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Development of Buzzyhive: A Sustainable Bee Farming With Apitourism Management System

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ABSTRACT

This study addresses the challenges faced by Malaysia's bee farming and apitourism sectors, including reliance on conventional methods, limited digital technology adoption, and fragmented operational processes. Based on these gaps, a software prototype is proposed and developed named BuzzyHive, an integrated web application system designed to unify hive monitoring, product sales, and apitourism bookings in a centralized platform thereby enhancing sustainability, market access, and operational management. By implementing a waterfall methodology, the system was developed using PHP, MySQL, with Bootstrap HTML5 to ensure responsiveness and scalability. Key modules include user management, hive management, product inventory, booking management, and reporting analytics in business intelligence dashboard. The user interface of software prototype is also presented as the result of this study. BuzzyHive has potential to empower bee farmers and apitourism operators by providing a unified platform that reduces reliance on third-party services and manual record-keeping. This modular integration helps in improving data accuracy, consistency, operational transparency, and customer engagement, supporting both economic viability and ecological sustainability. Limitations include the absence of empirical testing and challenges related to system scalability and data quality, which are acknowledged as areas for future enhancement. BuzzyHive offers a foundational digital solution that bridges sustainable bee farming and apitourism, promoting environmental conservation and rural development **in Malaysia especially in SDG 8 Decent Work and Economic Growth and SDG 15 Life on Land.**

Keywords: apitourism, bee farming, eco-tourism, hive management, digital beekeeping, business intelligence

INTRODUCTION

Bee farming, or apiculture, commonly known as beekeeping, plays a critical role in sustainable production systems by contributing to food security and biodiversity through pollination. In addition to its environmental benefits, bee farming promotes economic growth due to global demand for bee-based products such as honey, beeswax, royal jelly, and propolis. This growth can improve rural livelihoods, strengthen local economies and promote sustainability as well as ecosystem biodiversity.

There are many common problems encountered by bee farming industries. Traditional methods of bee farming and apitourism are often manual and labour-intensive, making operations tedious, time-consuming and error-prone, which reduces operational efficiency. This practice also limits bee farmers' ability to market their products as manual sales processes and fragmented marketplace distribution affecting honey sales and apitourism services. Moreover, the lack of automated reporting systems prevents accurate monitoring of hive performance, honey production and market trends, which limits data-driven decision making and operational optimization.

The objective of this study is to improve efficiency in bee farming and apitourism operations by centralizing the core operational activities for efficient record tracking. This study also aims to develop a digital platform that improves marketability for bee-related products and apitourism services through the systematic process and to generate analytic reports that provide data-driven insights for informed decision-making and improve operational efficiency in bee farming and apitourism services. The target users are customers which are individuals that are buying the products and services; staff, which are the individuals that manage the beekeeping; and finally, the administrators who manage and generate the reports of the system. Each of the users has different roles and capabilities to access the system.

The significance of the project is that it can improve bee farming by streamlining operations, enable systematic data collection, and improve hive monitoring and inventory tracking, thereby boosting productivity and accuracy. This improves direct market access for bee farmers to expand their market outreach, increase profits and improve operational challenges such as missing and inconsistent record keeping thereby improving operational transparency and management. Therefore, BuzzyHive provides a sustainable, scalable, and efficient solution that supports the economic viability of apiculture, promotes sustainable agricultural practices, and raises community awareness about the importance of the ecological role of bees and the importance of protecting bee populations for ecosystem balance and food security. In the next section, literature review of the related works is presented. Followed by methodology in Section 3 and results and discussion in Section 4.

Related Work

In Malaysia, bee farming is an emerging sector with significant potential for growth, particularly with native bee species such as Apis cerana (Asian honeybee) and Heterotrigona itama (stingless bee or *kelulut*). The country's rich biodiversity and tropical climate provide an ideal environment for bee farming, supporting honey production and pollination services for agricultural crops. Apiculture contributes to sustainable communities by promoting natural pollinations, enhancing nonsynthetic crop yields, and supporting conservation of native flora. It also provides source of income for local communities through the sales of honey and bee-related products. Additionally, bee farming enriches apitourism by offering visitors the opportunity to interact with nature and learn about environmental sustainability.

Bee farming is not only a source of high-value products such as honey and beeswax, but it also plays a critical role in enhancing agricultural productivity through pollination [1]. Vysochanska (2023) emphasized the role of bees beyond honey production and places them at the center of pollinators for biodiversity, food security and rural economic development. Additionally, it encouraged a change to more ecologically friendly methods, like restoring habitat and reducing pesticides. However, the study lacks discussion of localized strategies and practical challenges faced by beekeepers, such as technology adoption and economic feasibility, indicating the need for more empirical studies to develop adaptive solutions.

