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THE HIVE BICYCLE HUB DESIGN

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ABSTRACT

The International Islamic University Malaysia (IIUM) is committed to fostering a sustainable and bike-friendly campus environment as part of its broader green initiative. This research seeks to identify a comprehensive design approach for a bicycle hub facility that resolves bicycle users' issues, such as bicycle safety and storage facilities. Utilising a qualitative approach, data was gathered through case studies, surveys, and observations. A multidisciplinary KAED student group named "Arkana", comprised of architecture, quantity surveying, and applied arts and design students, collaborated to design the bicycle hub facility. The beehive concept has been applied to establish a connection between bicycle users and nature to create a sustainable campus and develop a healthy mindset for a greener future in IIUM. The "Hive" bicycle hub design includes a modular hexagonal honeycomb structure that enhances durability, accessibility, safety, and convenience to encourage increased bicycle use among students and staff of IIUM. Key features include sheltered bicycle storage, a repair workshop, a retail outlet for bicycle parts and accessories, a cafeteria, a washroom, and a locker room. The "Hive" bicycle hub supports IIUM's sustainability goals, reduces carbon emissions, and promotes a healthier campus lifestyle by providing these amenities. Its design incorporates universal and passive principles, including natural lighting, ventilation, and a rainwater collection system. The project is expected to significantly contribute to the university's green initiatives and create a model for other institutions aiming to adopt similar bike-friendly strategies.

Keywords: Bicycle Hub, Modular Design, Passive Design
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INTRODUCTION

Cycling offers numerous benefits, including reduced carbon emissions, alleviated traffic congestion, and improved personal health. However, the effectiveness of these advantages hinges the availability of well-designed facilities that meet the needs of cyclists. Cyclists at IIUM face several challenges that can impact their commuting experience and the overall adoption of cycling as a primary mode of transport. One of the primary concerns for cyclists is the risk of bicycle theft due to insufficient bike storage facilities. Another challenge is the lack of infrastructure, maintenance and repair stations. Bicycle breakdowns or maintenance needs can cause significant inconvenience and disruptions to their commute.

Providing sheltered bicycle parking and repair facilities can help mitigate these challenges and make cycling more appealing regardless of adverse weather conditions, such as heavy rain or intense heat, which can discourage cycling. Accordingly, this study presents the outcomes of a comprehensive design approach for a bicycle hub facility to address these challenges. A bicycle hub refers to a location where bicycle parking is provided in broad capacity, often contained within a secure and covered structure and offers additional facilities, such as lockers, bicycle repair and maintenance stations (Urbanspec, 2023).

In alignment with its green campus initiative, IIUM recognises the importance of integrating efficient and accessible cycling infrastructure to support and promote sustainable transportation. The proposed "Hive" bicycle hub design is a pivotal component of this initiative, envisioned to transform the campus into a model of eco-friendly commuting. The "Hive" bicycle hub facility includes bicycle storage facilities, a bicycle workshop, a retail outlet for bicycle parts and accessories, a cafeteria and a locker room that can effectively support a thriving cycling community.

The site for this proposed project is within Mahallah Zubair Al-Awwam in International Islamic University Malaysia (IIUM), Gombak (Figure 1). It is located beside the main road, Jalan Sungai Pusu and behind Mahallah Zubair Block G.

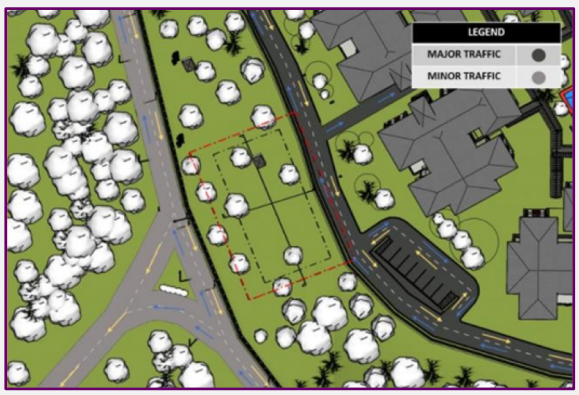


Figure 1: Proposed site location at Mahallah Zubair Al-Awwam, IIUM

METHOD

The method employed to achieve the objective of the design project is as follows:

1. Site analysis
2. Literature review
3. Design proposal of "Hive" bicycle hub comprising of bicycle garage, bicycle workshop, bicycle retail, cafeteria, and storage lockers
4. Cost estimation
5. Final model development

SITE ANALYSIS

Site analysis is conducted to synthesise the characteristics of the proposed site into visual information, as illustrated in Figure 2 and Figure 3, for making informed decisions throughout the design process.

