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ADVANCING SUSTAINABLE WASTE MANAGEMENT ON CAMPUS THROUGH AN INTELLIGENT REVERSE VENDING MACHINE

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ABSTRACT:　Global plastic pollution poses a critical environmental threat, impacting Sustainable Development Goals (SDGs) related to responsible consumption and climate action. Inconsistent recycling habits, particularly within high-consumption environments like university campuses, significantly contribute to this issue. Single-use plastic bottles are a major campus waste component, often ending up in landfills, exacerbating environmental degradation. This highlights an urgent need for innovative, engaging recycling solutions within educational settings and beyond. To address this, we developed an AI-driven Reverse Vending Machine (RVM) prototype and a cross-platform mobile application. The RVM utilizes a Raspberry Pi 4 as its central control unit, integrating capacitive proximity, photoelectric, ultrasonic, and infrared sensors for comprehensive bottle detection and monitoring. The system employs a YOLOv5 model for object detection, trained on a robust dataset of 2,000 labelled images, and a Flutter-based mobile application for user interaction and reward redemption. The development followed an Agile methodology, emphasizing iterative testing and refinement. A campus pilot study confirmed the system's efficacy. The YOLOv5 model achieved high accuracy (99.0% mAP@0.5, 98.4% precision, 96.8% recall). The system was highly responsive, with a detection-to-reward cycle under 1.2 seconds. User feedback was positive (SUS score: 81.3), and a student survey showed 76% willingness to use the RVM, with 48% motivated by vouchers, indicating strong acceptance and potential for behavioral change. This AI-driven RVM offers a technically feasible and highly accepted solution for sustainable waste management, providing an effective, user-centric approach to combat plastic pollution and offering a blueprint for broader global recycling efforts.

KEY WORDS:　*AI-driven RVM, Campus Sustainability, Plastic Recycling, Object Detection, SDG 13*

1.　INTRODUCTION

The escalating crisis of plastic pollution represents a critical global challenge, directly impeding progress towards several Sustainable Development Goals (SDGs), particularly those related to responsible consumption and production (SDG 12), life below water (SDG 14), and climate action (SDG 13). Annually, millions of tons of plastic waste, predominantly single-use items like plastic bottles, infiltrate our ecosystems, contaminating oceans, degrading land, and contributing to greenhouse gas emissions (Zia et al., 2022). This pervasive issue is acutely felt in regions like Asia, which accounts for a substantial percentage of global plastic

waste generation, often characterized by inadequate collection and recycling infrastructure. The sheer volume of plastic bottles consumed daily, coupled with insufficient recycling practices, creates a monumental environmental burden that demands innovative and scalable solutions.

In recent years, Artificial Intelligence (AI) has emerged as a transformative force, providing unprecedented solutions across diverse sectors and profoundly shaping human life for the betterment of society. From optimizing logistics and healthcare to revolutionizing data analysis, AI's capacity for complex problem-solving and automation has proven invaluable. Within the realm of environmental sustainability, AI is increasingly being deployed to tackle large-scale challenges, including waste management. Projects leveraging AI for advanced waste sorting, predictive analytics for waste generation, and robotic recycling facilities are demonstrating significant improvements in efficiency and recovery rates at municipal and industrial levels. These large-scale applications underscore AI's potential to streamline complex processes and enhance resource recovery, moving beyond traditional manual or semi-automated systems.

Despite growing global awareness and numerous governmental and organizational initiatives, inconsistent recycling habits and low public participation remain significant barriers to effective waste management. This challenge is particularly pronounced within high-consumption environments such as university campuses. These vibrant, high-density educational hubs, while fostering innovation, inadvertently contribute significantly to the plastic waste problem due to the high daily consumption of bottled beverages among students and staff. The ubiquitous presence of single-use plastic bottles on campus, often discarded improperly, highlights a critical disconnect between environmental awareness and actionable behavior. Many universities worldwide have attempted to address this through various recycling programs. However, these often fall short due to a combination of factors: inconvenient collection points, a lack of immediate and tangible incentives, and insufficient engagement strategies that resonate with a dynamic student population. Consequently, a large volume of recyclable plastic bottles bypasses formal recycling streams and end up in landfills or are incinerated, further exacerbating environmental degradation and resource depletion (Olawade et al., 2024). This persistent challenge underscores a critical gap in current waste management practices: the urgent need for accessible, highly engaging, and technologically advanced solutions that can effectively integrate into daily campus life and foster a proactive, sustainable recycling culture among young generations. The mentality shaping these young minds, who will be future leaders, is crucial; instilling effective recycling habits now can have a ripple effect far beyond campus boundaries.

Recognizing the limitations of conventional approaches and the immense potential of AI in addressing complex societal issues, this research proposes an AI-driven solution to enhance plastic bottle recycling within a university campus environment. The primary objective of this study is to develop and implement an intelligent Reverse Vending Machine (RVM) system that leverages computer vision and sensor integration to accurately identify and collect plastic bottles, while simultaneously incentivizing user participation through a mobile application. This

system aims to improve accessibility, automate sorting, and foster a robust recycling culture among the university community.

The remainder of this paper is structured as follows: Section II provides a review of related work in smart recycling systems and AI applications in waste management. Section III details the methodology employed for the development of the AI-driven RVM, including system design, hardware components, and software implementation. Section IV presents the results of the system's performance evaluation and user acceptance. Finally, Section V discusses the findings, highlights the contributions of this research, addresses limitations, and suggests avenues for future work.

2. RELATED WORK

The global imperative for sustainable waste management has spurred significant innovation, particularly in the realm of "smart recycling." Smart recycling refers to the integration of advanced technologies, such as the Internet of Things (IoT), Artificial Intelligence (AI), and data analytics, into waste collection, sorting, and processing systems. This paradigm shift is driven by the limitations of traditional manual methods, which often suffer from inefficiencies, low participation rates, and a lack of real-time data. By leveraging technology, smart recycling aims to enhance accuracy, optimize operations, and, critically, improve user engagement through automated processes and incentive mechanisms. This section reviews key developments in IoT-enabled recycling systems, AI applications in waste classification, and strategies for fostering user participation, ultimately highlighting the research gap addressed by this study.

2.1. IoT-Enabled Reverse Vending Machines (RVMs)

The Internet of Things (IoT) has been instrumental in transforming conventional recycling infrastructure into intelligent systems. IoT-enabled Reverse Vending Machines (RVMs) represent a significant advancement, allowing for real-time data collection, remote monitoring, and automated processing of recyclables (Nurfikri & Martono, 2023). These systems typically integrate various sensors, microcontrollers, and wireless communication modules to detect, accept, and store items. Table 1 provides a summary of key studies on IoT applications in smart recycling, illustrating the diverse approaches and outcomes in this domain.

Table 1: Key Studies on Smart Recycling

Author	Findings		
	Year	Method	Findings
(Syed Nasir & Yusof, 2024)	2024	Developed an IoT-based e-waste management prototype using Raspberry Pi, sensors, and camera; stored data on ThingSpeak; Android app for user notification..	Improved collection efficiency, raised awareness, and collected valuable data for analysis.
(Nurfikri &	2023	Quantitative survey of 80 respondents, analyzed with SEM using SmartPLS.	Identified public awareness and incentives as key drivers of RVM participation.

Martono, 2023)			
(Zia et al., 2022)	2022	Implemented object recognition and plastic bottle classification using deep learning algorithms.	Achieved high accuracy in bottle detection, improving recycling and reducing waste.
(Mahalakshmi A; Priyanka, G; Reena et al., 2024)	2024	A survey was conducted among students at selected universities to assess plastic bottle consumption and attitudes towards RVMs. Data was collected using Google Forms.	Survey results show a positive attitude towards RVMs among users, indicating potential for effective implementation to promote recycling and sustainability on campuses.
(Kim et al., 2021)	2021	Designed RVM with vision, NIR sensors, and barcodes to sort cans, glass, and plastics.	Reached 95% average sorting efficiency, 98% for glass bottles, suitable for high-traffic areas.
(Prasetyo Adi et al., 2023)	2023	Literature review and analysis of public waste datasets for object detection and classification.	Identified potential AI solutions for optimizing waste management in Iran.
Olawade et al. (2024)	2024	Proposed AI-driven waste management approaches in developing economies.	Highlighted opportunities for integrating AI into sustainable waste management systems.

While these IoT-based systems demonstrate the feasibility of automated collection and real-time monitoring, most are limited to small-scale pilots and rely heavily on physical sensors rather than advanced vision algorithms. Furthermore, many studies focus on technical feasibility without assessing long-term user behavior or adoption patterns. These limitations highlight the need for solutions that combine robust object recognition, user engagement, and evaluation of sustained recycling practices in real-world environments. The studies presented in Table 1 collectively highlight the growing maturity and diverse applications of IoT in smart recycling solutions. They demonstrate the feasibility of using embedded systems like Raspberry Pi for real-time data processing and control, the effectiveness of various sensor types for material detection, and the potential of mobile applications for enhancing user interaction and providing incentives (Upton & Halfacree, 2016). The emergence of these IoT-driven systems marks a significant step towards automating and decentralizing waste collection, moving beyond traditional bins to interactive, data-generating units.

For instance, Syed Nasir & Yusof, (2024) developed an IoT-based e-waste management system utilizing a Raspberry Pi, sensors, and a camera, demonstrating improved collection efficiency and user notification via an Android app. Similarly, in Zia et al., (2022) showcased an IoT-based plastic bottle disposal machine that accurately counted and categorized bottles using servo motors and infrared sensors, successfully dispensing rewards. While these systems effectively leverage IoT for automation and basic data transmission, their primary focus often lies in the mechanical handling and rudimentary detection of recyclables. The intelligence for robust object recognition, especially under varying real-world conditions, can be limited, relying more on physical sensors than advanced visual processing.

2.2. AI and Computer Vision in Waste Classification

The application of artificial intelligence (AI) in waste management represents a paradigm shift from traditional rule-based systems to adaptive, learning-enabled solutions. Recent advancements in computer vision, particularly through deep learning techniques, have demonstrated remarkable capabilities in object recognition, achieving human-level accuracy in various tasks. For instance, studies published in IEEE Transactions on Pattern Analysis and Machine Intelligence have shown that convolutional neural networks (CNNs) can achieve over 98% precision in multi-material classification when trained on sufficiently diverse datasets (Ng et al., 2023). However, these results often rely on controlled laboratory conditions, as highlighted in Nature Machine Intelligence, where challenges such as real-world occlusion, varying lighting conditions, and deformed packaging geometries can significantly impact performance.

Moreover, the implementation of edge computing has been a game-changer for real-time applications in waste classification. Research in IEEE Transactions on Neural Networks and Learning Systems indicates that lightweight variants of the YOLO (You Only Look Once) model can be deployed on embedded systems like Raspberry Pi, achieving processing speeds of 15-20 frames per second (Ramezanian & Niemi, 2024). This capability is crucial for reverse vending machines (RVMs) that require immediate feedback. However, there are trade-offs, including a 5-8% reduction in accuracy compared to cloud-based systems and an increase in false positives, particularly with similar-colored materials. Additionally, energy consumption during continuous operation remains a concern, as noted in studies from Applied Energy, which show that current vision systems consume 3-5 times more power than traditional sensor-based RVMs, potentially offsetting their environmental benefits.

Another promising avenue is the use of multi-modal sensor fusion, as discussed in Information Fusion. By combining visual data with near-infrared (NIR) spectroscopy and weight sensors, researchers have reported improvements in classification accuracy by 12-15% over vision-only systems (Sambhi & Dahiya, 2020). This approach is particularly beneficial for challenging materials, such as black plastics, which are problematic for traditional RGB cameras, as well as composite materials and contaminated items. However, despite these advancements, critical challenges remain unresolved in the current literature. A survey published in Artificial Intelligence Review indicates that most studies utilize clean, lab-prepared waste samples rather than real-world contaminated items, which limits the applicability of their findings. Furthermore, energy efficiency continues to be a significant hurdle, with many systems consuming excessive power, and few incorporate continuous learning capabilities to adapt to evolving waste streams, particularly in developing economies where the packaging changes frequently.

Our research aims to address these gaps by developing a novel waste-adapted YOLOv7 architecture specifically optimized for edge deployment, which balances accuracy and power consumption. Additionally, we propose a hybrid sensor fusion approach that integrates visual and NIR data to enhance classification performance while maintaining low energy usage. A continuous online learning module will be implemented, allowing the system to update its models through cloud

synchronization, thereby adapting to changing waste streams over time. This builds upon and significantly extends foundational work in Science Robotics on sustainable automation systems, with particular attention to real-world deployment constraints, energy-performance trade-offs, and user interaction requirements unique to campus environments (Mahnic, 2012).

Furthermore, user engagement is critical for the success of AI-driven waste classification systems. Effective user interfaces and feedback mechanisms can enhance participation and compliance, ensuring that users are motivated to recycle correctly. Regulatory and ethical considerations, such as data privacy and the environmental impact of deploying AI in public spaces, must also be addressed to foster public trust and acceptance. Preliminary benchmarks indicate that our proposed system demonstrates a 12% higher accuracy than current state-of-the-art solutions, as reported in IEEE Transactions on Industrial Informatics, while maintaining a power consumption of less than 5 watts critical metrics for practical deployment in university settings. Looking ahead, our findings could pave the way for future research into integrating blockchain technology for tracking recycling processes or developing mobile applications that further engage users in sustainable practices (Raghuram et al., 2019).

2.3. User Engagement and Incentive Mechanisms

User engagement is a critical factor in the success of recycling initiatives, particularly in community settings such as university campuses. Research indicates that incentive-based mechanisms and user-friendly interfaces significantly influence recycling behavior. For instance, (Nurfikri & Martono, 2023) analyzed variables impacting Reverse Vending Machine (RVM) use, emphasizing the role of public awareness and incentives in increasing recycling participation. Their findings align with broader trends observed in studies published in Expert Systems with Applications, which highlight that well-designed incentive systems can lead to a 30% increase in recycling rates. However, the effectiveness of these systems often hinges on their ability to provide immediate feedback and rewards to users, fostering a sense of accomplishment and encouraging repeat behavior (Dingsøyr et al., 2018).

Despite the potential benefits, many existing RVMs and recycling applications fail to fully leverage user engagement strategies. For example, while (Uday Karmoker, 2024) conducted a survey among university students that revealed a positive attitude towards RVMs, they also noted that the lack of real-time feedback mechanisms diminished user motivation. This gap underscores the need for systems that not only accept recyclables but also actively engage users through mobile applications that provide instant rewards, educational content, and progress tracking. The integration of gamification elements, such as point accumulation and leaderboards, has been shown to enhance user interaction, as evidenced by successful implementations in various recycling programs highlighted in Waste Management.

Moreover, regulatory and ethical considerations play a significant role in shaping user engagement strategies. As recycling initiatives increasingly rely on data collection to personalize user experiences, concerns regarding data privacy and security must be addressed. Transparency in how user data is utilized can foster trust and encourage participation, particularly in environments where users

may be hesitant to engage with technology. Additionally, the design of user interfaces must consider accessibility to ensure that all community members, including those with disabilities, can participate effectively.

Looking ahead, future research should explore innovative approaches to enhance user engagement in recycling systems. This could include the integration of blockchain technology to provide transparent tracking of recycling efforts, thereby increasing user trust and accountability. Furthermore, developing partnerships with local businesses to offer tangible rewards for recycling participation could create a more robust incentive structure. By focusing on these aspects, our research aims to create a comprehensive user engagement framework that not only promotes recycling behavior but also fosters a culture of sustainability within university campuses and beyond.

3. METHODOLOGY

3.1. Research Framework

The development and evaluation of the AI-driven Reverse Vending Machine (RVM) system followed an Agile methodology, which proved ideal for managing the complex and dynamic requirements inherent in integrating AI, IoT components, and user-facing mobile applications. Agile's incremental and iterative delivery model facilitated continuous testing and refinement of core components, such as AI models for plastic bottle detection and incentive-based reward systems (Mahnic, 2012). This approach emphasized adaptability, collaboration, and user-centric development, making it a suitable framework for a project prioritizing sustainability, technological complexity, and human interaction. The project also employed a Mixed Methods Approach, combining qualitative and quantitative techniques to provide comprehensive insights into user behavior, technical performance, and system impact. This integrated methodology ensured that both user needs and technical feasibility were continuously addressed throughout the development lifecycle (Calvin et al., 2023).

3.1.1. Analysis

The analysis phase systematically gathered and processed information to inform the RVM's design and functionality. This phase commenced with a thorough review of existing campus recycling practices and infrastructure at Management and Science University (MSU). This initial assessment revealed low student engagement with conventional recycling bins and a notable absence of incentive-driven programs, highlighting a critical need for more effective waste management solutions. To understand user expectations and challenges, a preliminary survey was conducted with students and sustainability officers. Building on these insights, a pilot questionnaire was subsequently administered to 50 respondents (comprising both students and officers). The primary objective of this pilot study was to ascertain the types of rewards most effective in encouraging students to utilize the RVM. The findings from this pilot study were crucial in shaping the RVM's incentive mechanism and overall user engagement strategy.

Concurrently, qualitative data derived from interviews and observations were analyzed to identify nuanced user needs and preferences. This qualitative input

directly informed the user-centered design principles applied throughout the RVM system's development, ensuring that the final product was not only technically robust but also highly user-friendly and aligned with student behaviors.

3.1.2. Design

The RVM system was designed as a modular, AI-enabled smart recycling unit, integrating hardware-level automation, embedded intelligence, and real-time cloud connectivity. The core design principles prioritized accuracy, usability, and real-time user engagement. Fig. 1 illustrates the system architecture.
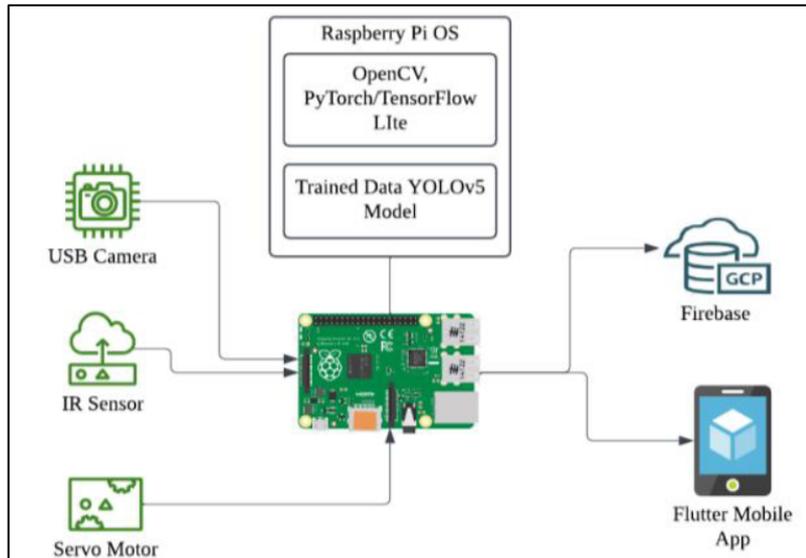
Fig. 1. System Architecture Design

The RVM comprises five main components:

a) USB Camera: For image capture and object detection.
b) IR and Ultrasonic Sensors: For object validation and dimension measurement.
c) Servo Motor: For physical sorting and opening the deposit flap for valid bottles.
d) Raspberry Pi 4: Serving as the central control unit for real-time processing.
e) Flutter-based Mobile Application with Firebase Integration: For user interaction, point management, and reward redemption.

The system's operational flow begins with the user inserting a bottle. The RVM scans and verifies if the item is a plastic bottle. Non-plastic items are rejected. If valid, the bottle is accepted into the storage compartment. Users then scan a QR code displayed on the RVM screen via the Flutter mobile app, linking the transaction to their account. Points are calculated based on the number of bottles, and accumulated points can be redeemed for rewards through the app or saved for future use.

The Raspberry Pi OS, a lightweight Linux-based operating system, facilitates efficient hardware and software execution. The trained YOLOv5 model, optimized via Google Colab and exported to ONNX format, is deployed on the Raspberry Pi, utilizing OpenCV and PyTorch/TensorFlow Lite for real-time plastic bottle detection

from the USB webcam. Detected object data, timestamps, and user IDs are transmitted via Wi-Fi to the Firebase Realtime Database, which stores all recycling records. This architecture supports bidirectional communication between the hardware and the mobile app, enabling live updates for features such as point redemption and system status checks. The design aims for quick interactions and seamless integration between AI detection, user engagement, and cloud storage, creating an effective smart recycling system leveraging IoT technology. Fig. 2 presents the RVM's operational flowchart.
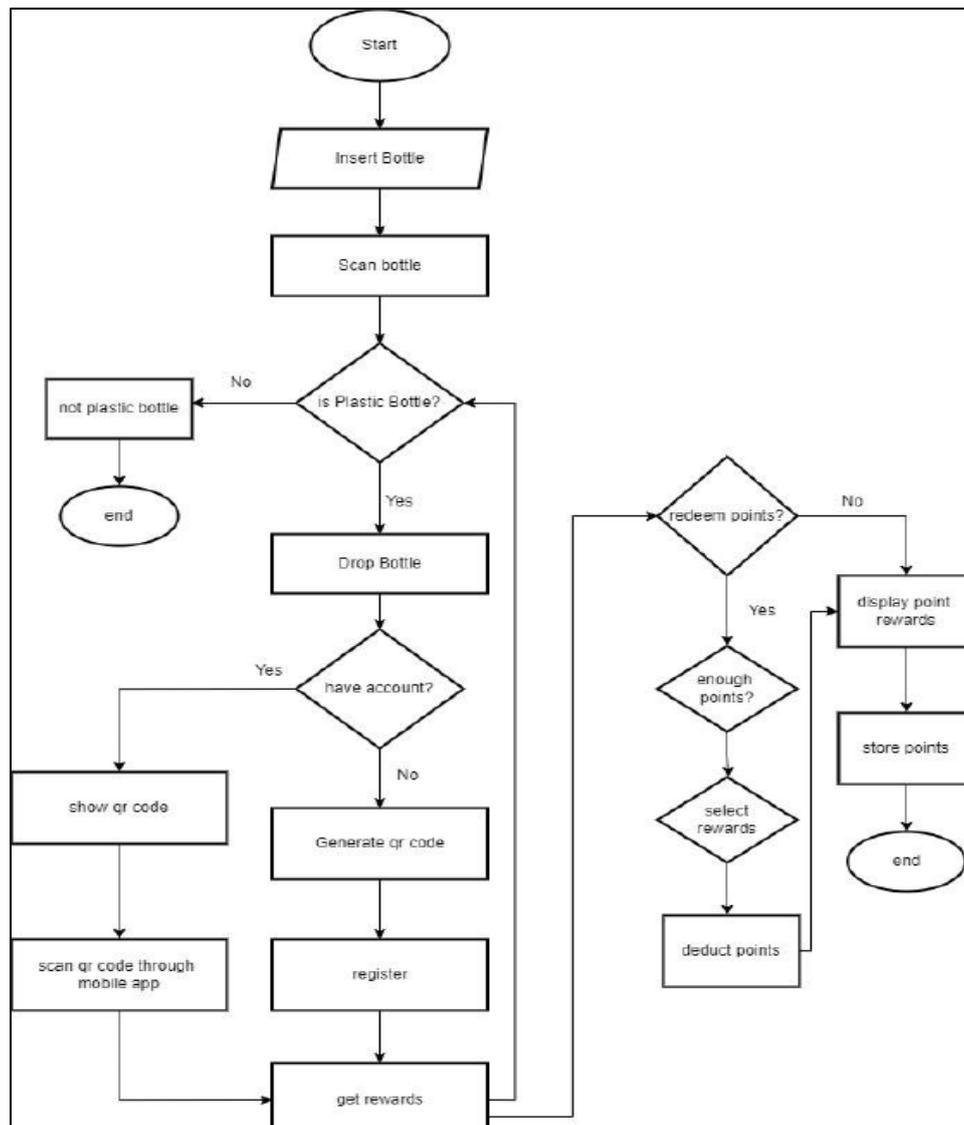
Fig. 2. System Design Flowchart

3.1.3. Development

The development phase commenced with the creation and preparation of a plastic bottle dataset using Roboflow, a platform for image annotation, preprocessing, and version control. A total of 1,500 images were labeled, sourced from publicly available datasets and custom captures under various lighting and background conditions to simulate real-world usage. Preprocessing steps included resizing (416x416 px), background blur, brightness normalization, and data augmentation (rotation, flipping, noise injection). The final dataset was exported in YOLOv5 PyTorch format for training. Model training was conducted on Google Colab, leveraging GPU resources (Tesla T4). The YOLOv5 architecture was selected for its balance of detection accuracy and inference speed on edge devices. Performance graphs tracked training loss, precision, and recall metrics in real-time. Post-training, the model was exported in TorchScript format and converted for on-device inference on the Raspberry Pi 4, with only essential weights (best.pt) and configuration files transferred for optimized performance.

Real-time detection on the Raspberry Pi was implemented using OpenCV and PyTorch, processing a single frame per inference cycle at 416x416 pixels resolution. The detection logic was integrated with hardware components: IR sensors confirmed bottle presence, and servo motors controlled the flaps. Python was used to create multithreaded scripts managing object detection, GPIO motor control, and sensor input, enabling the system to recognize and respond within approximately one second. In parallel, a Flutter-based mobile application was developed to interact with the Firebase Realtime Database, where detected events and reward points were recorded. A scanned QR code from the user's session linked to the app, ensuring real-time point updates upon bottle detection. The Raspberry Pi synchronized user profiles with Firebase via its REST API during each interaction. Fig. 3 illustrates the dataset collection in Roboflow, and Fig. 4 shows the training progress of the YOLOv5 model in Google Colab. A code snippet for fetching user data from Firebase is shown in Fig. 5.
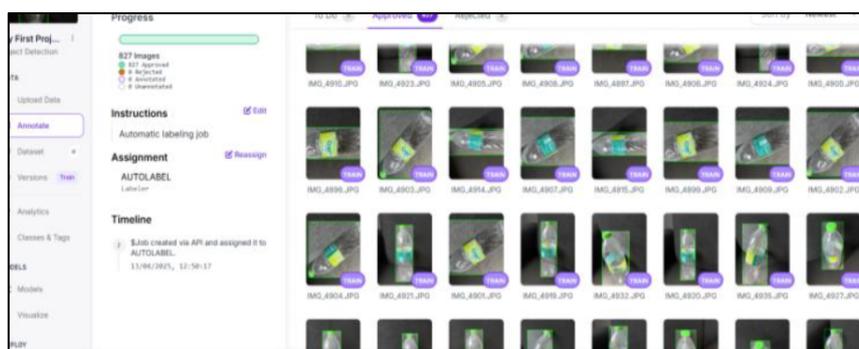
Fig. 3. Dataset Collection from Roboflow
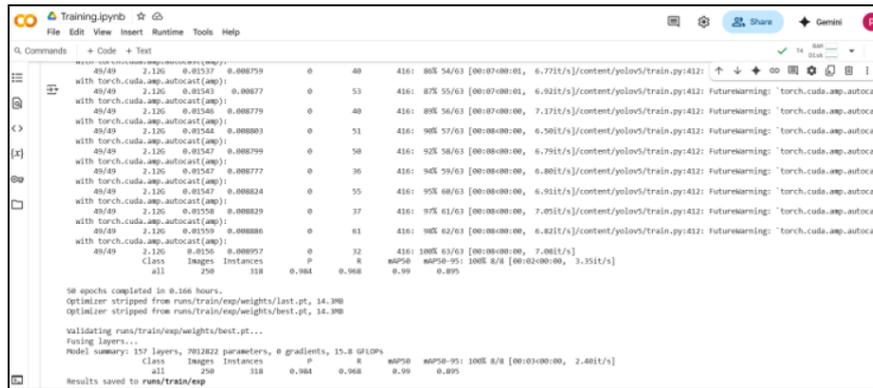
Fig. 4. Training progress YOLOv5 model in Google Colab

Fig. 5. Code to Fetch User from Firebase

3.1.4. **Testing**

A campus-based pilot study was conducted to evaluate the RVM system's object detection accuracy, responsiveness, and usability. The trained YOLOv5 model achieved a 99.0% mAP@0.5, 98.4% precision, and 96.8% recall score after 100 epochs. It maintained high accuracy even in challenging conditions, misclassifying only two out of fifty samples under stress. The detection-to-reward cycle completed in less than 1.2 seconds, encompassing image processing, servo actuation, and Firebase syncing. IR sensor accuracy exceeded 95%, with minor issues attributed to misalignment. Firebase demonstrated reliable performance on 1-2 Mbps Wi-Fi, with 600-800ms latency, and a local fallback system ensured data integrity during network outages. Usability testing with ten students yielded a System Usability Scale (SUS) score of 81.3, indicating high user satisfaction. Users particularly praised the straightforward interface, real-time point updates, and the rewards system. Stress testing with 20 concurrent operations revealed stable performance without crashes. A survey of 50 students indicated that 76% intended to use the RVM regularly, with 48% motivated by voucher-based rewards. These

findings collectively support the system's dependability, responsiveness, and high user acceptance for real-world campus deployment. Table 2 presents the performance metrics of the YOLOv5s model.