Alakoç Burma (2023) highlighted the importance of management information systems to support digital transformation in the beekeeping process to address challenges such as climate change, disease threats and habitat loss. The study explored the integration of modern technologies such as IoT, big data, and artificial intelligence in the digital transformation of beekeeping, all of which help in enhancing hive productivity, monitoring bee colony health and optimizing decision-making processes [2]. Nonetheless, existing digital beekeeping applications are limited in both number and functionality, which further restricts bee farming operation. Some features operated independently without integrating into a digital platform, hindering the operational efficiency due to tedious and time-consuming process to ensure data consistency. This can result in errors and inaccurate beekeeping records.

This need for digital beekeeping platform is further supported by Huet et al. (2022) [3] which was due to the declining of bee populations in ecosystems. Huet et al. (2022) proposed architecture to improve decision-making through sensor and open data integration that can be adapted across emerging agricultural technologies. By using a flexible framework, it can further improve the management and operation of bee keeping processes for bee farmers. However, the effectiveness of the proposed architecture relies heavily on the availability of and the quality of sensor data from the hives. Inaccuracies or inconsistencies of data can reduce decision-making effectiveness and overall system reliability. Moreover, using open data integration in heterogeneous sources may limit not only system reliability but also the system scalability and usability of deployment, especially in resource constrained environments.

Adoption of beekeeping technology has been examined in several European countries, highlighting the significant influence of social norms and perceptions on the adoption of digital agricultural technologies within the apiculture sector [4]. The concept of Digital Beehive Monitoring Technology (DBMT) is introduced to improve awareness and facilitate the adoption of digital innovations among professional and hobbyist bee farmers. Nevertheless, the study lacks discussion on the specific adoption factors and real-world capabilities of the DBMT particularly regarding its practical scope and direct functionalities. Despite the potential of DBMT to improve sustainable bee farming and production, overcoming technical and awareness barriers remains essential to improve adoption rates among bee farmers.

Conventional record keeping in beekeeping commonly involves manual and paper-based work, which is tedious and time-consuming and error-prone especially for regular hive inspections. According to the Food and Agriculture Organization of the United Nations [5], they recognized the importance of technological solutions and challenges of adoption for improving conventional record-keeping in bee farming practices, thus increasing market differentiation and profits for bee farmers. The adoption of digital technology is necessary to help bee farmers improve market access of their bee products, provide better decision-making and improve their livelihoods through innovative practices (e.g., sunlight detectors, motion detection cameras, microphones) using technology [5]. Despite these benefits, some technological solutions for beekeeping may not be feasible for all bee farmers, as some of them are expensive to implement such as IoT devices and sensors. Moreover, some technologies may require specific or expert knowledge, which further complicates the practical use of technology performance or reliability, thereby discourages their willingness to adopt it due to its complexity. Regardless of that, the study signifies that digital solutions such as record-keeping platforms are beneficial for bee farmers as the tracking information of hives, queens and colonies provide valuable information for the beekeepers.

The study by Abdurofi et al. (2021) examined the economic feasibility of stingless bee (Trigona spp.) farming in Malaysia, using cost-benefit and break-even analysis [6]. The study highlights the importance of digital transformation in beekeeping and how IoT sensors and data analytics facilitate hive monitoring, diseases detection and beekeeping processes optimization and productivity. However, the study is limited by its reliance on theoretical models and secondary data, which lacks detailed discussion on the practical challenges faced during the technological adoption. The lack of scalability and adaptability of the proposed digital solutions limits their use in all socio-economic conditions, which may further limit beekeepers' willingness to adopt.

Digital solutions in bee farming are also complimenting for bee tourism or apitourism. Apitourism is form of eco-tourism that combines beekeeping with travel experiences in bee museums, hands-on training, participation in workshops, apitherapy to provide awareness on ecosystem sustainability, culture and heritage [7][8][9]. For example, Senkiv et al. (2020) discussed that apitourism is linked to traditional beekeeping methods and products in Slovenia and Ukraine, with Slovenia being particularly noteworthy for its cultural focus on bees and measures to protect native bee species [7]. This is further supported by Akyürek (2022) which noted that apitourism offers visitors unique educational, emotional and cultural experiences such as visits to beekeeping museums [8]. In rural areas like Catolina, Spain, apitourism leverages local cultural and natural resources for sustainable tourism, with an emphasis on creativity and entrepreneurship [9]. Likewise, studies from Republic of Benin and Southern Tanzania described the potential for apitourism is linked to biodiversity and local training[10][11].

In Sabah, Malaysia, the stingless bee plays a prominent role in socio-economic development and environmental conservation [12]. Sumin et al. (2024) highlighted that the adoption of modern hives is still limited due to the tendency of many beekeepers to use conventional methods, which may potentially disrupt the ecosystems' health. Complementing this, Mustaffa et al. (2022) examined the visitor perception towards existing apitourism facilities in Malaysia. The study highlighted the need for facilities designed with space that supports both ecological education and tourism satisfaction [13]. Both studies underscore the need for integrated approaches that support both sustainable bee farming and apitourism practices.