The findings from the site analysis are summarised as follows:

1. Ordinary earth soil
2. Vertically sloped ground
3. Poor drainage system
4. Scattered trees on site
5. The speed bump around the proposed site has faded in colour
6. Insufficient number of functional streetlights
7. Availability of temporary electrical and water supply from adjacent buildings
8. Existing access - private road to the site

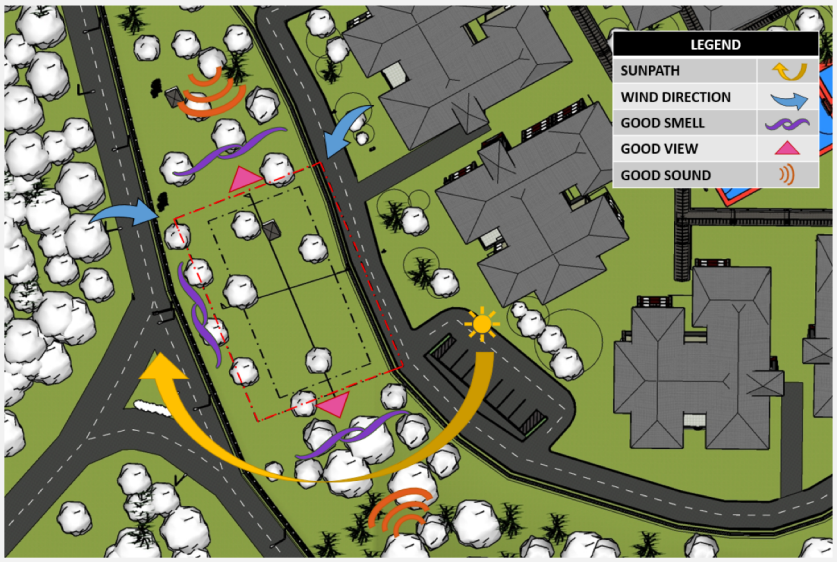


Figure 2: Site Analysis

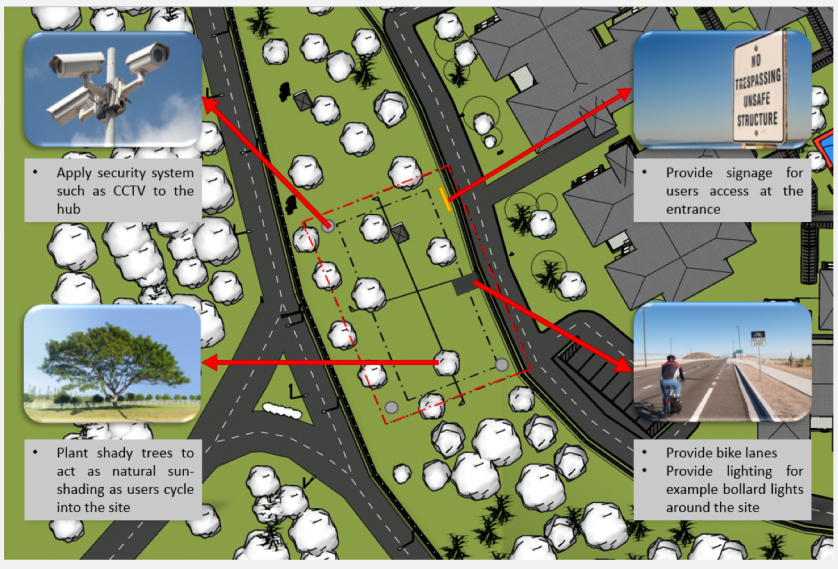


Figure 3: Site Synthesis

LITERATURE REVIEW

1. CASE STUDIES

Five precedent bicycle hub designs are reviewed in this study.

1.1 The Bicycle Garage, Sweden

Background

Architects: Tengbom
Area: 2000 sqm
Year: 2019
Capacity: 1200 Bicycles

Figure 4: The Bicycle Garage, Sweeden (Source: Pintos, 2021)

Design Statement

The Bicycle Garage is designed with a robust geometrical design concept combined with practical functionality, creating a safe space while still reinforcing the identity of the bicycle community in Sweden. The building was triangular, mirroring glass facades clad over an exposed wooden frame (Figure 4). The overall design of the building promotes both environmental and social sustainability, which aligns with the city's green movement. Ramps provide accessibility to People with Disabilities (PWD) up towards the second level (Figure 5). The architects emphasised the wooden structure inside the building with lighting effects that were added to the soles of the wooden beams to give an illusion of the northern lights (Figure 6). The design plans for the ground and first floor of the building are shown in Figure 7 and Figure 8.

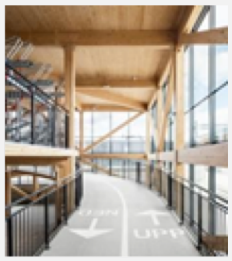


Figure 5: Ramp to Second Floor

Figure 6: Lighting fixtures on wooden beams

Figure 7: Ground Floor Plan (Source: archdaily.com)

Figure 8: First Floor Plan (Source: archdaily.com)

1.2 Coffee and Bikes, The Netherlands

Figure 9: Coffee and Bikes
(Source: Pintos, 2019b)

Background

Architects: Biq Architecten, Bureau Vaneig
Area: 1800 sqm
Year: 2018
Capacity: 1000 Bicycles

Design Statement

The Coffee and Bikes looks like a pavilion rather than a bicycle storage designed to provide a suitable hangout attraction for students (Figure 9). The staircase positioned at the entrance of the coffee bar functions as a 'lazy gallery', which serves the aim of this project (Figure 10). The second parking level is cantilevered to act as a canopy to give shade towards the coffee bar (Figure 11) . The steel structure uses joints to link the column to the beams to prevent cross braces and save space. The bicycle spaces are made available on both the ground and upper levels for accessibility to People with Disabilities (PWD). The all-sided building design provides a spacious place with optimum natural lighting. The design plans for the ground floor and first floor are shown in Figures 12 and Figure 13.

