCD occurrences among office workers working in Putrajaya.

## 2.METHODS

### 2.1 Selected Measured Sites

Putrajaya (2.943°N, 101.699°E) was chosen as the site study due to its implementation of the Low Carbon City Framework (LCCF) urban design concept. Accordingly, thirty eight percent of the total land area have been reserved for wetlands, green space and water body making it the pioneer green township in Malaysia (KeTTHA, 2011). Putrajaya consists of governments' administration, commercial, public buildings and recreational facilities that serve a diverse population on a daily basis. In this study, three sites in Putrajaya, namely, Ministry of Higher Education, Malaysia (B1), The Energy Commission Building (B2), and Galeria PjH (B3) were considered as the study area to investigate transient thermal comfort conditions of office workers. Transient thermal comfort conditions were assessed due to the assumption that office workers would have the tendency to walk from one place to another within their indoor to outdoor environment and vice-versa. The three study

areas were chosen based on their different level of implementation of LCCF criteria, such as mixed-use development and green infrastructure settings (Moser, 2010). Local area maps indicating the locations of all three selected buildings are shown in Figure 1. Walking and cycling amenities as well as facilities situated within a 400 m radius from each of the selected buildings are illustrated in Figures 2(a) to 2(f). Four hundred meter is the recommended distance by Barton, Grant, and Guise (2003) for a person to willingly walk to his/ her destination without riding a motor vehicle (Azmi, Karim, & Amin, 2012; Butera, 2018; Murata, Campos, & Lastra, 2017).

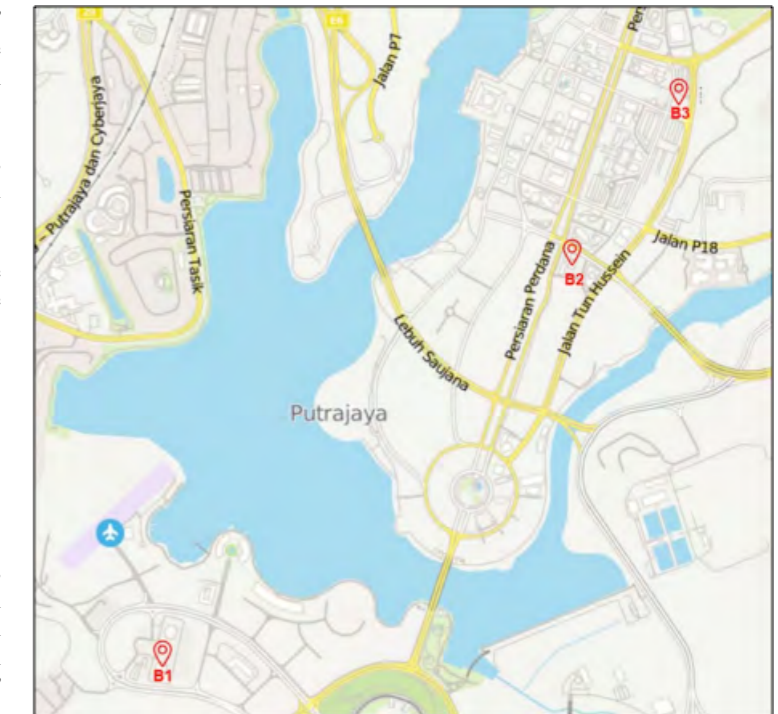


Figure 1: Local area map indicating the three selected buildings



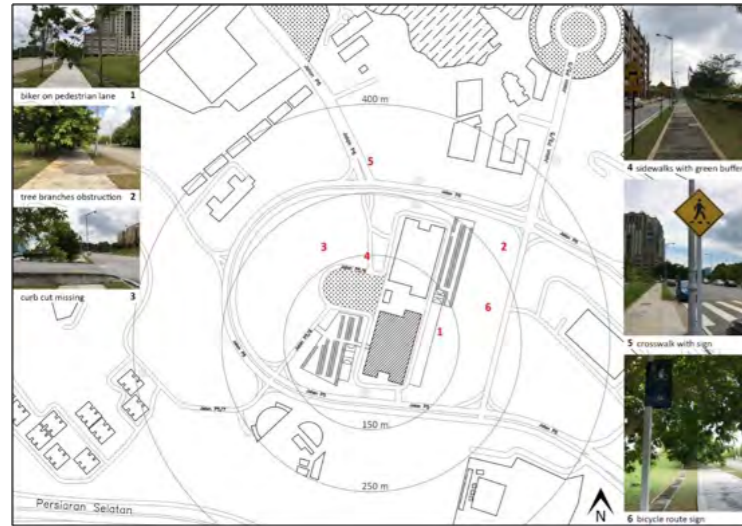


Figure 2(a): Walking and cycling amenities at B1 site



Figure 2(c): Walking and cycling amenities at B2 site



Figure 2(d): Facilities in close proximity to B2 site



Figure 2(b): Facilities in close proximity to B1 site



Figure 2(d): Facilities in close proximity to B2 site



Figure 2(d): Facilities in close proximity to B2 site

## 2.2 Research Design

This study adopted a cross sectional investigation approach, wherein microclimate monitoring and administration of questionnaires were carried out simultaneously at the three selected buildings from 23rd of July until 26th of July, 2018 during working hours, that is from 9:00 a.m. to 4:30 p.m. Permission from building managers and head of human resource officers were obtained prior to the actual field measurements.

## 2.3 Microclimate Monitoring

The OHM Delta Thermal Microclimate HD32.2 was used to log four basic environmental parameters known to influence thermal comfort namely, air temperature ( $T_a$ ), relative humidity (RH), globe temperature ( $T_g$ ), and air velocity ( $V_a$ ). Readings were logged every ten minutes for a period of four days. The devices were calibrated prior to actual field measurements. Air temperature and relative humidity sensor, omnidirectional air velocity probes and globe temperature sensor (type T thermocouple inside black painted 38 mm diameter globe) were calibrated using laboratory-grade instruments performed within the requirements of ISO 7730 standard (ISO, 2005). Subsequently, all four sensors were then connected to one OHM Delta data logger. Three OHM Delta data loggers were placed side by side and at a similar height of 1.5 m above the ground level. The calibration results indicated that the deviation percentage of the readings among the three devices was close to 0.4% for  $T_a$ , RH, and  $T_g$ , whereas the deviation percentage for  $V_a$  was about 4%. Three measuring devices were necessary as they were placed at three different locations for simultaneous data logging. The devices were located at the pedestrian level, 1.5m above ground (Figure 3) under shaded walkways and less than 2m from pedestrians (Niu et al., 2015; Zhou, Chen, Deng, & Mochida, 2013).

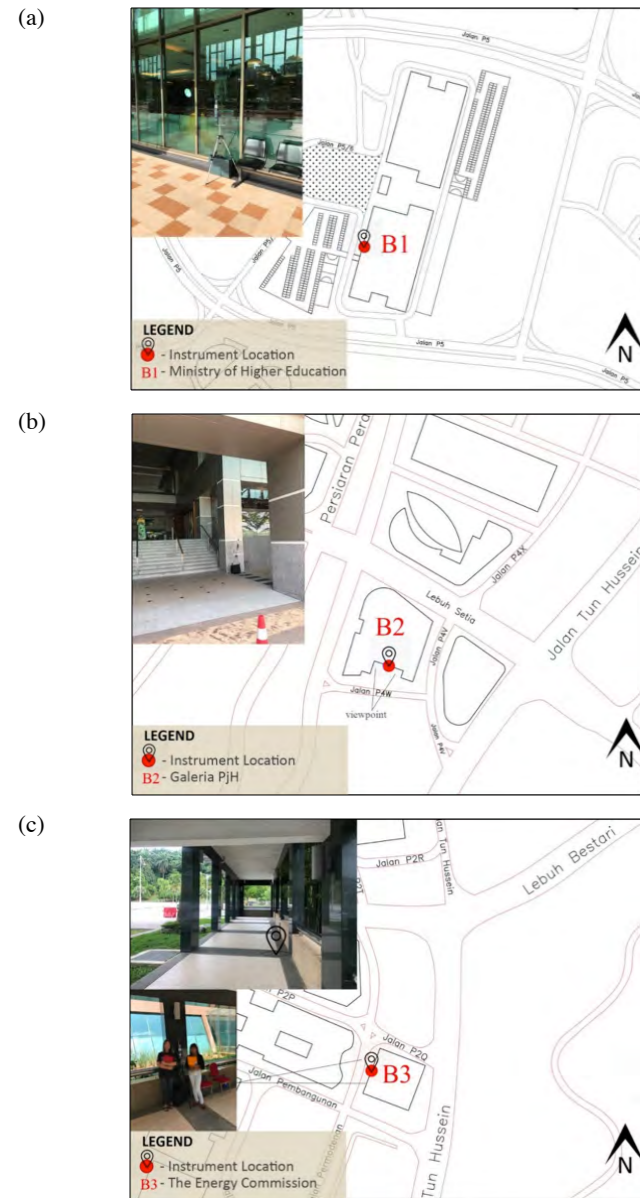


Figure 3: Instrument location at a) B1 site; (b) B2 site; and (c) B3 site

## 2.4 Questionnaire

Self-administered questionnaires were distributed to respondents that worked at the chosen study sites. To aid the respondents, the questionnaire contained bilingual questions that are in English along with the Bahasa Malaysia translation and a glossary of comfort terminologies. Respondents were asked for their personal information, namely, height, weight, age, gender, and health to aid in the calculation of metabolic rate to assess thermal stress in tropical climate cities (Höppe, 1999; Lin, 2009; Nasir, Ahmad, & Ahmed, 2012; Taib, 2018). The respondents' clothing ensembles were recorded and each garment was summed up in accordance to the clothing insulation (I<sub>cl</sub>) values for tropical climate ensembles provided by Havenith et al. (2015).

Thermal comfort and thermal sensation data were collected questionnaires modified from ASHRAE's 7-point thermal comfort and sensation scale (Table 1) (ANSI/ASHRAE, 2010). Respondents' perceptions for both thermal sensation and thermal comfort were based on their personal experience for the last six months when working at their respective office buildings. These questions were repeated thrice in order to evaluate respondent's thermal sensation and thermal comfort votes at different times of the day, namely, morning (7:00 – 11:59 a.m.), afternoon (12:00 – 3.59 p.m.) and evening (4:00 – 6:30 p.m.).

Table 1: ASHRAE 7-point thermal comfort and sensation scale

Thermal Sensation		Thermal Comfort	
hot	-3	very uncomfortable	-3
warm	-2	uncomfortable	-2
slightly warm	-1	slightly uncomfortable	-1
neutral	0	neutral	0
slightly cool	+1	slightly comfortable	+1
cool	+2	comfortable	+2
cold	+3	very comfortable	+3

The respondent's physical activity information was gathered using questionnaire adapted from the International Physical Activity Questionnaire's (IPAQ) (Craig et al., 2003). The respondents were asked regarding their commuting preference from place to place with a reference period of one week and whether they have been performing active transportation activities (i.e., walking and bicycling) during that particular week (Craig et al., 2003; Ekelund

et al., 2007; Papathanasiou et al., 2009; Rivière et al., 2016). Respondents were also asked whether they reside within 400m from their workplace and their mode of commute to work (Adams, Bull, & Foster, 2016). Commuting modes were divided into four that is motor vehicle (car/motorcycle), public transportation, bicycle, and walking (Figure 5). Subsequently, the awareness level on risks of NCD among urban dwellers when physical activities are neglected was assessed (Booth et al., 2012; Müller-Riemenschneider et al., 2013)

## 2.5 Sampling Method

Purposive sampling technique was applied to the samples of sedentary office workers performing clerical works at the three selected buildings. Sample size of 430 respondents was determined after obtaining the total population of sedentary office workers from the selected buildings with a +/-5% margin of error and a 95% confidence interval using the Raosoft Sample Size Calculator (Raosoft, 2004).