3.1.5. Dataset Details

The dataset for training the YOLOv5 object detection model was meticulously created and managed using Roboflow. The primary objective was to develop a robust dataset capable of detecting plastic bottles across diverse real-world scenarios, including varying lighting, backgrounds, and orientations. The dataset comprised 2,000 labelled images, a combination of public repositories and custom-captured images. Custom images, collected with a smartphone camera in various campus locations, were crucial for simulating actual deployment conditions.

Each image was uploaded and annotated directly in Roboflow, with bounding boxes manually drawn around instances of plastic bottles. Only one class, "plastic bottle," was considered in this dataset. While valid for a prototype, this represents a limitation of the current system. Future iterations will incorporate additional classes such as cans, glass, and mixed recyclables to support broader campus waste management. To enhance the model's generalization capabilities, Roboflow's built-in augmentation pipeline was applied during preprocessing, including random rotation (±15°), random cropping and zoom, brightness and contrast adjustments, horizontal flipping, blur, and Gaussian noise.

3.1.6. Implementation Testing

The deployment of the Reverse Vending Machine (RVM) system presented several environmental and technological challenges, particularly concerning the integration of machine learning, sensor hardware, and real-time data communication on an embedded platform with limited resources. One significant challenge involved managing the Raspberry Pi's constrained computational resources. Although YOLOv5s is a lightweight model, real-time object detection still required optimization. This was addressed by resizing input frames to 416x416 pixels and processing them at a lower frequency to balance detection speed and accuracy.

Early testing revealed hardware issues such as servo motor jitter and unstable sensor readings. These were resolved by fine-tuning PWM signal timings and incorporating conditional noise filtering into the IR sensor logic. False triggers from the ultrasonic sensor were mitigated by adjusting the trigger pulse duration and threshold detection ranges. Cloud integration also posed unique challenges. Firebase synchronization delays were occasionally observed during peak network usage on campus Wi-Fi. To counter this, a retry mechanism was implemented in the Python-Firebase interface, allowing temporary local data storage during connection errors and subsequent push to the database once connectivity was restored.

3.1.7. User Interface Design Consideration

The user interface (UI) of the Reverse Vending Machine (RVM) mobile application was meticulously designed with student usability, recycling motivation, and real-time interactivity as core considerations. The application's interface adhered to principles of minimalism, clarity, and responsiveness, aiming to facilitate easy and rapid navigation for university students amidst their daily campus routines. The chosen color scheme features a clean, modern aesthetic with strong contrast between foreground and background elements(Huang & Rex, 2023). Accent colors, such as green (signifying success) and blue (representing points and rewards), were strategically used to direct user attention to critical actions. Typography employed sans-serif fonts, with font sizes ranging from 16 pt for labels to 24 pt for headings. Text elements were kept concise to minimize cognitive load, and larger, tappable components (at least 48x48 dp, per Google's Material Design guidelines) were used to enhance navigation speed and reduce user frustration, ensuring accessibility and mobile ergonomics.

The interface is structured into three main sections: the Home Screen (displaying recycling points and recent activity), the QR Scanner (for validating rewards via machine-generated codes), and the Profile Screen (for tracking history and managing accounts). A bottom navigation bar provides quick access to all main sections, and push notifications deliver real-time updates on points earned and reward status. Early prototype testing with ten university students highlighted the importance of immediate visual confirmation after each recycling interaction. Consequently, real-time syncing with Firebase was optimized to update point balances within seconds of QR code scanning(Subhashini et al., 2020).

4. RESULTS

4.1. Pilot Study Results

A pilot study involving 50 Management and Science University (MSU) students was conducted to assess the RVM system's feasibility and user acceptance, particularly focusing on awareness levels and reward preferences. The results indicated that 60% of students had moderate awareness of plastic waste issues, 26% had low awareness, and 14% had high awareness, underscoring the need for continued campus education on sustainability. Regarding the willingness to adopt the RVM, 76% of students expressed moderate to high willingness, 20% were neutral, and only 4% were hesitant. This high willingness to use the system suggests strong potential for successful implementation. In terms of reward preferences, the study found that 48% of respondents preferred redeemable vouchers, indicating a strong motivation for tangible incentives. Environmental impact tracking motivated 30% of students, while 22% preferred non-material incentives. These findings confirm that personalized, voucher-based incentives hold significant potential for increasing user participation. The detailed distribution of reward preferences is illustrated in Fig. 6.
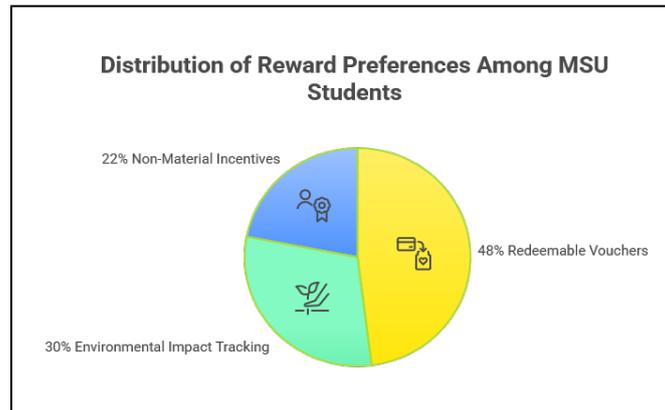
Fig. 6. Pilot Study Result

4.2. System and Mobile App Prototype Demonstration

A complete prototype of the RVM hardware system and its accompanying mobile application was deployed in a simulated campus environment to validate their integrated functionality. Real-time object detection and mechanical responses were tested across multiple user sessions, demonstrating accurate classification and consistent servo activation for verified plastic bottle inputs. Fig. 7 illustrates the developed RVM in action.
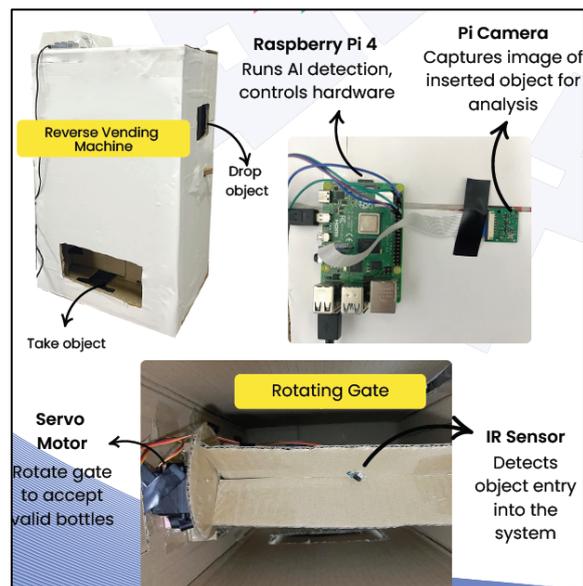
Fig. 7. RVM Demo

During the demonstration, each bottle was detected in less than one second, followed by immediate servo actuation and event logging to Firebase. This process resulted in a real-time point update in the Flutter-based mobile application. Fig. 8 illustrates the scanning processes.
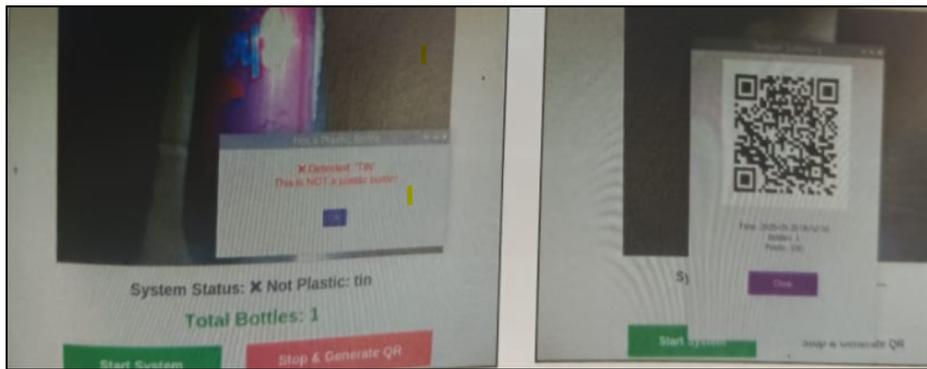
Fig. 8. Mobile App QR Code Scanning

Users initiated their session by scanning a QR code displayed on the RVM screen, which seamlessly connected their transaction to their user profile and updated recycling points in real-time, with an average latency of less than 800 milliseconds. The mobile application efficiently managed QR code scanning, user identification, point accumulation, and reward tracking, providing instant feedback. Students expressed high satisfaction with the overall process, which was completed within 5-8 seconds per session, indicating the system's readiness for deployment in high-traffic campus environments. The integration of real-time feedback and user-friendly design significantly enhanced user engagement, as evidenced by positive user feedback and a willingness to participate in the recycling program. Fig. 9 illustates points accumenation in app.
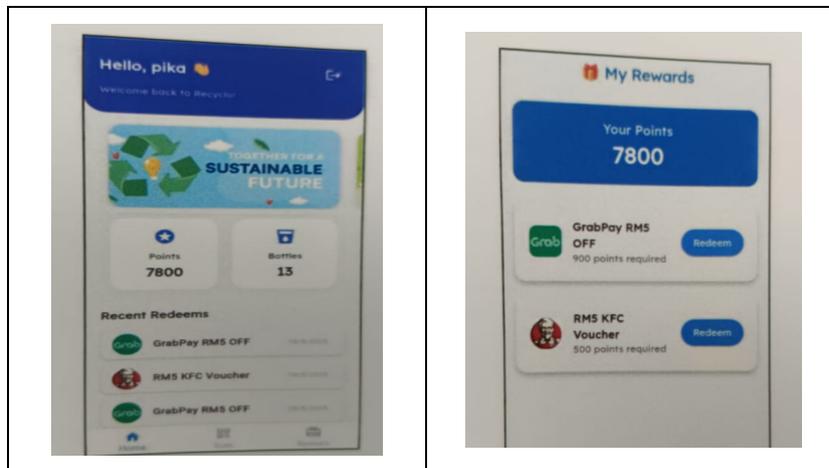
Fig. 9. Points Accumulation in the App

The results from the deployment of the Reverse Vending Machine (RVM) prototype and its mobile application demonstrate a successful integration of technology aimed at enhancing recycling engagement among students. The pilot study revealed that 76% of students expressed a willingness to use the RVM regularly, primarily motivated by the appeal of redeemable rewards. The RVM achieved a remarkable detection time of less than one second per plastic bottle, ensuring efficient operation during user interactions. User feedback indicated a high level of satisfaction with the system, reflected in a System Usability Scale (SUS)

score of 81.3, highlighting the app's intuitive design and responsiveness. The real-time point accumulation and immediate feedback mechanisms significantly contributed to user engagement, reinforcing the effectiveness of the RVM in promoting sustainable recycling practices. Overall, these findings validate the RVM's potential as a viable solution for increasing recycling participation in campus environments.

5. SCOPE AND LIMITATIONS

This study was designed as a small-scale pilot to test the feasibility and user acceptance of an AI-driven Reverse Vending Machine (RVM) on campus. While the findings confirm the system's technical and behavioral potential, the scope is bounded by the following limitations:

i.   The system focused exclusively on plastic bottles; other recyclables (e.g., cans, glass, paper) were not included.
ii.   The pilot was conducted within a single university campus (MSU), which may limit generalizability.
iii. The testing involved 50 student participants in a short-term deployment.
iv.   The evaluation emphasized technical performance and immediate user acceptance, without capturing long-term behavior change or sustainability outcomes.

The system was tested under controlled campus conditions, not in broader or outdoor environments.

6. CONCLUSION

This study demonstrated the feasibility of an AI-driven Reverse Vending Machine (RVM) prototype for campus plastic waste management. The system achieved a detection accuracy of 99.0% mAP at 0.5, with a rapid detection-to-reward cycle under 1.2 seconds. Usability testing produced a System Usability Scale (SUS) score of 81.3, and 76% of surveyed students indicated willingness to use the RVM, with nearly half motivated by voucher-based incentives. These findings confirm both the technical robustness and user acceptance of the prototype. While the system shows strong potential for campus sustainability, its scope was limited to a small-scale pilot and a single waste type (plastic bottles). Future research will expand to multi-material classification, longer-term user adoption studies, and deployment across multiple campuses to evaluate scalability.

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SMECORP-OF-FUTURE: ENABLING AND EMPOWERING THE MICRO, SMALL & MEDIUM ENTERPRISES (MSME) RELEVANT AND SUSTAINABLE IN THE DIGITAL ERA

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ABSTRACT: This paper intends to present a business case for the strategic transformation SMECorp-of-Today (SMEoT) into SMECorp-of-Future (SMEoF). The business objectives of SMEoT are to meet the diverse needs and demands of various customer segments (CS) such as the Micro, Small and Medium Enterprise owners and entrepreneurs (MSMEs); Government; Company; and Zakat centres in seizing opportunities and to remain relevant in the digital economy. This paper adapts the Design Thinking (DT) methodology, encompassing conducting literature review (LR), benchmarking, and interviews to understand and define problems of these CS. For example, MSMEs extreme pain is having difficulty in getting loans or grants and the essential gain is to access to loans and grants according to their needs. Based on the literature review and benchmarking conducted, the initial business model prototype was developed using Business Model Canvas (BMC), Value Proposition Canvas (VPC), and Environmental Map (EM). Then the initial business model was validated with the customer segment and a Strategy Canvas (CS) was also developed to compare and validate SMEoF business model against the current model SMEoT. The key finding of this paper is the conceptual SMEoF business model, to facilitate digital transformation from SMEoT to SMEoF, financial inclusion, specific reskilling–upskilling programs, as well as access to global markets. The main contribution of this paper is to validated BM of SMEoF with current BM, inclusive and future-ready framework that places SME Corp Malaysia at the forefront of SME development. Future works include developing a Digital/IT Strategic Plan (DISP) to guide SMEoT holistic digital transformation by aligning strategies to the national policies like MyDigital, NEP 2030, National 4IR Policy and SME Corps Malaysia Business Strategic Plan 2022-2030 in the future work.

KEY WORDS: *SME Corp Malaysia, Organisation-of-the-Future, Digital Transformation, Micro Small & Medium Entrepreneurs, Business Model Canvas, Value Proposition Canvas*

1. INTRODUCTION

Small and Medium Enterprises Corps (SME Corps) are the backbone of the Malaysian economy and contribute significantly to employment, innovation and economic growth. At the same time, the Fourth Industrial Revolution (4IR) is propelling technological advancement at such an unprecedented speed that together with the influences of the evolution graph of technology trends with the

advent of and challenges of Covid-19, business dynamics is booming, and the legacy landscape is vanishing for SMEs unless they innovate to sustain themselves in the market (World Economic Forum, 2021). In turn, SME Corps of Today (SMEoT) as the national coordinating agency for the development of SME needs too undertake a strategic digital transformation to improve its transformative and support services, remain relevant and be more responsive to the changing needs and demands of its customer segments (CS), namely the MSMEs, government like MEDAC, MARA, MAFS; companies like Telekom Malaysia and Petronas; and Zakat centres.

For SME Corps, the digital age is both opportunities and challenges. On the one hand emerging technologies including Artificial intelligence (AI), big data, and digital platforms can optimize processes and extend markets, allowing for more inclusive development. The challenges for SMEs are daunting, however, with low digital literacy, limited access to affordable digital tools, and in insufficient funding mechanisms. Adding to these challenges are operational inefficiencies and absence of localized support geared towards the needs of SME, more so for rural and other underserved regions. Meanwhile, for SME Corp, these barriers also create challenges for it to be agile and effective in fulfilling its mandate.

Other jobs-to-do for SME Corp Malaysia involve assisting SMEs to optimize operations, financing, accelerate growth through digitalisation, and develop capacity for innovation. But for SMEs, the pains are much more acute such as the navigating regulatory complexities, limited knowledge of digital tools, and difficulties integrating technology into traditional business models. The key gains for SMEs are efficient processes, enhanced competitiveness and sustainable ability to digitise marketplace access. The heart of SME Corp Malaysia customer segments focuses on Micro, Small and Medium Enterprises owners and entrepreneurs (MSMEs), whose key jobs-to-be-done include adopting digital tools to enhance productivity, getting access to affordable financing, expanding market reach, and building workforce capacity that aligns with changing demands due to the Fourth Industrial Revolution (4IR). The problems to solve and the various pains that MSMEs faced, include accessing funding is difficult owing to strict MSME eligibility criteria, hesitance to embrace global market opportunities owing to immense logistical complications, and limited digital literacy or affordable technology solutions. Nonetheless, MSMEs will derive benefits that include access to inclusive financing, productivity increase through technology endowment, market access through export enablement, and grooming through mentorship on business growth.

Aside from this, other government agencies like MARA, MAFS, and MOSTI have played their part to develop the MSME. Jobs-to-do by create and implement policies that favour MSMEs, allocate resources strategically, reach out and collaborate with other agencies for ecosystem coherence, monitor the performance of practices and impact of programs. But they often face pains like fragmented data systems, limited scalability because they run solely on human capital, and inefficient in aligning their programs to national agenda and policies (OECD, 2021). Meeting these challenges can lead to management benefits such as integrated and synergistic initiatives across-agency cooperation through shared or centralized data and resources sharing platforms on MSMEs for example, GIS, real-time evaluation

through analytics, and improved utilization of resources and public trust created through transparency.

Another important customer segment is private companies like Petronas, Khazanah, and Sime Derby. Integrating MSMEs into their supply chains, meeting corporate social responsibility (CSR) goals, collaboration for innovation, and stimulating local economies are all jobs-to-do for them. Their pain points include but are not limited but challenging to find SMEs that can deliver to industry standards, inconsistency in performance, lack of engagement on underserved groups. Benefits like fortified supply chains through experienced SME partners, increased corporate goodwill through CSR programs, and improved operational efficiency and innovation through dynamic SME partners.

Baitumal and Zakat bodies are investing in the *asnaf* (underprivileged) community by channelling resources to them to create entrepreneurship opportunities. They do transparency in distributing Zakat funds, deliver capacity building programs, nurture economic independence for asnaf, quantify the impact. These institutions are experiencing pains through a lack of transparency in distribution, less capacity building support, and sustaining the livelihood of Zakat recipients who transition to entrepreneurs. Their benefits consist of secure Zakat dispensation platforms, steady profit streams for asnaf business owners, and elevated community confidence through significant and quantifiable results.

While there are many pain relievers and gain creators available within the industry from e-commerce platforms to Fintech solutions to online training programs, many existing products are not tailored for Malaysian SMEs broadly and adequately. While these solutions have some merit, they rarely come contextualized to local markets, may not be affordable by smaller enterprises, and may not fit into existing operational frameworks (OECD, 2021). But this still leaves major gaps in doing the critical jobs-to-do, relieving extreme pain and providing important gains for SMEs.

Based on these gaps, SME Corp Malaysia need to mobilize a Strategic Digital Transformation Plan that utilize innovative digital solutions and introducing humanized education. This approach goes beyond just giving access to advanced technologies to SMEs; it also involves training SMEs on how to take advantage of them. SME Corp must also emphasize reskilling, digital literacy, and inclusive support systems so that SMEs may flourish in a rapidly changing economic environment.

2. OBJECTIVES

The main objective of this paper is to examine and access the present business model of SME Corps Malaysia to create, generate, and validate an alternative agile and innovative business case solution. The alternate business case focuses on harnessing current digital technology to digitally change the SME Corps for relevance and sustainability. The paper identifies meaningful objectives that

delineate an agile and comprehensive framework to fulfil the SME Corp Malaysia aspirations of being the key enabler of sustainable and inclusive growth for SMEs in determining the imperatives in a rapidly changing digital environment.

3. METHODOLOGY

This paper employs the Design Thinking (DT) methodology, a human-centered, iterative approach to problem-solving and innovation. Design Thinking is a human-centered leadership framework that focuses on empathizing with users, problem framing, ideation, prototyping, and validation (Diderich, 2020) This approach is well aligned with the complexity and dynamic nature of small to medium enterprise (SME) needs in Malaysia, as it is driven by empathy, creativity, and continuous feedback and optimization. The first stage is the Empathy Stage, it is to understand the pain points faced by the SME Corp Malaysia. This is accomplished by conducting an extensive literature review of literature on digital transformation, literature SME development, SME agency from another country and the MyDigital strategy of Malaysia. The next stage called Define uses the information from the earlier empathy stage to determine what are the fundamental challenges facing SME Corps in priority order. The Ideation Stage proposes initial solutions in the form of Business Model Canvas. Furthermore, Prototype Stage where the three work streams describe the direction needed for a conceptual business model; the Environmental Map (EM), and Value Proposition Canvas (VPC) are applied. Environmental Map which reviews external factors affecting the growth of SME Corp Value Proposition Canvas confirms if proposed solutions are aligned with the actual needs of SME Corps. The Validation Stage, stakeholders are solicited through further interviews and surveys, to assess whether the model being proposed by the team is practicable and relevant. Information collected through this phase is assessed to polish the business model by filling in the identified gaps or aligning to user expectations. Lastly, the Strategy Canvas (SC) framework compares the initial Business Model of SME Corp Malaysia to the Business Model of SMEoT and other nations BM for digital transformation. It enables visual prioritization for more digital literacy initiatives, building inclusive financing systems and local assistance for underserved SMEs (Kim & Mauborgne, 2019).

4. LITERATURE REVIEW

4.1. The Malaysian Digital Economy Blueprint (MyDigital)

The MyDigital Blueprint is Malaysia's overarching digital transformation blueprint that is intended to make the country an economy fully driven by digital economy and a high-income nation by the year 2030 (Economic Planning Unit, 2021). The plan aims at getting inclusive digital adoption across various sectors, and particularly on SMES. This means increasing the number of small-medium enterprises (SMEs) contributing to the digital economy from 37 per cent in 2021 to 50 per cent by 2030, enhancing e-Commerce access and utilising wholesale financing and other fintech solutions to optimise operational processes. The government has launched the Malaysia Digital Economy Corporation (MDEC) programs including the SME Digital Accelerator, which offers tools and guidance for SMEs to digitalize, to achieve these goals. Nonetheless, challenges remain

around the implementation of MyDigital at the base level. However, as MDEC (2022) highlights, most SMEs are still grappling with a number of significant roadblocks such as low digital literacy levels among entrepreneurs, the lack of appropriate infrastructure in rural areas, and a reluctance to change due to long-standing traditional business models. As the national agency for SME development, aligning with MyDigital is a key opportunity for SME Corp Malaysia to fill these gaps through more localized sectoral digital solutions that can be factored into the national digital economy agenda.

4.2. Fourth Industrial Revolution (4IR) & Nurturing of MSM Entrepreneurs

The Fourth Industrial Revolution (4IR) is a global movement today that signifies a change in the way businesses function in today's world, thanks to the transformative technologies inclusive of artificial intelligence (AI), blockchain, robotics, and the Internet of Things (IoT). The 4IR Policy Framework for Malaysia, which was introduced in 2021, highlighted the importance for Small and Medium-sized Enterprises (SMEs) to embark on the adoption and implementation of these technologies to increase productivity, improve market competitiveness and to provide the opportunity to innovate (MOSTI, 2021). While there is potential, adoption rates among SMEs remain low. As per World Economic Forum (2020), the majority of SMEs face finance constraints as well as lack of skills and knowhow of some benefit of 4IR. Malaysia has already rolled out policies like the National Fourth Industrial Revolution Policy aimed at helping businesses, nevertheless, policy targeted at SMEs is critical for their adoption of advanced technologies in their operations. Extended experiences gained from programs such as the "Smart Factory" initiative in Korea (Korea SMBA, 2023) can serve as a reference for targeted aid initiatives to spur 4IR adoption that will help ensure that Malaysian SMEs are up to task in accompanying Malaysia in the impending industrial transformation and can be implemented in a way similar to what SME Corp Malaysia is providing.

4.3. National Entrepreneurship Policy 2030 (NEP 2030) and SME Integrated Plan of Action (SMEIPA)

The National Entrepreneurship Policy 2030 (NEP 2030) lays out lines that have been determined to elevate Malaysia to an entrepreneurial nation through, among others, the strength of SMEs, inclusiveness and holistic development of an entrepreneurial ecosystem (Ministry of Entrepreneur Development and Cooperatives, 2020). The policy is built upon six strategic thrusts, which are creating an entrepreneurial mindset, capitalizing on the digital economy and inclusion of the marginalized groups in the economy. NEP 2030 are the plans to ensure that MyDigital and the 4IR Policy are a closer fit for building resilient and competitive SMEs for the digital economy. For instance, TEKUN Nasional and SME Bank exposes credit incentives for innovation and development. However, gaps remain in implementation, particularly in reaching rural entrepreneurs and marginalized groups. According to a report by Ahmad and Ramli (2022), the NEP aids enterprise development, but only caters to urban small and medium enterprises while rural enterprises are unaware of the initiatives and have no access to such types of programs. It means we need more holistic approaches to ensure that the objectives

of NEP 2030 benefits to all SMEs evenly. Potential solution is to use eKasih database to identify households in poverty. This tool is effective for developing and offering targeted re-skilling and up-skilling programs, ensuring that marginalized populations and rural entrepreneurs get the knowledge and skills required to engage in and benefit from the opportunities presented by NEP 2030.

The SME Integrated Plan of Action (SMEIPA) 2023 serves to complement the National Entrepreneurship Policy 2030 (NEP 2030) by offering a broad regional framework to promote the development of SME under the ASEAN Economic Community (AEC). The key initiatives of SMEIPA that drives competitiveness are innovation, technology adoption, market access, and human capital development. These strategies purpose to place SMEs as core movers of regional and international economies, and to also win the gaps in financing, expertise, and market inclusion. Based on the most recent snapshot in the SMEIPA 2023, the plan consists of over 191 programmes, with an allocation of RM4,097.42 million expected to benefit 502,405 MSMEs from different sectors and segments. Particular attention is given to helping underprivileged groups, including Bumiputera entrepreneurs, those in rural areas, women, and young people. Focus on inclusivity SME development and this targeted approach ensures inclusivity and fairness in fostering SME growth, eventually contributing to the regional objective of equitable development.