While existing studies highlight the importance of digital solutions for bee farming and apitourism in promoting biodiversity conservation, most digital beekeeping platforms primarily focus on operational management and hive monitoring, whereas digital tourism systems are mainly directed at booking and visitor engagement. These solutions often function separately, leading to fragmented and inefficient operational management, as well as data inconsistencies and inaccuracies. As a result, users face challenges such as tedious, time-consuming work, error-prone, limited data integration, and difficulty in managing combined operation.

Moreover, due to socio-economic barriers and cost constraints, the widespread adoption of these technologies remains limited, particularly among small-scale bee farm operators. Hence, BuzzyHive is proposed with aims to bridge this gap by integrating both bee farming and apitourism management within a unified digital platform. This integrated approach not only improves operational management but also enables seamless data exchange across different modules, which is currently lacking in existing systems. Consequently, further research and empirical testing are needed to assess and refine this integrated approach. In the following section, we will present our methodology, along with the introduction of a proposed software prototype known as BuzzyHive, which is inspired by these gaps.

METHODOLOGY

In this section, the methodology of software development named BuzzyHive is presented.

System Analysis and Design

The software prototype is developed using Waterfall methodology. It is used for constructing sequential phases, detail planning and linear approach with each phase finished before proceeding to the next phases. Waterfall methodology also allows well-structured project requirements to provide a foundation for each phase and require minimal requirements changes making it stable as it relies on fixed requirements without frequent revisions.

In the context of this study, the process started with the collection and analysis of requests. Several interviews are conducted in this stage, during on-site visits to GiantB Melaka, one of the largest bee galleries and museums in Malaysia. The visit included interview briefings with apitourism operators to get a comprehensive understanding of the current working practices and user requirements. Direct stakeholder involvement has provided a rich insight into bee farming activities as well as market activities, which have allowed all critical, functional and non-critical requirements to be identified and documented.

The collected information is then synthesized with a thorough literature review of related works that are carried out to compare best practices and identify research gaps in the design phase. Design activities are included in the development of module specifications, data flows and architectural diagram to translate business requirements into a clear process of business logic for implementation.

Upon finalizing the design, the project is proceeded to the implementation phase, where a prototype of the BuzzyHive software is developed. This phase is focused on translating the design documents into working software modules using the selected technology stack and ensuring that all required features, such as management of hives, sales, bookings and reports, are in place.

Following the development phase, the project is moved to the testing phase. The prototype is systematically assessed to verify that it fulfilled the requirements and performed well in both isolated and integrated scenarios. It is ensured that the tests have identified and resolved problems prior to deployment. Finally, limited deployment and evaluation activities is carried out, which setting the groundwork for empirical studies as described in the results and discussion section.

The current scenario in bee farming in Malaysia is commonly managed by bee farmers; some are supported by government agencies but still lack resources and inconvenience the community. In apitourism, the current scenario is a heavy reliance on third-party tourism agencies' tourism packages that include visits to the bee gallery in Melaka. The lack of marketing strategy and reliance on tourism agencies causes low numbers of customers and sales. Fig.1 and Fig. 2 show existing scenarios encountered during operation in GiantB, Melaka.

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In current practice, the operational workflow of a typical bee farm is both sequential and labour-intensive, involving several critical stages that are essential for maintaining colony health and ensuring a continuous supply of bee products as shown in Fig.1. The process begins with the setup of both hive and queen, which forms the foundation for establishing a productive and resilient bee colony. At this stage, beekeepers must carefully assign a suitable bee species and introduce a new queen bee into the hive. The compatibility of the queen with existing worker bees is crucial; if the queen is deemed incompatible or fails to be accepted by the colony, she is swiftly replaced to prevent disturbances in hive activity and productivity.

Once the queen is compatible with the hive colony, the hive will be monitored regularly by the inspectors (i.e., staff). The hive inspections are scheduled regularly, where each hive will assess the overall condition of the hive, the health status of the queen, pests, and the hive produce (e.g. honey, royal jelly, beeswax). The current practice during the inspections involves manual paper-based record keeping, which may result to errors due to human error, data loss, and data inconsistency. If the queen displays any unhealthy signs during the inspection, such as low egg production, disease or aggression, or failing state, an immediate replacement of the queen bee will be required. This is to ensure only healthy and productive queens lead the bee colonies, which is important in production yield. During inspections, some factors before harvesting are considered, such as honey ripeness and sufficient produce quantity. If the hive is not yet ready, the monitoring cycle continues. When harvesting criteria are met, beekeepers proceed to extract honey and other bee products from the hive. Harvested products are then processed and packaged via manual methods.