## 2.6 Data analysis

Descriptive analyses were used to obtain insights into individual characteristics and environmental monitoring results. One-way ANOVA test was used to determine mean differences in the thermal sensation votes (TSV) and thermal comfort votes (TCV) among respondents at three different times of the day. Cronbach's alphas for TSV and TCV at three different times at of the working weekdays (i.e., three items each vote) were found to be acceptably reliable with  $\alpha = 0.74$  and  $\alpha = 0.76$ , respectively. One-way ANOVA tests were also useful in identifying mean differences in walking behaviours observed between the genders, age groups, and body mass index (BMI) of the respondents at three different building sites. Statistical tests were conducted with less than 5% significance level ( $p < 0.05$ ). Pearson correlation was computed to see the relationship between variables. All data were analysed using the statistical software IBM SPSS Statistics v20.

## 3.RESULTS

### 3.1 Meteorological Monitoring

Figures 4a, 4b, and 4c show the meteorological measurements of Ta, RH, and wind velocity (Va), respectively, that were recorded from 9 a.m. to 4.30 p.m. throughout the four-day field measurement period from 23rd to 26th July, 2018. A mean temperature difference of approximately 1 K was detected

among the three sites, particularly from 9:00 to 9:30 a.m. It was believed to be due to the building's orientation, façade material properties, structure of verandas, and placement of measuring instruments.

B2 building has a quadrangle form with a prolonged and fully glazed west side that absorbs more daily solar radiation due to the high angles of the sun in the tropics (Qaid & Ossen, 2015; Sharmin, Steemers, & Matzarakis, 2015). Vitreous enamelled steel sheets, having a high reflective value of 0.57 (Riley, Cotgrave, & Farragher, 2017), were used as a façade material at pedestrian level for B2, thus increasing outdoor human thermal stress (Erell, Pearlmutter, Boneh, & Kutiel, 2014). The OHM delta instrument was placed in the south direction near the main entrance at B2 with maximum daylight penetration. However, the remaining two devices located at B1 and B3 were placed at the west side of the buildings and close to their main entrances. Therefore, there was a distinctive difference in Ta among buildings due to morning and afternoon sun exposure (Figure 4a).

Relative humidity varied the most between B1 and B2, with the difference between maximum and minimum relative humidity being ~40%. Fluctuation in relative humidity was the lowest in B3, where the difference between the maximum and minimum RH approached 36%. From the plots in Figures 3a and 3b, it can be clearly seen that Ta and RH produced opposing readings, such that an increase in Ta decreased the RH level. This can be explained by the role of water vapour in ambient Ta acting as a source of moisture content. B2 showed the highest mean RH levels throughout the study period compared to other two buildings (Figure 4b). This was probably due to the proximity of man-made water bodies running through the area through the west and east side of the building within a 480 to 580 m radius.

Air velocity demonstrated a maximum reading of 3.9 m/s at B2, with the highest mean Va due to its large cross-ventilated ground floor atrium design. The difference in mean wind speed between B2 and B3 was marginal as both of these areas maintain higher height to width ratio, permitting the wind to permeate as compared to B1 (Figure 4c). B1 site showed the least mean Va value because of the deserted urban layout within 300 m radius of the instrument and the absence of proper vegetation to improve the air velocity.

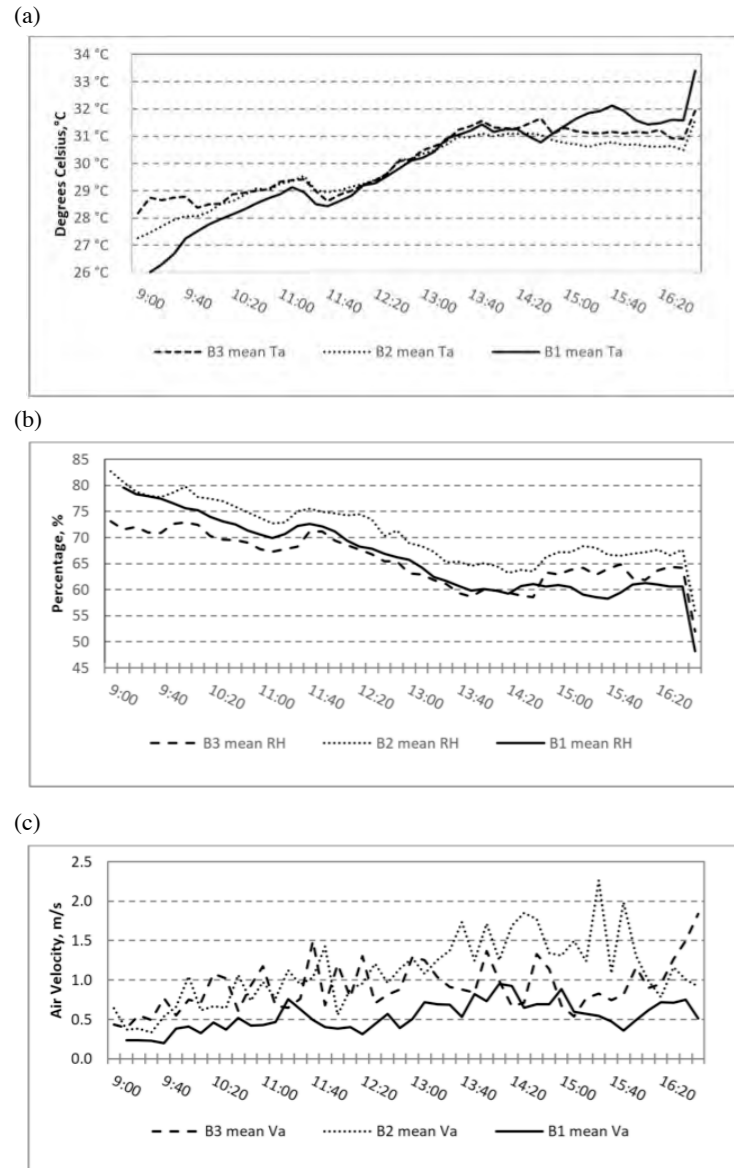


Figure 4: a) Mean Ta (°C); b) Mean RH (%); c) Mean Vs (m/s) during field measurements from 23rd to 26th July, 2018

### 3.2 Demographic and Personal Details

Three hundred and ninety-one respondents from the three selected building sites, namely, B1 (n = 166), B2 (n = 75) and B3 (n = 150) participated in the field survey. There were 10% invalid responses out of the calculated sample size of 430. There were more female (63%) respondents than male (37%). In terms of the age group, 35% of the respondents were between the ages of 31 to 35, 23% were between 36-40 years, and about 20% were within the 26-30 year age group. The remaining 22% of the respondents were below 25 (9%) and above 41 years (13%)

Almost half of the total respondents (47%) were found to reside in Putrajaya, whereas 53% of the respondents were non-Putrajaya residents. Among the respondents residing in Putrajaya, 27% were from B1, 24% from B2, and 6% from B3. 85% of the respondents were vehicle dependent and used private cars and motorbikes to reach their destinations (Figure 5a). Moreover, 81% of TLCC workers never walked to work and 90% never cycled to work for more than 15 minutes (Figure 5c and 5d). In addition, 30% used public transport, whereas remaining 70% did not (Figure 5a).

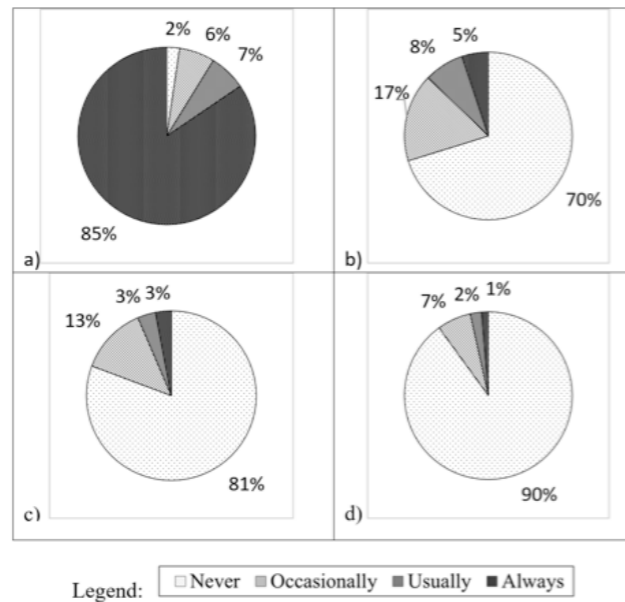


Figure 5: Total number of respondents commuting via: a) motor vehicle; b) public transport; c) walking; and d) bicycle

The percentage of respondents found to be free from NCDs (i.e. based on findings from the self-reported instrument) at the three sites was 85%. The remaining respondents claimed to have been suffering from at least one type of NCDs, namely, cardiovascular (n = 5), diabetes (n = 6), hypertension (n = 10), chronic respiratory disease (n = 2), high cholesterol (n = 9), and others (n = 6), such as, arthritis, chronic kidney diseases, and eczema. Also, some respondents (n = 26) stated to have contracted more than one type of NCD.

Figure 6 represents the self-reported BMI of the respondents from the three selected sites. In total, half of the population across the three sites showed normal BMI of 18.5 to 25 kg/m<sup>2</sup>, whereas 29% were overweight (25 to 30 kg/m<sup>2</sup>), 11% were obese (above 30 kg/m<sup>2</sup>), and 10% were underweight (below 18.5 kg/m<sup>2</sup>).

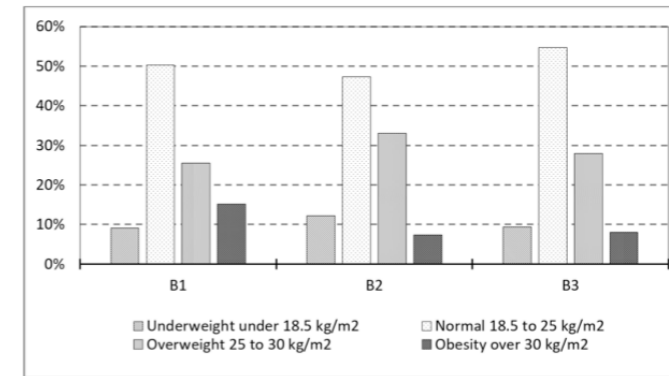


Figure 6: BMI percentage per site

Mean clothing ensemble insulation values gathered from all three sites suggest that male Icl was higher (M = 1.3, SD = ±0.3), which commonly contained men's briefs, work shirt, work pants, socks, and shoes, compared to females (M = 1.1, SD = ±0.3) who typically wore underwear, long sleeved shirt, suit pants or skirt, hijab, socks, and shoes. Calculations using T-test indicate significant mean difference between genders in all three sites, as follows:

- i) B1: males (M = 1.39, SD = ±0.61) and females (M = 1.15, SD = ±0.26), p < 0.01,
- ii) B2: males (M = 1.46, SD = ±0.27) and females (M = 1.07, SD = ±0.43), p < 0.01, and
- iii) B3: males (M = 1.28, SD = ±0.16) and females (M = 1.12, SD = ±0.31), p < 0.05.

### 3.3 Relationship between Thermal Sensation and Thermal Comfort Votes

One-way ANOVA tests were conducted to compare the TCV and TSV votes in the three selected sites at three difference times of the day, namely, morning (7:00-11:59 a.m.), afternoon (12:00-15:59 p.m.), and evening (16:00-18:30 p.m.) (Figure 7).