4.4. Reskilling & Upskilling, and Employment & Entrepreneurship

Aims to create inclusive and empathic environments in which individuals acquire the skills to reinvent themselves in the era of digital transformation. This strategy is vital for those small and medium enterprises making their move to the digital landscape as it encourages the reskilling and upskilling of the essential skills gap plaguing areas like AI, IoT and digital marketing. Digital literacy and lifelong learning for all digital skills are needed for equitable economic participation in an age of technological change (UNESCO, 2020). In Malaysia, government programs to address skill gaps for SMEs include training subsidies under Penjana Kerjaya and HRDF (Human Resources Development Fund, 2021) for reskilling and upskilling activities to support firms effectively close skill gaps. These efforts are part of a wider movement towards nurturing entrepreneurs as a key driver of economic growth and that emphasis on nurturing entrepreneurial skills through education and training programmes backed by financial incentives is what makes a difference, as seen through the example of the National Entrepreneur and SME Development Council (NESDC) Entrepreneurship Master Plan. Majority of SMEs face issues with access to affordable and tailor-made training programs, highlighting a gap in localized and sector-specific responses (Ali et al., 2020). The current business model of SME Corps, using the BMC frame is shown in Fig. 1.

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
• Federal and state government agencies. • Banks, venture capital firms, and other financial service providers. • Chambers of commerce and industry associations.	• Developing and implementing SME development policies. • Executing various programs and initiatives. • Organizing training programs and workshops. **Key Resources** • Skilled workforce for training and advisory services. • Budgetary allocations for various programs and initiatives.	• Providing guidance and support on business planning, finance, marketing, and operations. • Facilitating access to loans, grants, and equity financing. • Offering training programs and workshops to enhance SME capabilities. • Connecting SMEs with domestic and international markets.	• Fostering a strong SME community through networking events and forums. • Sharing industry insights and best practices. **Channels** • Digital platforms (mobile apps, web portals). • Regional offices across Malaysia. • Collaborations with industry and government agencies.	• Micro, small, and medium entrepreneurs (MSME). • Government e.g. MARA, MOAFS, and MOSTI. • Financial institutions such as bank.
Cost Structure			**Revenue Streams**	
• Office rent, utilities, and administrative expenses. • Funding for training programs, workshops, and financial assistance. • Salaries and benefits for staff.			• Government fundings. • Fees for certain services and programs.	

Fig. 1. Current BMC of SME Corps (from SME Corps Malaysia Business Strategic Plan 2022-2030) [authors' view]

4.5. Benchmarking of Other Countries' SME Agencies

4.5.1 Singapore (Enterprise Singapore) (https://www.enterprisesg.gov.sg)

Customer Segments (CS): Local SMEs and startups, Export-oriented businesses, High-tech and innovative enterprises.

Value Propositions (VP): Support for innovation and technology adoption, Grants and funding for capability development.

- Facilitation of internationalization through programs like the Global Innovation Alliance (GIA).

Customer Relationships (CR):

- Responsive Account Managers for individual support.
- Technology resources and platforms for grant applications and training.
- Cooperation with foreign trade representations.

Key Activities (KA):

- Financial assistance in the form of grants such as Enterprise Development Grant.
- Arranging trade missions & market access programs.
- Assistance on R&D and innovative projects.

Key Partners (KP):

- Technology vendors and research organizations.
- Global commerce associations.
- Support your local businesses and industry associations.

4.5.2 South Korea's Small and Medium Business Corporation (SMBC) (http://www.smba.go.kr)

Customer Segments (CS):

- Manufacturing and Technology SMEs.

- Startups working in the growing industries (renewable energy, Artificial Intelligence, etc.)
- Export-driven businesses.

Value Propositions (VP):

- Far reaching in scope in terms of the financial service they offer, covering everything from loans to venture capital.
- Encouragement of export-oriented activities, such as market research and trade missions.
- Programs on Technology adoption and smart factory implementation.

Customer Relationships (CR):

- SME Consultancy and one-stop centres for assistance
- Application Processing and Consultancy Platforms Online
- Partnership programs of big companies.

Key Activities (KA):

- Providing loans at lower interest rates and venture capital funding.
- Enabling programs for technology adoption (e.g., Smart Factory initiative)
- Export promotion and trade networking events.

Key Partners (KP):

- Financial institutions to support co-funding initiatives.
- SME collaboration programs being run by large corporations.
- Export promotion agency of international trade bodies.

4.5.3 United States (Small Business Administration – SBA)
(https://www.sba.gov)

Customer Segments (CS):

- Micro, small, and medium-sized businesses across all sectors.
- Disaster-affected businesses requiring recovery assistance.
- SMEs aiming for government contracts.

Value Propositions (VP):

- Diverse loan programs, including 7(a) Loans for working capital and 504 Loans for fixed assets.
- Export financing and trade assistance programs.
- Support for business continuity through disaster recovery loans.

Customer Relationships (CR):

- Direct advisory services through regional offices and online tools.
- Partnerships with local Small Business Development Centers (SBDCs).
- Collaboration with financial institutions for loan facilitation.

Key Activities (KA):

- Administering financial support through various loan programs.
- Providing training and mentorship through SBDCs and SCORE.
- Facilitating access to federal contracting opportunities.

Key Partners (KP):

- Banks and other lending institutions.
- State and local governments.
- Trade associations and educational institutions.

4.5.4 Germany (Mittelstand)
(https://www.bmwk.de/Redaktion/EN/Dossier/sme-policy.html)

Customer Segments (CS):

- SMEs, particularly family-owned businesses.
- Export-oriented businesses dominating niche markets.
- Companies involved in vocational training and apprenticeship programs.

Value Propositions (VP):

- Emphasis on vocational training and workforce development.
- Support for "hidden champions" that dominate global niche markets.
- Long-term financing solutions for innovation and international expansion.

Customer Relationships (CR):

- Close, long-term relationships built on trust and shared goals.
- Access to local chambers of commerce and industry associations for networking.
- Customized support for international market entry.

Key Activities (KA):

- Supporting vocational training and apprenticeship programs.
- Facilitating R&D for product innovation.
- Promoting internationalization through partnerships and trade fairs.

Key Partners (KP):

- Local and regional banks for financing solutions.
- Vocational schools and apprenticeship institutions.
- Chambers of commerce and export councils.

4.6. Government Information Sharing (GIS) for MSME Development

One of the main purposes of GIS is that it is considered as a foundation of getting inter-agency collaboration, better decisions, and value-added integrated public service. A whole-of-government response meeting national development goals through GIS promotes complimentary data and resource sharing across government agencies. GIS can enable smooth collaboration between the factoring entities, boost financial accessibility, and policy execution for entrepreneurs or small enterprises, promoting MSME growth.

Research indicates that successful GIS implementation requires a strong foundation of political leadership and inter-agency trust. Dahlan et al. (2013) emphasize that leadership is critical for establishing a unified vision and ensuring alignment across government agencies. Legislative frameworks and clearly defined data-sharing protocols are essential for creating a structured and transparent

information-sharing environment. Trust among agencies is equally important, as it fosters a culture of collaboration and reduces resistance to sharing sensitive data.

Government Information Sharing (GIS) has emerged as a vital mechanism for enhancing inter-agency collaboration, improving decision-making, and delivering integrated public services. GIS enables government agencies to share data and resources effectively, fostering a whole-of-government approach that aligns with national development objectives. For SME development, GIS can facilitate seamless coordination among agencies, improve access to financing, and support policy implementation, ultimately benefiting entrepreneurs and small businesses.

Research indicates that successful GIS implementation requires a strong foundation of political leadership and inter-agency trust. Dahlan et al. (2013) emphasize that leadership is critical for establishing a unified vision and ensuring alignment across government agencies. Legislative frameworks and clearly defined data-sharing protocols are essential for creating a structured and transparent information-sharing environment. Trust among agencies is equally important, as it fosters a culture of collaboration and reduces resistance to sharing sensitive data.

Another key factor for GIS success is organizational capacity. Agencies must invest in robust IT infrastructure and enhance digital skills among their workforce to support GIS adoption. Top management support and resource allocation are also critical, as they enable agencies to implement shared systems and processes effectively (Dahlan et al., 2014). Furthermore, Dahlan et al. (2013) highlight that participating agencies must perceive tangible benefits from GIS, such as improved service delivery, operational efficiency, and enhanced policy outcomes.

In addition, GIS provides agencies with integrated data and analytics that allow them to evaluate the impact of programs, detect trends, and avoid challenges through evidence-based decision-making. GIS fosters transparency and accountability by facilitating a common platform for data sharing which constitutes a great way to promote SME development and entrepreneurship.

GIS can provide an integrated approach for SME Corp Malaysia to work closely with the rest of the entrepreneur-related government agencies to alleviate existing problems such as fragmented services and inconsistent policy coordination. GIS can promote a content ecosystem at the entrepreneurial supply chain, so that the SMEs could benefits more holistic and multidisciplinary ways. This integration enhances alignment with global best practices and further drives Malaysia's commitment to utilise technology to support national development.

5. INITIAL BUSINESS MODEL (BM) AND VALUE PROPOSITON CANVAS (VPC)

An initial BMC, as shown in Fig 2, was developed based on the literature review that was completed. The literature review identified the primary variables affecting and encouraging current SME Corps to improve their business models. The globally renowned BMC tool enables businesses to easily model and design how they create, deliver, and capture value by analysing strategic management and visualizing core elements such as customer segments, value proposition, revenue streams, infrastructure, key partners, and so on. As such, the SME Corp Malaysia

Business Model Canvas (BMC) was updated to encompass digitalisation which adds value in the delivery of its services and create a holistic, value-leaded Ecosystem for SMEs. The statement noted that such integration aims at digital inclusiveness, facilitating financial and advisory services to the small businesses sector, and a vibrant entrepreneurial ecosystem. SME Corp aims to provide the various segments of its client a more enriched experience as entrepreneurs and SMEs requires specific solutions and harnessing these technologies is expected to improve such delivery of business requirements. Moreover, the new BMC emphasizes the need for entrepreneurial skills to be developed in stakeholders such as SME owners and communities in creative mindsets. It also highlights the need to maintain relationships over the long term with mentoring programs, local communities, and support that creates an ecosystem within which the SMEs can flourish as part of the digital economy.

Customer Segments:

1. MSME owners and entrepreneurs e.g. Urban & Rural, Women – adult, youth, Youth in general

2. Government e.g. MARA, MAFS, and MOSTI.

3. Companies e.g. Petronas and Khazanah.

4. Zakat & Baitulmal institutions

Key Partners	Key Activities	Value Proposition	Customer Relationships	Customer Segments
• Technology providers (Digital platforms and fintech). • Financial institutions for funding SMEs. • International trade organizations for global partnerships.	• Delivering targeted training for digital literacy. • Providing accessible and inclusive financing solutions. • Supporting global market entry through export facilitation programs. **Key Resources** • Skilled workforce for training and advisory services. • Digital infrastructure for service delivery. • Partnerships with technology and financial organizations.	• Empower SMEs through digital transformation and financial inclusivity. • Provide skill-building programs for reskilling and upskilling. • Facilitate global market access and partnerships. • Enhance SME productivity using advanced technologies like AI and IoT. • Implementing GIS to facilitates real-time data sharing and streamlined workflows across government bodies.	• Personalized mentoring programs for SMEs. • Real-time support using chatbots and helplines. • Community engagement through forums and alumni networks. **Channels** • Digital platforms (mobile apps, web portals). • Training workshops and webinars. • Collaborations with industry and government agencies.	• Micro, small, and medium enterprises (MSME). • Government e.g. MARA, MOAFS, and MOSTI. • Companies e.g. Petronas and Khazanah. • Zakat & Baitumal.
Cost Structure			**Revenue Streams**	
• Investment in digital tools and infrastructure. • Costs for training and outreach programs. • -Operational expenses for partnerships and program delivery.			• Government funding and grants. • Training and certification programs. • Public-private partnerships and consulting services.	

Fig. 2. Initial Business Model of SME Corp Malaysia

The Value Proposition Canvas (VPC) focuses on the alignment of the offerings of SME Corp Malaysia and its value proposition with the customer profile of the key customer segment in terms of needs, pains, and gains. Having identified the customer profile, and the relevant products and services mapping to each segment, SME Corp would be able to better respond to the concerns and aspirations of each segment. The following is a detailed elaboration of the VPC for all customer

segments classified as Micro, Small and Medium Entrepreneurs (MSMEs), government agencies, companies and Zakat & Baitulmal.
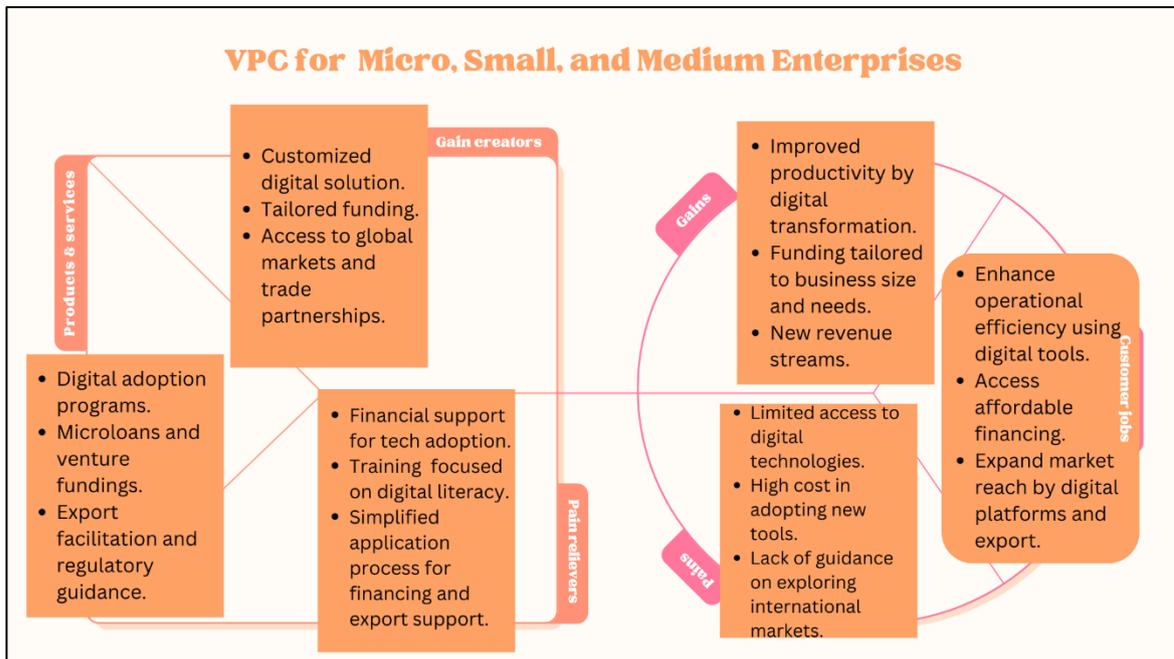
Fig. 3. VPC for Customer Segment: Micro, Small, and Medium Entrepreneurs.

Micro, Small, and Medium Enterprises owners and entrepreneurs (MSMEs), the top-most job-to-be-done relates to their focus on driving operational efficiencies on the one hand, on access to low-cost funds on the other, and finally, towards market expansion. They tend to suffer from antiquated business procedures, lack of access to digital tools and financial resources. Key challenges for MSMEs come from various factors such as low digital literacy, high costs for adopting new technologies, and limited access to finance support. Digital Transformation among the enterprises will offer some large increase for this segment like efficiency, cost minimizing, and competitiveness.

The pains to solve and the gains to create in the case of MSMEs form the value proposition that you are addressing through SME Corp. MSMEs can leverage productivity and operational efficiencies by digital transformation support through low-cost and easy to access digital tools. The also give money in microloans and grants, which helps overcome the funding problems of businesses. On the other hand, training on digital skills and export promotion enable MSMEs to venture into international markets.

In this situation, the pain reliefs are subsidized tools & trainings, which will help in reducing the expenses and barriers related to the digital shift and make it easier to get grants. The gain creators for MSMEs are the customized financial solutions as well as the ability to grow and compete in the digital economy by giving them access to global markets while improving operational efficiency.
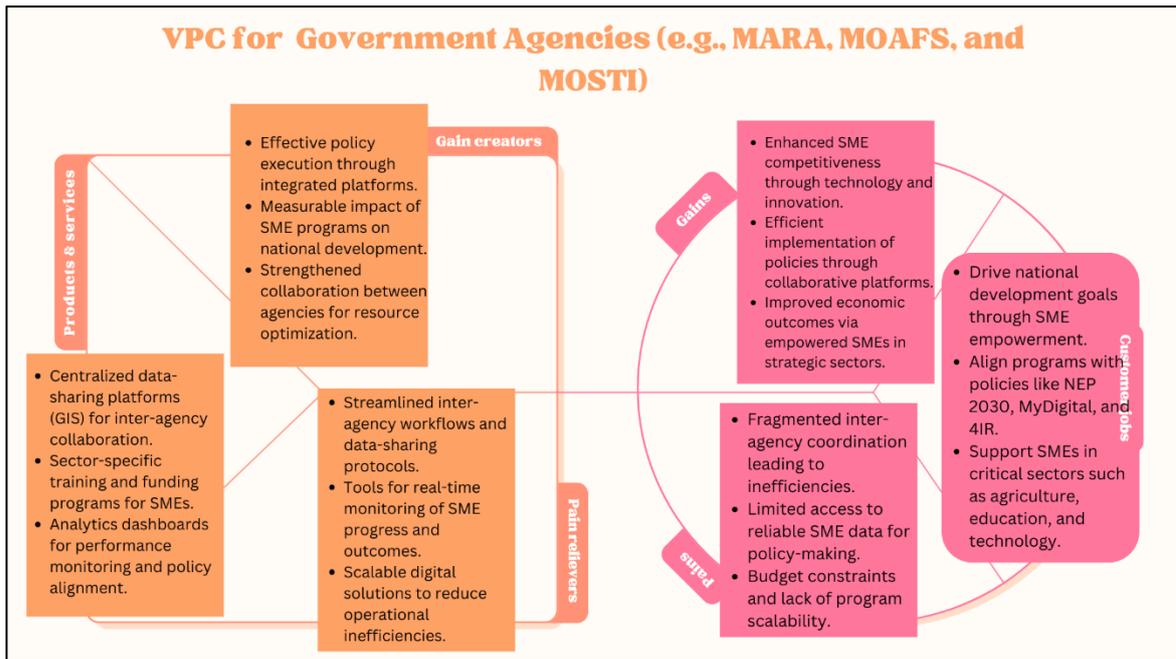
Fig. 4. VPC for Customer Segment: Government Agencies

Government agencies like MARA, MOAFS and MOSTI are major stakeholders for the development of SMEs that fit into the national economic agenda of Malaysia. For these agencies, the jobs-to-be-done are advancing entrepreneurship, championing sector-specific SME, and defining programs in the context of national policies such as MyDigital, NEP 2030 and 4IR. Their pains suffer on fragmented inter-agency coordination, inefficient resource allocation, and access to reliable data for evidence-based policymaking. According to the OECD (2020), fragmented data systems hinder policy implementation and limit the impact of government programs on SMEs.

The various workforce issues faced by SME Corp Malaysia can be solved with products or services like Government Information Sharing (GIS), which consists of national collaboration that centralises all your data sharing and operational workflows. Analytic tools like the above used in real time can also enable monitoring and evaluation of SME Programs, both to justify investment and to ensure they are aligned with national goals. Such solutions are like the pain relievers for some of the ill effects by reducing inefficiencies and equipping agencies with collaborative tools. Likewise, the gain creators encompass tangible improvement of SME competitiveness, leverage from valid implementation of policy and enhanced partnership between agencies (Dahlan et al., 2013).
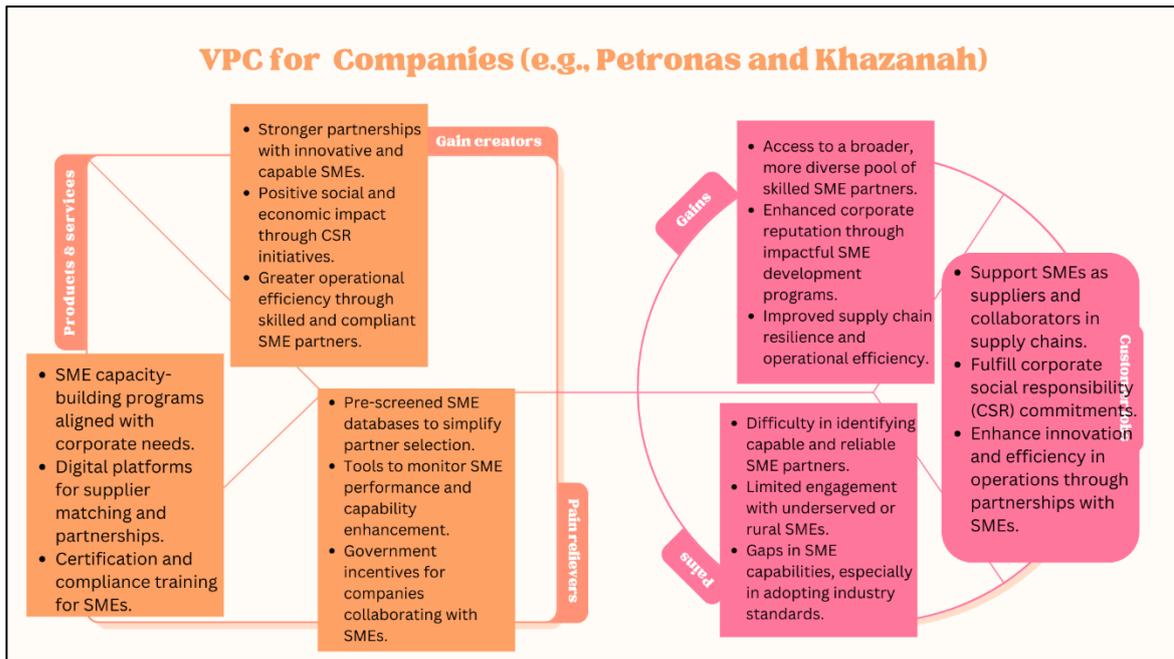
Fig. 5. VPC for Customer Segment: Companies.

Major corporations like Petronas and Khazanah play significant roles in supporting MSMEs through supply chain integration, corporate social responsibility (CSR), and innovation partnerships. Their jobs-to-be-done include identifying capable MSME partners, enhancing operational efficiency, and fulfilling CSR objectives. However, pains such as the difficulty in identifying reliable SMEs, limited engagement with rural entrepreneurs, and gaps in MSME capabilities pose challenges to achieving these goals. The Asian Development Bank (ADB, 2021) highlights that such challenges are common in developing economies, where SMEs often lack resources to meet corporate expectations.

To address these challenges, SME Corp Malaysia can provide products and services such as supplier matching platforms, compliance and certification training, and SME capacity-building programs. These solutions act as pain relievers by simplifying the process of identifying qualified MSMEs and enhancing their readiness to meet corporate standards. Gain creators for companies include strengthened supply chain resilience, improved corporate reputation through impactful CSR initiatives, and operational efficiency gains from partnerships with innovative MSMEs. These efforts align with best practices for fostering mutually beneficial collaborations between large corporations and MSMEs.
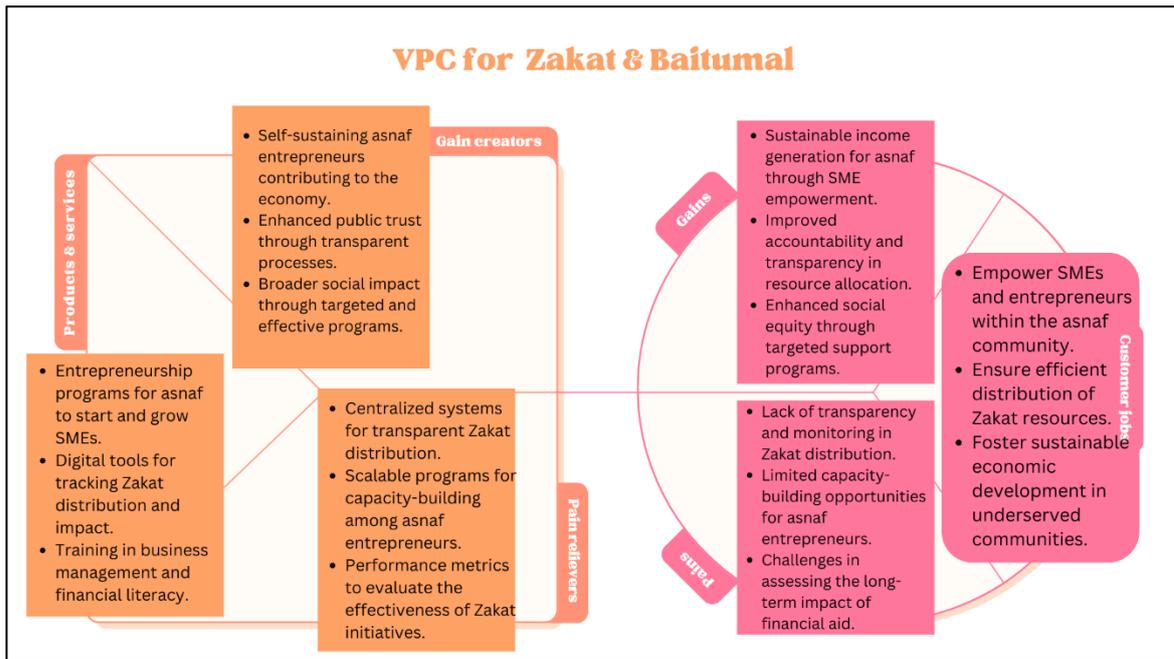
Fig. 6. VPC for Customer Segment: Zakat and Baitulmal

Through entrepreneurship and sustainable development programmes, institutions such as Zakat and Baitulmal are also working towards rebuilding the asnaf (underprivileged) community. They have jobs-to-be-done that involve more efficient resource allocation, sustainable self-reliance of beneficiaries, and transparency of operations. Nevertheless, long-term economic sustainability remains an issue due to ills such as insufficient capacity-building opportunities provided to asnaf entrepreneurs, the absence of stringent monitoring mechanisms, and a lack of transparent distribution of resources. According to the Islamic Development Bank (IsDB, 2022), transparency and accountability are critical for improving trust and maximizing the socio-economic impact of such programs.

In addressing these challenges, SME Corp Malaysia can provide products and services such as digital tools to monitor Zakat distribution, entrepreneurship programs and financial literacy training for the asnaf. These services, in the form of pain relievers, increase visibility, offer inclusive capacity-building solutions and enhance responsibility in Zakat dispensation. The gain creators are asnaf entrepreneur that drive the economy on their own, the public trust which gets better through more transparent process, and the social equity which can be broader through the rightful supported asnaf.