The processed goods are subsequently marketed either directly in on-site galleries or through digital platforms such as the website and WhatsApp. Each product is then tracked manually for sales and inventory, which often involves logbooks or spreadsheets. While this conventional method may suffice for small-scale operations, it can pose challenges in order fulfillment and operational fragmentation, which later cause the delay of operations.

In apitourism, the current practice of the booking process at GiantB begins with customers initiating contact with the customer service representatives through various channels, such as email, phone, or WhatsApp. Once they have received the inquiry, the representatives will respond by sending detailed information about the available tour and training packages. The package includes a free complimentary bee farm visit and a paid personalized bee training session. Customers then review the options and select their preferred package. Following this selection, customers will confirm the booking details, including the number of participants, chosen date, and preferred time slot with the representatives.

For customers opting for the bee training or workshop package, payment is required before the booking can be completed. Customers will receive an official digital receipt via email or their chosen channel once the transaction is completed. In contrast, for the bee farm visit free package, the payment step is skipped. Then, all customers, regardless of their selected package, will receive booking confirmations and official receipts. The flow of the current apitourism scenario is depicted in Fig.2, which relies heavily on manual communication and coordination between the customer representatives and customers. This process can be time-consuming and limit overall efficiency.

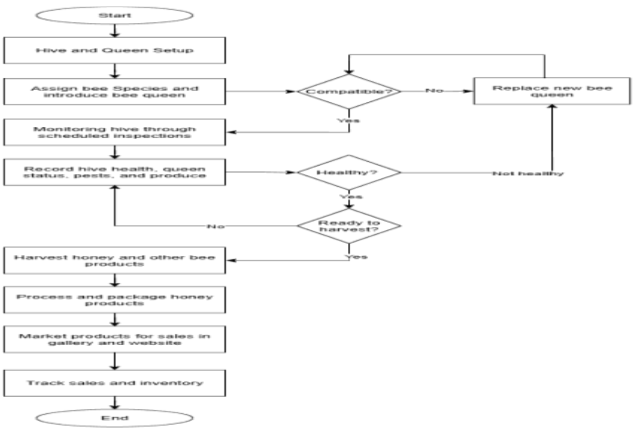

Fig.1 Current Scenario of Bee Farm to Market Operational Flow

In conclusion, the current operational flow in GiantB is conventional, which the process being described as tedious and requiring laborious work, since no systematic and centralized approaches are implemented for this operation. Hence, a systematic and centralized system that connects this operational flow to improve bee farming management and apitourism is introduced in BuzzyHive. The BuzzyHive prototype also allows for operational scalability, as suggested by modular integration and the flexibility of workflow in the next sub-section.

Implementation Scope

Software prototype BuzzyHive has five (5) major cores modules which are the scope of this project. The proposed prototype allows direct marketing access to customers with integrating honey-products sales management, bee farm apitourism services and hive management. User Management Module: Allows users to register and manage profiles including customers, staff and administrator.

- **Product and Sales Management Module:** Allows staff to manage honey-based products in the web catalogue. This module also allows customers to purchase products and make payments. It also allows staff to view and manage customers' orders accordingly.
- **User Management Module:** Allows users to register and manage their profiles. This module is implements database-level authentication for role-based access control.
- **Apitourism Booking Management Module:** Allows customers to book apitourism services such as visits, bee training and workshops. This module also allows staff to manage the booking schedules efficiently.
- **Hive Management Module:** Allows staff such as beekeepers, inspectors to track the condition of the hive, queen status, honey production, and inspection logs.
- **Reporting and Analytics Module:** Allows administrators to view and generate performance reports in business intelligence dashboard for informed decision-making process

The architecture of the BuzzyHive prototype is centered around relational database design to store, manage, and retrieve data associated with bee farming and apitourism services. Fig.3 shows the layered architecture of the BuzzyHive prototype. The architecture consists of User access layer, Security layer for user authentication, Application layer for operational modules, Business Logic layer to control payment processing, validation and notification, and finally, the Data layer for storing and retrieving data from the database for the business intelligence analytics dashboard. Later, these data can be accessed via specific users through the application layer.