Figure 10: Staircase at the entrance of coffee bar as a 'lazy gallery'

Figure 11: Staircase towards the second floor with bicycle railway

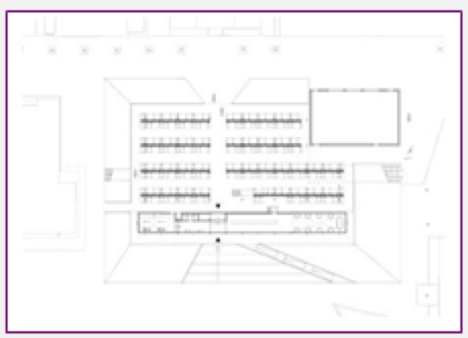


Figure 12: Ground Floor Plan
(Source: archdaily.com)

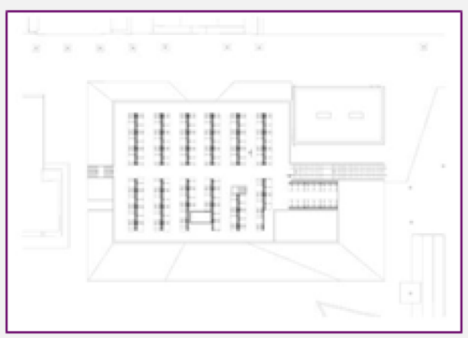


Figure 13: First Floor Plan
(Source: archdaily.com)

1.3 Bicycle Parking Main Station Karlsruhe, Germany

Figure 14: Bicycle Parking Main Station Karlsruhe (Source: Pintos, 2019a)

Background

Architects: Tafkal
Area: 1440sqm
Year: 2018
Capacity: 670 Bicycles

Design Statement

The design scheme was an adaptive reuse of a car park with a colourful atmosphere that fits up to 670 bicycles, including cargo bikes, bikes with trailers and e-bikes (Figure 14 and Figure 15). Some of the spaces provided are a reserved room, a modern locker room with changing facilities and fresh water, and a minimal workshop offering professional bicycle maintenance tools. The interiors of the garage change from a dusty grey to a colourful and friendly space with its interior graphic communication inspired by the metro maps of Karlsruhe, which guide the cyclists to the chosen storage (Figure 16). The ground floor plan is shown in Figure 17.

Figure 15: Bicycle storage that fits up to 670 bicycles of different types

Figure 16: Colourful and friendly space with graphics inspired by the metro map of Karlsruhe

Figure 17: Ground Floor Plan
(Source: archdaily.com)

1.4 Hex House, Canada

Background

Architects: Architect by Society (AFS)
Area: 40sqm compact to 2 bedrooms, 80sqm compact to ¾ bedrooms
Year: 2016

Figure 18: Hex House
(Source: Architects for Society, n.d)

Design Statement

The Hex House is designed to create housing for displaced individuals who are in the long term (Figure 18). The section for a single unit of the Hex House is shown in Figure 19. The design aims to create an environment that supports interaction and exchange of ideas among the community members. Whether linear or radial, the clusters of houses can be oriented to allow accessibility for drivers and pedestrian walkways and to form connections with the surrounding city, essential for integrating displaced communities into society (McKnight, 14 April 2016). Some design technologies implemented are rainwater harvesting, carried through an integrated gutter and downspout system, and used for washing and flushing. Efficient energy is maintained through solar panel placement and self-supporting wall and roof panels that are locked with strong integral locking joints, which form a rigid structural shell. On the other hand, the interior spaces are designed with minimal finishes such as gypsum walls, bamboo plank floors, kitchen cabinets and solid surface kitchen counters (Figure 20). Figures 21 and Figure 22 display the design plans for the single-unit floor and double-unit floor.

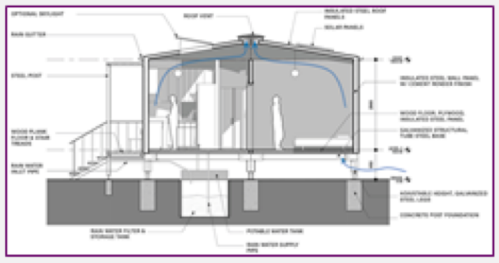


Figure 19: Sectional Cut for single unit Hex House

Figure 20: Interior spaces with minimal furnishing and finishes

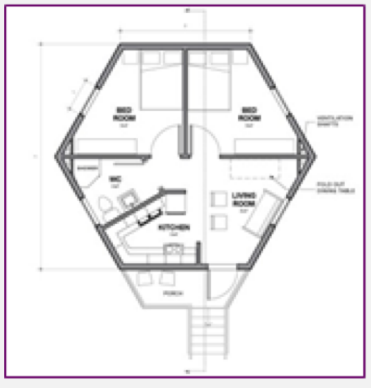


Figure 21: Single Unit Floor Plan
(Source: dezeen.com)

Figure 22: Double Unit Floor Plan
(Source: dezeen.com)

1.5 Park in Green – Modular Bicycle Parking

Background

Architects: Rafal Pieszko, Liliana Krzycka
Year: 2012

Figure 23: Picture of Park in Green
(Source: Menthol Architects, 2013)

Design Statement

The key to this project is to create modern and modular furniture, as many cities are currently undertaking the bicycle scheme. The design of this bicycle parking facilitates a greener design, with benches and a small space for a vending machine and advertising cabinet incorporated into the organised form (Figure 23). The proposed modules are prefabricated reinforced concrete moulds and frames with infill screens made of wooden profiles. The concrete used is from old concrete bus shelters that are applied to the production process, thus implementing sustainable design awareness through reused materials.