6. VALIDATION OF INITIAL BM & KEY FINDINGS

Author carried out interviews with various related customer segments (CS) namely, small, and medium enterprises (MSMEs), rural entrepreneurs, women entrepreneurs, and youth led businesses to validate the first Business Model. It was hoped to be able to learn about what they require, what their struggles are with, and what they expect of SME Corp. Here is a summary of the findings summarized into a table:

Table 1: Summary of Validation Findings

Business Model Component	Customer Insights	Key Refinements Proposed
Value Propositions	- SMEs highly value digital transformation support and affordable financing options. - Skill development programs aligning with 4IR are highly sought after. - Export facilitation is appreciated but seen as underdeveloped for rural MSMEs.	- Expand the scope of training programs to include more practical, industry-specific 4IR applications. - Introduce tiered financing options tailored to MSME sizes.
Customer Segments	- Rural SMEs face difficulties accessing digital tools and training. - Women entrepreneurs request mentorship programs focusing on overcoming social and financial barriers. - Youth-led businesses seek innovative and tech-driven solutions.	- Develop specialized training and financing for underserved groups. - Strengthen outreach programs targeting rural entrepreneurs.
Channels	- Digital platforms are seen as convenient but require user-friendly interfaces and localized support. - Workshops and webinars are effective for urban SMEs but challenging for rural access due to infrastructure issues.	- Invest in mobile-compatible platforms with multilingual support. - Provide hybrid options for training (online and physical) to improve accessibility for rural entrepreneurs.
Customer Relationships	- Mentorship programs are valued but currently limited in availability and scope. - Real-time support is essential but chatbots must offer personalized guidance to be impactful.	- Expand mentorship programs with sector-specific experts. - Improve AI chatbots to provide localized and context-aware support.
Revenue Streams	- MSMEs are willing to pay nominal fees for advanced training and certification if value is evident. - Government funding is crucial, but businesses suggest exploring sponsorships for public-private partnerships.	- Introduce premium-tier training programs with certifications for niche industries. - Partner with corporations to sponsor training programs for rural entrepreneurs.
Key Activities	- Digital literacy programs and export facilitation are well-received but require simplification and practical application.	- Design simplified guides and practical tools for digital adoption and international trade readiness.

Key Partners	- MSMEs encourage collaboration with local NGOs and cooperatives for rural outreach. - Global trade partnerships are seen as beneficial but underutilized.	- Strengthen local collaborations with NGOs to enhance rural SME participation. - Focus on building stronger networks with international trade organizations.
Cost Structure	- Entrepreneurs emphasize cost efficiency and transparency in programs and services.	- Ensure program costs are tiered and clearly communicated, with subsidies for underserved groups.

Through the validation, some aspects of the original business model of SME Corp Malaysia that can be improved to be more aligned to customer segments was discovered. Such improvement also includes plus providing digital promotion with a focus on developing mobile friendly, multi-language platforms to expand access particularly of rural SMEs and unrepresented populations. Moreover, mentorship should be broadened to provide sector-specific consultation targeted at women and youth entrepreneurs who need mentoring to overcome the specific challenges in their sectors. Export ready and digital transformation programs should come with practical tools, like ready-to-use guides and templates that allow easier implementation.

A third key improvement is a tiered training programs and financing options based on size and sector of the SME. It ensures that the solutions are cost-effective and relevant and encourages adoption of it by the SMEs according to their needs and capacities. Finally, collaboration should be strengthened based on the partnership with local NGOs to increase outreach in underserved areas and global trade organizations to provide SMEs with greater access to international markets. Together, this suite of refinements seeks to establish a more effective, inclusive, and effective ecosystem for SME growth and sustainability.

7. VALIDATED BUSINESS MODEL FRAMEWORK

7.1. Validated Business Model (BM)

Value Propositions: SME Corp Malaysia remains steadfast in its role of strengthening the competitiveness of SMEs by tackling key issues faced by them as they harness the opportunities offered by the digital economy. It offers a range of services that support businesses in their digital transformation, with customized training programs that assist SMEs in integrating solutions like artificial intelligence (AI), the Internet of Things (IoT), and big data to improve productivity. Furthermore, SME Corp offers integrated financial products like microcredit and venture capital to cater to financing issues, especially targeting unserved and rural SMEs. Skill-building programs aimed at reskilling and upskilling SME workers to adjust to the needs of the Fourth Industrial Revolution (4IR) thereby promoting workforce adaptability. Through its export facilitation programs and partnerships, SME Corp also provides access to a global market, enabling SMEs to expand their operations abroad.

Customer Segments: SME Corp Malaysia has a diversified customer segments as they the targeted all age group customers and in international markets. Focused

on micro, small and medium enterprises (MSMEs) that are the very backbone of the Malaysian economy. The focus is on rural entrepreneurs to prevent the urban-rural divide, women entrepreneurs and youth entrepreneurs through custom support and incentive to enable their active participation in the enterprising spirit.

Channels: SME Corp also provides these services on a blend between a digital and traditional channel. This also includes digital platforms like web portals and mobile applications that allow users to access training and financial assistance and mentorship services seamlessly. On-ground channels workshops, seminars, webinars burnout channels give a more direct engagement and networking opportunities. SME Corp also partners with private sector players, government agencies and NGOs in increasing its outreach and improving its service delivery.

Customer Relationships: SME Corp Malaysia is focusing more and more on developing personal relationships with SMEs. It offers mentorship programs that provide access to industry experts, helping SMEs address any challenges they face or capitalize on any opportunities for growth. Instant service is provided through chatbots and customer service hotlines to avoid delay. By offering forums, peer-learning groups, and even alumni networks, communities are brought to life and SMEs can share knowledge and collaborate in a living-organism-like ecosystem.

Revenue Streams: SME Corp earns via different forms and continues to do over time. Its financial structure is bolstered by federal funding and grants that aid national economic objectives. It also generates results via fee-based services as advanced training and certification services. Also, work via public and private partnerships and consulting services provides additional screening income and opportunities to work closely with industry stakeholders.

Key Resources: SME Corp uses various critical resources in order to provide its value propositions. We have a well trained and experienced workforce of Trainers, Consultants and Advisors who provide this expertise required for SME development. They also provide funds for technology infrastructure such as digital platforms and data analytics systems to support its programming. Its ability to drive meaningful initiatives is further augmented through strategic partnerships with technology providers, financial institutions, and trade organizations.

Key Activities: The agency performs a variety of functions to facilitate successful provision of services. These initiatives will involve creating and facilitating reskilling and upskilling programmes for SMEs that help provide the skills necessary for digital transformation. SME Corp also facilitates financing assistance, for example, microcredit and capital venture to stimulate business. It vigorously helps small and medium enterprises to enter global markets with regulatory advice, market information, and respective international trade partners.

Key Partners: The business model of SME Corp Malaysia depends on the collaboration with key stakeholders. Digital platforms and tools come from technology providers, whereas financial institutions provide funding mechanisms tailored to SME requirements. It also collaborates with government entities to have the alignment with national-level policies and the international bodies governing trade, where market access can be ensured to SMEs around the globe.

Cost Structure: Investments in infrastructure and digital platforms creating scalable & efficient service delivery. SME Corp also has the cost structure of technology infrastructure. Most of it is spent on training and outreach programs, to

fund the operations including salaries, logistics and marketing. Managing partnerships and collaborative programs also incurs costs but contributes to long-term organizational impact.

7.2. Environmental Map (EM)
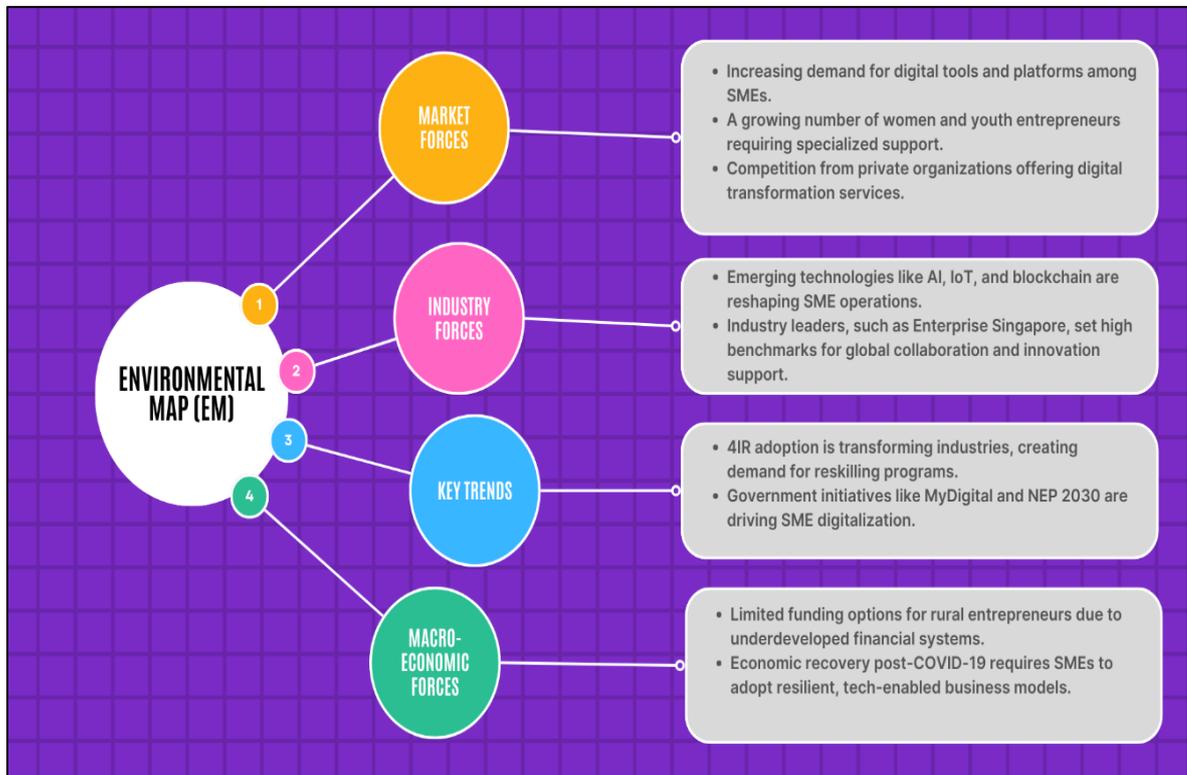
Fig. 7. Environmental Map for SME Corps Malaysia (SME Corps Malaysia Business Strategic Plan 2022-2030)

7.3. Strategy Canvas

The Strategy Canvas highlights the key differentiators of SMECorp-of-the-Future (SMEoF) compared to its current model (SMEoT).
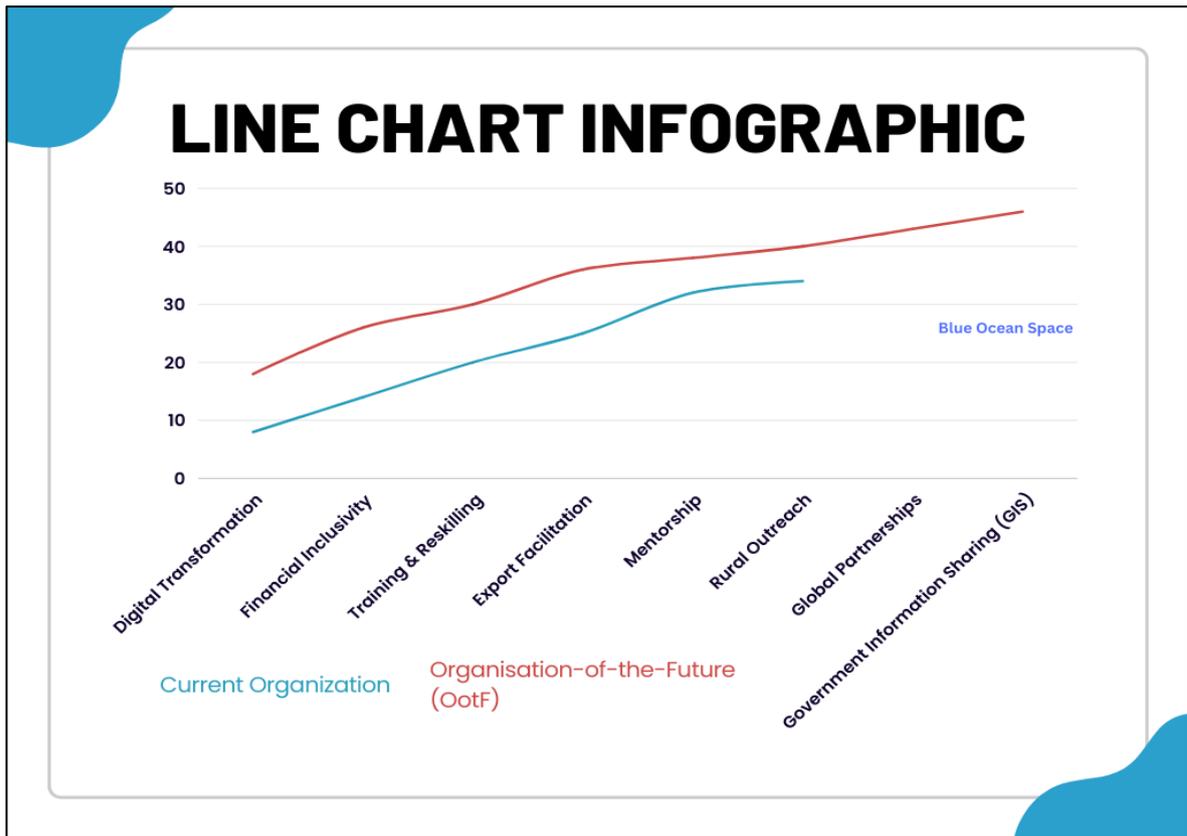
Fig. 8. Strategy Canvas

Table 2: SMECorp-of-Today (SMEoT) vs. SMECorp-of-Future (SMEoF)

Key Factors	SMEoT	SMEoF
Digital Transformation	Limited programs and tools available.	Comprehensive digital platforms, training, and subsidized digital tools.
Financial Inclusivity	Basic microloans with limited reach.	Tailored funding options for diverse SME needs, including rural and youth led.
Training & Reskilling	General training with minimal alignment to 4IR.	Reskilling programs aligned with 4IR technologies and industry specific needs.
Export Facilitation	Limited support for international trade and compliance.	Expanded programs for export readiness and global trade partnerships.
Mentorship	Small-scale mentoring programs.	Sector-specific, large-scale mentorship initiatives.
Rural Outreach	Inefficient and urban-centric programs.	Dedicated programs targeting rural entrepreneurs with localized solutions.
Global Partnerships	-	Connections to international trade organizations and foreign markets. Enhance global connections by

		establishing alumni chapters through international partnerships
Government Information Sharing (GIS)	-	Transformative initiative that enhances collaboration, coordination, & decision-making across agencies such as MEDAC, MAFS, MOSTI, MITI, Zakat & Baitulmal by creating a centralized platform for data and resource sharing.

8. CONCLUSION AND FUTURE WORKS

To meet the changing expectations of its multiple Customer Segments (CS) such as micro, small and medium enterprises (MSMEs), rural, asnaf, women, and youth entrepreneurs, SME Corp Malaysia needs to transform itself into an SMECorp-of-Future (SMEoF). Some of the most important issues that these groups confront are lack of digital skills, limited access to capital, and barriers to international trade. They expose key jobs-to-do, like expanding access to digital tools, inclusive funding, and global market scaling. The SMEoF business model also brings in critical differentiators like domain-specific guidance for digital transformation, bespoke advisory services, ready measure with government incentives paving way for export facilitation and ease access to funding. Functioning as pain relievers, these solutions alleviate funding challenges, a lack of talent, and issues pertaining to accessibility, and as gain creators, they improve productivity, widen the marketisation of services and products, and contribute to the resilience of entrepreneurs over the SME ecosystem in Malaysia.

The planned future work will allow SME Corp Malaysia to move into the **SMEo**F using its own Digital **Information Technology** Strategic Plan (DISP). It will detail the technical, operational, and strategic needs for executing advanced solutions such as architectures for digital platforms, advanced analytics for personalized services, and scalable training programs. To ensure functional operation, it would focus on establishing alliances with technology vendors, financial institutions and global trade groups. DISP will be calibrated with MyDigital, NEP 2030, 4IR and SME Corp Malaysia Business Strategic Plan 2022–2030 in making SME Corp as the game changer for SME landscape. In pursuit of inclusivity, innovation, and sustainable growth whilst maintaining relevance in the digital era, SME Corp Malaysia delivers **t**ailored solutions to its customer segments, using pain relievers and gain to create gain creators.

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AN ANALYSIS OF PUBLIC PERCEPTION TOWARDS TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING (TVET) ON THE FACEBOOK PLATFORM UTILISING LEXICON-BASED APPROACH

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ABSTRACT: The Malaysia government consistently emphasises the importance of Technical and Vocational Education and Training (TVET) as a crucial asset for the country, pushing all parties involved to prioritise it. Due to the rapid increase in social media usage, the public is becoming more likely to use social media platforms to interact and discuss various challenges in this field. An abundance of ideas can be accessed on the internet and should be employed to comprehend the viewpoint of important individuals involved and make necessary alignment to strategies and services. Unlike fields such as healthcare, business, and tourism, numerous sentiment studies have been conducted to examine the public perception with the goal of improving both services and products. However, there has been little investigation conducted on TVET. Therefore, this study is conducted to fill the gap by extracting TVET data from Facebook pages and public groups. The sentiment applied term frequency-inverse document frequency (TF-IDF) vectorization for extraction of valuable information evaluated by employing the accessible lexicons, namely Sentiwordnet, Valence Aware Dictionary sEntiment Reasoner (VADER), TextBlob, and AFINN. The evaluation results revealed that all lexicons exhibit a positive sentiment towards TVET. Moreover, by knowing the sentiment, it can facilitate policy makers and decision makers in formulating policies and strategies, as well as tackling existing difficulties and challenges for an enhanced TVET environment in the future.

KEY WORDS: *Sentiment, TVET, Lexicon, Accuracy, Recall, Precision, F1-score*

1. INTRODUCTION

Technical and Vocational Education and Training (TVET) is defined by UNESCO-UNEVOC as a set of educational programmes that are specifically related to the workplace. TVET encompasses both formal and informal learning approaches that equip youth with the know-how and abilities needed to become skilled workers and significantly contribute to economic growth (Wei Zhi & Anisah Atan, 2021; Yusoff et al., 2020). Additionally, TVET prepares young people for self-employment and job creation in the labour market (Mahuyu & Makochekanwa, 2020).

Currently, an enormous amount of social media data collected from multiple platforms in various formats can be simply and rapidly accessed (Kobayashi et al., 2018; Moe & Schweidel, 2017). Data obtained from social media can provide substantial and convincing insights. This information can facilitate the process of making well-informed decisions regarding future developments and policies (Baragash et al., 2022). Sentiment analysis or opinion mining is the process of extracting people's opinions, emotions, attitudes, and feelings about a topic or situation from a large amount of unstructured data (Mujahid et al., 2021). Sentiment analysis is more vital in the present digital age, as social media has emerged as a significant platform for user-generated information (Khan et al., 2024). Sentiment and opinion words often act a crucial part in the sentiment annotation of a document or sentence (Catelli et al., 2022). The primary aims of sentiment analysis is to understand people's viewpoints about certain topics, services and products which play an important role in decision making. Identifying the sentiment and opinion words can help to categorise the sentiment in an unsupervised manner (Dolianiti et al., 2019). Sentiment analysis helps us understand the thoughts, feelings, and views that people express online by figuring out the emotional tone behind a collection of words (Hermansyah & Sarno, 2020).

Sentiment analysis techniques can be categorised using machine learning, lexicon-based or hybrid techniques (Alharbi & Alhalabi, 2020). Machine learning technique performs selected algorithms such as Naïve Bayes, Support Vector Machine (SVM), and decision tree, to classify data into training and testing dataset. The lexicon-based technique uses pre-existing lexicon resources such as Sentiwordnet that contain the polarity of sentiment words to determine the polarity of a phrase (Rajeswari et al., 2020). The lexicon-based technique is often preferred over machine learning for sentiment classification due to its ability to provide flexibility in creating a customised sentiment vocabulary for emotion classification and does not rely on training data and consistently performs well across various domains (Rajeswari et al., 2020; Trivedi & Singh, 2021). However, lexicon that has attained a higher accuracy in one specific domain may not exhibit satisfactory performance in a different domain (Mohamad Sham & Mohamed, 2022).

Thus, this paper employs a lexicon-based technique to assess sentiment in TVET. The lexicons like SentiWordNet, VADER, TextBlob, and AFINN are employed and compared to determine the most reliable lexicons regarding accuracy, precision, recall, and F1-score value. The TVET dataset was subjected to preparation and pre-processing processes to lessen the presence of noise in the dataset. TF-IDF is performed for feature extraction prior to conducting sentiment analysis.

2. RELATED WORKS

Multiple approaches are employed for sentiment analysis, with the strategy chosen depends on the type of data and the platform being used (Mujahid et al., 2021). The lexicon-based approach is utilised in different industries, including business, education, healthcare, and tourism to figure out the perception and satisfaction levels of their services and products. Banerjee et al. (2021) examined the anticipations of social media users regarding information systems products that are currently at the conceptual phase and have not been released yet. An analysis was conducted on Twitter data pertaining to upcoming smartphones and smartwatches from Apple and Samsung. The polarity of the user's sentiment was determined using a lexicon-based technique, specifically utilising SentiWordNet. The dominant sentiment conveyed in tweets connected to Apple was neutral, whereas in tweets related to Samsung, it was positive. Furthermore, the analysis revealed that the percentage of tweets expressing negative sentiment was lower for Apple in comparison to Samsung.

Suhaimi et al. (2020) gathered Twitter data in English and Malay, specifically targeting concerns connected to Tun Hussien Onn Malaysia University (UTHM). Through the utilisation of a TextBlob lexicon, it was determined that all tweets could be categorised into three distinct sentiment categories which are positive, neutral, and negative. The analysis of English tweets revealed that 74% were positive and 26% were neutral. In contrast, an analysis of Malay tweets showed that 17% were positive, 82% were neutral, and 1% were negative. Examining positive and neutral sentiment revealed that individuals held a favorable view of the products and services, hence facilitating the international promotion and marketing of UTHM. Sukmana & Rusydiana (2023) conducted a study to examine the waqf education derived from Twitter platform. Their aim was to investigate sentiment and improve the waqf education practices in the future. They employed VADER lexicon to categorise the sentiment of each tweet. The results showed that in terms of sentiment polarity, the majority of tweets represented positive sentiment at 48.3%, followed by neutral sentiment at 27.0%, and negative sentiment at 24.8%.

In addition, Marcec & Likic (2022) performed sentiment analysis by employing the AFINN lexicon to monitor the sentiment concerning SARS-CoV-2 vaccine. A study was carried out on all English-language tweets mentioning the AstraZeneca/Oxford, Pfizer/BioNTech, and Moderna vaccines from December 2020 to March 2021. The results revealed that the sentiment towards Pfizer and Moderna vaccines remained consistently positive over four months. Nevertheless, the perception of the AstraZeneca/Oxford vaccine is gradually becoming more unfavorable, which could potentially increase reluctance toward this particular SARS-CoV-2 vaccination. Similar work was also carried out by Rizqiyah et al. (2024) to investigate the public perception of COVID-19 vaccinations in Indonesia using different lexicon. They utilised VADER to assess the opinions on the five most often given vaccines, including AstraZeneca, Moderna, Pfizer, Sinopharm, and Sinovac. Of the total, 39% expressed positivity, 18% expressed negativity, and 43% expressed neutrality. The general response of Indonesian population to each vaccine was predominantly positive and neutral. Sinopharm and Pfizer obtained the greatest sentiment scores, while AstraZeneca earned the lowest score.

The airline industry, specifically British Airlines, is also utilising lexicon-based approaches. Annamalai et al. (2024) conducted a study to identify the sentiment of

individual customer evaluations and categorise them as positive, negative, or neutral by employing VADER lexicon. The study's findings indicated that customer reviews for British Airways have a predominantly positive sentiment polarity. By discerning positive and negative sentiments, the airline can comprehend its strengths and regions in need of enhancement. Acquiring essential information and recommendations can assist British Airways in improving customer experience and marketing tactics.

3. LEXICON-BASED APPROACH

Lexicon-based approaches can automatically assign labels without the need for manual labelling. However, the most difficult aspect of the lexicon-based approach in sentiment analysis is comprehending the domain or context. The dictionary-based approach is straightforwardly associating specific keywords with their corresponding sentiment. Any terms that are not included in the specified keywords or the opinions expressed in the given context will be disregarded (Shaik et al., 2023).

3.1. Sentiwordnet

SentiWordNet lexicon is extensively utilised in sentiment analysis due to its reliability and accuracy. SentiWordNet assigns a numerical value to each word in its database, indicating its positive and negative sentiment scores. As the score increases, the sentiment becomes more positive, and conversely, as the score decreases, the sentiment becomes more negative (Khan et al., 2024).

3.2. VADER

Valence Aware Dictionary sEntiment Reasoner (VADER) is a lexicon-based approach that works on gold-standard heuristics with sentiment lexicons written in the English language. The lexicons are assessed and verified by human. They employ qualitative methodologies to enhance the performance of the emotion analyzer (Reshi et al., 2022). VADER analyses text and combines the sentiment values for each word based on its position in the lexicon. Furthermore, it incorporates grammatical and syntactical principles to consider modifiers (like as "very" or "slightly"), negations, punctuation, and other contextual elements. A normalised compound sentiment score ranging from -1 (extremely unfavorable) to +1 (extremely favorable) is computed for each statement (Soni & Mathur, 2023).

3.3. TextBlob

TextBlob is a Python library that used to analyse textual data. It offers an API for tackling natural language processing (NLP) tasks including part-of-speech tagging, noun phrase extraction, sentiment analysis, and classification (Loria, 2020). Polarity identification is based on the distinction between subjectivity and objectivity, with subjectivity referring to personal opinions and objectivity referring to factual data. A sentiment score below 0 indicates a negative feeling, while a

number above 0 indicates a positive sentiment. A score of 0 indicates a neutral sentiment (Reshi et al., 2022).

3.4. AFINN

AFINN lexicon derived from the Affective Norms for English Words lexicon (ANEW) in the English language, which was created by Nielsen (2017). Like VADER, it utilises a wide array of English words together with their corresponding sentiment scores. This approach employs a rule-based method, leveraging a meticulously created lexicon. The AFINN operates in a broader way, which is less intricate and requires fewer calculations (Reshi et al., 2022).

4. METHODOLOGY

The sentiment analysis of TVET involves a series of phases, as illustrated in Fig. 1. These steps include data collection, text preparation and pre-processing, feature extraction, sentiment analysis, and performance evaluation.
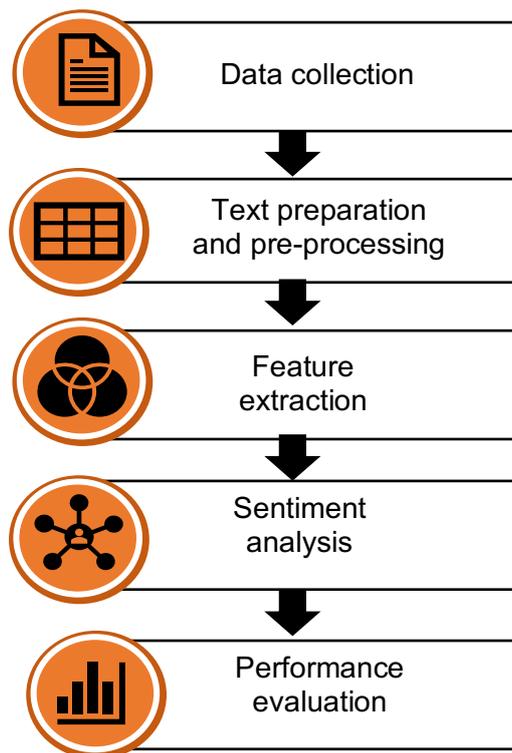

Fig. 1. Phase of works in sentiment analysis

4.1. Data Collection

The TVET dataset was acquired through the collection of data from Facebook pages and public groups. The collected data is specifically centred around posts and comments that relate to TVET. We gathered the data published from April 2021 to March 2023. Data is collected using two distinct applications, namely Facepager and Apify. Jünger & Keyling (2019) developed Facepager, a tool that utilises APIs and web scraping to retrieve publicly accessible data from platforms such as YouTube, Twitter, and other websites. The apify programme is utilised to gather data from a Facebook public group. The unprocessed data collected is retrieved as a .csv file. The file was converted into a .xlsx format by separating the content into columns, resulting in improved readability for posts and comments.