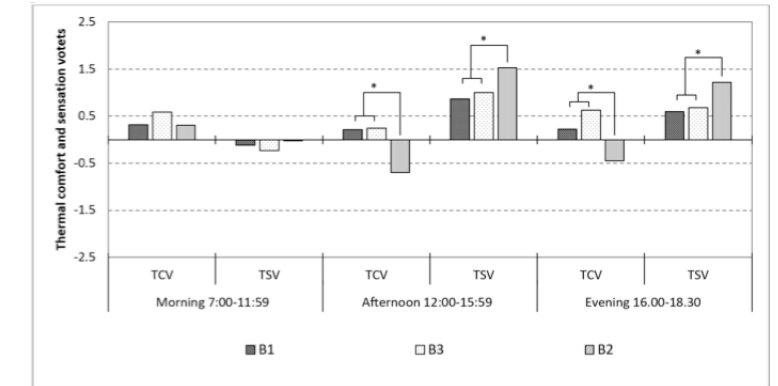


Figure 7: Mean Thermal Comfort and Thermal Sensation Votes among the three sites. Note: \* Correlation is significant at p < 0.01 level (2-tailed)

Figure 7 shows that TCV and TSV are deemed to be neutral and neither cold nor hot, respectively in all three selected sites using one-way ANOVA tests. However, there are significant mean differences between two votes in the afternoon and evening when walking outdoors. B2 respondents expressed that their thermal comfort during afternoons and evenings were low, with mean scores of -0.7 (SD = ±1.5) and -0.5 (SD = ±1.5), respectively. These results are also reflected in the respondents' TSVs, wherein, walking outdoors in the afternoons and evenings were deemed to be warm (mean = 1.5, SD = ±1.2) and slightly warm (mean = 1.2, SD = ±1.1), respectively. Post hoc using Bonferroni tests suggested that mean TCV and TSV responses from B2 respondents were significantly different in comparison to their B1 and B3 counterparts. Therefore, it can be assumed that the office workers felt that the surrounding built environment at B2 contributed to their thermal discomfort, particularly when moving from indoor to outdoor spaces during their lunch break.

### 3.4 Relationship between BMI and Walking

The Pearson correlation was performed to assess the relationship between the BMI status of respondents and their weekly walking patterns. The number of office workers who walked habitually on a weekly basis based on their BMI is shown in Figure 8. Although subjects with normal and overweight BMI that walked more surpassed the ones who did not, the difference in the three sites was not significant in B1 ( $r = 0.095$ ,  $n = 165$ ,  $p = 0.224$ ), B2 ( $r = 0.103$ ,  $n = 148$ ,  $p = 0.213$ ), and B3 ( $r = -0.218$ ,  $n = 75$ ,  $p = 0.061$ ).

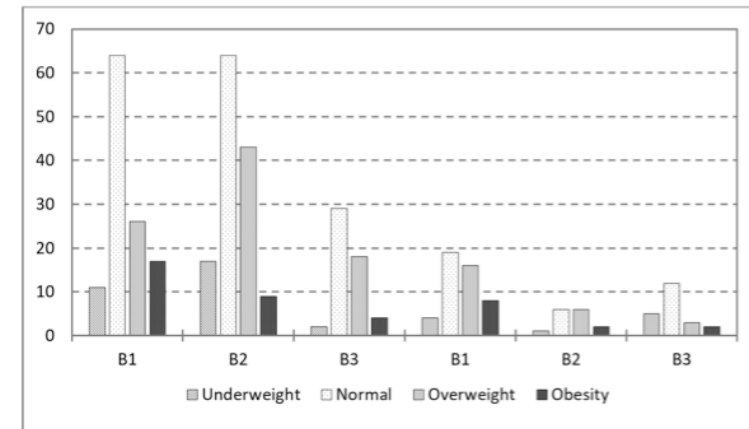


Figure 8: General weekly walking vs. BMI

The Pearson correlation was computed between the frequencies of weekly walking by office workers and their BMI status. Despite a large number of office workers stating that they walk five times per week or more across three sites, a non-significant difference was established for B1 ( $r = -0.152$ ,  $n = 165$ ,  $p = 0.051$ ), and B3 ( $r = 0.184$ ,  $n = 75$ ,  $p = 0.115$ ) (Figure 9). However, B2 showed a statistically significant effect ( $r = -0.185$ ,  $n = 148$ ,  $p = 0.024$ ), with the Bonferroni test indicating that the mean score for the underweight group ( $M = 3.61$ ,  $SD = \pm 0.778$ ) was higher than that for the overweight group ( $M = 2.84$ ,  $SD = \pm 1.106$ ), suggesting that respondents who fall in underweight category at B2 walk more often compared to the overweight type.

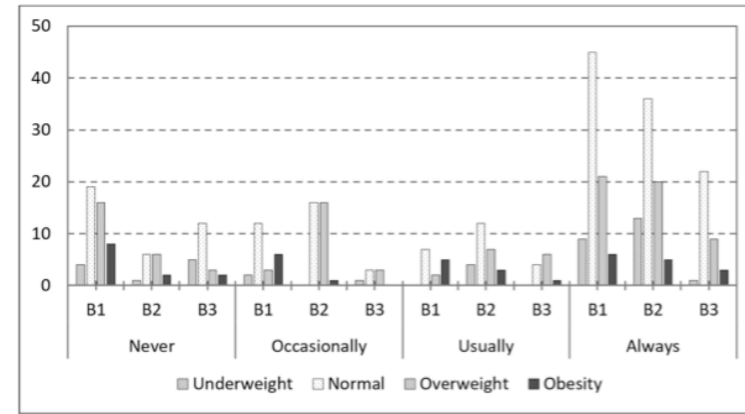


Figure 9: Moderate weekly walking vs. BMI

The relation between time spent walking per day based on the BMI status of respondents across the three study areas, that is B1 ( $r = -0.062$ ,  $n = 165$ ,  $p = 0.431$ ), B2 ( $r = -0.076$ ,  $n = 148$ ,  $p = 0.359$ ), and B3 ( $r = 0.147$ ,  $n = 75$ ,  $p = 0.208$ ) was not significantly different according to the Pearson correlation. Figures 10a to 10c show that more number of normal and overweight people spend 30 minutes or less to walk from one place to another.

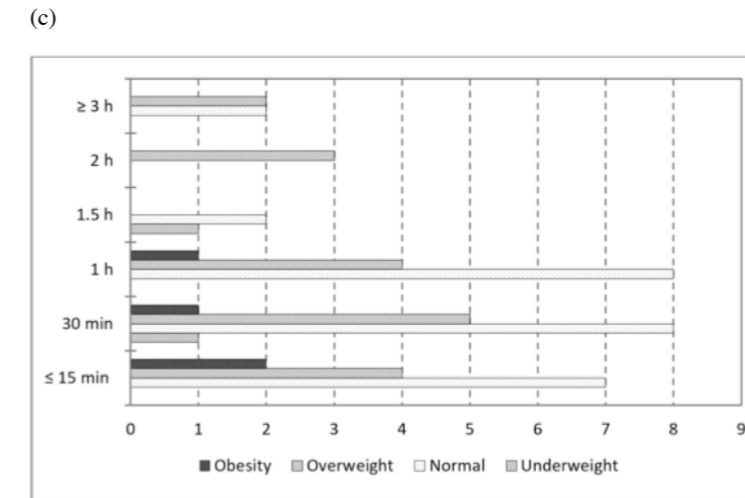
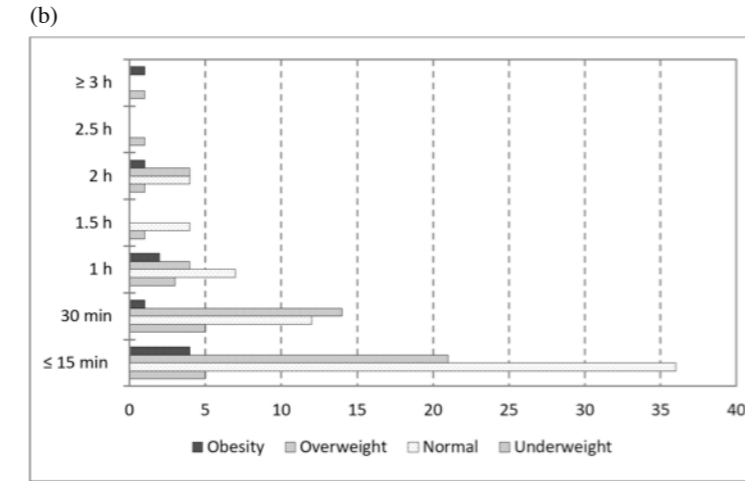
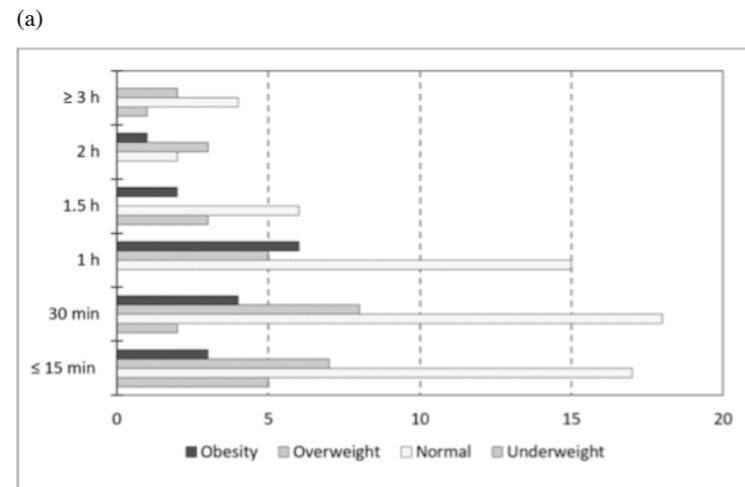


Figure 10: Time spent walking per day by respondents with respect to BMI at (a) B1,  $n = 165$ ; (b) B2,  $n = 148$ ; and (c) B3,  $n = 75$

### 3.5 Relationship between Gender and Walking

It was hypothesized that the gender of respondents might contribute to overall weekly walking, frequency of weekly walking pattern, or time spent walking per day, but that effect might differ across office buildings selected. Generally, 79% respondents stated that they walked for at least 10 minutes per day. Referring to Figure 11, a greater number of non-walkers were observed at B1 and B3, with the number of male office workers slightly higher compared to females. Overall, almost one-fifth of respondents (22%) acknowledge that they did not walk for at least 10 minutes per day.

A 2 x 2 between-subjects ANOVA was conducted on general weekly walking, with gender and the three chosen sites being the factors. Employees from B1 (72%) and B3 (71%) sites showed lower level of weekly walking scores compared to B2 (90%) with a significant effect at  $p < 0.01$  level. The influence of gender along with gender and site interaction at B2 was not significant at  $p > 0.05$  level, with males (10%) and females (10%) each constituting nearly one-tenth of the overall non-walkers.

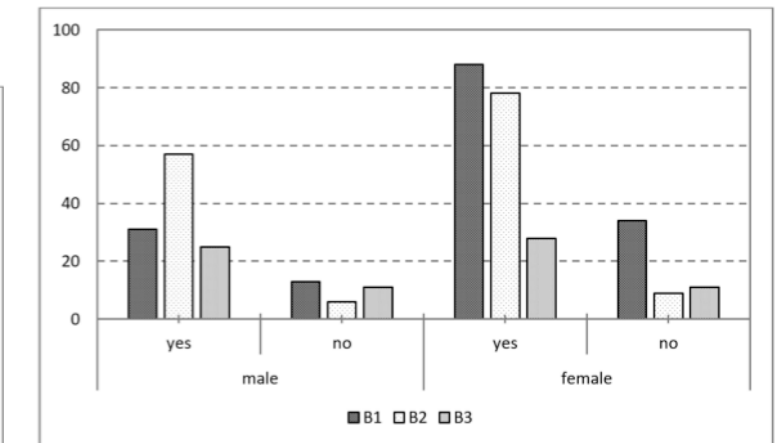


Figure 10: Time spent walking per day by respondents with respect to BMI at (a) B1,  $n = 165$ ; (b) B2,  $n = 148$ ; and (c) B3,  $n = 75$

A two-way analysis of variance tested the frequency of weekly walking of males and females among respondents at B1, B2, and B3 study sites. The main effect of gender and site on frequency of weekly walking showed no significant difference at  $p > 0.05$  level. The gender and site interaction were not significant at  $p > 0.05$  level (Table 2).