2. MODULAR DESIGN

A modular design approach subdivides a part into smaller parts that can be independently used in different systems, linked to each other, replaced, and added. In the building construction, the modules can be created in a factory and then transported to the site to attach the modules to the foundation of the building. The most common materials used are steel, wood and concrete due to their mechanical characteristics, which adapt perfectly to modular architecture.

The advantages of modular design are flexibility in design, speed in construction, replaceable elements, high quality and controlled construction, and reduced costs. It is also versatile and can be used in permanent and temporary installations.

Generally, there are two types of modular buildings:

1. Temporary Modular: a structure that meets interim needs for additional space and can be either leased or purchased to be used in a short period
2. Permanent Modular: an alternative building method to conventional onsite construction that can be used for an extended period

An example of a bicycle parking facility that uses modular design is Park in Green by Menthol Architects, as explained in the previous section (Figure 23).

3. TECHNOLOGY

3.1 LED Lighting System

- Safety: lower voltage reduces the risk of electric shock
- Versatility: varied fitting designs with small bulbs
- Long life span: lower voltage creates an ideal condition for long-lasting bulbs and requires only minimal maintenance

3.2 Closed Circuit Television (CCTV)

- CCTV stands for closed-circuit television and is commonly known as video surveillance.
- “Closed-circuit” means broadcasts are usually transmitted to a limited number of monitors, unlike “regular” TV, which is broadcast to the public at large.
- It is useful for tracking suspected activities for the detection of what is happening at the bicycle hub where they are installed.

3.3 PIR Motion Sensors

- "Passive Infrared", "Pyroelectric", or "IR motion" sensors to detect human motion within its range.
- It uses low power and has a wide lens range.

3.4 Easy Lift Two-Tier Bicycle Parking System

- Gas-assisted, two-tier bicycle parking system to allow effortless bicycle storage (example as shown in Figure 24).
- Ideal bicycle storage for space efficiency and aesthetics (Get Cycling, n.d.)
- It is user-friendly, safe, and stable, with a locking system that prevents falls.

Figure 24: Cyclepod’s easy lift two-tier bicycle storage. Retrieved 7 August 2021, from https://www.cyclepods.co.uk/bsfg-product-focus-easylift-premium-two-tier-cycle-rack/

4. UNIVERSAL DESIGN

Universal design is a framework for designing living and working spaces and products that benefit the most comprehensive possible range of people in the broadest range of situations without a unique or separate design (Rossetti, 2006). Designing a bicycle hub facility with universal design principles means ensuring the space is accessible and usable by everyone, regardless of age, ability, or background.

The principles of universal design to consider are:

- Equitable Use: The design is helpful to people with diverse abilities
- Flexibility in Use: The design accommodates a wide range of individual abilities
- Simple and Intuitive Use: The use of the design is easy to understand regardless of the user’s knowledge, skills, and experience
- Perceptible Information: The design communicates necessary information effectively to the user
- Tolerance for Error: The design minimises hazards and the adverse consequences of accidental or unintended actions
- Low Physical Effort: The design can be used efficiently and comfortably with a minimum of fatigue

By integrating these universal design principles, a bicycle hub can become a welcoming, functional, and inclusive space for all users.

5. USER ANALYSIS

The primary target users of the bicycle hub are:

- Students studying in IIUM Campus
- IIUM staff who are living on campus as fellows and those who ride bicycles within the campus
- IIUM students and staff with disabilities in terms of long-term physical, mental, intellectual, or sensory impairments that prevent their full and effective social participation when faced with challenges

Wan Zafirah and Abdul Azeez (2021) identified several key challenges faced by cyclists at IIUM, including:

- Inadequate infrastructure provided for cyclists such as lack of bicycle parking
- Safety and security concerns, such as sharing traffic lanes with motor vehicles and inadequate parking locations
- Additional factors, including uncertainty of climate and weather conditions and socioeconomic influences

These findings are consistent with findings by Ahmad Afiq, Haryati, Siti Rasidah, Othman, and Daljeet (2023), who also highlighted these issues in promoting cycling as part of the green campus initiatives in Malaysian public universities. Therefore, designing dedicated bicycle hub facility is essential to address these challenges and improve the cycling experience.

DESIGN CONCEPT

Biophilic Design

The design concept is Biophilic or Biophilia that aims to fulfill human's intrinsic need to connect with nature within modern built environments. In essence, biophilic design emphasises incorporating aspects of the natural world that enhance human health and productivity. It integrates natural elements in a way that is cohesive and harmoniously embedded within the overall environment. This design concept fosters a continuous relationship between human and their surroundings. A fundamental principle of biophilic design is its consistency and comprehensiveness.

Design Inspiration

Biomimicry of Beehive

The concept is inspired by the honeycomb, which is a cluster of repeating hexagonal beeswax cells that act as a storage unit for a honeybee hive (Figure 25). When these hexagon geometries are combined or arranged next to each other, this avoids wastage of space and thus allows the minimisation of the amount of material to reach minimal weight and material cost.

Figure 25: Concept Images

Islamic Perspectives

"And your Lord inspired to the bee, "Take for yourself among the mountains, houses, and among the trees and [in] that which they construct.

Then eat from all the fruits and follow the ways of your Lord laid down [for you]."

There emerges from their bellies a drink, varying in colours, in which there is healing for people. Indeed, in that is a sign for a people who give thought.
(*An-Nahl, verse 68-69*)

Honey produced by bees is very beneficial to humans and nature.