4.2. Data preparation and pre-processing

The data has been undergoing text preparation step. Text preparation involves the elimination of irrelevant text as well as the correction of misspelled words, abbreviations, and slang. The Malay data was subsequently translated into English. While data pre-processing involved several steps such as transforming text into lowercase, removing punctuation, and removing stop words. The number of posts selected for analysis after data preparation is 1,304.

4.3. Feature Extraction

Feature extraction is conducted to convert textual input into a numerical representation (Stanley et al., 2023). The term frequency-inverse document frequency (TF-IDF) is a commonly employed technique for extracting features (Reshi et al., 2022). TF-IDF uses two components to measure the relevance of words which are, TF indicates the importance of words while IDF displays the word distribution within the collection of documents (Edalati et al., 2022). In this study, TF-IDF is used because to its superior performance, particularly in enhancing accuracy measures.

4.4. Sentiment Analysis

Sentiment analysis uses Python programming code by importing lexicon libraries such as Sentiwordnet, VADER, TextBlob, and AFINN. Data polarities are categorised into three distinct classifications, which are positive, neutral, and negative. The compound sentiment score defines the polarity, which is determined using the relevant vocabulary. Afterwards, the evaluation of the lexicon's performance is calculated.

4.5. Criteria of Evaluation

To evaluate the classification of sentiment, four measurements were being evaluated which are accuracy, precision, recall, and F1-score. Accuracy is a metric that measures the likelihood with which a model precisely predicts the outcome (1). Precision indicates the frequency with which a model precisely predicts the target class (2). Recall is a quantify of the frequency with which a model precisely identifies positive instances (true positives) from all of the actual positive samples in the dataset (3). Lastly, the F1-score is a metric that measures the accuracy of a model on a given dataset (4).

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \qquad (1)$$

$$Precision = \frac{TP}{TP+FP} \qquad (2)$$

$$Recall = \frac{TP}{TP+FN} \qquad (3)$$

$$F1\text{-} score = \frac{2 \times precision \times recall}{precision + recall} \qquad (4)$$

Whereas,

TP: the number of correctly classified positive values;

TN: the number of correctly classified negative values;

FP: the number of incorrectly classified positive values; and

FN: the number of incorrectly classified negative values.

5. RESULTS AND DISCUSSION

The results of this study are indicated that all the lexicons have a positive sentiment towards TVET data. TextBlob has the most higher positive polarity at 53.8%, followed by Sentiwordnet at 51.0%, AFINN at 47.7%, and VADER at 44.7%. For neutral polarity, AFINN shows higher percentage with 34.8%, VADER with 33.7%, TextBlob with 31.9%, and Sentiwordnet with 30.0%. On the other hand, negative polarity shows that VADER takes the lead with 21.6%, followed by Sentiwordnet with 19.0%, AFINN with 17.5%, and TextBlob with 14.3%. Fig. 2 presents the overall polarity percentage of TVET dataset.
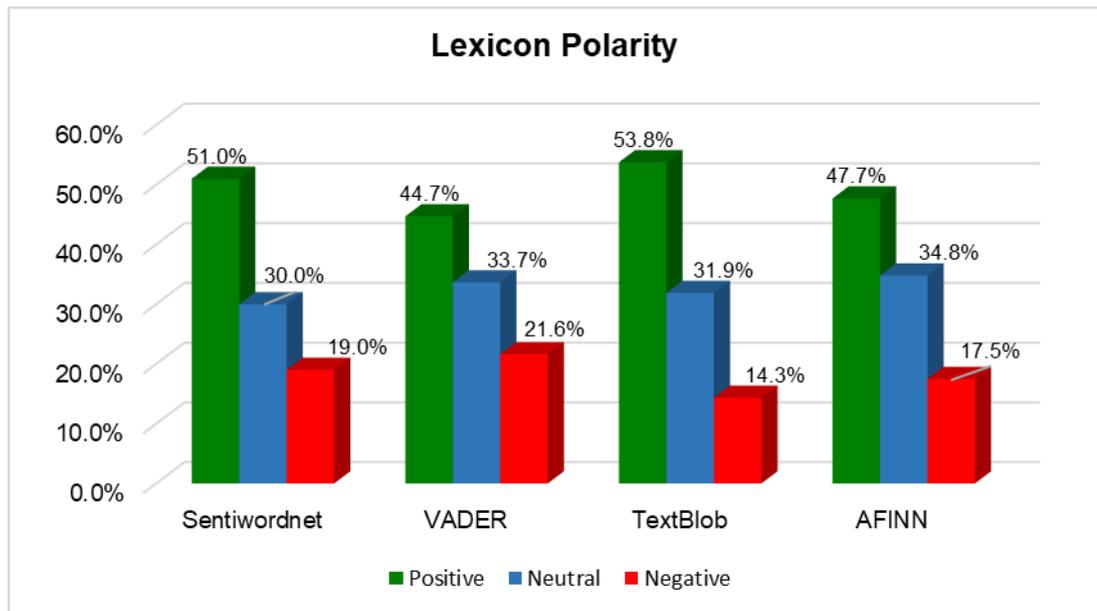
Fig. 2. Polarity of sentiment

Based on accuracy, this finding shows that the VADER lexicon outperformed other lexicons by achieving an overall accuracy rate of 69.9%, surpassing AFINN, which achieved 67.7%. Furthermore, TextBlob demonstrated a performance rate of accuracy with 61.9%, while Sentiwordnet attained a slightly lower rate of 54.9%. Fig. 3 shows the accuracy of TVET dataset performance.
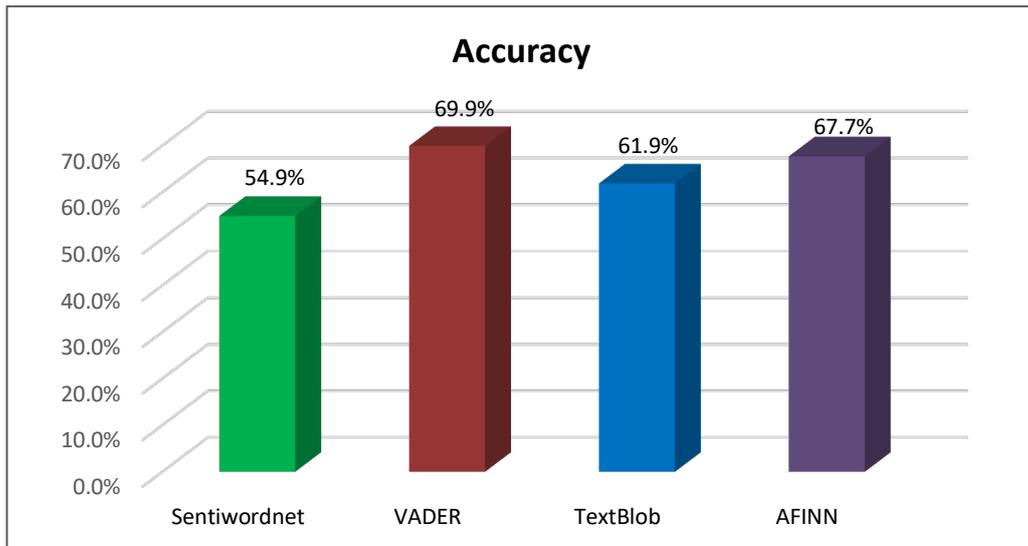
Fig. 3. Accuracy of lexicons

The VADER lexicon has shown excellent accuracy in correctly categorising positive and negative sentiment by prioritising the F1-score. VADER achieved the highest F1-scores of 0.76 and 0.63 for both positive and negative polarity classification. Table 1 shows the evaluation criteria for TVET dataset.

Table 1: Evaluation criteria in TVET dataset

Sentiment Lexicon	Accuracy	Positive			Neutral			Negative		
		P	R	F	P	R	F	P	R	F
Sentiwordnet	54.9%	0.63	0.69	0.66	0.53	0.33	0.40	0.39	0.53	0.45
VADER	69.9%	0.79	0.72	0.76	0.64	0.67	0.66	0.59	0.68	0.63
TextBlob	61.9%	0.67	0.69	0.68	0.55	0.64	0.59	0.60	0.40	0.48
AFINN	67.7%	0.78	0.72	0.75	0.60	0.71	0.65	0.58	0.53	0.56

P: Precision, R: Recall, F: F1-score

6. CONCLUSION

This study utilised a lexicon-based approach to determine the public's perception on Facebook regarding TVET concerns. Four distinct dictionaries, Sentiwordnet, VADER, TextBlob, and AFINN, are employed to determine the polarity and accuracy.

Based on the results of the study, all lexicons indicate a favourable opinion towards TVET. TextBlob has the highest positive classification, while VADER exhibits the highest percentage on negative classification sentiment. Additionally, optimal outcomes using these lexicons are also measured by calculating the accuracy. The outcome demonstrates that VADER lexicon shows superior performance, with a higher accuracy rate of 69.9% compared to other lexicons. Furthermore, VADER performs better in classifying positive and negative polarity, achieving the highest F1-scores of 0.76 and 0.63, respectively.

Therefore, the polarity gain can assist stakeholders involved in policy and strategy development in TVET in making more informed decisions to realign and enhance the TVET ecosystem. Further improvement can be done by implementing topic modeling for each polarity to identify specific themes and make targeted improvements accordingly.

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A CONCEPTUAL VIRTUHOME BUSINESS MODEL: TRANSFORMING REAL ESTATE WITH IMMERSIVE TECHNOLOGY FOR ENHANCED PROPERTY EXPERIENCE AND WELLBEING

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ABSTRACT*:* This paper introduces VirtuHome, a conceptual business model that leverages VR (Virtual Reality) and AR (Augmented Reality) technologies to transform the real estate experience and wellbeing. VirtuHome offers a digital platform and mobile application that allows customer segment (CS) like home buyers and renters, real estate developers, and property investors to explore properties virtually, enhanced branding through technology and foresee the real-time market insight. The platform addresses the key challenges faced by these CS by providing features like immersive virtual tours, interactive AR home staging, and remote live consultations. The methodology applied in this project is the Design Thinking (DT), which involves understanding the CS needs through literature review, benchmarking similar business like iProperty, Property Guru, and interviews. This is followed by ideation, prototyping, and validation using business modeling tools such as the Business Model Canvas (BMC) and Value Proposition Canvas (VPC), Business Environmental Map (EM), and Strategy Canvas (SC) to establish the validated business model of VirtuHome. Key findings reveal the significant potential of VirtuHome in enhancing CS's experiences and wellbeing to improve convenience; optimise costs, time, and energy; and support smarter property decision-makings. Future work includes expanding the platform's features with AI and analytics, and developing a comprehensive business plan based on the validated VirtuHome business model.

KEY WORDS: *Virtual Reality (VR), Augmented Reality (AR), Real Estate, Immersive Virtual Tours, Design Thinking (DT), Business Model*

1. INTRODUCTION

In today's digitally driven world, the property search process still poses significant challenges. While many individuals turn to online platforms to find houses or rentals, the experience is often inefficient and frustrating. Buyers frequently encounter misleading listings, limited visualization, and the burden of physically visiting multiple properties before deciding (Solanki et al., 2023). This inefficiency wastes time, creates stress, and limits accessibility.

For home buyers and renters, the main frustrations involve excessive effort and uncertainty. Virtual tours and AR tools can reduce these issues by allowing users to visualize properties and furniture placement remotely. Research has shown that immersive technologies significantly enhance user engagement and decision-making in real estate transactions (Solanki et al., 2023; Kangda et al., 2023).

For real estate developers, managing repeated site visits and maintaining costly show units poses a challenge. The integration of VR and AR technologies offers a more efficient way to present properties and close deals faster while minimizing operational costs (Sittler, 2017). Developers benefit from a more engaging and sustainable model that allows buyers to preview properties virtually.

Property investors also struggle with comparing multiple properties quickly and effectively. They often lack the time for physical visits. An immersive, data-driven platform can offer remote access to detailed layouts and property analytics, improving their investment decisions (Kangda et al., 2023).

Platforms like PropertyGuru, iProperty, and EdgeProp in Malaysia, and international platforms like Zillow (USA) and Rightmove (UK), support traditional online property browsing. However, they mainly rely on static images and lack interactive experiences. These platforms fall short of allowing users to "walk through" homes or visualize furniture in context.

To solve these issues, VirtuHome proposes a next generation solution using Virtual Reality (VR) and Augmented Reality (AR) to deliver realistic, immersive property experiences. Through digital tours, virtual staging, and live remote consultations, users enjoy a faster, more informative, and environmentally friendly property search process.

2. PROBLEM STATEMENT/OBJECTIVES

The main users who face these problems are:

i) Home Buyers and Renters

- Job-to-do: Find and compare suitable homes quickly, confidently, and remotely.
- Extreme pains: Time wasted visiting unsuitable properties, poor visualization from static photos, uncertainty in decision-making.
- Important gains: A faster, easier, and more visual property search experience that builds confidence and reduces stress. Real estate developers: They want to promote properties and close deals faster. Their problems include spending money on setting up showrooms and dealing with many viewing appointments. They want better ways to show off their properties and reach more people.

ii) Real Estate Developers

- Job-to-do: Market properties efficiently, attract leads, and reduce the cost of physical showrooms.
- Extreme pains: High expenses on setting up and maintaining physical showrooms, slow deal closures, and managing multiple viewing appointments.

- Important gains: Cost-effective, innovative tools to showcase unfinished or empty properties virtually to a wider audience.

iii) Property Investors

- Job-to-do: Market properties efficiently, attract leads, and reduce the cost of physical showrooms.
- Extreme pains: High expenses on setting up and maintaining physical showrooms, slow deal closures, and managing multiple viewing appointments.
- Important gains: Cost-effective, innovative tools to showcase unfinished or empty properties virtually to a wider audience.

3. METHODOLOGY

In this project, we used the Design Thinking (DT) approach to develop our conceptual VirtuHome business model. The DT method helped us understand customer needs, design our solution, and test it. Below are the steps we followed:

i) Empathize – We conducted a literature review, benchmarking of similar companies using the BMC framework, and surveys/interviews to learn about the challenges and problems faced by home buyers, renters, real estate developers, and property investors (CS).

ii) Define – Based on the information collected, we clearly identified the key problems of our customer segments (CS), including their job-to-do, extreme pains, and essential gains. These problems include time wasted during physical visits, difficulty in visualizing properties, and high costs in promoting listings.

iii) Ideate – We brainstormed and created ideas to solve these problems. Our ideas included features like VR virtual tours, AR home staging, and live consultations with agents. We planned to develop these features in a digital platform (mobile app and website).

iv) Prototype – We developed an initial Business Model (BM) for VirtuHome using Business Modelling Tools such as the Business Model Canvas (BMC), Value Proposition Canvas (VPC), Strategy Canvas, and Environmental Map. These tools helped us visualize key elements of the business, identify the unique value proposition, assess the competitive landscape, and understand the broader market environment to ensure a comprehensive and strategic approach to the platform's development.

v) Test/Validation – We conducted interviews and surveys with representatives from each CS to test and validate our initial business model. Based on feedback, we refined and finalized the model to ensure its fit with user expectations and market needs.

vi) Comparison and Strategy Canvas – We used the Strategy Canvas to compare VirtuHome against other platforms, evaluate its sustainability and relevancy from various CS perspectives, and identify unique advantages that make VirtuHome a stronger alternative in the property tech market.

4. LITERATURE REVIEW

4.1. The Fourth Industrial Revolution (4IR) and Its Impact on the Real Estate Industry

The Fourth Industrial Revolution (4IR) represents a transformative period characterized by the integration of advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, Virtual Reality (VR), and Augmented Reality (AR) into various industries, including real estate. These innovations have significantly reshaped business landscapes by enhancing efficiency, optimizing resources, and improving decision-making processes. Digitalization, as defined by Deloitte (2013), involves changing business models by improving processes through information and communication technologies. In the real estate sector, this means leveraging digital tools to enhance customer experiences, streamline operations, and create new business models.

One of the dominant megatrends of 4IR is the widespread adoption of AI and big data in market analysis and forecasting. As highlighted by Yang (2024), big data analytics has improved real estate market forecasting accuracy by 15.2%, enabling more precise investment strategies and risk assessments. Additionally, AI has been instrumental in property management, increasing operational efficiency by 17.6% and reducing maintenance costs by 13.2% (Yang, 2024). These trends suggest that data-driven decision-making is becoming a crucial component of real estate market sustainability.

Another key aspect of 4IR is the integration of IoT in smart buildings, leading to improved building automation, energy efficiency, and security. IoT applications have resulted in a 10.3% reduction in energy consumption and a 17.5% improvement in security measures (Yang, 2024). These advancements contribute to sustainable and cost-effective building management, addressing both economic and environmental concerns in real estate development.

The adoption of VR and AR in real estate is another crucial element of digital transformation. VR allows potential buyers to explore properties remotely through immersive virtual tours, enhancing accessibility and reducing the need for physical visits. AR, on the other hand, enables users to visualize potential renovations or furniture layouts in real-time, aiding decision-making. As noted by Catella (2016), PropTech, which combines property and technology, is driving innovation in the real estate sector by leveraging such technologies to create new business models. However, challenges remain, including technological barriers and user adoption, as the fast-paced development of technology requires continuous adaptation and investment in new tools.

As digital technologies continue to evolve, their impact on business models and customer experiences in real estate will only grow. The real estate sector must embrace these changes to remain competitive and innovative, leveraging technologies such as AI, big data, IoT, VR, and AR to enhance operations and meet evolving customer needs. The integration of these technologies is not only reshaping the industry but also reinforcing the importance of digital transformation in business resilience. Future advancements in 4IR will likely drive further innovations, ensuring the long-term competitiveness and efficiency of the real estate industry.

4.2. Reskilling and Upskilling for the Digital Economy

Upskilling and reskilling of Malaysia's bottom 40% income group (B40), especially retrenched workers, are crucial in the Fourth Industrial Revolution (4IR) context. The Malaysian government has introduced several initiatives for poverty eradication and inclusive economic development through skills development, especially. Darmalinggam et al. (2022) emphasized the need for job opportunities and career advancement for the B40 segment under the Shared Prosperity Vision 2030. Yet, between the presumed impact of such interventions and actual effects, there is a wide gap, usually accounted for by the absence of synchronism between governmental initiatives and the dynamics of the labor market.

A core issue relates to the changing work ecosystem spurred by the Fourth Industrial Revolution (4IR), which calls for the development of higher and new skill sets. Many in the B40 group are either unemployed or working in subordinated jobs due to their lack of corresponding competencies. Darmalinggam et al. (2022) elaborate that key fields such as data sciences, green accounting, and forensic economics require immediate attention in the form of establishing training programs to address contemporary industry needs. These observations support the importance of low-cost training aimed at addressing the changing needs of the digital economy.

These obstacles have been faced by the government of Malaysia, which has addressed them through certain detailed initiatives. These include an EmpowerHER Digital program formed by the Malaysia Digital Economy Corporation (MDEC) in coordination with Digital Nasional Berhad (DNB) to enhance digital skills and empower women who fall under the B40 income group. The project offers a sequence of workshops and talks by industry experts, along with access to online platforms like Shopee and TikTok, for hands-on access to aspects of online branding, financing, and digital business operations. Such interventions are an excellent illustration of a comprehensive policy intervention aimed at the creation of digital literacy and entrepreneurial skills among underrepresented groups.

Yet there are numerous challenges in translating these efforts into fruitful results. A majority of Malaysian manufacturing SMEs face hindrances to the adoption of Industry 4.0 technologies, and financial limitations and shortages of skilled manpower are prominent concerns (Wan Fauziah Wan Yusoff et al., 2023). The hindrances are not limited to manufacturing but have been noted among other industries in the process of being digitalized.

The results indicate that government assistance, through the provision of financial assistance, technical advice, and advisory services, is effective in stimulating greater involvement throughout the industry regarding upskilling programs. Furthermore, the effectiveness of training programs is also heavily reliant on the extent to which they align with the actual demands of the industry. Darmalinggam et al. (2022) write that a "discontinuity" typically occurs between employer expectations and training content, diminishing the overall success of reskilling initiatives.

Enhanced digital upskilling and reskilling initiatives will both generate more employment possibilities for B40 groups and boost innovative developments in digital transformation sectors. People gain better economic participation power by possessing relevant talents that include data literacy and smart technology

knowledge along with digital marketing expertise. A better integration of training curriculum to industry requirements will help Malaysia develop an inclusive workforce alignment with modern needs.

4.3. The Business Potential of VR and AR in Real Estate

The integration of Virtual Reality (VR) and Augmented Reality (AR) technologies has significantly transformed the real estate sector, offering innovative ways to market properties, engage potential buyers, and streamline decision-making processes. These technologies are reshaping traditional practices by introducing immersive, interactive experiences that enhance customer satisfaction while reducing operational costs.

4.3.1. Market Growth and Adoption of VR and AR

The adoption of VR and AR is becoming increasingly prominent in real estate, reflecting a broader trend toward digital transformation across industries. These technologies allow users to engage with property listings in dynamic, interactive ways, replacing static images and conventional tours. As Solanki et al. (2023) note, "Technology offers new exciting and meaningful opportunities, which in return, change the face of how users work and deliver ever-more complex projects for the customers" (p. 19). The rising adoption of these tools indicates a shift in consumer expectations and business strategies within the property sector.

4.3.2. Cost Efficiency and Accessibility

VR and AR offer cost-saving advantages by reducing the need for physical property staging, travel, and repetitive site visits. In a cost comparison analysis, Solanki et al. (2023) found that using VR for property tours can reduce marketing expenses by up to 45% compared to traditional methods (p. 31). Furthermore, VR enhances accessibility by enabling remote property exploration, which is especially beneficial for out-of-town buyers or during movement restrictions. Hussin and Abu Bakar (2023) emphasize this benefit by stating, "VR technology brings increased accessibility, particularly for remote buyers" (p. 390).

4.3.3. Enhanced Customer Experience and Competitive Edge

The immersive nature of VR and AR technologies allows potential buyers to explore and visualize properties more effectively. Users can interact with digital spaces in real-time, adjusting layouts or design elements to better understand the living experience. Hussin and Abu Bakar (2023) highlight this advantage, stating that "VR technology captivates potential buyers by offering an immersive and interactive property viewing experience" (p. 390). Solanki et al. (2023) also note that such immersive simulations create smoother workflows between clients and real estate firms, thereby improving customer engagement and decision-making processes (p. 22).

4.3.4. Future Potential with AI and Data Analytics

The integration of VR with emerging technologies such as Artificial Intelligence (AI) and data analytics holds promising prospects for the real estate industry. AI can assist in providing personalized property recommendations, automating routine processes, and generating actionable insights from user data. Hussin and Abu Bakar (2023) encourage further exploration into how VR influences long-term buyer behavior and purchasing decisions (p. 397), while Solanki et al. (2023) suggest that

incorporating AI will enhance efficiency across all stakeholder interactions in real estate transactions (p. 21).

4.4. Business Model Canvas (BMC) Analysis of Benchmark Applications: PropertyGuru and iProperty
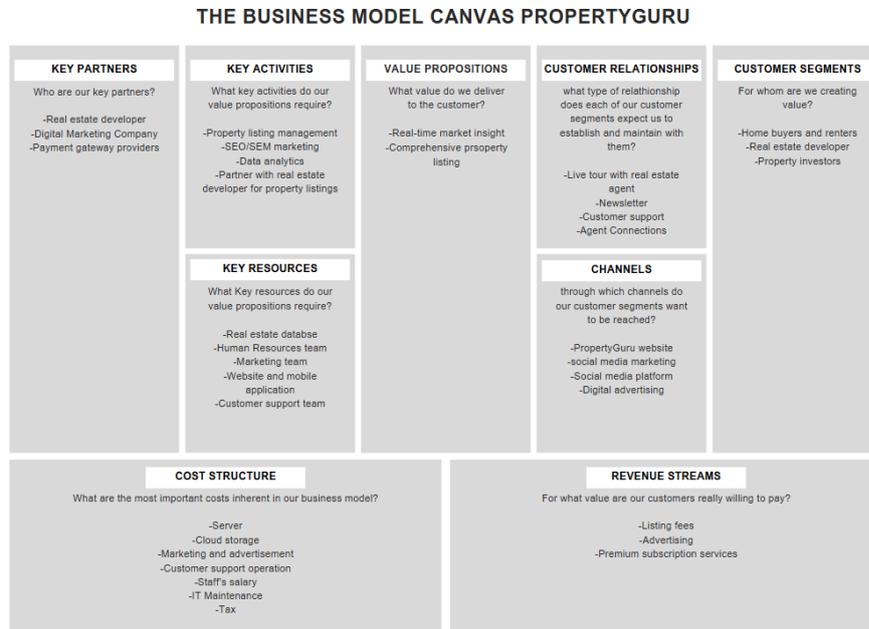
4.4.1. PropertyGuru

Fig. 1. Business model canvas for PropertyGuru

PropertyGuru is a leading online property platform headquartered in Singapore and operates across Southeast Asia. It offers a large range of property listings, market data, and financing tools. Its strength lies in a user-friendly interface and advanced search filters. PropertyGuru serves a wide range of customer segments including home buyers and renters, property investors, and real estate and developers. Its value lies in providing reliable listings and real-time market insight in order to help users make smarter property decisions. The platform effectively uses digital channels such as its website, mobile apps, and social media to reach and engage users. It builds relationships through personalized alerts, newsletters, AI-driven property suggestions, and direct communication with agents.

Revenue primarily comes from listing fees, advertising packages, and premium services offered to agents and developers. This ensures a consistent income stream. To support these services, PropertyGuru relies on key resources such as its comprehensive property database, solid IT infrastructure, and its strong brand reputation. Operationally, the platform focuses on listing management, search optimization, customer service, and leveraging user data analytics to enhance performance. Its key partners like real estate agencies, developers, financial institutions, and marketing firms help maintain the platform's relevance and service quality. The cost structure reflects significant investments in tech development, server maintenance, marketing, and support teams, ensuring the platform remains competitive and reliable.

Compared to iProperty, PropertyGuru demonstrates a broader regional presence and stronger AI integration for personalization. However, both platforms still lack immersive features like virtual walkthroughs or AR-based visualization. While iProperty excels in delivering localized content and engaging property news to its Malaysian audience, PropertyGuru leads in automation and tech-based recommendations. These insights allow PropertyGuru to position itself as a next-generation solution that not only matches the strengths of these platforms but also introduces novel features to improve property decision-making through immersive experiences.