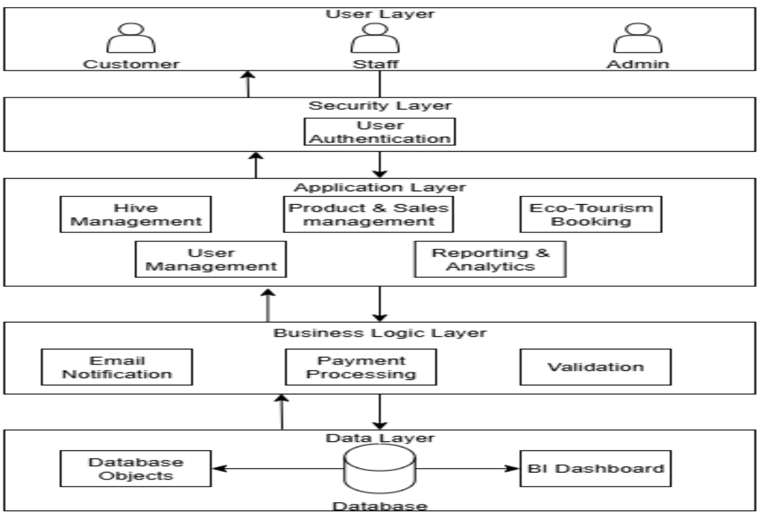

Fig.3 BuzzyHive Layered Architecture

The prototype design emphasizes modularity and key relationships between operational entities such as users, staff, products, orders, booking, and hive. Fig.4 illustrates the Entity Relationship Diagram (ERD) of BuzzyHive prototype. The main entities include are Users, Staff, Hive, Queen, Produce, Inspection, Product, Orders, Order_Item, Package, Booking, Payment. The relationships are structured as follows to reflect real-world operations of a bee farm with apitourism service and product marketplace components.

- Each user can place multiple orders and make bookings for apitourism packages.
- Staff are responsible for conducting multiple-hive inspections and managing bookings.
- Each hive is associated with one or more queen and can yield multiple produce outputs such as raw honey or wax. However, only one queen can be allocated at one time in an hive.
- Inspections are for observing multiple hives and include details such as date, temperature, pest observations, and hive conditions.
- Payments are processed either for bookings or product orders and include payment method, card type, and transaction details. Only one payment transaction will be required for one booking or one order only.
- The package entity defines the apitourism experiences offered, such as farm tours or workshops, which users can book.
- Each product may have one or multiple orders by customers and an order may consist of multiple products.
- Each booking includes the number of guests and is linked to both users and staff.

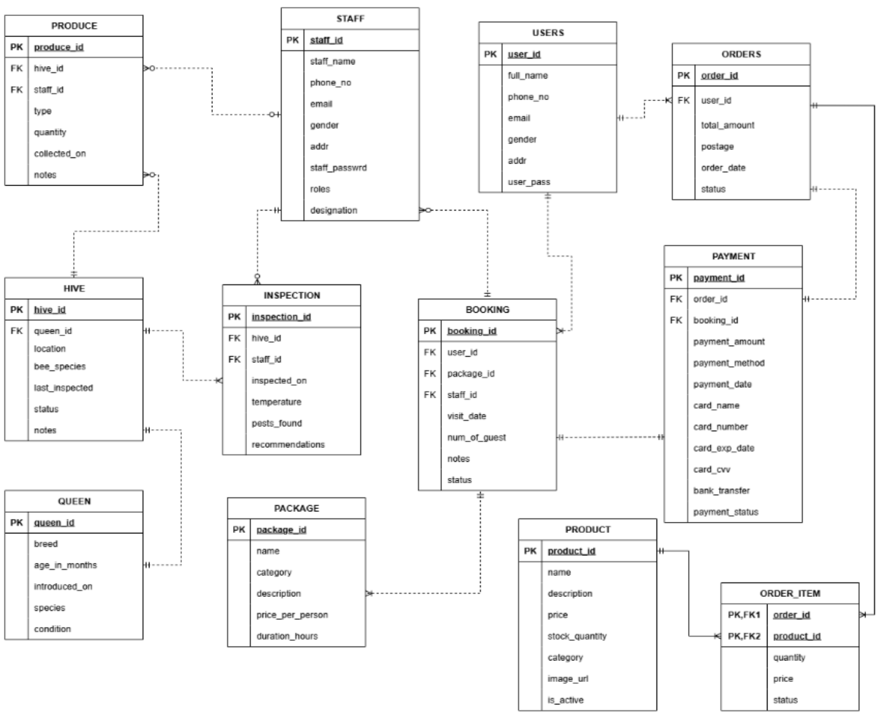

Fig.4 Entity Relationship Diagram

BuzzyHive is implemented using PHP 8 for the back end, with HTML5 and Bootstrap employed to ensure a responsive user interface across various device platforms. The development process utilizes Visual Studio Code (VS Code) as the Integrated Development Environment (IDE). For data storage, the system relies on MySQL 8, a relational database chosen for its robustness in security, reliability, and availability. During database implementation, stored procedures and triggers are used in the database-level. Samples of trigger and stored procedure for booking status and sales summary are shown in Fig 5 and Fig. 6 below.