Table 2: Mean level of frequency of weekly walking by site and gender of respondents

		B1	B2	B3
Male	M	2.82	3.18	2.92
	SD	±1.35	±1.03	±1.36
Female	M	2.78	3.01	2.67
	SD	±1.31	±1.08	±1.26
p-value		0.86	0.42	0.38

In Figures 12a, 12b, and 12c, the time spent walking per day for more than 10 minutes per trip was cross-tabulated by gender at B1, B2, and B3. It was revealed that the percentage of office-workers who walked for 15 minutes or less during the day at B1 and B3 were 19% and 17%, respectively, whereas almost half of the B2 respondents walked for 15 minutes or less per day. Overall, respondents walked one hour or less across the three different sites, with females surpassing males at the three study areas. Subsequently, the time spent walking per day was analysed in a two-way mixed factorial ANOVA, with the chosen study areas manipulated as a within-subjects variable and gender as a between-subjects variable.

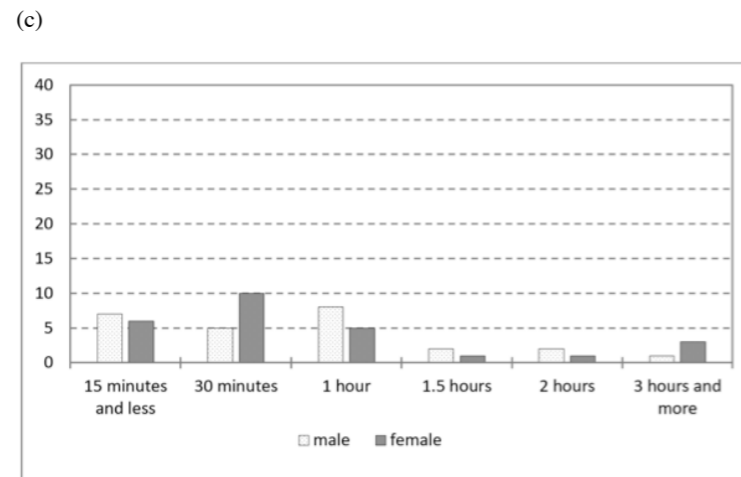
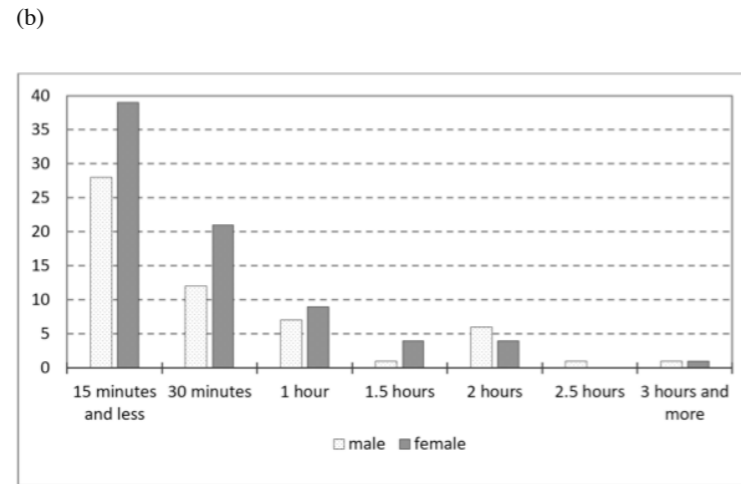
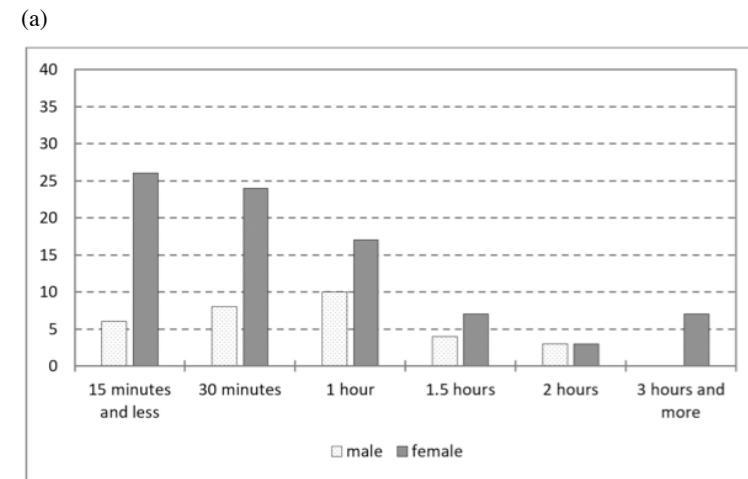


Figure 12: Time spent walking per day in reference to gender at (a) B1; (b) B2; and (c) B3

### 3.6 Relationship between BMI and Thermal Sensation Vote Outdoor

A two-way analysis of variance was conducted to compare the main effects of respondents' BMI and working neighbourhood and the interaction effect between BMI and working area on the TSV outdoors. BMI comprised of four levels (underweight, normal, overweight, and obesity). The two main effects were statistically significant at the  $p < 0.01$  significance level; however, the interaction between the employees' BMI and their working area was not statistically significant  $F(6,376) = 0.744, p = 0.61$ . The main effect for BMI yielded an F ratio of  $F(3,376) = 4.73, p < 0.01$  indicated a significant difference between underweight ( $M = .88, SD = \pm 1.20$ ), normal ( $M = 1.25, SD = \pm 1.26$ ), overweight ( $M = 1.12, SD = \pm 1.32$ ), and obesity ( $M = 1.67, SD = \pm 1.16$ ) levels. A post-hoc Tukey's HSD test showed that obese respondents had significantly higher TSV scores (feeling warmer outdoors) than the underweight ones, at a .05 level of significance. The main effect of chosen sites yielded an F ratio of  $F(2,376) = 5.60, p = .004$ , indicating that the effect of the site was significant, such that B1 ( $M = .92, SD = \pm 1.30$ ), B2 ( $M = 1.41, SD = \pm 1.17$ ), and B3 ( $M = 1.51, SD = \pm 1.28$ ). A post-hoc analyses using Tukey HSD test were conducted on all the possible pairwise contrasts, with B1 and B2, and B1 and B3 pairs showing significance at a .01 level (Figure 13).

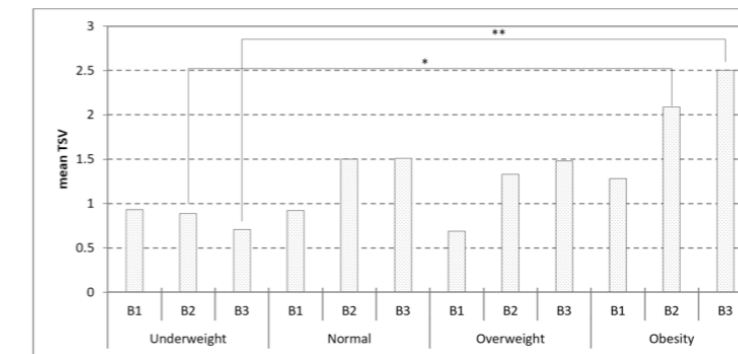


Figure 13: Mean Thermal Sensation Votes by their BMI across three sites. Note: Correlation is significant at  $*** p < 0.01$  level,  $* p < 0.05$  level (2-tailed)

### 3.7 Relationship between Gender and Thermal Sensation Vote Outdoor

Males ( $n = 44, M = .82, SD = \pm 1.3$ ) and females ( $n = 122, M = .96, SD = \pm 1.3$ ) in B1 were associated with approximately equal outdoor TSV ( $-3 = \text{cold}$ , to  $+3 = \text{hot}$ ) in the area. However, males in B2 ( $n = 63, M = 1.10, SD = \pm 1.0$ ) and B3 ( $n = 36, M = 1.28, SD = \pm 1.5$ ) were associated with numerically smaller TSV. To test the hypothesis that gender was associated with statistically significant different mean TSV, an independent sample t-test was performed, and it was associated with a statistically significant effect only on B2 at  $p < 0.01$  level. Thus, females felt warmer outdoor near their working area compared to males (Figure 14).

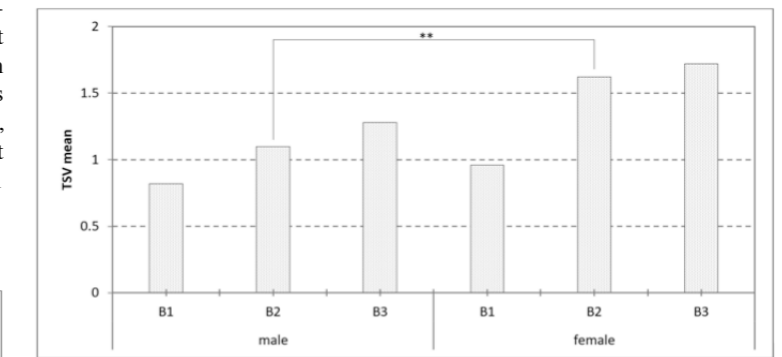


Figure 14: Outdoor Thermal Sensation Vote bar graph. Note: Correlation is significant at  $*** p < 0.01$  level (2-tailed)

### 3.8 NCD Awareness in Relation to Willingness to Walk

The Pearson correlation was performed to assess the relationship between the NCD status of respondents and their physical inactivity awareness. The number of office workers' awareness level that physical inactivity leads to NCDs is shown in Figure 15. Although most of the subjects with NCDs agreed that physical inactivity led to diseases, the difference between the awareness level between respondents with and without NCDs in B1 ( $n = 166, r = -0.04, p = 0.59$ ), B2 ( $n = 150, r = 0.05, p = 0.58$ ), and B3 ( $n = 75, r = 0.05, p = 0.66$ ) was not significant.

Furthermore, the Pearson correlation was performed to assess the relationship between the NCD status of respondents and their willingness to walk more. The number of office workers who were willing to walk more is shown in

Figure 16. Meanwhile, 17.4% of overall respondents could not decide whether they would like to walk more or not. Five percent of the office workers who did not suffer from NCDs were not ready to change their lifestyle. Even though 86% of the respondents with NCDs showed their willingness to walk and adopt an active lifestyle across three sites, no significant mean differences were calculated between B1 (n = 166, r = 0.04, p = 0.59), B2 (n = 150, r = 0.02, p = 0.83), and B3 (n = 73, r = 0.16, p = 0.18).

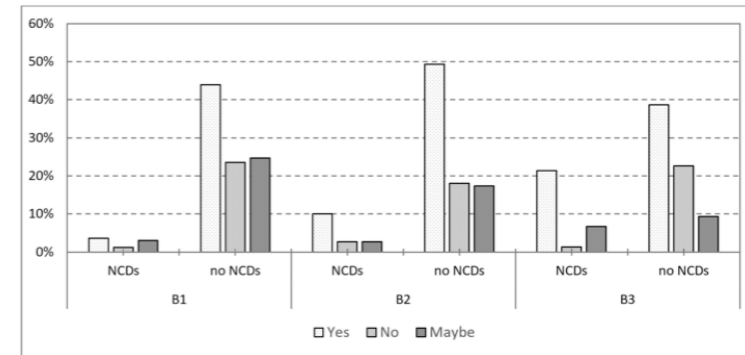


Figure 15: Percentage of respondents with NCDs with an awareness of physical inactivity vs. without NCDs

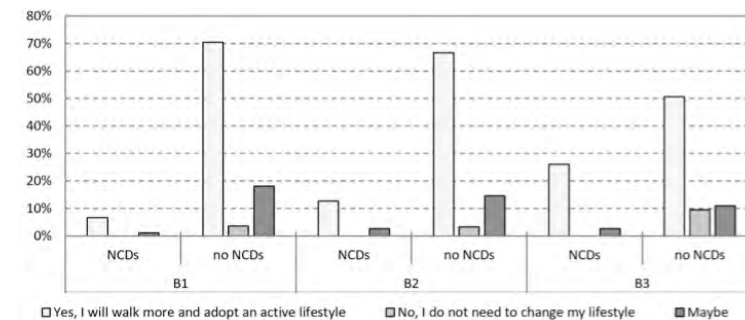


Figure 16: Percentage of respondents with NCDs with willingness to walk more vs. without NCDs

#### 4. DISCUSSION

This study investigated the physical inactivity among sedentary office workers, particularly through the lack of walking in relation to their perceived thermal judgements (via thermal sensation and thermal comfort) when exposed to transient indoor-outdoor movements at three different building sites in Putrajaya. Based on the microclimate monitoring on site, it was observed that the lack of a more pedestrian-friendly pavement in B2 made respondents feel much warmer and thermally discomfort during the afternoon and evening, as compared to B1 and B3 (Figure 6). Moreover, a higher mean Icl value of 1.46, based on male respondents in B2, related to a higher indoor-outdoor temperature difference during the field measurement. Unexpected rise in temperatures and stunted evaporative heat loss from the human skin have been reported to cause thermal discomfort in moving through spaces with temperature step-changes (Dahlan & Gital, 2016; Fountain, Arens, Xu, Bauman, & Oguru, 1999; Hitchings & Shu Jun Lee, 2008; Jing, Li, Tan, & Liu, 2013).