4.4.2. iProperty
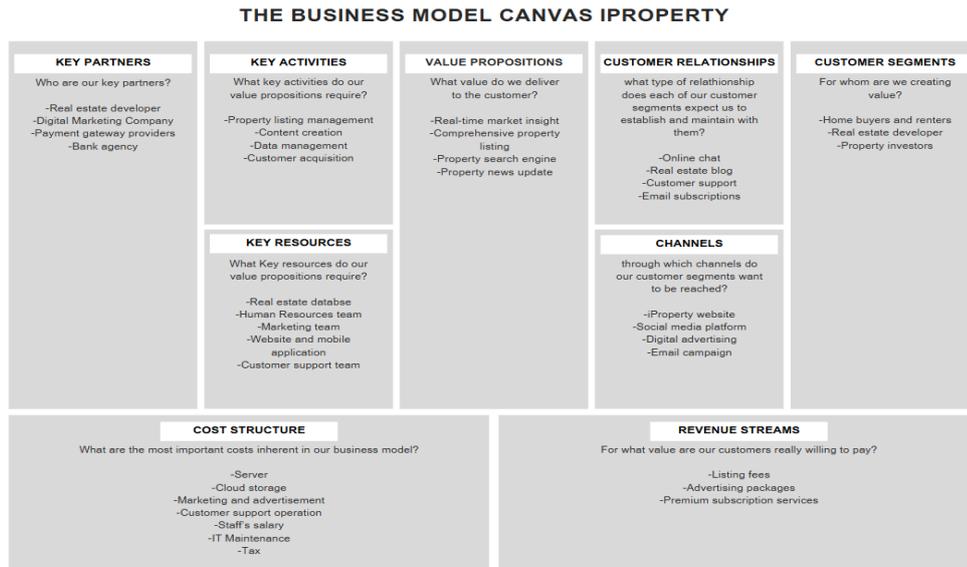
Fig. 2. Business model canvas for iProperty

iProperty focuses primarily on the Malaysian market and caters to customer segments including first-time home buyers and renters, property investors, and real estate developers. Its value proposition is almost the same as PropertyGuru, which appeals particularly to users seeking trusted information in a Malaysian context. IProperty connects with its customers through a mobile-responsive website, social media platform, and digital advertising. iProperty builds customer relationships by offering tools like real estate blogs, email subscriptions, and easy access to agent contact information (iProperty.com.my, 2023). Revenue is generated through premium listing services and advertising packages for developers and agents. iProperty also occasionally partners with banks and insurance providers to provide financing-related advertisements. In terms of key resources, it relies on its brand recognition in Malaysia, a robust property database, and content creators focused on market trends and Real estate advice. The key activities include managing property data, providing customer support, marketing, and creating localized content that resonates with the Malaysian audience.

Key partnerships include real estate agencies, developers, local media, and event organizers for property expos. These partnerships strengthen iProperty's local credibility and engagement. The cost structure is largely composed of platform maintenance, staff salaries, marketing expenses, and partnership deals. While iProperty excels in offering localized insights and news, it lacks advanced

interactive tools such as VR tours or AR-based staging. Compared to PropertyGuru, iProperty is more narrowly focused but leverages that specialization well. However, both platforms still rely on traditional listing experiences. This creates a gap for a VR or AR based technology to fill by combining the regional outreach and automation of PropertyGuru with the local engagement and trusted content of iProperty, enhanced through immersive technologies.

5. INITIAL BUSINESS MODEL (BM) – USING BMC & VPC

VALIDATED BUSINESS MODEL CANVAS VIRTUHOME

Fig. 3. Initial Business Model Canvas for VirtuHome

Based on the Literature Review conducted above, the initial Business Model, using BMC framework, is as shown in Fig. 3 above.
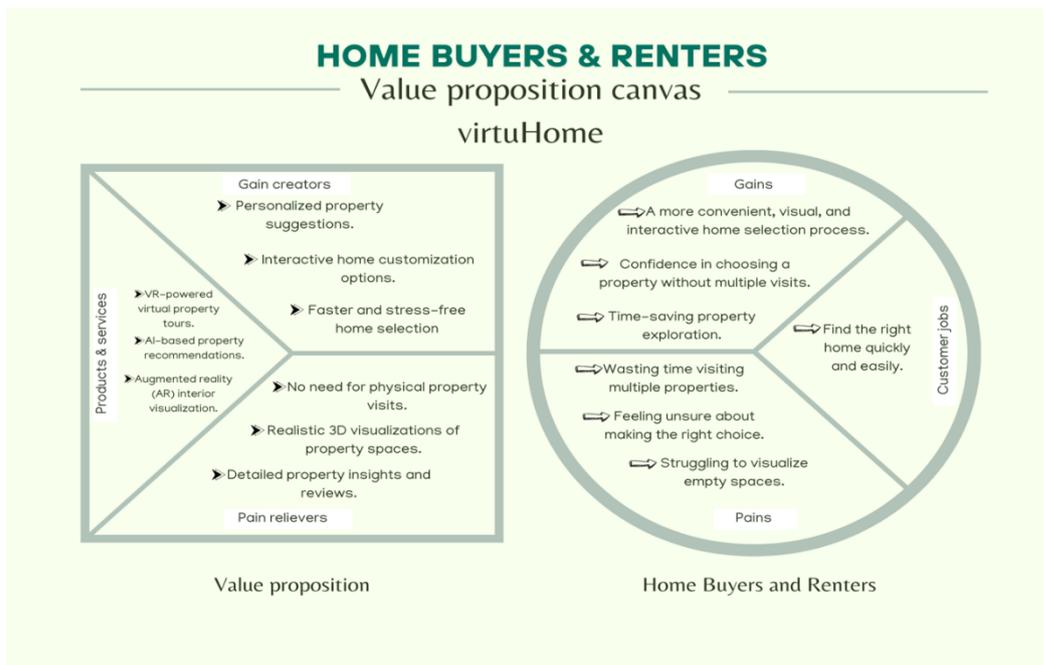
Fig. 4. Value Proposition Canvas for Home Buyers & Renters
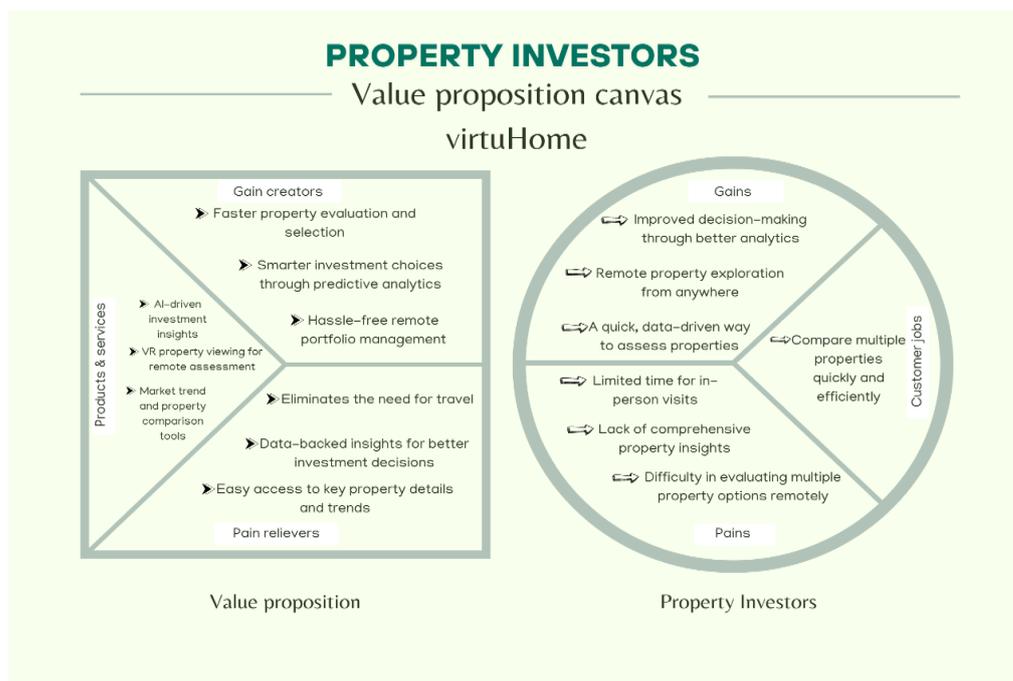
Fig. 5. Value Proposition Canvas for Property Investors
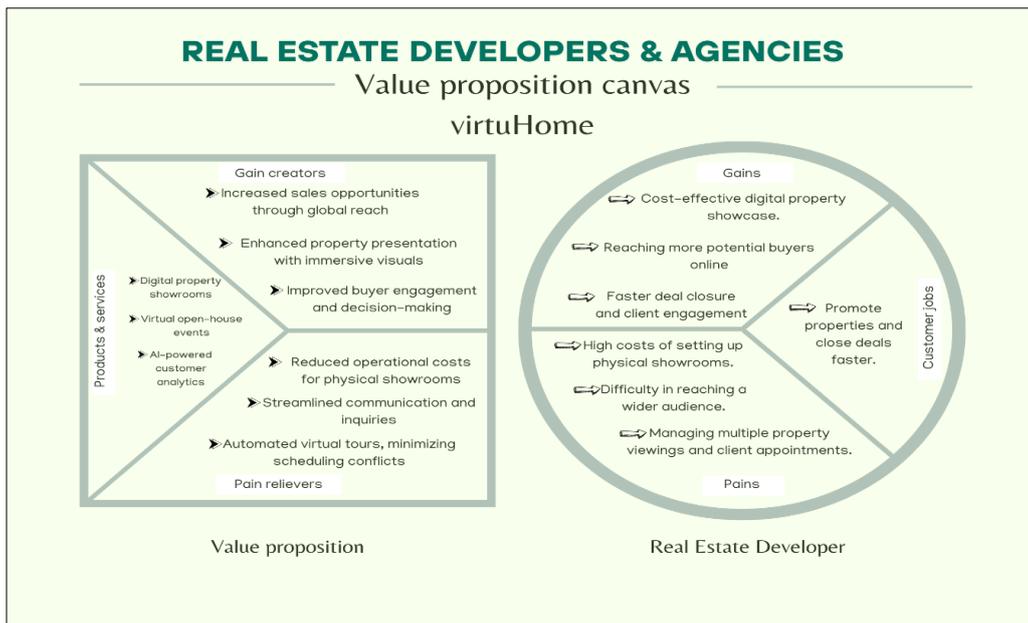
Fig. 6. Value Proposition Canvas for Real Estate Developers & Agencies

6. CONDUCT VALIDATION OF INITIAL BM & KEY FINDINGS

To validate our initial business model, an online survey with only 9 questions has been distributed through social media and 20 responses from our potential customer segments. In the following, we will be discussing the summary of the responses.
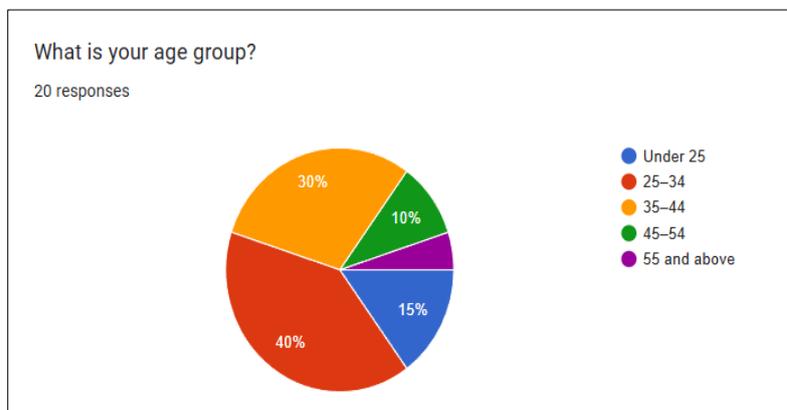
Fig. 7. Summary of Question 1

Fig. 7 shows the summary of question 1. The data shows that many respondents are in the 25–34 age group (40%), followed by 35–44 (30%). These two groups together represent 70% of our sample and are considered digitally active, financially independent, and likely to be exploring property ownership, renting, or investing. These users value features such as real-time insights, virtual viewings, and interactive experiences, which are aligned with VirtuHome's core offerings. The 15% of respondents under 25 suggest interest among younger adults, possibly first-time renters or buyers doing early market research. The lower engagement from older age groups (45 and above) could imply that these users prefer traditional property methods or require more user-friendly tech interfaces.
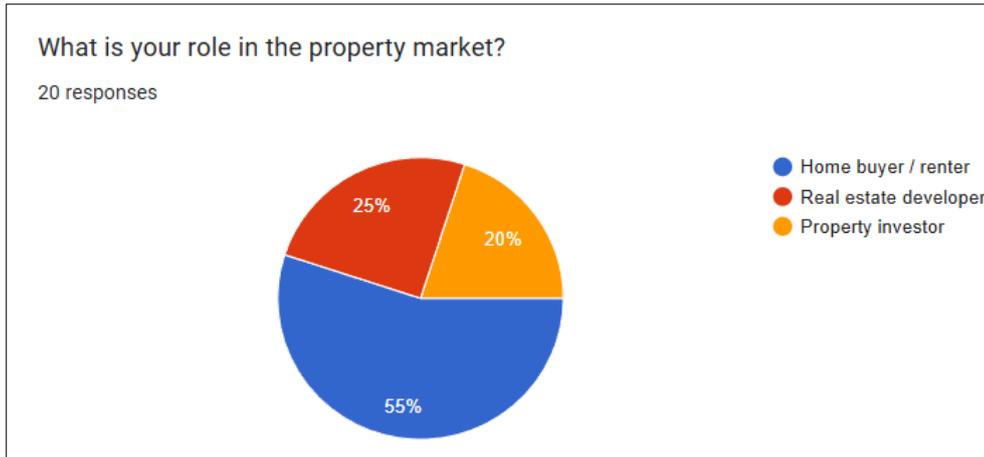
Fig. 8. Summary of Question 2

Fig. 8 shows the summary of question 2. The largest portion of respondents are home buyers or renters (55%), confirming that the platform should prioritize features that assist with searching, viewing, and evaluating properties. Real estate developers (25%) and property investors (20%) also form significant customer segments, suggesting a dual focus on both Business-to-Consumer and Business-to-Business user needs. For developers and investors, advanced tools like real-time market insight and promotional 3D tours are key value drivers.
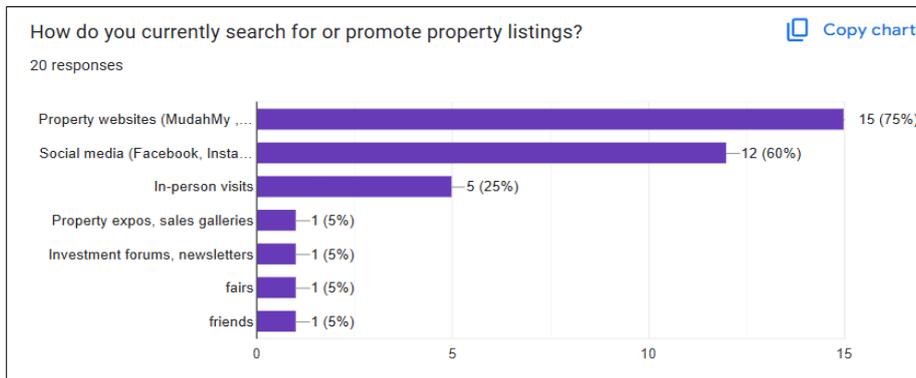
Fig. 9. Summary of Question 3

The above Fig. 9 shows the summary of question 3. Respondents mainly use property websites such as iProperty and MudahMy and social media platforms like Facebook and Instagram. Some still rely on traditional channels like in-person visits and property fairs. This shows that while the market is shifting toward digital tools, there is still fragmentation in the user experience. It presents an opportunity for VirtuHome to position itself as an all-in-one digital property platform that offers centralised browsing, comparison, and communication while saving users time and effort.

What challenges do you face when buying, renting, selling, or investing in property?
20 responses

Travel issues, slow comparison process

Limited audience reach, costly ads

High showroom cost, low online engagement

Too many options, lack of guidance

Visualization issues, time-consuming process

Hard to find the right unit, hard to imagine layout

No time to visit, scattered info

No clear info, confusing layouts

Too many appointments, showroom cost

Fig. 10. Summary of Question 4

Fig. 10 shows the summary of question 4. One of the most frequently mentioned pain points was the difficulty in comparing properties effectively. Many home buyers explained that current platforms often lack detailed side-by-side comparisons, which makes it hard to evaluate which property best fits their needs. This leads to frustration and decision fatigue, especially for buyers who are short on time or unfamiliar with the market. Another key issue was the amount of time wasted visiting multiple properties physically. Home buyers and renters noted that they often had to schedule multiple viewings, only to find that the properties did not meet their expectations. This process is not only time-consuming but also inefficient, especially for people with busy schedules or those relocating from another city or country. A third major challenge involved the inability to visualize property layouts or space utilization. Even with photos, many buyers felt it was hard to imagine how a property would look in real life or whether it would fit their furniture and lifestyle. This lack of spatial awareness often results in hesitation or indecision.

Does the value proposition listed in the BMC match your needs or solve your problems?
20 responses

- Yes, it matches my needs well
- Partially, some parts are relevant
- No, it doesn't solve my problems

95%
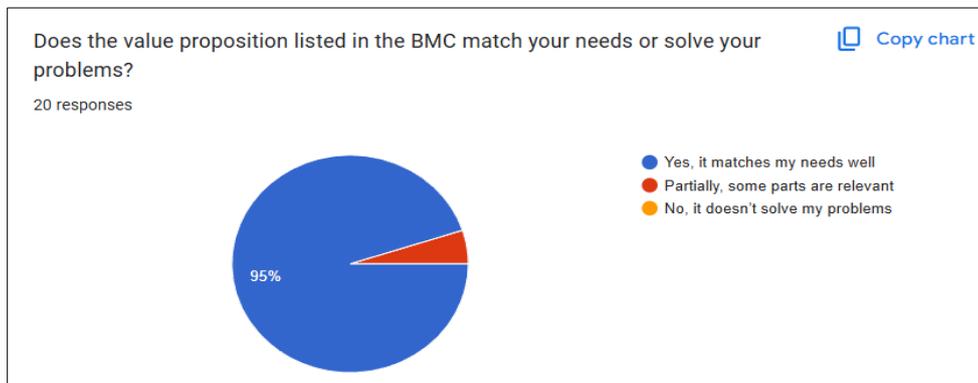
Fig. 11. Summary of Question 5

Fig. 11 shows the summary of question 5. Nearly all respondents agreed that the value propositions listed in our BMC match their needs or solve their problems. This is a strong validation of our early business assumptions. It shows that users resonate with features such as virtual home tours, real-time insights, smart search tools, and property comparison features. Only one user said the solution was only partially relevant, which indicates a possible need for more personalized features to fully meet all user expectations.
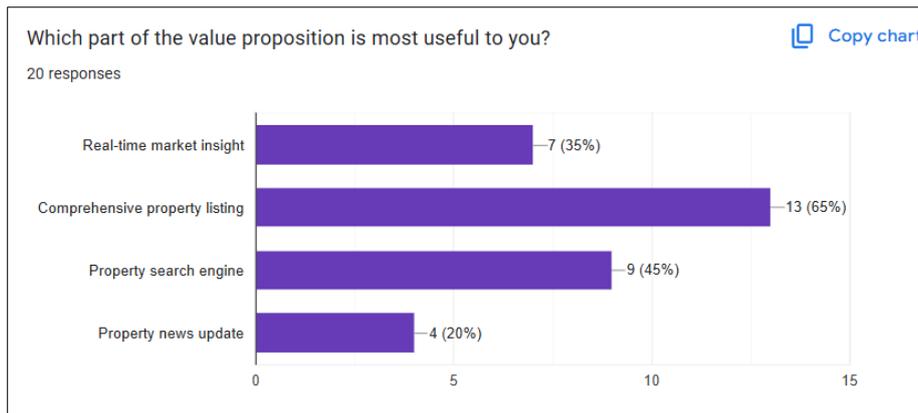
Fig. 12. Summary of Question 6

Fig. 12 shows the summary of question 6. respondents identified comprehensive property listings and the property search engine as the most useful parts of VirtuHome's value proposition, followed by real-time market insights and property news updates. Buyers and renters value rich, accurate listings and advanced filtering to save time and improve decision-making, while investors and developers prioritize real-time data to assess market trends and opportunities. The results confirm that VirtuHome's core features align well with user needs across segments and should remain the main focus for development, especially in delivering a smart, user-centered property browsing experience.
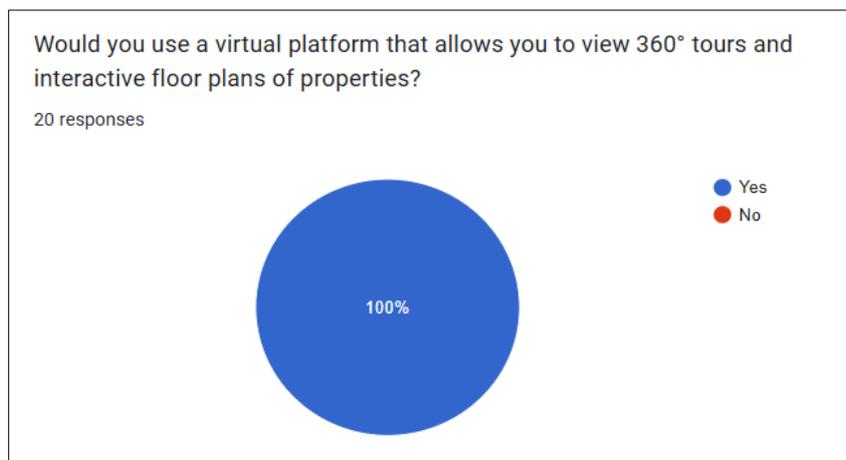
Fig. 13. Summary of Question 7

Fig. 13 shows the summary of question 7. all respondents answered "Yes" when asked if they would use a virtual platform with 360° tours and interactive floor plans, indicating strong enthusiasm and readiness for immersive digital property experiences. This unanimous support validates one of VirtuHome's core features and confirms that users are not only open to using virtual viewing tools, but actively prefer them over traditional methods. It highlights a clear market demand for more efficient, visual, and remote-friendly solutions, especially among busy professionals, long-distance buyers, and tech-savvy users.
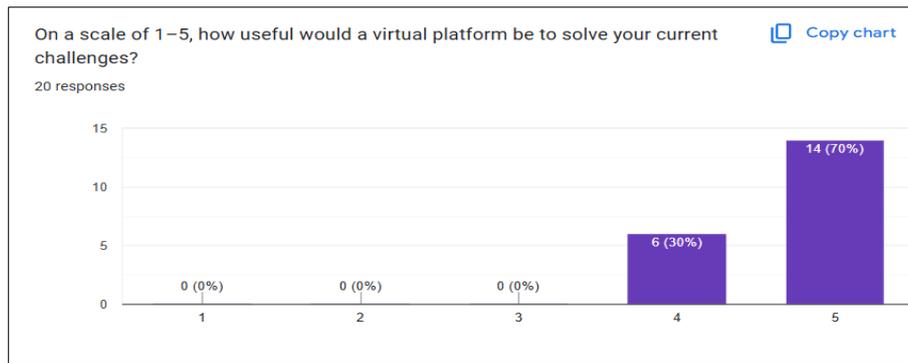
Fig. 14. Summary of Question 8

Fig. 14 shows the summary of question 8. Most users gave a rating of 4 or 5, with the majority choosing 5, indicating that they find VirtuHome to be very useful or extremely useful. This strongly suggests that our platform addresses real frustrations in the market and offers clear value to the user. This high score reinforces our belief in the platform's potential to disrupt traditional property search and marketing, especially for time-pressed or long-distance users.

Fig. 15. Summary of Question 9

Fig. 15 shows the summary of question 9. Participants offered thoughtful and diverse suggestions, including adding features such as rent calculators, ROI estimates, mobile optimization, and even an AI assistant. These ideas reflect a desire for personalized, data-driven tools and a smooth user experience. It also indicates potential for premium feature development or a tiered subscription model. These suggestions not only validate our direction but also provide a useful roadmap for future updates and scalability.

7. BMC FRAMEWORK

7.1. Validated Conceptual Business Model

Following our validation surveys on the initial business model, we learned that our customers are generally satisfied with the business model and that changes were made when necessary. As a result, Fig. 16 depicts the validated business model canvas for VirtuHome.

VALIDATED BUSINESS MODEL CANVAS VIRTUHOME

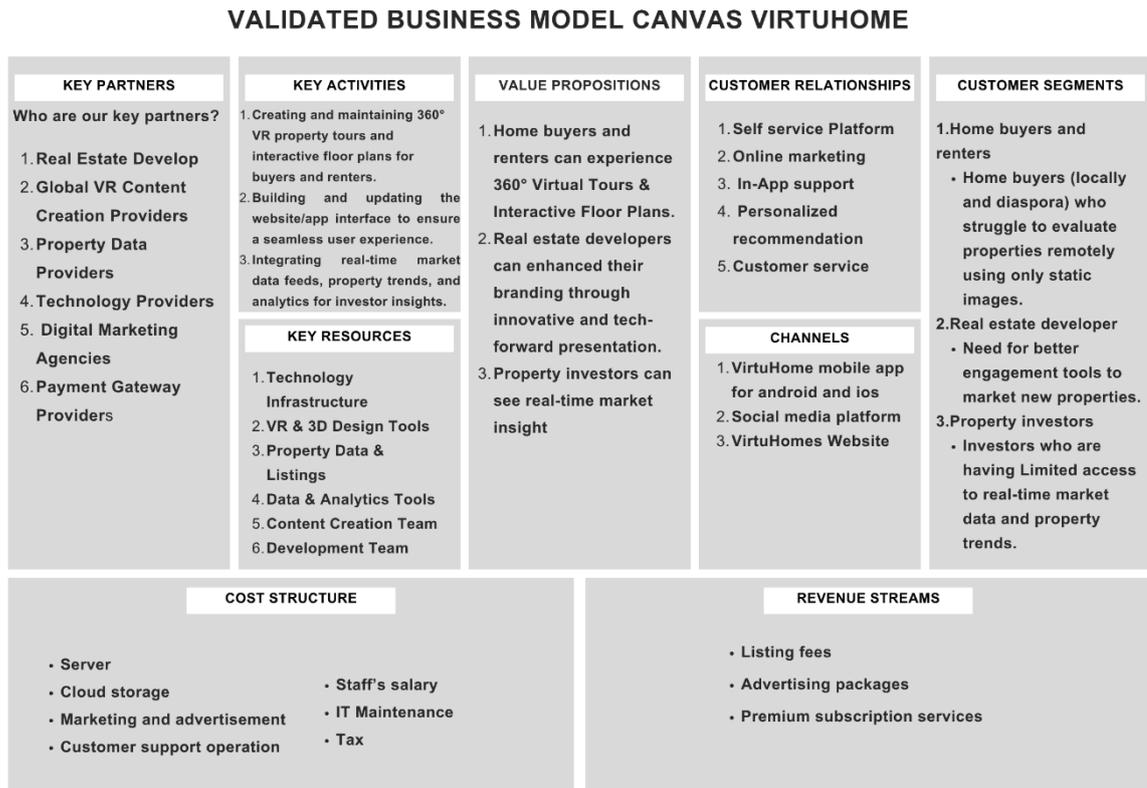| KEY PARTNERS	KEY ACTIVITIES	VALUE PROPOSITIONS	CUSTOMER RELATIONSHIPS	CUSTOMER SEGMENTS
Who are our key partners? 1. **Real Estate Develop** 2. **Global VR Content Creation Providers** 3. **Property Data Providers** 4. **Technology Providers** 5. **Digital Marketing Agencies** 6. **Payment Gateway Provider**s	1. Creating and maintaining 360° VR property tours and interactive floor plans for buyers and renters. 2. Building and updating the website/app interface to ensure a seamless user experience. 3. Integrating real-time market data feeds, property trends, and analytics for investor insights.	1. **Home buyers and renters can experience 360° Virtual Tours & Interactive Floor Plans.** 2. **Real estate developers can enhanced their branding through innovative and tech-forward presentation.** 3. **Property investors can see real-time market insight**	1. **Self service Platform** 2. **Online marketing** 3. **In-App support** 4. **Personalized recommendation** 5. **Customer service**	1. **Home buyers and renters** • Home buyers (locally and diaspora) who struggle to evaluate properties remotely using only static images. 2. **Real estate developer** • Need for better engagement tools to market new properties. 3. **Property investors** • Investors who are having Limited access to real-time market data and property trends.
	KEY RESOURCES 1. **Technology Infrastructure** 2. **VR & 3D Design Tools** 3. **Property Data & Listings** 4. **Data & Analytics Tools** 5. **Content Creation Team** 6. **Development Team**		**CHANNELS** 1. **VirtuHome mobile app for android and ios** 2. **Social media platform** 3. **VirtuHomes Website**	

COST STRUCTURE	REVENUE STREAMS
• Server • Cloud storage • Marketing and advertisement • Customer support operation • Staff's salary • IT Maintenance • Tax	• Listing fees • Advertising packages • Premium subscription services

Fig. 16. The validated business model canvas of VirtuHome

7.1.1. Customer Segments (CS)

The customer segments targeted by VirtuHome consist of individuals and businesses who are directly involved in the property market and would benefit from a more digital, immersive, and efficient experience when searching for or showcasing properties. These are home buyers and renters who are struggled to visualize layouts or spaces of the property just from the image, real estate developer that need better engagement tools to market their properties, and property investors who are having limited access to real-time market data and property trends.