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```sql
CREATE DEFINER=`root`@`localhost` PROCEDURE `sp_admin_report` ()   BEGIN
  -- 1. User & Order Summary
  SELECT
    (SELECT COUNT(*) FROM users) AS total_users,
    (SELECT COUNT(*) FROM orders WHERE status = 'Completed') AS total_orders,
    (SELECT SUM(payment_amount) FROM payment WHERE payment_status = 'Paid') AS total_revenue;

  -- 2. Product Sales Summary
  SELECT
    p.product_id,
    p.name,
    SUM(oi.quantity) AS total_sold,
    SUM(oi.quantity * oi.price) AS revenue
  FROM product p
  LEFT JOIN order_item oi ON p.product_id = oi.product_id
  LEFT JOIN orders o ON oi.order_id = o.order_id
  WHERE o.status = 'Completed'
    AND (@filter_category = '' OR p.category = @filter_category)
    AND (
      @filter_period = 'daily' AND DATE(o.order_date) = CURDATE()
      OR @filter_period = 'monthly' AND MONTH(o.order_date) = MONTH(CURDATE())
      OR @filter_period = 'yearly' AND YEAR(o.order_date) = YEAR(CURDATE())
      OR @filter_period = ''
    )
  GROUP BY p.product_id, p.name;
```

Fig.5 Sample Stored Procedure in database level for user, products and sales summary