The "Hive" bicycle hub should always benefit the IIUM community by engaging the community with nature.

Mohamed (2023) highlights key aspects for incorporating human needs and environmental responsibility into Islamic architectural design:

- Human-Centered Design: Developing spaces that prioritise user comfort and well-being by incorporating natural elements into the design.
- Sustainable Design: Employing eco-friendly and sustainable materials, along with implementing passive design techniques.

These concepts are incorporated in the design of the "Hive" bicycle hub and will be discussed in further detail in the following section of this paper.

IIUM Logo

Apart from honeycomb, the design also adapts the principles from the IIUM logo design and architecture, which uses geometric shapes in the basic design of the bicycle hub (Figure 26).

- Hexagonal Shapes

The design uses hexagonal shapes to mimic the natural structure of a honeycomb. This shape is efficient in terms of space and materials. Moreover, the hexagon is considered the most robust shape because its six sides and corners allow it to distribute weight and pressure evenly across its structure.

- Modular Design

The bicycle hub uses a modular design, where hexagonal units can be easily added or removed. This allows for scalability and customisation. On top of that, modular design is versatile in the sense that can be used in permanent and temporary installations.

- Balance and Harmony

The design incorporates symmetrical hexagonal patterns that create a balanced and harmonised design with its surroundings.

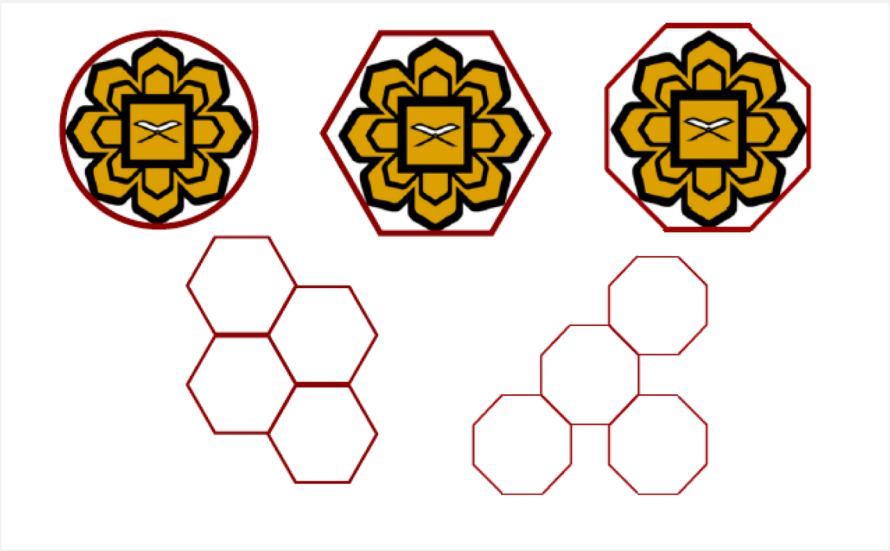
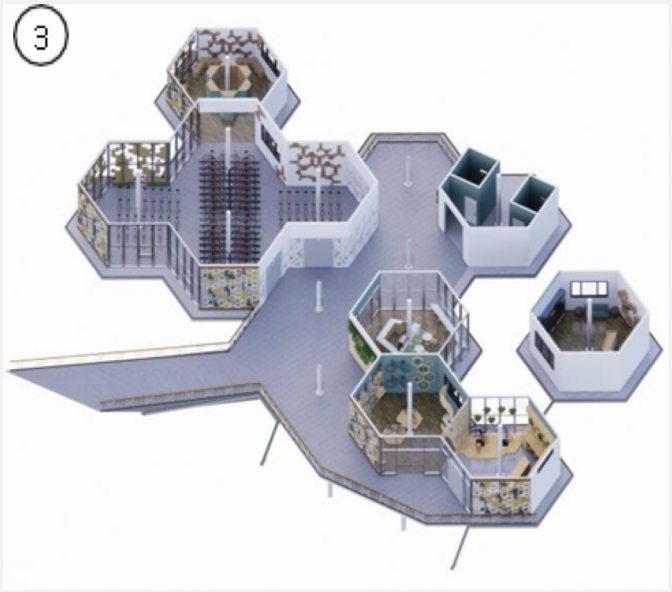


Figure 26: Picture of Form Development

DESIGN DEVELOPMENT

- Form derivation from design concept.
- Allocation of spaces with their functions.

- Designated flooring finishes according to each spaces.
- Space and roof pitch development.



- Addition of interior fittings, textures and lighting fixtures.

ZONING AND SPATIAL RELATIONSHIP

The zoning and spatial relationship of the bicycle hub is shown in Figure 27, while the bubble diagram is provided in Figure 28.