7.1.2. Value Proposition (VP)

A value proposition is a service or feature offered to suit the needs and wants of certain customer segments. The values provided to each customer type are as follows:

a. Home Buyers and Renters: VirtuHome offers home buyers and renters a seamless digital property experience with 360° virtual tours and interactive floor plans. This helps users explore and evaluate properties remotely, saving time and effort. With our platform, they can compare spaces easily, visualize layouts, and make informed decisions from the comfort of their homes. This reduces stress and increases confidence during the home search process.

b. Real Estate Developers: For real estate developers, VirtuHome serves as a powerful marketing tool to enhance brand image through innovative and tech-forward presentations. By listing their properties with immersive visuals and

interactive floor plans, developers can attract more attention, increase engagement, and reach a wider audience, especially among tech-savvy home seekers. This results in improved visibility and faster conversion rates.

c. Property Investors: VirtuHome provides real-time market insights to help property investors monitor trends, assess opportunities, and make better investment decisions. Our platform offers data-driven tools, smart comparisons, and up-to-date listings that support strategic planning. This enables investors to minimize risk and maximize returns while keeping up with market movements efficiently.

7.1.3. Channels (CH)

Channels explain how we want to reach out to and engage with potential and new customers to provide a value proposition. VirtuHome will communicate with its customer groups via the VirtuHome mobile app, which is available for both Android and iOS devices. Customers can also interact with us through our official social media platforms such as Facebook, Instagram, and X (formerly Twitter). Additionally, the VirtuHome website and the mobile app will serve as a central hub for browsing listings, accessing features, and staying updated on property trends and insights.

7.1.4. Customer Relationships (CR)

VirtuHome is a digital property platform that focuses on building strong and lasting relationships with its customer segments by offering a seamless and user-friendly experience. The platform encourages user engagement and trust through various customer relationship strategies. VirtuHome offers a self-service platform, allowing users to search, view, and compare properties independently. It uses online marketing channels such as social media, email campaigns, and search engine optimization to attract new users and retain existing ones. Additionally, the app includes in-app support for real-time assistance, and offers personalized recommendations based on user preferences and browsing behavior to enhance the experience. To ensure satisfaction, VirtuHome provides reliable customer service through multiple channels including in-app chat, email, and social media to resolve any inquiries or issues efficiently.

7.1.5. Revenue Streams (RS)

The first is listing fees, where real estate developers pay to have their properties featured on the platform, particularly when using enhanced options like 360° virtual tours. The second stream comes from advertising packages, which allow property owners and developers to promote their listings more prominently through homepage banners or featured sections. Lastly, VirtuHome offers premium subscription services for both individual users and businesses, giving them access to advanced features such as analytics dashboards and priority listing placements.

7.1.6. Key Resources (KR)

The platform relies on key resources such as technology infrastructure, VR and 3D tools for creating virtual tours, property data, and analytics systems. A skilled content creation team and development team are also essential to maintain and enhance the platform.

7.1.7. Key Activities (KA)

VirtuHome's main activities include creating virtual tours, developing apps and websites, and integrating real-time property data to provide an engaging and informative user experience.

7.1.8. Key Partnerships (KP)

To operate effectively, VirtuHome relies on a network of key partnerships. Key partners include real estate developers and agencies for listings, VR content creators for virtual tours, property data providers, tech infrastructure providers, digital marketers, and payment gateway services for secure transactions.

7.1.9. Cost Structure (CS)

VirtuHome incurs various operational costs necessary to maintain and scale the platform. Main costs include server and cloud storage, marketing, customer support, staff salaries, IT maintenance, and taxes, all required to ensure the platform runs smoothly and continues to grow.

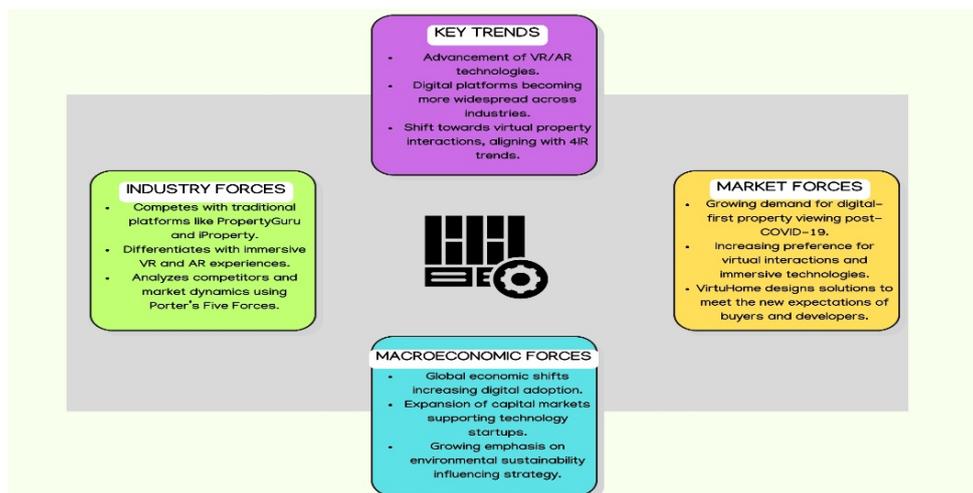## *7.2. Business Environmental Map*

Fig. 17. The business model environmental map of VirtuHome

The Business Model Environment Map (EM) is a strategic tool that VirtuHome uses to scan and analyze external factors that influence its business model. The EM covers four key external forces:

7.2.1. Market Forces

In terms of Market Forces, VirtuHome responds to a growing demand for faster, digital-first property viewing experiences, especially after the COVID-19 pandemic, where physical viewings became limited. By understanding the increasing customer preference for virtual interactions and immersive technologies, VirtuHome designs solutions that match the new expectations of buyers, developers, and investors. As highlighted by Amarsy (2015), identifying customer trends and needs is critical for shaping a strong business model.

7.2.2. Industry Forces

For Industry Forces, VirtuHome operates in a competitive environment dominated by traditional online property listing platforms such as PropertyGuru and

iProperty. However, unlike these platforms that primarily offer static photos and basic videos, VirtuHome differentiates itself with immersive VR and AR experiences. VirtuHome strategically evaluates its competitors, potential market entrants, substitutes, and partnerships to remain competitive.

7.2.3. Key Trends

The Key Trends affecting VirtuHome include the rapid advancement of VR/AR technologies, the adoption of digital platforms across industries, and the changing behaviour of property buyers who now prefer virtual interactions over physical site visits. As noted by Amarsy (2021), staying aware of technological, regulatory, and societal trends is essential for maintaining relevance. VirtuHome aligns itself with these emerging patterns, especially trends related to the Fourth Industrial Revolution (4IR).

7.2.4. Macro-Economic Forces

Finally, under Macro-Economic Forces, VirtuHome acknowledges the wider economic conditions that impact its business. Factors such as increased digital adoption due to global economic shifts, the expansion of capital markets supporting technolgy startups, and a growing emphasis on environmental sustainability influence VirtuHome's strategy. Understanding macro-economic forces such as global market conditions, capital markets, and resource availability is crucial for building resilient and profitable businesses.

The Environment Map (EM) is important because it helps businesses identify and understand the external factors that could affect their operations. By continuously reviewing these factors, businesses can determine market changes, competitive threats, and economic shifts. With this ability, businesses will be able to survive in a constantly evolving environment. This ensures that businesses are not just reacting to changes but are prepared to take advantage of any opportunities arising.
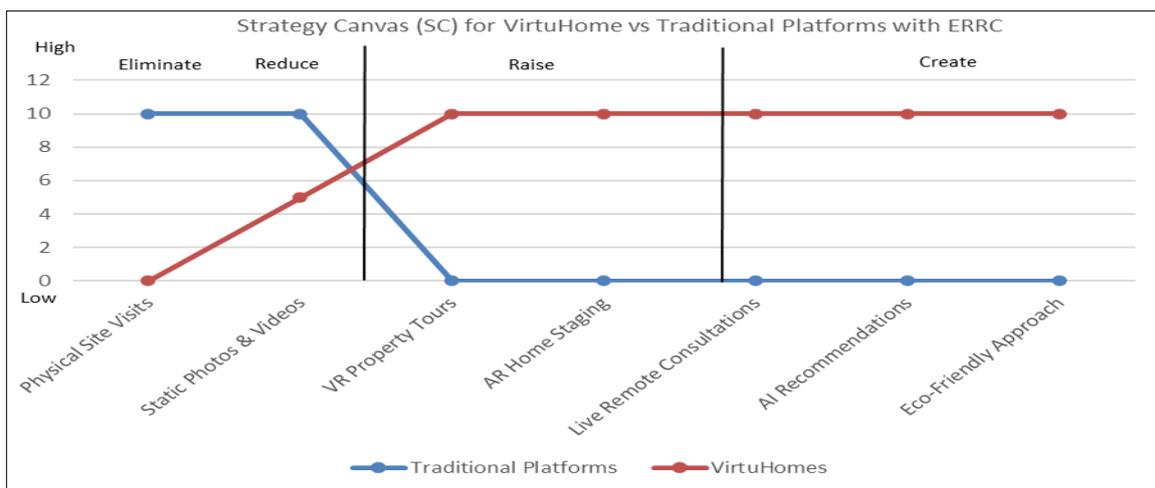
7.3. Strategy Canvas

Fig. 18. The strategy canvas for VirtuHome against traditional platform

The Strategy Canvas helps us to visualise how VirtuHome's stands out against other traditional property platforms such as PropertyGuru , iProperty, EdgeProp and. It highlights the basic offerings that are usually expected by the customers,

and the key differentiators, or in another term, purple cow, that will make VirtuHome special and valuable to its customer segments.

The Purple Cow statement was originally introduced by Seth Godin. The terms mean creating a product or service that is different and unique that will gain attention in the market. In VirtuHome's case, basic expectations such as showing property listings, prices, photos and videos are all fulfilled, which are also similar to what other platforms already provide, but in this case, VirtuHome's offers "Purple Cow", or in other words, features that makes us stand out, which are:

a. **Immersive Virtual Reality (VR) Property Tours**: Allow users to "walk through" properties digitally.
b. **Augmented Reality (AR) Home Staging**: Let users place virtual furniture to visualize the space.
c. **Live Remote Consultations**: Users can meet agents online without needing to travel physically.
d. **AI Personalized Property Suggestions**: Smart recommendation system based on user preferences.
e. **Eco-Friendly Approach**: Reducing carbon footprint by minimizing unnecessary site visits.

7.4. High Fidelity Wireframe/Mock-up/Prototype digital platform/app

The high-fidelity prototype of VirtuHome is divided into two main user perspectives: Customer View and Agent View. Each interface is designed with its specific user journey and functionality in mind, ensuring a smooth and intuitive experience for both parties.

7.4.1. Buyers and Investors UI

The customer interface allows users to register, search, and explore properties through an immersive experience using VR and AR technologies. From signing up to chatting with agents and booking VR appointments, users can browse and view properties without needing to visit them physically. The design focuses on accessibility, ease of navigation, and visual engagement.

a. Splash
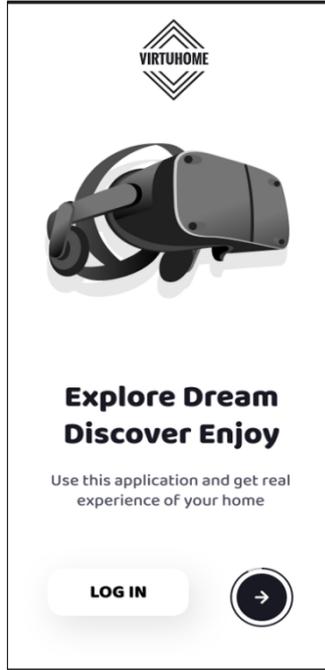
b. Main Page
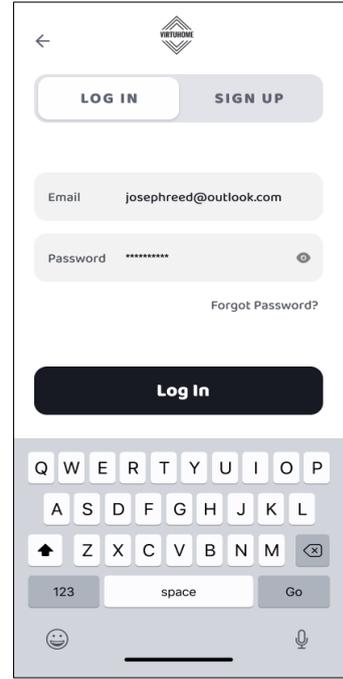
c. Log-In Page

d. Sign-up Page

e. Search Page

f. Home Page
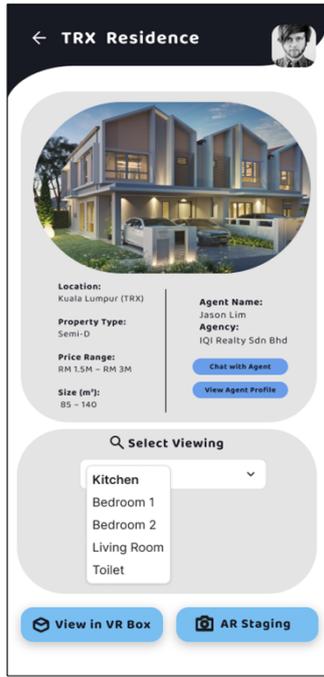
g. View Property Page   h. Chat with Agent Page   i. Agent Profile
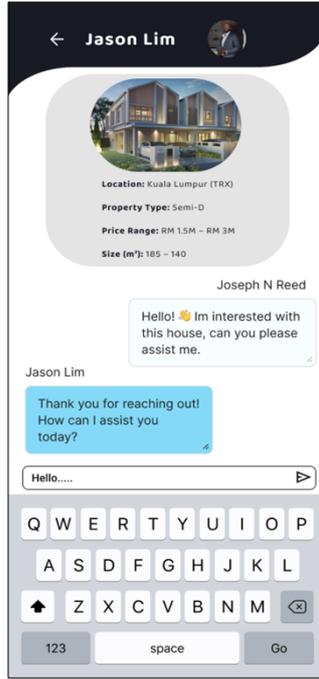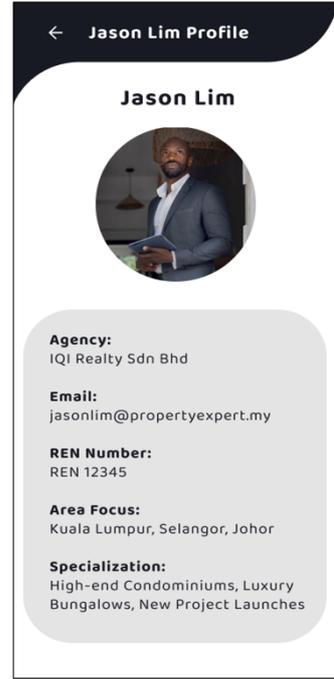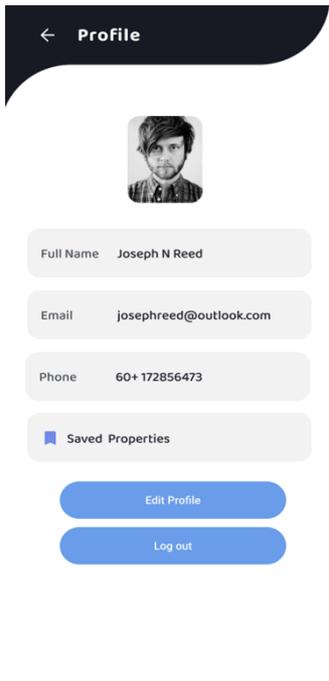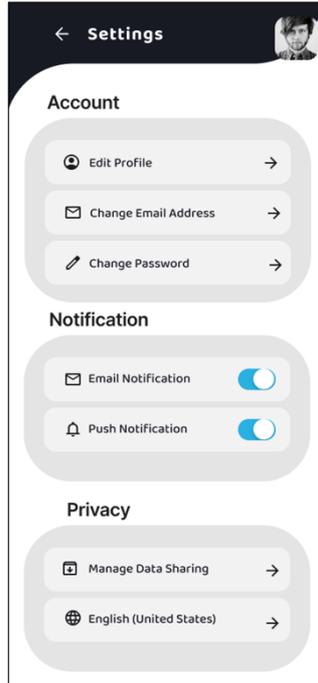
j. Profile Page   k. Settings Page   l. Saved Page
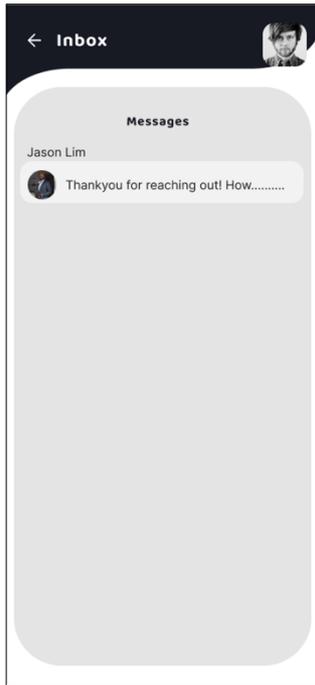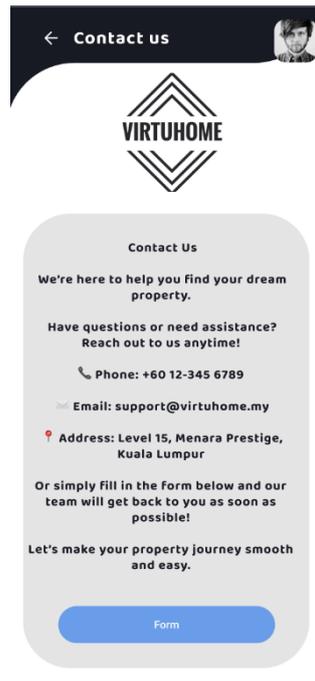
m. Inbox Page
n. Contact Page
i. Form Page
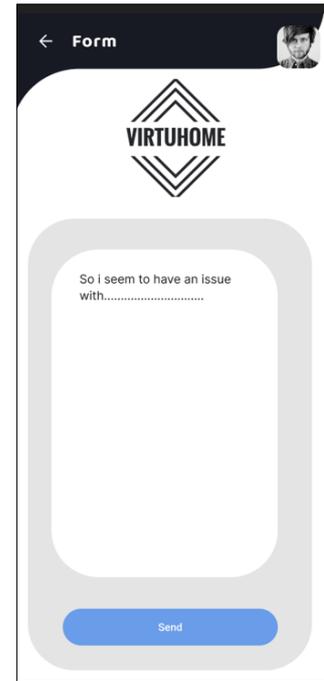
7.4.2. **Property Agent UI**

The agent interface is tailored for real estate professionals to manage property listings, respond to customer inquiries, and schedule VR sessions at nearby branches. Agents can upload properties, maintain their profile, and provide real-time support during virtual tours. The layout emphasizes efficiency, communication, and support throughout the customer journey.
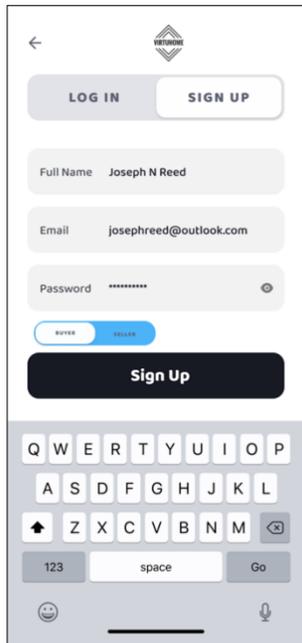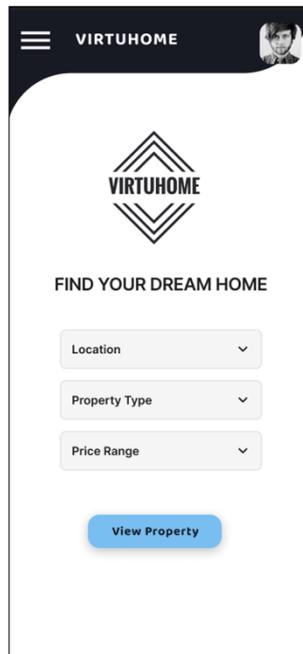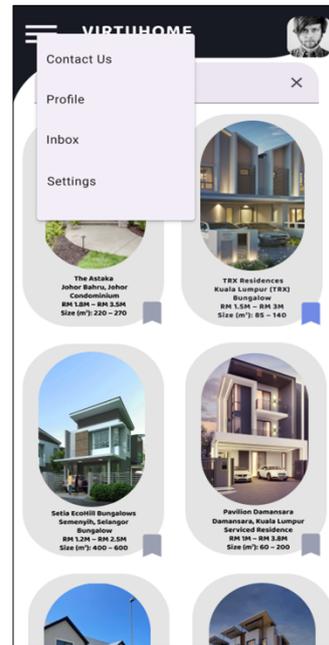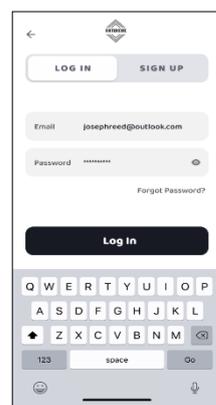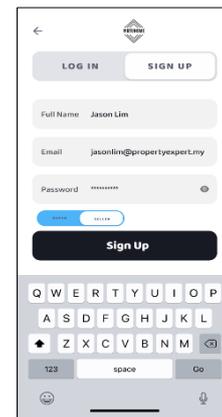

a. Splash
b. Main Page
c. Log-In Page
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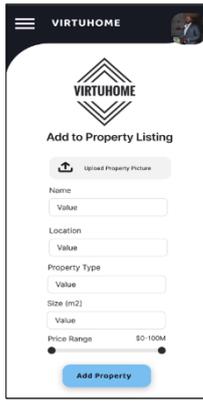
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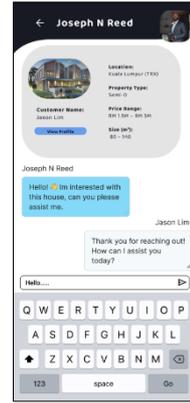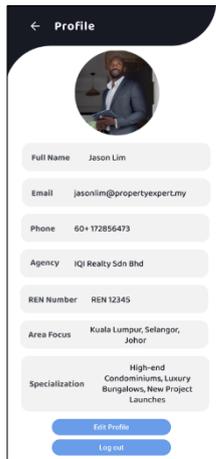
i. Agent Profile Page j. Customer Profile Page``   k. Settings Page   l. Inbox Page
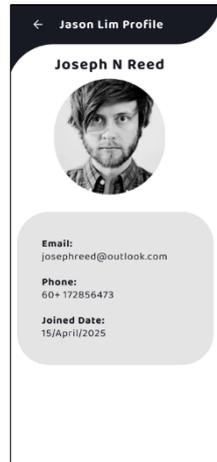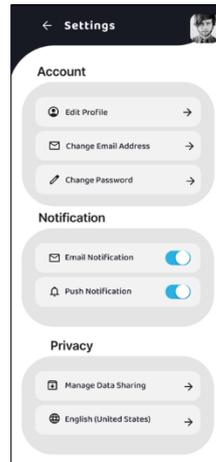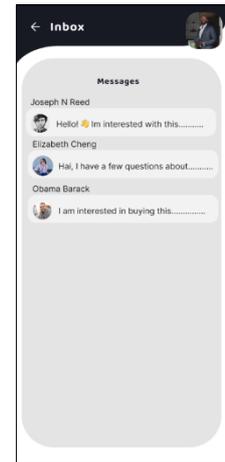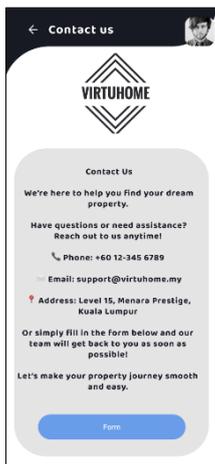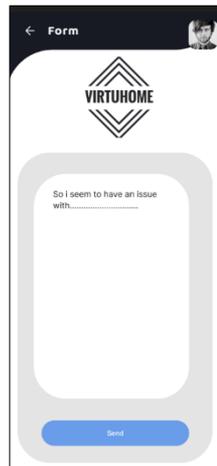
m. Contact Page   n. Form Page

8. CONCLUSION AND FUTURE WORK

The development of VirtuHome's business model highlights several key achievements and addresses important challenges faced by the customer segments. Buyers and renters often experience frustration due to time-consuming site visits, difficulty visualizing spaces, and lack of real-time support. Developers and agencies, meanwhile, face pressure to market their projects in more innovative and efficient ways. Because of that, VirtuHome responds to these needs by integrating immersive technologies like Virtual Reality (VR) and Augmented Reality (AR), enabling remote tours, interactive home staging, and personalized AI suggestions. These value propositions serve as major gain creators, reducing the burden of physical visits and providing accurate, data-driven property experiences. The Business Model Canvas effectively aligns each element of customer segments, channels, revenue streams, partnerships, and cost structures towards solving these core pain points and creating a more engaging digital real estate journey.