Influencing factors, such as BMI, gender, and Icl were tested against the modes of transportation in hot and humid weather. BMI level was found to influence the respondents' thermal sensation votes at a 0.05 level of significance, with obese respondents (BMI  $\geq 30$  kg/m<sup>2</sup>) reported feeling warmer as opposed to underweight respondents (BMI  $\leq 18$  kg/m<sup>2</sup>). Similarly, Habibi, Momeni, and Dehghan (2016) also found that overweight people are more susceptible to higher temperatures that may result in heat stress, thus limiting their outdoor physical activities (Alharbi & Jackson, 2017; Wagner, Keusch, Yan, & Clarke, 2019). However, the finding in this study is not in agreement with the results of Tuomala et al. (2013), which showed that when BMI increased, the thermal sensation value decreased in males (M = 0.09, SD =  $\pm 1.1$ ) and females (M = 0.10, SD =  $\pm 1.2$ ) using the Human Thermal Model, which takes into consideration both true anatomy (body part level tissue distribution) and physiology (thermoregulation) models. In addition, the previous model was also developed using samples that were acclimatized to temperate climate (Holopainen, 2012; Takada, Kobayashi, & Matsushita, 2009), which is in contrast with samples from this study.

In this study, when asked to rate their thermal sensation while walking within close proximity of their office building, there was a significant mean difference at p < 0.01 level between male and female respondents. In spite of male workers having to wear clothing ensembles (Icl) (M = 1.46, SD =  $\pm 0.3$ ) that are higher than the female workers' clothing ensembles (M = 1.07, SD =  $\pm 0.4$ ), females at B2 felt warmer outdoor near their working area compared

to their male counterparts. This result is in accordance with a study done by Lam, Loughnan, and Tapper (2018) in Melbourne, Australia where females were found to be less tolerant to the hot weather compared to males. Since females have a greater sensitivity to changes in thermal environment, they need higher individual temperature control and adaptive actions (Karjalainen, 2012; Tuomaala et al., 2013). The observed Icl value gathered from the male respondents was calculated to be approximately double the tested Icl value recommended by Havenith et al. (2015) for non-western countries, namely, 0.61. Meanwhile, the observed Icl value for the female respondents was quite similar, that is, 0.97 (Havenith et al., 2015). However, female respondents felt more uncomfortable compared to males when exposed to cold conditions and felt warmer than their male counterparts in warm conditions in spite of their ideal Icl value. This observation is in agreement with (Amindeldar, Heidari, & Khalili, 2017; Thapa, 2019). Furthermore, it was found that females presented a higher prevalence of physical inactivity in contrast to males partly due to the surrounding built environment. Previous studies have revealed that non-pedestrian-friendly built environment that impedes walking or cycling in urban areas will most likely lead to physically inactivate behaviours (An, Shen, Yang, & Yang, 2019; Farias et al., 2019; Transportation Research Board, 2005).

Respondents' awareness level in adopting an active lifestyle to improve their health was quite high for both healthy and NCD sufferers. However, when asked regarding their modes of transportation for daily trip to work, 85% of the respondents opted to use motor vehicles regardless of the provision of cycling lanes and related facilities to support walking activities available in the measured sites. This finding is also in agreement with the findings from Siti Fatimah Hashim et al. (2017) and observation by Abas (2018).

The study had some limitations. First, the cross-sectional nature of the study would not allow for cause-effect relationships to be established between the socio-demographic factors and NCD occurrences in office workers in Putrajaya. Second, the results of the study could only be generalized to office workers who use the designated pathway close to main entrance of their workplace, and were not applicable to all office workers who worked in all administrative building located in Putrajaya. A third limitation was that the self-reported questionnaire did not provide accurate estimates of BMI driven physical activity. Therefore, replication of this study using representative sample of the office worker population (local government study) is highly suggested. Due to overwhelming information observed in this article, it is decided that findings in regard to age group related investigations for this study will be reported in a separate article succeeding to the current article.

#### 5. CONCLUSION

The warm tropical weather was established as a hindrance to walking in cities. In the case of a Tropical Low Carbon City, such as Putrajaya, introducing a culture of walking in a population that is less likely to walk more than ten minutes may be more complex than simply providing pavements and covered walkways. Moreover, respondents were aware of the impacts of the built environment on their physical activities. Most of the respondents are willing to improve their health by walking more but expressed that the midday heat and natural humidity of the tropical weather coupled with the lack of shaded paths contributed to the high rate of motor vehicle dependency in Putrajaya. Nevertheless, further studies on perceived thermal hindrances based on transient thermal comfort is recommended based on the discrepancies in male respondents' clothing insulation value found in this study in comparison to findings from controlled experiment settings.

It is hoped that the findings from this study may contribute to the National Policy on Climate Change, particularly under the premises of societal well-being and environmental protection. The outcome of this study is likely to complement the Low Carbon Cities Framework considering the aspect of pedestrian well-being as there is no specific guideline for comfortable walking distance in Malaysia's urban built environment. In addition, strategies to follow an active lifestyle through walking and other physical activities should be encouraged for the prevention of NCDs in Malaysia.

#### ACKNOWLEDGEMENT

The research reported herein was supported by the Geran Putra 700-2/1/GP/2017/9553300. The authors would like to thank all respondents for their participation, Mohd Khairun Nizam Mohamad Noh and the enumerators for their involvement in this study.

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## INFLUENCE OF LANDSCAPE ENVIRONMENTAL SETTINGS ON OUTDOOR PEDESTRIAN THERMAL COMFORT IN TROPICAL CLIMATE

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### ABSTRACT

*A suitable microclimate can increase pedestrian comfort and encourage walkability and support sustainability. This study aimed at measuring the effectiveness of selected types of Landscape Environmental Settings for Pedestrian (LESP) in influencing the thermal comfort in tropical campus environments. Field measurement data was collected under 5 different types of LESP in a university campus. The types are; No shade (T1), Metal deck (T2), One row of trees (T3), Combined deck and trees (T4), and Two rows of trees (T5). Pedestrian thermal comfort is assessed by measuring i) Air temperature (Ta), ii) Globe temperature (Tg), iii) Wind velocity (v), iv) Surface temperature (Ts), and v) Relative humidity (Rh). Data were analysed and ranked according to the comfort level of the pedestrians. Results indicate the importance of natural and man-made shading and pavement materials on pedestrians' comfort. Shading can reduce the temperature of pavements even from low albedo materials such as dark grey asphalt and contribute to pedestrian thermal comfort. The findings can be helpful for landscape architects and urban planners in specifying appropriate microclimatic interventions to improve pedestrian comfort in the tropical environment.*

**Keywords:** : Landscape settings; urban microclimate; outdoor thermal comfort; tropical campus; landscape design.

### 1. INTRODUCTION

Understanding urban microclimate is essential in urban designing and campus planning (Brown, 2011). Microclimate is an important element in providing comfortable walking ambience. Pedestrian's thermal comfort is totally dependent on the microclimate of pedestrian walkways and their landscape settings in a tropical climate (Hwang et al., 2015). Brown and Gillespie (1995), defined microclimate as the condition of solar and terrestrial radiation, wind, air temperature, humidity, and precipitation in a small outdoor space. They highlighted that an understanding of microclimate can provide the tools for creating thermally comfortable habitats for people and provide energy-efficient landscapes for buildings. Toner (2015) defined microclimate as the climate within or surrounding a city block or development. He demonstrated that a microclimate can be designed through changing the forms of buildings, landscaping, and shading to allow or block wind or solar radiation at pedestrian level.

Microclimate can also be defined as the weather in a particular small area, especially when it is different from the surrounding area (Hornby, 2005). Microclimate is influenced by the characters of the landscape (Takács et al., 2016). On the other hand, landscape characters can influence the parameters of microclimate. These microclimatic parameters determine the weather of any microclimate. Therefore, local microclimate greatly affects people's



sensations of thermal comfort and also influences decisions on whether to use the space. For example, in their study Watanabe and Ishii (2016) analysed the effects of microclimatic conditions on pedestrians' behaviour in selecting shaded places when waiting at traffic lights in Nagoya, Japan. They used on-site microclimatic measurements and unobtrusive observations in the study. The study found that half of the pedestrians' selected shaded areas when stopping at traffic signals in a hot environment of over 40°C. Moreover, female pedestrians were more careful to protect themselves from solar radiation including ultra-violet rays than males. They also highlighted that "shade design in the city" will be a critical strategy to improve the safety, comfort, and attraction of cities in a hot environment. In relation to this, the Landscape Environmental Settings for Pedestrian (LESP) with shading either with man-made shading or shading by trees hypothetically provide better microclimate in terms of air temperature, surface temperature, relative humidity, mean radiant temperature, and thermal comfort.

Wind causes air movements and may have a cooling effect on people; making them feeling thermally more comfortable in tropical climates. The velocity and direction of wind can strongly affect the thermal comfort of pedestrians along walkways due to its cooling effect known as a "wind chill." It efficiently mixes the differences in temperature or humidity in the landscape. As a result, wind chill is the perceived decrease in ambient temperature due to the flow of air on exposed skin (Toner, 2015). However, wind temperature can also influence thermal comfort. It may become hot and dry as it travels over a mountain range and across the countryside. Thus, it would either increase the temperature to a thermally comfortable level or vice versa. Wind is important in order to overcome thermal discomfort when ambient temperatures are high or when there is direct solar radiation.

Some studies confirmed the effects of wind on human thermal comfort in urban squares microclimatic conditions. Such studies can be found in Ghasemi et al. (2015) where they discussed how the use of urban form and orientation in open spaces influenced the wind velocity indicating different layouts resulting in different wind flows. Indirectly, this will influence the thermal comfort of outdoor users resulting in their willingness to spend more time in outdoor spaces. Another study by Niu et al. (2015) evaluated an open space, open ground level building block, and a courtyard surrounded by building blocks in a Hong Kong university. They used the concept of continuous monitoring of winds at the pedestrian level and also sample thermal parameters for two days during a summer. The sampling includes air temperature, globe temperature, wind velocity, and humidity. Findings of the study indicate that wind velocity and radiant temperature differences made significant dissimilarity in thermal comfort. The study clearly proves that wind amplification combined with

shading effects can generate thermally comfortable conditions in the open ground floor areas beneath an elevated building, even on a sunny, hot summer day of a subtropical city. In another study Shi et al. (2015) designed a simulation of the pedestrian wind environment. This enabled them to gauge the impacts of design on wind velocity during the urban design stage. This is crucial because pedestrian wind environment is one of the urban physical environment variables that has a significant impact on the overall wellbeing of city dwellers.