```sql
DELIMITER $$
CREATE TRIGGER `trg_update_booking_status` AFTER INSERT ON `payment` FOR EACH ROW BEGIN
    IF NEW.booking_id IS NOT NULL THEN
        UPDATE booking
        SET status = 'Paid'
        WHERE booking_id = NEW.booking_id;
    END IF;
END
$$
DELIMITER ;
DROP TRIGGER IF EXISTS `trg_update_order_status`;
DELIMITER $$
CREATE TRIGGER `trg_update_order_status` AFTER INSERT ON `payment` FOR EACH ROW BEGIN
    IF NEW.order_id IS NOT NULL THEN
        UPDATE orders
        SET status = 'Paid'
        WHERE order_id = NEW.order_id;
    END IF;
END
$$
DELIMITER ;
```

Fig.6 Sample Trigger in database level for managing booking status

RESULTS AND DISCUSSION

In this paper, the user interface of the BuzzyHive web application is introduced as the result of the implementation. BuzzyHive interface platforms comprise functional modules such as Hive Management, Apitourism Booking, Product and Sales Management, User Registration and Reporting and Analytics. The user interface is designed to support and improve the efficiency of conventional bee farming and apitourism practices based on GiantB Melaka. The interface platform also enables responsiveness between different devices (i.e. desktop, mobile and tablet) to improve user access to their own devices. Fig. 7 to Fig. 16 shows the design of BuzzyHive user interface web application.

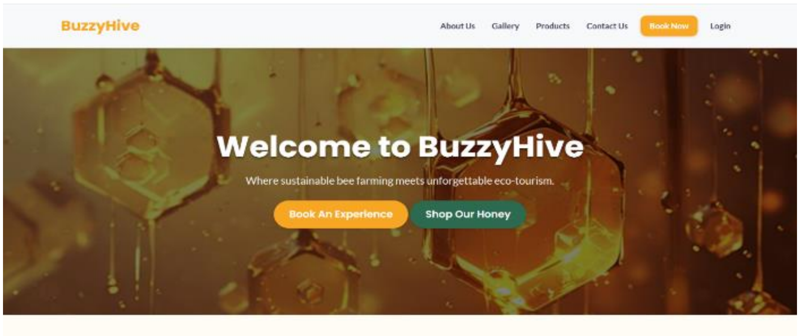

Fig.7 Main Page of BuzzyHive Web Application

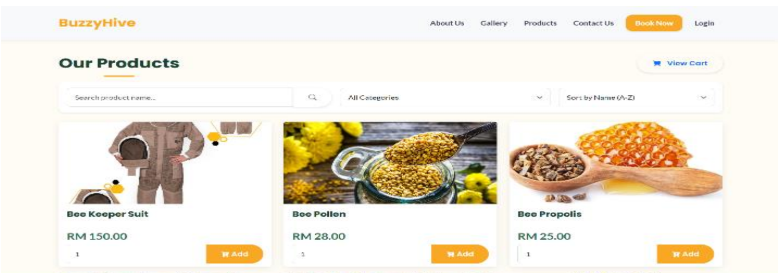

Fig. 8 Product Page display honey-based products in marketplace with carting system

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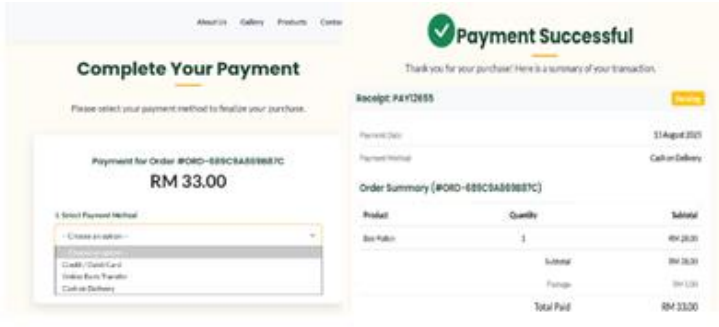

Fig.9 Payment Integration Module and generates the receipt of payment

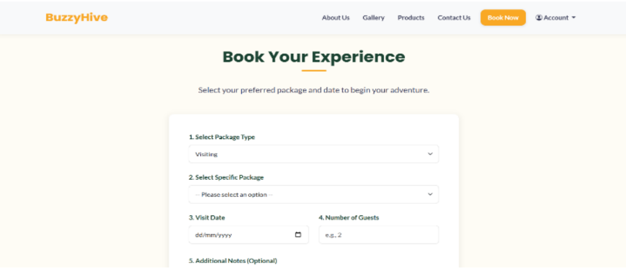

Fig.10 Booking Apitourism Package (Bee Training, Bee keeping tour, Workshops)

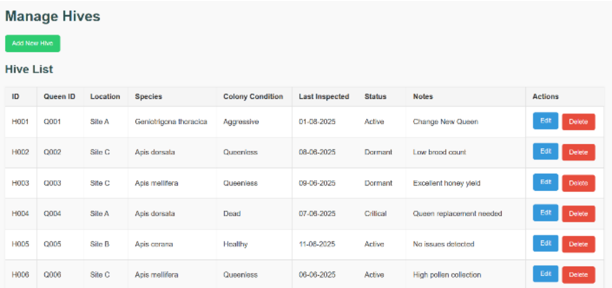

Fig.11 Centralized page for Hive management to manage hive colony, species, queen and hive condition during their regular inspection's schedules

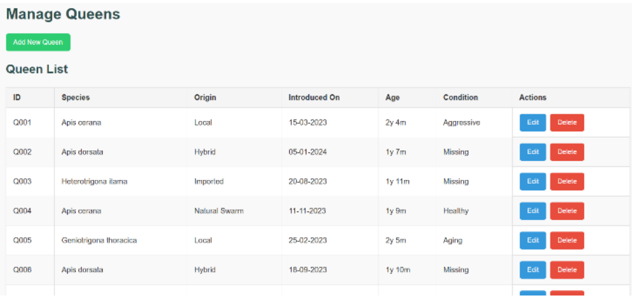

Fig.12 Manage Queen page under Hive Management allows queen lifespan tracking according to their species

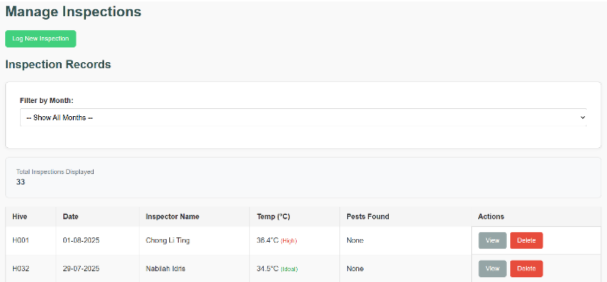

Fig.13 Inspection management page where inspector record the condition of the hive details to ensure hive in good health

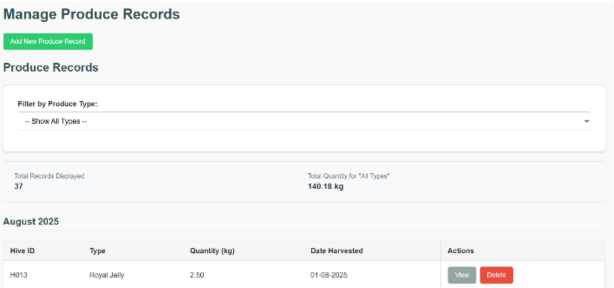

Fig 14. Harvest Record management where inspector can record the quantity of type of produces harvested from each hive

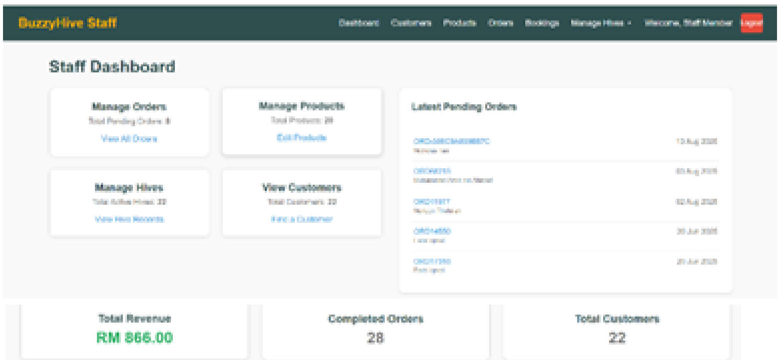

Fig 15. Centralized management page for staff such as inspectors and gallery workers

Fig. 16 BuzzyHive Overview of BI Dashboard

The potential impact of BuzzyHive is that it can provide direct access from customers to bee farmers through unified operational management instead of conventional methods. BuzzyHive allows their staff to manage their apitourism booking schedules effectively, promote farm visits, and sell bee-related products. This improved process through the digitization platform not only increases the profits and reduces third-party (intermediary) costs but also increases the autonomy and visibility for bee farmers.

BuzzyHive also allows scalable and sustainable bee farming practices through its dynamic modular structure for future expansion, such as payment gateway integration, loyalty rewards plans and Internet-of-Things (IoT) integration for hive and queen management. This implementation of BuzzyHive further supports conservation and preservation of biodiversity for colony and queen species through digital hive inspection and tracking. Moreover, this could promote awareness of bees as prominent roles in the ecosystem through the apitourism module, as it encourages low-impact, hands-on and on-site experiences like apitourism and bee training.

Regardless of BuzzyHive's unified and modular structure, the implementation also has some challenges. Since BuzzyHive is heavily reliant on internet connectivity, there is a possibility of a digital divide, especially in rural areas, as most bee farms are located in such areas. This is to conserve the habitat of bees surrounded by food abundance (e.g. flowers) for honey production. Hence, this further hinders data consistency and accuracy especially for beekeeping records.