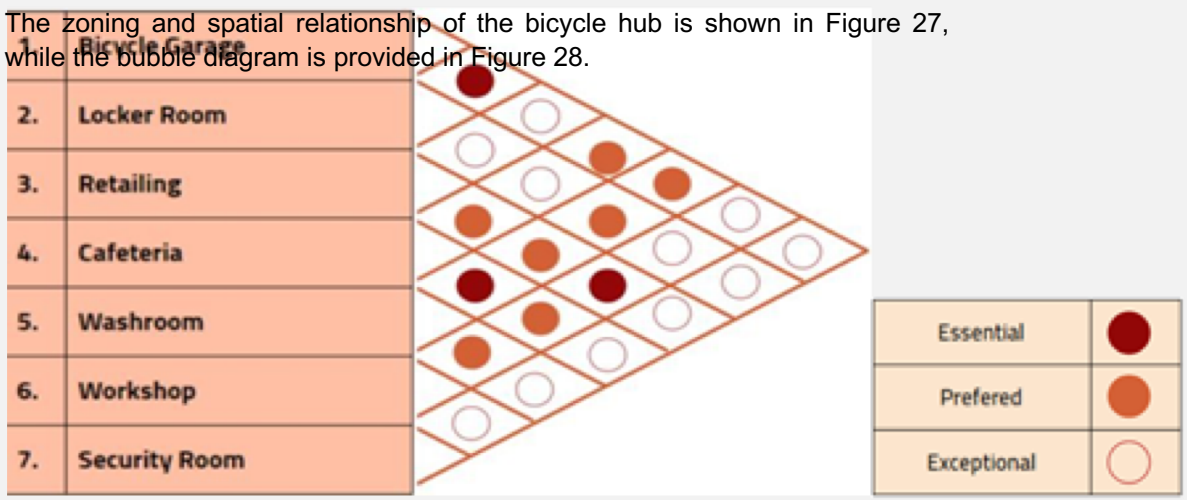


Figure 27: Zoning and Spatial Relationship of The Hive Bicycle Hub

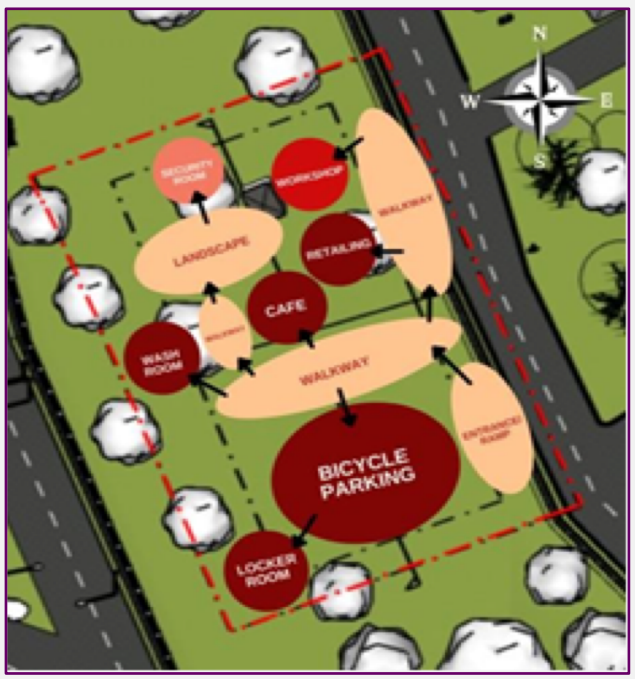


Figure 28: Bubble Diagramming of The Hive Bicycle Hub

PASSIVE DESIGN STRATEGIES

Natural Daylighting

Daylighting provides ambient lighting to the interior spaces during daytime hours (Figure 29). Implementing this strategy will create a uniform distribution of daylight to reduce any excessive or high brightness ratios, which are also controlled by the surrounding shades of the tree (Gregg, 2016). Natural daylighting allows user adjustment and override, provides a view and connection to the outdoors, and ensures adequate daylight distribution to all spaces. This strategy integrates with the architectural expression of the building from the inside out and other systems such as electrical, lighting, structural and interiors (Figure 30).

Figure 29: Daylighting

Components:

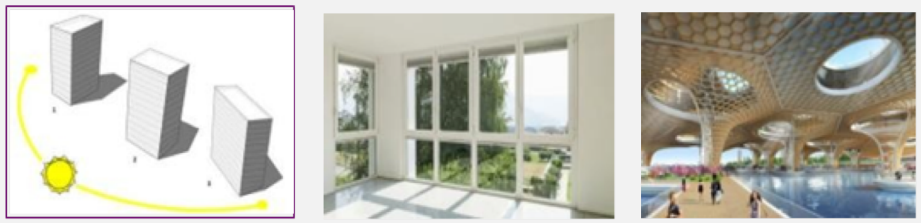


Figure 30: Daylighting Components (Building Orientation, Windows, Skylight)

Natural Ventilation

Natural ventilation moves outdoor air into a building or a room and distributes the air within the building or room (Figure 31). Natural ventilation in buildings provides healthy air for breathing by diluting the pollutants originating in the building and removing the pollutants (Atkinson et al., 2009). The advantages of a natural ventilation system are that it generally provides a high ventilation rate more economically, uses natural forces and large openings, and is also energy efficient.