Many researchers measured the parameters of microclimate such as air temperature, globe temperature, mean radiant temperature, wind velocity, and humidity in their studies on human thermal comfort in various urban microclimates (Chatzidimitriou & Yannas, 2016; Ignatius, Wong, & Jusuf, 2015; Nor et al., 2015; Salata et al., 2016; Salata et al., 2015; Sanusi et al., 2017). Included in these studies were urban squares, open spaces, streets, street canyons, pedestrian walkways and a park. Shahab Kariminia et al. (2015) investigated the effects of built environment and geometry within a city structure towards users' thermal comfort in an urban square in Isfahan, Iran. They measured air temperature, wind velocity, and mean radiant temperature. There are studies which proved that proper microclimatic planning and design can ameliorate the negative effects of the walking microclimate (Chatzidimitriou & Yannas, 2016). Previous researches have established that trees can play an important role in influencing the surrounding climate and that a large number of trees can improve thermal comfort in hot climates (Hien & Jusuf, 2008; Nyuk, Puay, & Yu, 2007). In fact, the cooling effect of trees in tropical climates is obvious (Morakinyo, Balogun, & Adegun, 2013). Tree shading from the sun and the process of evapotranspiration are important factors that contribute to this cooling effect (Vailshery, Jaganmohan, & Nagendra, 2013). In addition to moderating microclimate and thermal comfort of pedestrians, Sanusi et al. (2017) suggested that the different types and characteristics of trees surrounding pedestrian routes can result in different cooling effects. However, studies of tree species and their canopy compositions whether based on field measurements or modelling approaches are still lacking in tropical regions.

In a tropical environment, pedestrians are often exposed to high thermal loads, which can cause thermal discomfort and even heat-strokes. Makaremi et al. (2012) in a study of pedestrians in a higher learning institution campus found that 77% of the students felt uncomfortable walking. However, Shahidan et al. (2012), suggested that suitable environmental conditions can be created through proper treatment of these environments. By having campus environment conducive for walking outdoors, it can encourage people to walk more (walkability), improve urban microclimate, and reducing energy

consumptions. However, studies on understanding tropical microclimate are currently limited to analysis of i) perceptions and preferences of thermal comfort in outdoor urban spaces (Yang, Wong, & Jusuf, 2013), ii) evaluation of the air temperature (Hirashima, Assis, & Nikolopoulou, 2016), and iii) thermal comfort within tree canopies and shade microclimate in urban park (Adawiyah & Sh, 2015). Shade is crucial for pedestrian thermal comfort (Benrazavi et al., 2016). It can prevent pedestrians from direct exposure to solar radiation, which is the most important factor causing discomfort in a tropical climate. Studies on the effects of various types of landscape environmental settings for pedestrians towards microclimate are limited in a tropical climate. Yang et al. (2018) studied the effects of different landscape elements on human thermal comfort in Singapore. They demonstrated that the value of tree shade is critical to human thermal comfort. Another study by Johansson et al. (2018) investigated the outdoor thermal environment during daytime in 5 public places in a city in Ecuador. However, both of the studies did not focus on pedestrian's walkway environment which have various types of landscape settings. Therefore, the objective of this study is to investigate the influence of Landscape Environmental Settings for Pedestrian (LESP) on microclimate parameters towards pedestrian thermal comfort in tropical campus environments.

## 2. METHODOLOGY

Kasim et al. (2018) study on the use of LESP to enhance campus walkability has defined LESP as "everything that can be seen in the pedestrian's walkway within a 3.0-meter radius that affects the thermal comfort/behaviour of the pedestrians at the particular type of situation". Different types of LESP contribute to different effects on the site microclimate and pedestrian thermal comfort. This study was conducted to answer the research question: How various scenarios of LESP affect pedestrians' thermal comfort in tropical campus environment.

According to Ng and Cheng (2012), it is reasonable to assume a consistent microclimatic condition occurring within a 3.0 meter radius. It can be determined by measuring the physical properties of the landscape setting and its surrounding environment. Five types of LESP were identified this study. They are No shade (T<sub>1</sub>), Metal deck (T<sub>2</sub>), One row of trees (T<sub>3</sub>), Combined deck & trees (T<sub>4</sub>), and Two rows of trees (T<sub>5</sub>) (See Fig. 1). These were selected based on previous studies (Kasim et al., 2018; Naderi & Raman, 2005; Ng & Cheng, 2012).



Figure 1: Locations of the 5 LESP Types  
(Source: Google Earth and Google Maps)

This is a descriptive study and measured 5 different types of pedestrian environmental settings on a university campus in Selangor. The campus is located (Lat. 03°N, Long.101°E) between Kuala Lumpur and Putrajaya, experiences hot and humid conditions year round, with daily air temperatures varying from a low of 24°C at night and up to 38°C at noon time. The study measured 5 variables: Air temperature (T<sub>a</sub>), Globe temperature (T<sub>g</sub>), Surface temperature (T<sub>s</sub>), Wind velocity (v) and Relative humidity (Rh).

This study applied the Physiological Equivalent Temperature (PET) to identify the pedestrian thermal comfort. PET is a universal thermal index represented in degrees of Celsius which is used to indicate pedestrian thermal comfort in various outdoor environments. In addition, PET can demonstrate the difference between the microclimate parameters in open space walkway (as in LESP T<sub>1</sub>: No shade) and those walkways under shade (as in LESP T<sub>2</sub>: Metal deck to LESP T<sub>5</sub>: Two rows of trees).

PET is calculated using Ray-Man software version 1.2 by computing the value of T<sub>a</sub>, Rh, v and Mean Radiant Temperature (T<sub>mrt</sub>) of microclimate in each LESP (Matzarakis, Rutz, & Mayer, 2007). The calculation of the T<sub>mrt</sub> is by using the ASHRAE formula as shown in Equation (1), with the value of measured T<sub>g</sub>, T<sub>a</sub> and v at each points in all the LESP (Thorsson et al., 2007). Studies on thermal comfort use PET classification as suggested by Lin and Matzarakis (2008) and as a reference to investigate the impact of LESP in a hot humid tropical climate of Malaysia as shown in the Table 1 (Makaremi et al., 2012).

Table 1: Thermal perception classification (TPC) for temperate region and (sub) tropical region. Source: (Makaremi et al., 2012)

Thermal perception	TPC for (sub)tropical region (°C PET)	TPC for temperate region (°C PET)
Very cold	<14	<4
Cold	14-18	4-8
Cool	18-22	8-13
Slightly cool	22-26	13-18
Neutral	26-30	18-23
Slightly warm	30-34	23-29
Warm	34-38	29-35
Hot	38-42	35-41
Very hot	>42	>41

Equation (1):

$$T_{mrt} = [(T_g + 273.15)^4 + \frac{1.1 \times 10^8 V_a^{0.6}}{\varepsilon D^{0.4}} \times (T_g - T_a)]^{1/4} - 273.15$$

$T_{mrt}$  = Mean radiant temperature (°C)

$T_g$  = Globe temperature (°C)

$V_a$  = Wind velocity (m/s)

$T_a$  = Air temperature (°C)

$D$  = Globe diameter (mm)

$\varepsilon$  = Globe emissivity (0.95)

## 2.1 Study site and measurement period

The study focuses on all 5 types of LESP in order to assess the influence of different landscape settings on pedestrian thermal comfort. These LESP types are represented by different scenarios. The process of selecting suitable sites for this study was done using a site selection survey. The survey was carried out from 21st to 28th of January 2018. First, the researcher identified and labelled the sites according to the LESP types. None of the sites identified have walkways of more than 250m long. Then, the length is marked at 10m intervals, starting with Point 1 until Point 25. Measurements were then made from Point 1 and ending at Point 25.

The field measurements were carried out on the hottest part of the day (12:00 to 15:00) from 7th to 15th of February 2018. On site measurements are critical to investigate the best effect on the pedestrians' thermal comfort from the 5 types of LESP. According to Shahidan et al. (2010), in tropical climate, the best time to measure is when the sun is overhead from 12:00 to 13:00 and the shade is concentrated directly around the tree canopy. Similar shading effects occur until 14:00. After that the shadow will be stretched to the east from 14:00 to 15:00. Thus, the best time for the measurement is from 12:00 to 15:00. The Air temperature ( $T_a$ ), Globe temperature ( $T_g$ ), Surface temperature ( $T_s$ ), Wind velocity ( $v$ ) and Relative humidity ( $R_h$ ) were measured repeatedly for 3 days at each point in order to get the average reading of daily weather. This was done similar studies in Singapore requiring outdoor temperature measurements at different locations (Hwang et al., 2015). Figure 1 illustrates the locations of the 5 types of LESP.

## 2.2 Field measurement of the site settings

Each LESP type shows differences in site settings. LESP  $T_1$  (No shade) is a walkway measuring 2.0 m in width with concrete interlocking paver as the only landscape element in the walkway environment. LESP  $T_2$  (Metal deck) comprises of both interlocking pavers and metal-deck shade structure. This differs slightly from LESP  $T_3$  (One row of trees) which consists of concrete slabs with white pebbles paving and shade provided by columnar shaped trees (*Juniperus chinensis*). LESP  $T_4$  (Combined deck & trees) consists of concrete slabs pavement and shading from both a metal-deck shade structure as well as from shade trees (*Mimusops elengi*). And finally, LESP  $T_5$  (Two rows of trees) has dark coloured asphalt pavement in between two rows of *Angsana* (*Pterocarpus indicus*) shade trees.

Each LESP type comprises of five microclimate parameters; Air temperature ( $T_a$ ), Globe temperature ( $T_g$ ), Surface temperature ( $T_s$ ), Wind velocity ( $v$ ) and Relative humidity ( $R_h$ ). This study measured the microclimatic parameters for all 5 LESP types. Measurements were taken on three sunny days from 12:00 to 15:00. The measurements were taken at a height of 1.5m from the ground except for  $T_s$  which uses the ground as the base for measurement. The data was then analysed and the mean for every parameter of each type was recorded.

## 2.4 Field measurement equipment and procedure

Measurements for each site were made with the help of two trained research assistants who measured the microclimate parameters at all 25 points on each site.

Table 2: Microclimate measurement parameters and equipment specifications

Measurement parameters	Equipment	Measurement range	Accuracy
Air temperature	Testo 925, with robust air temperature probe (TC type K) with fixed cable 1.2m probe	-50 °C to +1000°C	± 0.5 °C from -40.0°C to + 900°C
Globe temperature	Extech HT30 (Ø = 40 mm)	0 to 80 °C	± 2 °C
Surface temperature	Testo 905-T2, with short measurement type	-50 °C to +350°C	± 1 °C
Wind velocity	Testo 425, thermal anemometer with permanently attached flow probe	0.0 to +20 m/s	± 5% or 0.03 m/s whichever is greater
Relative humidity	Testo 625, thermo hygrometer, with connectable humidity sensor head	0 to +100%RH	± 2.5%RH

Four portable measuring equipment, Testo 925, Testo 905-T2, Testo 425, and Testo 625 were used to measure air temperature, surface temperature, wind velocity and relative humidity, respectively while Extech HT30 with a 40 mm diameter black globe was used to measure the globe temperature. The instruments were chosen due to their quick responses, convenient sizes, and their accuracy conforms to ISO 90001:2008 and German Federal Physical and Technical Institution. The instrumentations are reliable to be measured in outdoor environment (Hwang et al., 2015). Table 2 lists the detail specifications of equipment used during field measurement.

## 2.5 Data Analysis

To investigate the influence of LESP on microclimate parameters, three sets of data were averaged to obtain a single mean of  $T_a$ ,  $T_g$ ,  $T_s$ ,  $v$  and  $R_h$  for each point in each type of LESP. Then  $T_{mrt}$  and PET were calculated based on the mean of  $T_a$ ,  $T_g$ ,  $T_s$ ,  $v$  and  $R_h$  for each point in each type of LESP. Data for  $T_a$ ,  $T_s$ ,  $v$ ,  $R_h$ ,  $T_{mrt}$  and PET were analysed using a One-way Analysis of Variance (ANOVA). A one-way ANOVA was adopted to test the significant differences among 5 types of LESP at  $p < 0.05$ . Various comparative statistical analyses with Post-Hoc Comparisons test to detect which pair of scores resulted in the significant differences were also performed on the data.

## 3. RESULTS

Results from data analyses disclosed essential findings of the Landscape Environmental Settings for Pedestrian (LESP) thermal comfort tested. Results for Physiological Equivalent Temperature (PET) are significantly different amongst the 5 types of LESP ( $T_1$ = No shade,  $T_2$  = Metal deck,  $T_3$ = One row of trees,  $T_4$ = Combined deck & trees, and  $T_5$ = Two rows of trees) with  $p < 0.05$  (Table 3).