Another significant challenge is long-term sustainability and accessibility, particularly for resource-limited bee farmers. The initial cost of adopting digital platforms like BuzzyHive may present a barrier to widespread use, potentially limiting participation among small-scale bee farm operators. Furthermore, the effectiveness of the prototype is closely linked to the digital literacy as some users may find advanced technology is complex to use, highlighting the importance of user training and ongoing support to ensure successful adoption and continued operation over time.

Data privacy and system security are also critical aspects of sustainable digital transformation. At present, BuzzyHive's data protection measures are primarily limited to user authentication and role-based database access. However, as the system evolves, it will be essential to implement enhanced security features, such as multi-factor authentication (MFA) and data encryption, to secure sensitive operational and personal data. Additionally, continuous updates and maintenance is necessary to adapt the platform to emerging security standards and user future requirements.

Despite these challenges, BuzzyHive offers flexible architecture for future improvements, such as mobile applications and integration with IoT devices. Collaboration with local bee farmers will be crucial to adapt the digital platform to facilitate user adoption through training and support. The adoption of the BuzzyHive digital platform can therefore effectively help to achieve the objective of sustainable bee farming and apitourism management.

Limitation and Future Work

The limitation of this study is that there is no empirical validation in the field by bee farm operators, which limits the ability to assess the performance and usability of the prototype quantitatively. All results are based on simulation data and system design functionalities of the prototype. The software prototype may face challenges in gaining wider user acceptance, particularly in locations where access to the internet is limited and digital literacy is low.

In future work, we will extend these limitations through field pilot studies and systematic evaluations with end-users, including both bee farmers and apitourism operators. To provide a more solid foundation of evidence for system improvement, planned activities include gathering operational data, user feedback, performance metrics, and usability assessments. Comparative analysis with existing digital solutions will be carried out to highlight the unique contribution of BuzzyHive and its practical analysis. Moreover, future research will also explore the full integration of mobile platforms for field use and advanced Internet of Things (IoT) technologies for real-time monitoring of hives and automate data capture and analysis for improving sustainable bee farming practices. Presentation of visual analytics, such as dashboard and summarized pilot testing, will be incorporated to enhance the practical credibility and findings. By addressing these aspects, BuzzyHive can be highlighted as an efficient and sustainable digital platform for integrated beekeeping and apitourism.

CONCLUSION

In conclusion, we presented the motivation for this work and identified gaps for bee farming and apitourism practices based on a real case-study from GiantB, Melaka. We also presented BuzzyHive software prototype that connects the operational flow of management processes from bee farming, apitourism, product sales and reporting analytics in their modular integration to streamline the process. BuzzyHive encourages sustainable practices by giving beekeepers the tools they need to responsibly manage hives, market products, and promote apitourism. This supports biodiversity, minimizes resource waste, and strengthens the economic resilience of rural areas, without directly interfering with environmental processes. The result of this study will contribute to Sustainable Development Goals (SDG), specifically in SDG 15, Life on Land, by promoting biodiversity and conservation of bee as prominent pollinators in the ecosystem, and SDG 8, Decent Work and Economic Growth, by supporting livelihoods through sustainable bee farming and apitourism practices.

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