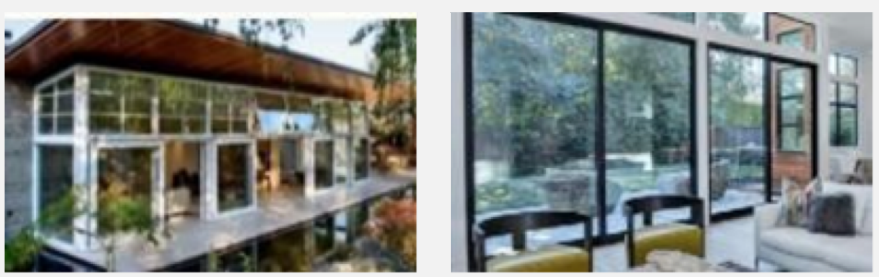


Figure 31: Natural Ventilation

Elements of natural ventilation:

- Ventilation rate
- Airflow direction
- Air distribution

Types of natural ventilation:

- Wind-driven ventilation
- Pressure-driven flows
- Stacked ventilation

Rainwater Harvesting System

The rainwater collection system collects and stores rainwater for non-portable usage (Green Master Harvest, 2021). The strategy implemented collects drain water from the roof and purifies it through filters, which can water nearby plant beds, wash bicycles or washroom usage. This system helps reduce water bills and supports water conservation efforts, contributing to overall energy efficiency. It is cost-effective and eco-friendly because the system does not require an electrical pump, only a gravitational force. Additionally, the rainwater harvesting system accumulates the fountain's water flow, and this strategy reduces cost and prevents water wastage. The rainwater harvesting system is shown in Figure 32.

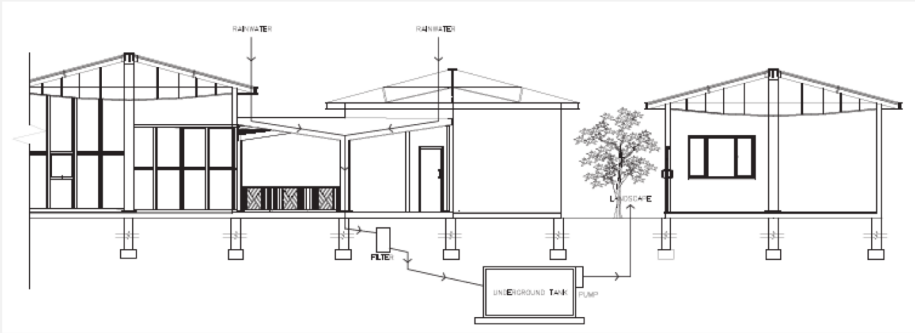


Figure 32: The “Hive” Rainwater Harvesting

SUSTAINABLE MATERIALS

Sustainable building materials that are considered in the project are as follows:

Tempered Glass Wall Panels

Figure 33 shows the tempered glass wall panels at the “Hive”. These panels are heat-resistant and durable, allowing natural light to enter while reducing heat gain and providing sound insulation. They also enhance indoor lighting and energy efficiency while improving acoustic comfort.

Figure 33: Tempered Glass Wall Panels of the Hive Bicycle Hub

SUSTAINABLE MATERIALS (Cont'd)

Aluminium Composite Panel (ACP) Roofing

These panels are lightweight, fire-resistant, and recyclable. They offer durability and are easy to install, contributing to safety and sustainability in building design. ACP roof of the "Hive" is shown in Figure 34.

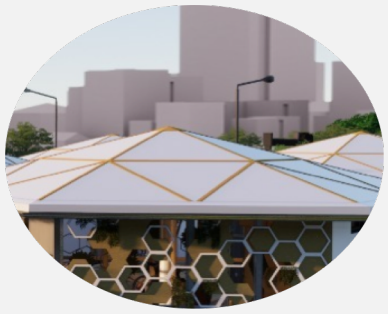


Figure 34: ACP Roof of the Hive Bicycle Hub

Steel Beams and Columns

Steel is highly recyclable and known for its strength and longevity. The use of steel beams and columns in the project (Figure 35) reduces the need for additional materials and speed up the building process, leading to a more efficient and sustainable construction project.

Figure 35: Steel Beams and Columns

LED Lights

These lights are energy-efficient and have a longer lifespan than traditional incandescent bulbs. The use of LED lights in the project (Figure 36) reduce maintenance costs, lowering energy bills and reduce carbon footprint.

Figure 36: LED Lights at the Hive

DESIGN FEATURES

Double Skin Façade

The exterior view of the bicycle hub showcases a double skin façade that acts as a sun shading device, reduces excessive daylight, and allows sufficient lighting into the interior spaces (Figure 37).

Figure 37: Exterior View of The Hive Bicycle Hub

Signage and Wayfinding

Signage and wayfinding are essential components in a building design as they inform, direct, and guide people to each designated space (Figure 38). Each space in the bicycle hub is displayed and illuminated at strategic points where it is visually convenient for visitors to see and locate the wayfinding. Figure 39 shows the exterior hardscape on the bicycle hub.

Figure 38: Signage & Wayfinding

Figure 39: Exterior Hardscape

DESIGN FEATURES (cont'd)

Bicycle Garage

The bicycle garage features a spacious layout through the interconnection of the building's hexagonal forms, with optimal lighting and natural ventilation through window openings. The two-tier bicycle storage system provides secure and proper parking for bicycles that saves space and can cater for 100 over bicycles (Figure 40).

Figure 40: Bicycle Garage

Storage Lockers

The locker room serves as a space for students to store their belongings (Figure 41). The space features modular custom lockers that can be expanded to cater for more storage spaces and modular bench seating that can be combined to accommodate more student seating areas (Figure 42).

Figure 41: Locker Room

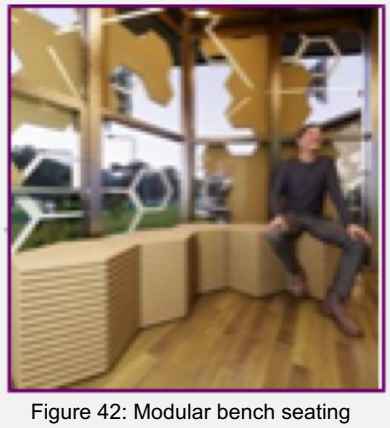


Figure 42: Modular bench seating

Bicycle Workshop

The workshop aims to provide professional maintenance service, which allows riders to send their bicycles for repair (Figure 43). The custom tools and working table feature steel pegboards that can be dismantled and rearranged for easy accessibility to working tools.