Table 3: Result of Post Hoc Tests (Multiple Comparison) for PET

I (LESP)	J (LESP)	Mean PET	Std. Error	Sig.
		Difference (I-J)		
T <sub>1</sub> (no shade)	T <sub>2</sub> (metal deck)	6.11	0.3431	0.000
	T <sub>3</sub> (one row of trees)	4.16	0.3431	0.000
	T <sub>4</sub> (combined deck & trees)	5.43	0.3431	0.000
	T <sub>5</sub> (two rows of trees)	6.74	0.3431	0.000
	T <sub>2</sub> (metal deck)	-6.11	0.3431	0.000
T <sub>2</sub> (metal deck)	T <sub>3</sub> (one row of trees)	-1.94	0.3431	0.000
	T <sub>4</sub> (combined deck & trees)	-0.67	0.3431	0.287
	T <sub>5</sub> (two rows of trees)	0.62	0.3431	0.361
	T <sub>1</sub> (no shade)	-4.16	0.3431	0.032
T <sub>3</sub> (one row of trees)	T <sub>2</sub> (metal deck)	1.94	0.3431	0.000
	T <sub>4</sub> (combined deck & trees)	1.27	0.3431	0.003
	T <sub>5</sub> (two rows of trees)	2.57	0.3431	0.000
	T <sub>1</sub> (no shade)	-5.43	0.3431	0.000
T <sub>4</sub> (combined deck & trees)	T <sub>2</sub> (metal deck)	0.67	0.3431	0.287
	T <sub>3</sub> (one row of trees)	-1.27	0.3431	0.003
	T <sub>5</sub> (two rows of trees)	1.30	0.3431	0.002
	T <sub>1</sub> (no shade)	-6.74	0.3431	0.000
T <sub>5</sub> (two rows of trees)	T <sub>2</sub> (metal deck)	-0.62	0.3431	0.361
	T <sub>3</sub> (one row of trees)	-2.57	0.3431	0.000
	T <sub>4</sub> (combined deck & trees)	-1.30	0.3431	0.002

### 3.1 Air temperature (T<sub>a</sub>)

Figure 2 shows the graph of T<sub>a</sub> for all types of LESP. In LESP T<sub>1</sub> the mean temperature ranges from 31°C to 34.5°C and the mean is 33.1°C. LESP T<sub>2</sub> has a range of 30.2°C to 32.5°C and the mean is 31.6°C. The result for LESP T<sub>3</sub> has a range of 31.6°C to 33.3°C and a mean of 32.5°C. Mean-

while, LESP T<sub>4</sub> and LESP T<sub>5</sub> recorded a range of 30.8°C to 32.2°C with a mean of 31.4°C and 30.7°C to 31.8°C with a mean of 31.3°C respectively.

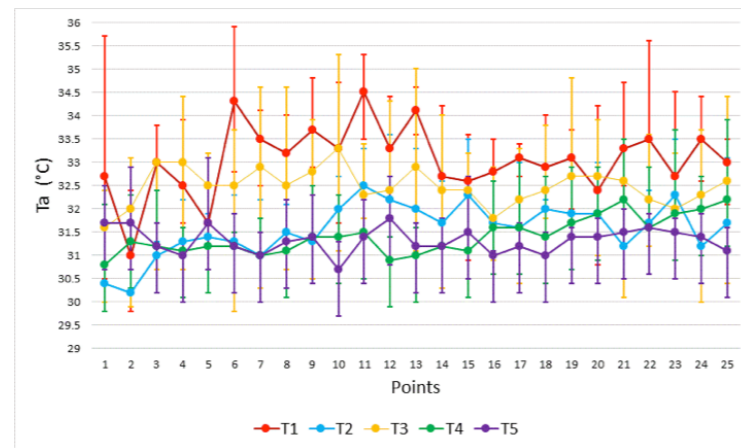


Figure 2: Air temperatures (T<sub>a</sub>) between LESP Types

In term of LESP type, LESP T<sub>5</sub> is considered as the most stable as it presents a minimum gap in T<sub>a</sub> which is 1.1°C. This is followed by LESP T<sub>4</sub> at 1.4°C, LESP T<sub>3</sub> at 1.7°C, LESP T<sub>2</sub> at 2.3°C and LESP T<sub>1</sub> at 3.5°C. The ranking in means for the five types of T<sub>a</sub> is LESP T<sub>5</sub>, LESP T<sub>4</sub>, LESP T<sub>2</sub>, LESP and LESP T<sub>1</sub>. T<sub>5</sub> recorded the lowest mean for air temperature and the lowest gap in temperature range. The comparison of two microclimates, LESP T<sub>4</sub> has man-made shading (metal-deck shade structure) and shading by trees. Meanwhile, LESP T<sub>3</sub> has two rows of dense vertical trees (Pterocarpus indicus) on both sides providing the walkway with some shade and breeze.

### 3.2 Surface temperature (T<sub>s</sub>)

Surface temperature (T<sub>s</sub>) is measured by positioning the head of the instrument directly on the surface of walkway pavement to record the minimum, maximum, and mean of the surface temperature. Materials used for LESP T<sub>1</sub> and LESP T<sub>2</sub> are interlocking concrete paver, LESP T<sub>3</sub> is concrete slabs with white pebbles finishes, LESP T<sub>4</sub> is concrete slabs while LESP T<sub>5</sub> is dark grey asphalt. The lowest temperature recorded is 31.8°C (in LESP T<sub>3</sub> and T<sub>4</sub>) and the highest is 43.4°C (in LESP T<sub>1</sub>). In terms of differences in range, LESP T<sub>2</sub> has the smallest range which is 4.8°C and this is followed by LESP T<sub>1</sub> and LESP T<sub>4</sub> with a similar value of 6.3°C. LESP T<sub>5</sub> has a range of 8.2°C and the biggest range value is 9.0°C recorded for LESP T<sub>3</sub>.

In Figure 3 the graph shows the fluctuation of temperature at every point in each type. It is clearly shown that LESP T<sub>1</sub> has the highest range of temperatures. The trend of LESP T<sub>2</sub> to LESP T<sub>5</sub> is almost similar although LESP T<sub>5</sub> illustrates a stable range of temperature as compared to the others. LESP T<sub>5</sub> recorded the smallest mean value of 33.8°C and followed by LESP T<sub>4</sub> with 34°C. The mean values in LESP T<sub>2</sub> and LESP T<sub>3</sub> are 34.4°C and 34.6°C respectively. LESP T<sub>1</sub> recorded the highest mean for T<sub>s</sub> with the value of 40.7°C. The mean value ranking of T<sub>s</sub> for the 5 types is LESP T<sub>5</sub>, LESP T<sub>4</sub>, LESP T<sub>2</sub>, LESP T<sub>3</sub> and LESP T<sub>1</sub>.

T<sub>s</sub> at point 1 and at point 12 in LESP T<sub>5</sub> are hotter compare to other points. The recorded temperature for these points are 38.9°C and 36.6°C respectively. In LESP T<sub>5</sub>, point 1 recorded the highest temperature. This is caused by lack of shading at that particular point.

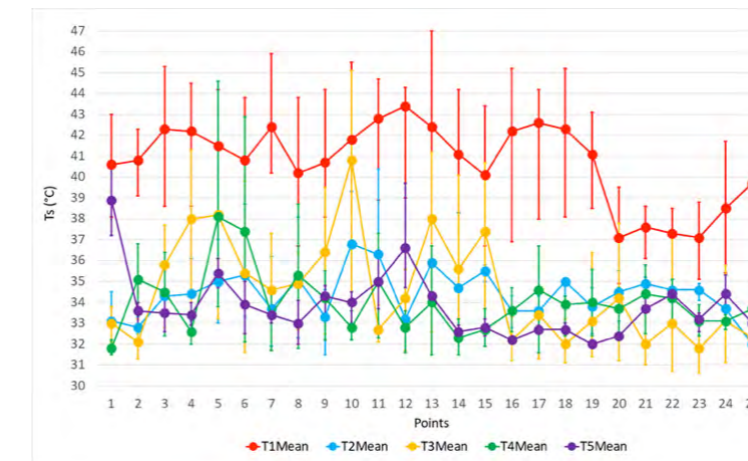


Figure 3: Trends of T<sub>s</sub> in all LESP Types

The point acts as the beginning of LESP T<sub>5</sub>. The case is almost similar with point 12 as the gap between trees are larger compare to other points. This results in the absence of tree shades, hence the temperature at that point is higher. The case is repeated in LESP T<sub>3</sub>, where T<sub>s</sub> has increased by 4.4°C from 36.4°C to 40.8°C taken at Point 9 to Point 10. This is due to the larger distance between trees as compared to other points along the walkway. In LESP T<sub>1</sub> there is a big drop in T<sub>s</sub> from Point 19 to Point 20 (41°C to 37.1°C). This decreased in T<sub>s</sub> by 3.9°C was due to the row of trees present near to Point 20 and onwards.

### 3.3 Wind velocity (v)

Figure 4 shows the graph of v in all types of LESP. LESP T<sub>2</sub> has the biggest range with 1.5 m/s followed by LESP T<sub>5</sub> with value of 1.2 m/s, and LESP T<sub>1</sub> with value of 1.1 m/s. LESP T<sub>3</sub> and LESP T<sub>4</sub> share a similar range of v with the value of 1.0 m/s. Among all the types of LESP, LESP T<sub>2</sub> records the highest mean for v (mean = 0.87 m/s). The lowest mean

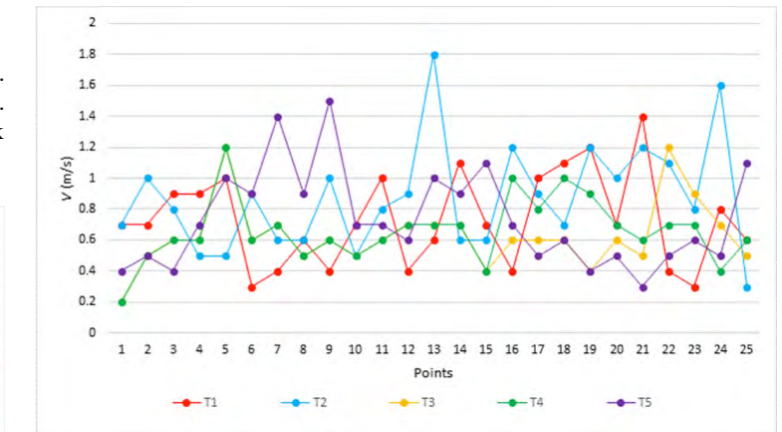


Figure 4: Trends of v in LESP Type 1 to LESP Type 5

for v is in LESP T<sub>3</sub> with the value of 0.63 m/s. The v in all types of LESP can be regarded as very weak as the highest value is only 1.8 m/s (6.5km/h). It is very difficult to find a relationship between LESP types with v results in each LESP largely due to the microclimate space of only 3.0 m radius covered in this study.

### 3.4 Relative humidity (Rh)

As can be seen in Figure 5, the graph clearly indicates the lowest Rh occurred in LESP T<sub>1</sub> as compared to a small difference between other scenarios. These results indicate that trees affect the Rh value of the surrounding microclimate. Rh value is higher in a microclimate that has a lot of trees through their evapotranspiration.

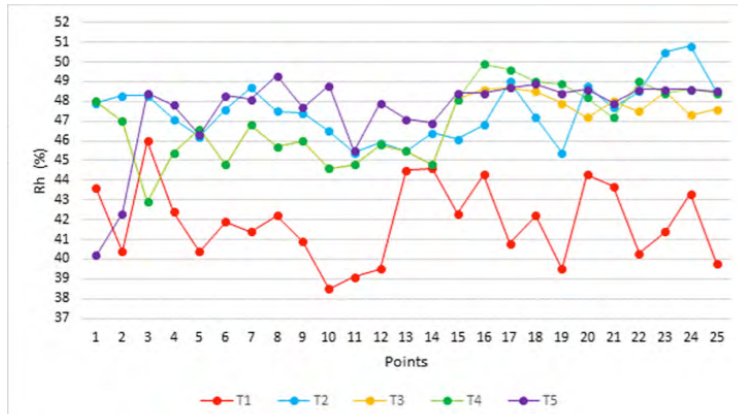


Figure 5: Trends of Rh in LESP Type 1 to LESP Type 5

### 3.5 Mean Radiant Temperature (Tmrt)

The Tmrt is defined as the ‘uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure’ (ASHRAE, 2001). Tmrt shows the actual radiations (short and long radiation) exposed to the pedestrian and one of the most important meteorological parameters to the outdoor thermal comfort.

Tmrt is calculated by replacing the values of Ta, v and Rh (from field measurement) into the ASHRAE formula as shows in Equation (1). Figure 6 shows the graph of Tmrt in all types. The graph clearly indicates the difference between LESP T1 (no shade) with LESP T2, T3, T4 and T5 (have shades). In LESP T1, the mean temperature ranges from 42.3°C to 51.8°C. Meanwhile in LESP T2 to LESP T5 ranges below 43°C. Generally, this data has proven that shading over pedestrian can reduce the radiation effects. In contrast to Ta, the Tmrt value in LESP T2 is lower than LESP T4. LESP T2 and LESP T4 have a range of 34.8°C to 39.7°C and 32.2°C to 42.1°C respectively. LESP T2 and T4 are similar as both have continuous man-made shading. But it is interesting to note that LESP T4 has higher Tmrt than LESP T2. Tmrt’s findings show clearly the difference effects of trees shading in LESP T3 and LESP T5.

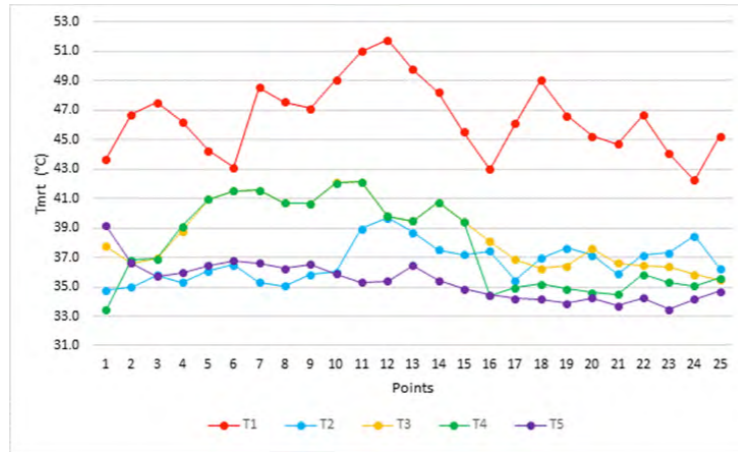


Figure 6: Trends of Tmrt in LESP Type 1 to LESP Type 5

### 3.6 Physiological Equivalent Temperature (PET)

Figure 7 shows the graph of PET values for all LESP types. It clearly indicates that LESP T1 has the highest range of PET whilst LESP T5 recorded the lowest range of PET. The ranking in mean values for PET in all 5 types is LESP T5, LESP T2, LESP T4, LESP T3, and LESP T1 in ascending order. PET values of all types were generally above the upper comfort range limit of 30°C. PET values in LESP T5 and LESP T2: metal deck (with mean value of 32.7°C and 33.3°C respectively are in a range of slightly warm which is considered in an “acceptable range”. According to Lin and Matzarakis (2008), the “acceptable range” is for slightly cool, neutral, and slightly warm condition which ranges from 22°C to 34°C. PET values in LESP T3 and LESP T4 are in the range of warm whilst PET for LESP T1 is in the range of hot.

The results of PET indicate the effects of different types of LESP on pedestrian thermal comfort in a tropical climate. PET values in LESP T1: no shade (without shading and in the hot range), represents the actual thermal condition faced by pedestrians during the hottest time of the day, which is from 12:00 to 15:00. Thus, the findings show that there is only a statistically significant differences between no shade (LESP T1) and all the others in shading (LESP T2 to T5) as proven by Post-Hoc Comparisons statistical test (see Table 3). Indeed, Table 3 indicates that the LESP T5 recorded the biggest mean for

PET differences between LESP T1, followed by LESP T2, T4, and T3. These findings are in line with the findings by Makaremi et al. (2012) in connection with the shaded outdoor spaces in Malaysia.

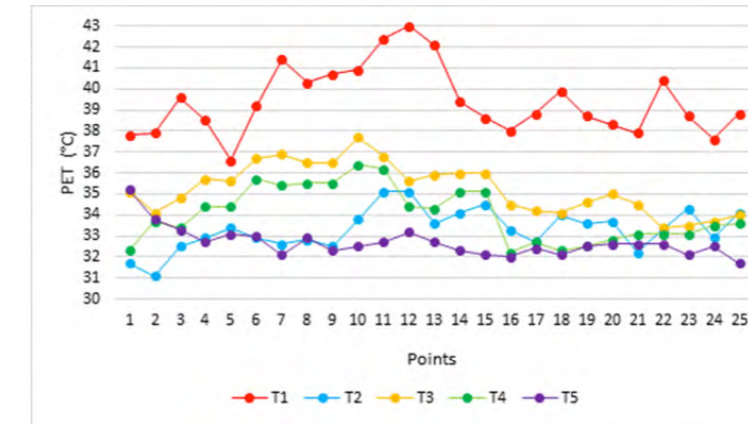


Figure 7: Trends of PET in LESP Type 1 to LESP Type 5

## 4. DISCUSSION

This study investigates the influence of Landscape Environmental Settings for Pedestrian (LESP) on microclimate parameters towards pedestrian thermal comfort in tropical campus environments. Results indicate that the importance of using sandwiched tree-shading to reduce the Ta as mentioned in a study done by Crum et al. (2017). The shading reduces Ta through reductions in heat fluxes from shaded pavement surfaces. In another microclimate situation, continuous man-made shading in LESP T2 (metal deck) provides better protection, hence reducing Ta compared to shading by trees which do not provide continuous shade as illustrated in LESP T3 (one row of trees). This fact supports the results found in Hwang et al. (2015) which highlighted the value of shade especially in terms of volume and continuity over the length of the walkway.

Dark grey asphalt materials have low albedo. However, when there is shading from the tree canopy as in LESP T5 (two rows of trees) situation, Ts is reduced. Similarly, shade is needed to reduce the surface temperature when interlocking pavers and white pebbles pavers are used in LESP T3 and in LESP T1 (no shade) situations respectively. These findings conform to an earlier

study suggesting that shade is more significant than water in influencing Ts reduction in a tropical climate (Benrazavi et al., 2016). In addition, the results support the idea that the use of high-albedo materials for urban surfaces is not significant for pedestrian users’ thermal comfort (Erell et al., 2014).

A larger environmental setting is needed to see the relevance of v in the outdoor environment. Previous studies proved the effects of wind towards human thermal comfort in bigger microclimate such as an urban square, a campus open space and an open ground level building block (Liu, Niu, & Xia, 2016; Shi et al., 2015; Zheng, Li, & Wu, 2016). Therefore, it is safe to deduce that wind is not a key determinant in pedestrian thermal comfort in this particular study. Furthermore, results show that Rh value is higher in a microclimate that has a lot of trees through their evapotranspiration. When humidity of the surrounding increases and thus reduces the hot tropical air temperature and enhances pedestrian comfort. This has been proven in many studies (Jiao et al., 2017; Rahman et al., 2017; Wu & Chen, 2017).

The effects of different LESP types on pedestrian thermal comfort can be clearly seen from the results discussed earlier. The final ranking of LESP types for pedestrian thermal comfort are i) LESP T5 (two rows of trees), ii) LESP T2 (metal deck), iii) LESP T4 (combined deck & trees), iv) LESP T3 (one row of trees), and v) LESP T1 (no shade). There is a difference between LESP T2 and LESP T4, where LESP T2 provides more comfort to pedestrians than LESP T4. LESP T2 gives better comfort to pedestrian users due to a wider shading area (3.43 meters wide) when compared to LESP T4 (2.5 meters wide). Wider shading area provides more thermal comfort for pedestrians in this situation. LESP T2 produces a better result in v, Rh, Tmrt and PET values when compared to LESP T4 even though there is no significant difference in the findings of Ta and Ts for both LESP types. The 0.93 meters difference in the width of the shading area has changed the pedestrian thermal comfort level from “warm” to “slightly warm”. This is an equivalent of 1.2°C difference. The findings also illustrate the different effects of trees shading in LESP T3 and LESP T5. In LESP T3 discontinuous tree shading provide less thermal comfort to pedestrians than LESP T2, T4, and T5. Pedestrian walkways with continuous tree shading provide thermal comfort to users as shown in the case of LESP T5.

In general, results of this study suggest that different types of LESP have different impacts on pedestrians’ thermal comfort. This finding is supported by Bakar and Gadi (2016), in a study on thermal comfort on a university campus in Kuala Lumpur, Malaysia. Their study also suggests that different sites produced different microclimates and highlighted that solar radiation plays an important role in influencing the pedestrian thermal comfort. Furthermore,

results clearly indicate that the thermal environment for walkway without shading (LESP T<sub>1</sub>) is hotter than semi-shaded walkway (LESP T<sub>3</sub>) and the semi shaded area is hotter than the covered walkway (LESP T<sub>2</sub>/T<sub>4</sub>/T<sub>5</sub>). In addition, good quality shading by trees can provide the thermal ameliorating effects (LESP T<sub>5</sub>). This is supported by a previous study Nouri et al. (2018) suggesting that it is possible to reduce PET values by as much as 16.6°C with public space design interventions. In other words, trees enhance the outdoor thermal comfort as reported by Amani-Beni et al. (2018). They reported that urban trees modify microclimate by reducing human thermal comfort index by 1.41 on hot summer days in Beijing, China. In another study (Xu et al., 2017) also indicates that trees, through their evapotranspiration shading, reduce PET by 2°C on hot summer days.

This study provides a preliminary assessment of the potential role of LESP in microclimate amelioration to enhance pedestrians' thermal comfort in the tropical outdoor environment. It investigated several types of landscape environmental settings of pedestrians' walkways in a tropical university campus. However, this study has several limitations. These include the difficulty in finding a uniform characteristic of the 5 LESP types in a 250.0 m length. It also lacks the same species of trees and their characteristics in the 5 LESP types, and it is hard to make sure every measurement at 25 points (250 m length) in the five LESP types is made at the same time in the 3-day field measurements. Nevertheless, despite these limitations, this study provides some clear evidences to landscape architects, urban planners and others on how different types of LESP can influence the microclimate and thus, pedestrians' thermal comfort in a tropical walkway environment.

## 5. CONCLUSION

The study concluded that pedestrian walkways with shading, either man-made shading or shading by trees, provide better microclimate in terms of air temperature, surface temperature, relative humidity, mean radiant temperature, and thermal comfort. The shading quality, either by man-made shading or shading by trees, affects the comfort of pedestrians. A continuous and wider shade can increase pedestrian comfort. It is suggested that a minimum width of man-made shading is 3.4 meters. Appropriate planting distances of trees are also important in providing continuous shading along the walkways. Walkways with continuous shading, either man-made shading or shading by trees, provide comfortable thermal environment for pedestrians. Continuous shading is essential to provide a consistent thermal comfort in pedestrian microclimate environment. High albedo pavement materials still require shading to lower the surface temperature for the comfort of pedestrian users. Low albedo pavement has low surface temperatures with shading. Finally,

providing a continuous row of tree planting on both sides of the walkway is suggested to enhance the quality of landscape environmental settings for pedestrian's thermal comfort in tropical climates.

## ACKNOWLEDGEMENT

This work was made possible by funding from IPS Putra Research Fund for post graduate students in Universiti Putra Malaysia, under Grant Number GP-IPS/2017/9556900

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