Figure 43: The Hive Bicycle Workshop

Bicycle Retail

Retailing is one of the significant activities in the bicycle hub as it provides various bicycle parts and accessories that students can purchase without having to leave the campus. The hive bicycle shop features custom hanging racks and display shelves offering a wide array of visual merchandising products for convenience (Figure 44). Modular furniture and display racks enable them to be dismantled and movable across the space to accommodate more product displays (Figure 45).

Figure 44: Hanging rack and display shelves

Figure 45: Furniture and display rack

DESIGN FEATURES (cont'd)

Cafeteria

The cafeteria offers a space where students can relax and enjoy light snacks and refreshments such as pastries and coffee. The island display counter provides efficient space circulation with window seating and tulip tables (Figure 46). The total height glass window offers the customers a nice view of the exterior hardscape and softscape.

Figure 46: Madoo Cafe @ The Hive

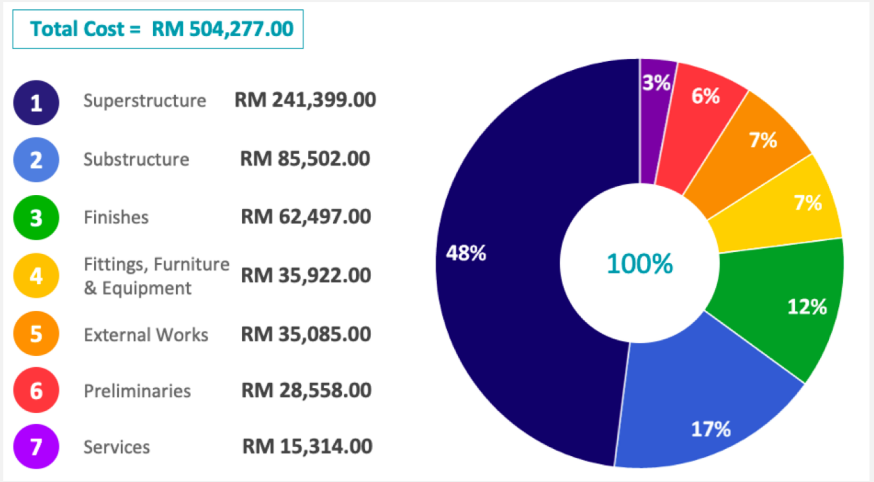
Pavillion

The Pavilion is thoughtfully designed to make a striking first impression with its open-air entrance, which serves as a welcoming gateway for cyclists. This entrance features a visually stunning canopy that provides shelter and an inviting aesthetic, with its sleek lines and transparent materials that blend well with the surrounding landscape (Figure 47). The lively and inviting space reflects the hub's commitment to providing comfort and well-being.

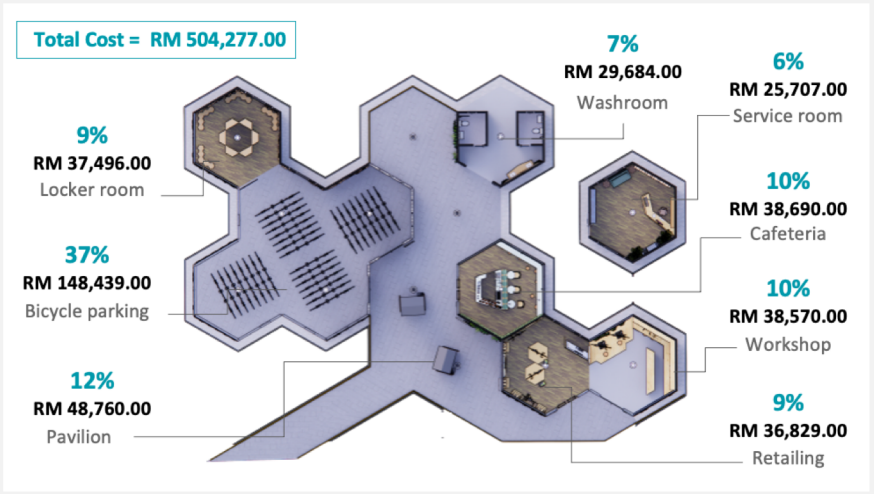
Figure 47: Paviliion @ The Hive

COST ESTIMATION

Cost Estimates by Elements



Cost Estimates by Spaces



CONCLUSION

In conclusion, this research presents the outcomes of a comprehensive design approach for a bicycle hub facility that emphasises sustainability and modularity. The whole concept of this project is to bring unity to the IIUM community, which is shown directly by implementing the IIUM geometric logo as its primary design idea. The development of the whole design is also inspired by the honeycomb, highlighting the balance and harmonious connection between bicycle users and nature in creating a sustainable campus. The main shape of the design, hexagonal, helps to fill in the empty spaces when they are arranged next to each other. Modular hexagons offer the most storage possible with the least amount of materials. Focusing on these characteristics and incorporating universal and passive principles translates to the design's aim to foster a bike-friendly campus environment and create a sustainable future.

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