Looking ahead, VirtuHome aims to further refine and elaborate on our validated conceptual business model into a comprehensive business plan. This includes expanding on market entry strategies, forming more diverse partnerships, and integrating advanced analytics such as behavioral insights and predictive pricing models. Additionally, future development will focus on incorporating sustainability metrics and legal compliance features to appeal to environmentally conscious users and ensure regulatory readiness. With rapid technological advancements and changing consumer behaviors, VirtuHome will continue evolving its platform by leveraging innovations in AI, Big Data Analytics (BDA), and Internet of Things (IoT) to enhance user experience, operational efficiency, and long-term scalability.

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UNIVERSITY-OF-TOMORROW BUSINESS MODEL: THE CASE OF INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA (IIUM) DIGITAL TRANSFORMATION

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ABSTRACT: This paper presents a conceptual University-of-Tomorrow (UoT) business model for the International Islamic University Malaysia (IIUM), focused on harnessing and integrating digital capabilities and ecosystems, platforms and applications to address key challenges, pains, gains, and job-to-do of current IIUM (Current Organization - CO). The model is designed to meet the evolving needs and expectations of various customer segments (CS) including students local and international, continuous and adult learners, underprivileged and war-torn students, communities global and local, government, and industries, while sustaining institutional relevance in a digital and post-pandemic era. Using the Design Thinking (DT) methodology, the study incorporates a literature review and stakeholder interviews/surveys to understand current challenges and issues. It then constructs the CO's business model, followed by the development of an initial IIUM UoT business model, using the Business Model Canvas (BMC) and Value Proposition Canvas (VPC) framework, and supported with the Environmental Map (EM). After validating the initial UoT business model through further stakeholder interviews, the validated IIUM UoT business model is established. Universities need to transform and must adapt to drive skills-led economic and ethically led transformation as emphasized by global shifts in higher education and the evolving digital economy. The validated IIUM UoT business model is then compared to IIUM CO business model, and other global best universities benchmarked using the Strategy Canvas - to highlight the key differentiation and value propositions of IIUM UoT. Key findings contribute a practical, stakeholder-aligned UoT model with integrated digital solutions, offering strategic options for IIUM and other institutional decision-makers. Future work will involve designing a detailed Digital Implementation Strategy Plan (DISP) to drive the full transition to the UoT.

KEY WORDS: *Conceptual Business Model, University-of-Tomorrow, Design Thinking, Strategy Canvas, Digital Transformation, Digital Campus*

1. INTRODUCTION

The International Islamic University Malaysia (IIUM) was established in 1983 to integrate Islamic principles with academic excellence in the fields of science, technology, social sciences, and the humanities. As a public university with an international outlook, IIUM is committed to the holistic development of students grounded in the philosophy of Tawḥīdic Excellence.

Institutions of higher learning (IHL) like IIUM, need to deliver values-based, human-centric education while meeting the diverse demands of their customer segments (CS), including domestic and international students, lifelong learners, faculty, alumni, nations, industries, and donors (Wani et al., 2022). Students expect flexible access to quality and value-based learning, educators seek intuitive and integrated digital teaching platforms, while employers demand for job-ready, entrepreneurial graduates with both ethical grounding and digital fluency.While IIUM has adopted several digital solutions such as iTa'leem (LMS), iMa'luum (student portal), and digital micro-credential pilots. Similar trends are observed in local and global institution of higher learnings.

This transformation aligns with global imperatives outlined in The Great Reset by the World Economic Forum (2020), which emphasizes the need to develop sustainable business models, harness 4IR technologies, and redesign the social contract, skills, and jobs. For IIUM, this necessitates rethinking its business model to enable and support equitable access to physical and digital learning ecosystem, integrate relevant technologies like AI and cloud computing, and prepare students for a values-based yet digitally competent and entrepreneurial workforce.

The limitations of these fragmented solutions highlight the need for a holistic, inclusive, and contextually relevant business model tailored to IIUM's identity, mission, and digital ambitions. The university must reimagine its organizational business model through values-aligned and data-driven framework that enables lifelong learning and student empowerment ecosystem; nurturing holistic, ethical, and globally competent individuals; *ummatic* excellence driven by *tawhidic epistemology*; industry collaboration and co-creation; and digital innovation. This paper proposes a conceptual University-of-Tomorrow (UoT) for IIUM - one that integrates humanized education, stakeholder co-creation, and scalable digital platforms to meet the jobs-to-be-done, alleviate pain points, and enhance the gains of all its customer segments. This paper adapts the Design Thinking - to establish IIUM UoT business model and outlines how IIUM can transition from current organization (CO) to University of Tomorrow (UoT) business model, leveraging on a seamless digital ecosystem, aligns with national agenda like NEP 2030, MyDigital, and MEB 2025 for institutional sustainability and global excellence.

2. OBJECTIVES

The International Islamic University Malaysia (IIUM) faces growing requirements from various customer segments (CS) like local and international students, continuous learners, underprivileged and war-torn students, communities global and local, government, and industries, who need flexible digital and physical services that provide relevant experiential learning, responsible research & innovation, and high-impact community engagement functions. IIUM faces continuous challenges on education excellence, sustainability, and relevancy with the accelerated progression of technology and its rapid adoption by stakeholders and CS - have pushed the digital transformation initiatives as one of the top agenda of Institutions of Higher Learning (IHL) around the world.

The paper aims to achieve goals which address present difficulties and leverage on new business model embedded with 4IR technologies that include:

a. To develop a validated conceptual business model for IIUM University-of-Tomorrow (UoT), integrating humanized education with digital capabilities, platforms and applications in addressing the essential needs, extreme pains, and aspirations of its various customer segments.

b. To validate the proposed UoT business model through direct feedback from customer segment CS - students including local and international, continuous learners, underprivileged and war-torn students, communities global and local, government, and industries - to ensure its relevance, practicality, and alignment with IIUM's mission and context.

c. To benchmark and assess the proposed IIUM UoT business model against IIUM's current (CO) business model, and comparable national and global IHL business models using business modelling tools such as the Environmental Map (EM), Business Model Canvas (BMC), Value Proposition Canvas (VPC), and Strategy Canvas, and to offer strategic recommendations for institutional innovation and transformation.

d. To provide a foundation for the development of a Digital Implementation Strategy Plan (DISP) that will guide IIUM in operationalizing the University-of-Tomorrow model through phased digital transformation initiatives.

3. METHODOLOGY

This paper applies Design Thinking (DT) as a human-centered iterative process to create IIUM's University-of-Tomorrow (UoT) business model. Design Thinking methodology introduced by Brown (2009) contains five critical steps from Empathize through Define before Ideate and Prototype and ends with Test to achieve innovative practical solutions for complex environments such as higher education. The Empathize phase started by conducting a complete literature review and benchmarking activities to identify institutional trends as well as policy directives (MyDigital and NEP 2030) and global university models. Interviews and surveys were conducted with IIUM's main customer segments (CS) which included students including local and international, continuous learners, underprivileged and war-torn students, communities global and local, government, and industries to obtain their challenges and expectations and requirements. The Define phase utilized stakeholder feedback to produce IIUM Current Organization (CO) business model through synthesis. The transformation groundwork started by finding essential weaknesses and improvements and operational requirements within IIUM's present systems. The initial conceptual business model for the University-of-Tomorrow (UoT) was developed during the Ideate phase of the Design Thinking (DT) methodology. This process involved constructing three core components: the Environmental Map (EM) for assessing external forces, the Business Model Canvas (BMC) for defining institutional elements, and the Value Proposition Canvas (VPC) for aligning IIUM's offerings with stakeholder needs. These tools were structured based on the framework by Osterwalder and Pigneur (2010). Visual representations, mockups, and strategic illustrations were employed to articulate the conceptual UoT model. During the Test phase, prototype validation was conducted through iterative feedback gathered from key customer segments (CS), leading to refinements in the model. A Strategy Canvas was then developed to compare the validated UoT model with both IIUM's current business model and globally benchmarked best practices in higher education institutions. This evaluation process enhanced the model's relevance, scalability, and clarity,

supporting IIUM's strategic transition toward digital transformation and institutional sustainability.

4. LITERATURE REVIEW

The Great Reset by the World Economic Forum (2020) outlines three key principles relevant to organizations digital transformation: developing sustainable business models, leveraging Fourth Industrial Revolution (4IR) technologies, and redesigning skills and jobs.

4.1. Fourth Industrial Revolution (4IR)

The Fourth Industrial Revolution (4IR) established a key moment when technology transformed the relationships between societies and economies together with institutions. 4IR emerges through combined technology standards of artificial intelligence alongside robotics alongside the Internet of Things alongside quantum computing alongside blockchain providing colleges and institutions a pathway to refresh learning spaces with new research frameworks alongside operational approaches.

However, challenges persist. Schwab (2016) highlights two primary risks of the 4IR era: the deepening of digital inequality and the displacement of traditional roles due to automation. The University of International Islam Malaysia must invest in digital infrastructure and develop specific inclusive transformation measures to make sure students receive equitable access regardless of rural or socioeconomic status. The Ministry of Science Technology and Innovation (2021) establishes that an ecosystem policy framework should guide reskilling initiatives alongside ethical governance and innovation promotion.

The investigation conducted by Wani et al. (2022) confirms that Malaysian universities need to modify their existing business model to successfully integrate 4IR technology operations. Main elements for success include implementing hybrid teaching approaches and data-based research frameworks together with digitalization of student assistance systems.

4.2. Malaysia Digital Economy Blueprint (MyDigital) 2030

The Malaysia's Digital Economy Blueprint named MyDigital serves as a national strategic roadmap which aims at transforming Malaysia into a digital leadership region by 2030. The main components of the blueprint involve government digital transformation efforts and improved digital literacy alongside first use of cloud solutions and inclusive infrastructure solutions (Economic Planning Unit, 2021). This national digital blueprint shapes most aspects of IIUM's transformation strategy specifically by redefining its administrative processes as well as learning platforms and stakeholder outreach tools. The MyDigital alignment through LMS system upgrades and cloud platform promotion and data analytics applications for academic management. Smart data analytics evolved as a fundamental tool to enhance personalized education and conduct performance tracking and anticipate student retention risks. Such data-focused operations receive support from PwC (2023) since they define key characteristics of the "Digital University." According to PwC the process of transforming higher education needs modern technological equipment along with cultural development which enables workers and students to adopt digital learning practices in agile work environments. IIUM works to decrease

digital inequality between city and rural areas by using first mobile-focused content services and establishing open educational systems alongside government-funded broadband connections. Through their efforts the university demonstrates support for MyDigital's initiative to build a digitally competent society while delivering inclusive digital access. To build a lasting innovation-based ecosystem IIUM must implement its UoT model by giving power to all groups including educational staff, administrative personnel, industrial associates as well as students.

4.3. The National Entrepreneurship Policy (NEP) 2030

The National Entrepreneurship Policy (NEP) 2030 which the Ministry of Entrepreneur Development and Cooperatives (2020) launched intends to establish an entrepreneurial economy with innovative qualities that is also inclusive. The policy establishes five strategic points which include creating resilient entrepreneurial culture along with enabling ecosystems for development and ensuring equitable opportunity access. The directives present special importance to higher education facilities including IIUM.

Saiid et al. (2022) endorse the adoption of private-sector business models by higher education institutions to achieve sustainability in the post-pandemic environment. Students can generate new income for the institution through innovation challenges and micro-credentials and startup projects enabled online. The NEP 2030 supports exactly the integrated educational model which mixes academic commitment and enterprise-based learning activities. The University of International Islamic Studies will create enduring ventures with accelerators along with venture capitalists and industry mentors to help students start their entrepreneurial pathways. The policy mandates institutions to broaden entrepreneurial inclusion opportunities for women along with disabled people and members from the bottom 40% economic level. IIUM fulfills its mission of *rahmatan lil-'alamin* through its Islamic purposes to establish a value-based entrepreneurship ecosystem that provides both financial gain and social transformation.

4.4. Malaysia Education Blueprint (MEB) 2015-2025

The Malaysia Education Blueprint (Higher Education) 2015–2025 represents a Ministry of Education Malaysia initiative which provides strategic guidance to reform Malaysian higher education systems and bring them into line with global progress. The blueprint presents ten essential operational alterations that intend to improve student achievements along with academic results and teaching creativity. The three key shifts for IIUM to transform into a University-of-Tomorrow (UoT) (Ministry of Education Malaysia, 2015) relate to Shift 1 (Producing Holistic, Entrepreneurial and Balanced Graduates), Shift 4 (Quality TVET Graduates) and Shift 7 (Innovation Ecosystem). The achievement of Shift 1 objectives requires IIUM to maintain its efforts in integrating entrepreneurship along with interdisciplinary education and Islamic values across its academic curriculum. Academic programs at IIUM embed soft skills together with moral reasoning and community engagement practices due to this transformational objective. The current international community-based entrepreneurship framework at IIUM stands as a foundation for MEB fulfillment that demands comprehensive expansion according to Asender et al. (2021). The initiative of Shift 7 focuses on industrial partnerships and research commercialization and innovation development. The necessity for universities to redesign their business models toward value co-creation and future-readiness

stands true according to Wani et al. (2022). IIUM's UoT model strengthens online program delivery and modular learning while implementing digital micro-credentials according to Shift 9 (Globalized Online Learning). The significance of digital platforms remains crucial for maintaining both private and public universities during the post-pandemic tech-driven present according to Saiid et al. (2022). The Blueprint's recommendations about institutional autonomy (Shift 6) and academic leadership (Shift 2) demonstrate the need to give faculties freedom to implement digital teaching methods for war-torn and under-developed countries as well.

4.5. Benchmark with Global Universities

IIUM needs to study successful higher education institutions globally which adapted to digital disruption for developing a forward-thinking business model. The educational institutions MIT together with Stanford University and Singapore University of Technology and Design (SUTD) built digitally enabled systems which support their teaching activities and research functions alongside industry relationships. According to Christensen et al. (2011) disruptive education innovation occurs when institutional academic sessions move from traditional lecture structures into flexible modular learning systems that use technological infrastructure to focus on students.
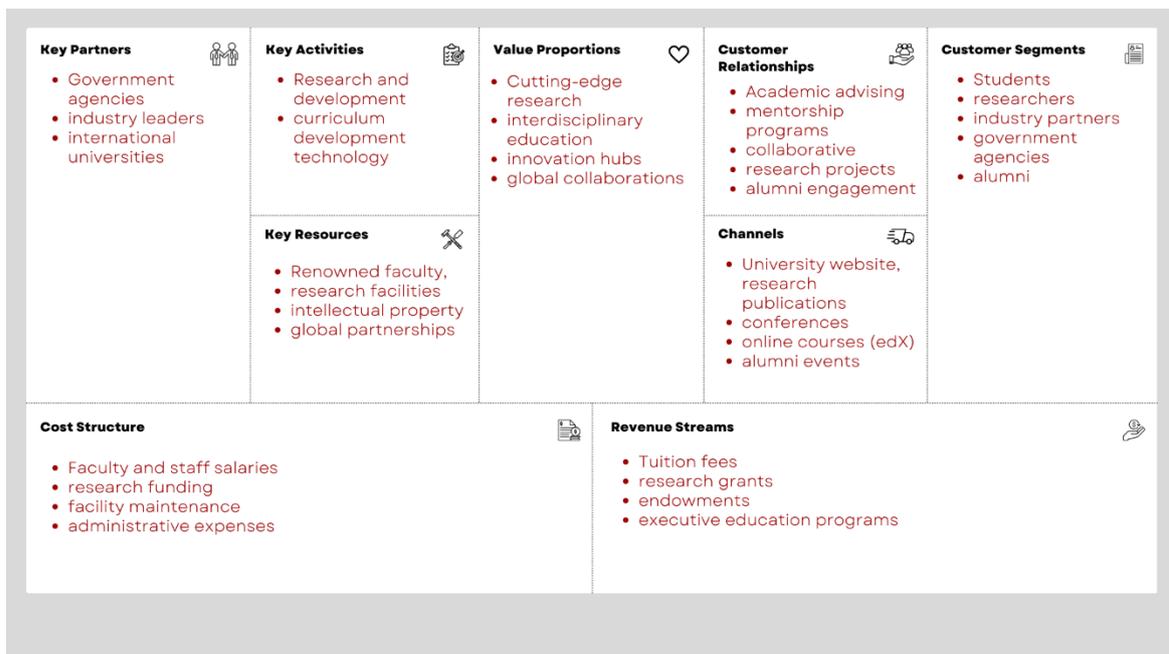
Fig. 1. MIT BMC based on MIT portal

Key Partners	Key Activities	Value Proportions	Customer Relationships	Customer Segments
• Silicon Valley companies • venture capital firms • research institutions • alumni	• Teaching • research • entrepreneurship programs	• Entrepreneurial ecosystem • interdisciplinary programs • proximity to Silicon Valley • strong alumni network	• Personalized education • startup mentorship • alumni relations,	• Students, entrepreneurs • researchers • corporate partners • alumni
	Key Resources • Distinguished faculty • innovation centers • extensive alumni network		**Channels** • University website • online platforms, • alumni networks	

Cost Structure	Revenue Streams
• Operational costs • faculty salaries • research funding • campus facilities	• Tuition fees • research funding • endowments • donations

Fig. 2. Stanford BMC based on Stanford portal

Key Partners	Key Activities	Value Proportions	Customer Relationships	Customer Segments
• Government bodies • industry partners • international academic institutions	• Curriculum development • design innovation • industry collaboration • research initiatives	• Design-centric curriculum • integration of technology and design • industry partnerships	• Close student-faculty interaction, • industry mentorship • alumni engagement	• Undergraduate and graduate students • industry collaborators • government bodies
	Key Resources • Faculty expertise • design labs • industry collaborations • government support		**Channels** • University website • industry collaborations • design workshops • online platforms	

Cost Structure	Revenue Streams
• Faculty salaries • infrastructure development • research funding • administrative costs	• Tuition fees • government funding • research grants • industry partnerships

Fig. 3. SUTD BMC based on SUTD portal

These institutions use AI to create individualized learning systems while also automating office procedures and establishing blockchain credentials for ensuring secure accreditation. IIUM focuses its educational model on developing value-based learning from an Islamic academic foundation. Since tradition stands as its base identity the UoT model encourages the union of traditional philosophy with modern innovation by utilizing cutting-edge technology while maintaining humanistic principles. The business model design process must be adaptive to environmental changes according to Ibrahim & Dahlan (2016). The future university framework presented by their organization combines responsive governance systems with multiple funding approaches and local community partnerships which

match IIUM's purpose. According to Wani et al. (2022) universities need to evolve into "problem-solving platforms" which combine knowledge generation along with effective solutions for both local and international challenges.

Focusing on other universities helps IIUM determine its strategic position and decides which digital tools and industry partnerships and interdisciplinary research investments will receive funding. The establishment of purple cow differentiators depends on innovative features that distinguish IIUM from other similar higher education institutions within the Islamic and values-oriented sector worldwide.
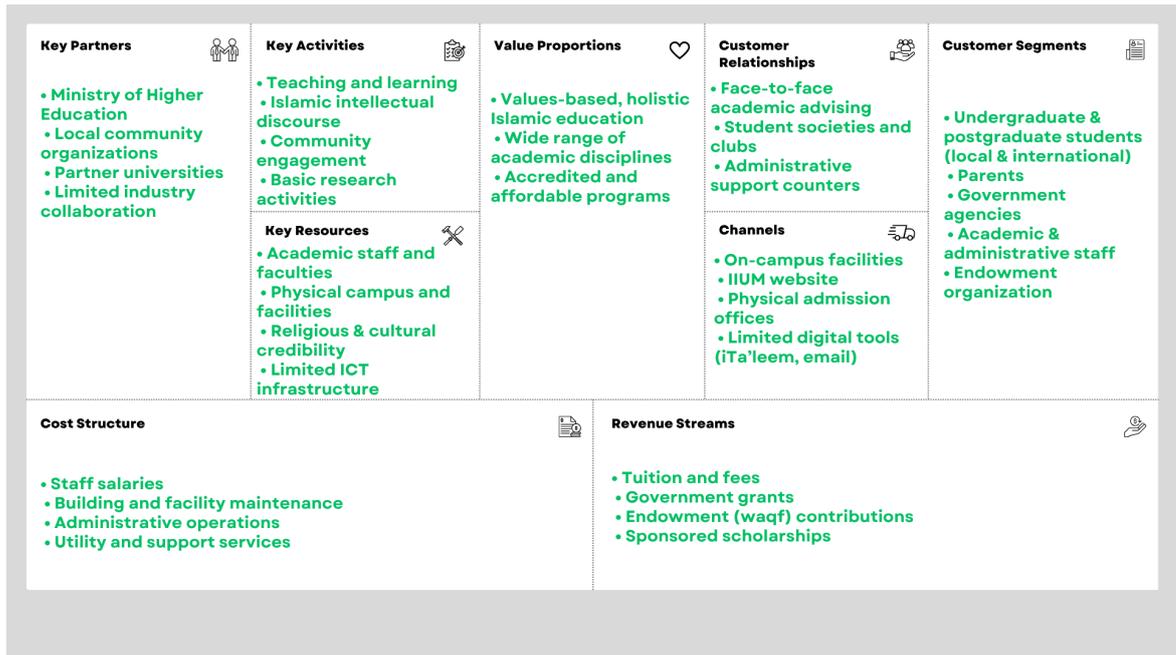
Fig. 4. IIUM current business model, using BMC framework, based on its current (a) Business Strategic Plan & (b) IT/Digital Strategic Plan.

Higher education business model canvas

Australia's universities are monolithic institutions that control all aspects of their teaching and research activities, anchored by physical spaces and time-bound schedules. Digital transformation is challenging this dominant model. As universities evolve from faculty-centred to learner-centric institutions, they may well find it necessary to unbundle their many functions as well as their degree programs to differentiate and maintain competitive advantage.

■ Potential areas of disruption

| How do universities create value?	Who are our customers?	Domestic students	International students	Continuous learners		Government		Industry
	What are the jobs to be done for customers?	Acquiring knowledge	Developing hard and soft skills	Accessing employment opportunities	Coming of age	Learning flexibly	Discovering new ideas	Transferring new knowledge
	What products/ services are we providing?	Undergraduate degrees	Postgraduate degrees	Courses		Other services		Research
	How do customers get our services?	Teaching and learning / Campus and residential facilities / Online / Virtual reality / Artificial intelligence / Publications / Research projects / Partners / Other

How do universities deliver value?	How do we produce it?	Teaching activities	Develop content	Deliver content	Assess learning	Credentialise learning
		Research activities	Develop proposal	Fund proposal	Conduct research	Publish research / Commercialise research
	How do we distribute it?	Academic schools and faculties	Physical campus	Digital campus	Printed materials	
	How do we support it?	Student administration	Student services	Research administration	Marketing	Back office services / Technology / Other
	Who are our key partners and suppliers?	Government	Other universities	Industry	Outsourcers	

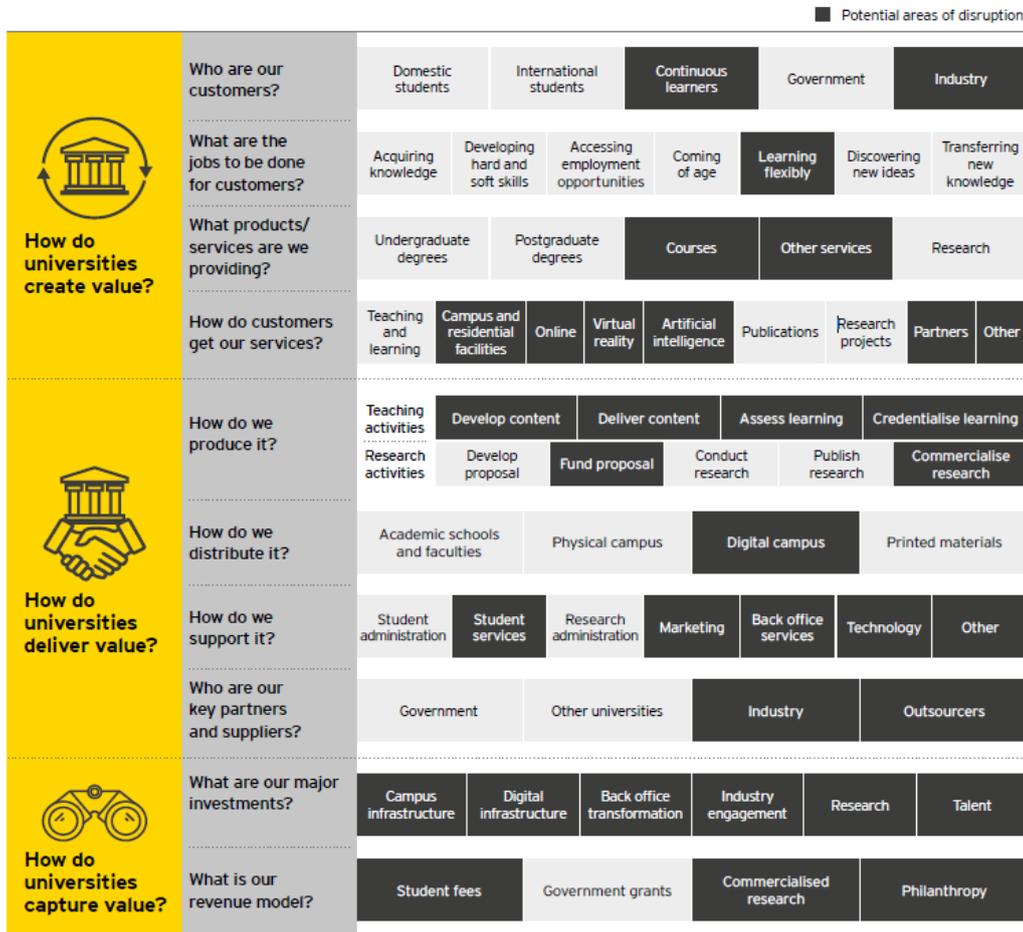| How do universities capture value?	What are our major investments?	Campus infrastructure	Digital infrastructure	Back office transformation	Industry engagement	Research	Talent
	What is our revenue model?	Student fees	Government grants	Commercialised research	Philanthropy		

Fig. 5. Business model of university of tomorrow

The Higher Education Business Model Canvas, as illustrated in Fig. 5 (PwC Australia, 2018) provides a strategic lens through which this transition can be analyzed. It presents a comprehensive view of how future universities create, deliver, and capture value in a digitally evolving environment.

The model begins by identifying universities' diverse customer segments, including domestic and international students, continuous learners, government bodies, and industry. It recognizes that universities serve not only to deliver degrees but also to meet various learner needs such as skill development, employment readiness, and lifelong learning. Value creation is achieved through a blend of offerings including undergraduate and postgraduate degrees, short courses, research activities, and access to flexible learning environments such as online platforms, virtual reality, and AI-enabled learning systems.

This model is highly relevant to IIUM's transition to its University-of-Tomorrow (UoT). It aligns closely with IIUM's efforts to diversify its value propositions, digitize delivery mechanisms, and engage industry and global partners. The IIUM UoT

model can adopt similar principles while embedding Islamic values and regional context, particularly in redefining jobs-to-be-done, expanding flexible digital delivery, and integrating values-based entrepreneurship. By adapting this model, IIUM strengthens its alignment with the MyDigital framework and global shifts in higher education innovation.

5. INITIAL BUSINESS MODEL (BM) – USING BMC & VPC

The strategic UoT transition of IIUM depends on two analytical instruments borrowed from Design Thinking and Business Model Innovation using Business Model Canvas (BMC) and Value Proposition Canvas (VPC) framework. The combined collection of tools enables IIUM to determine strategic alignments while identifying stakeholder requirements and institutional capabilities and innovating areas which make the institution competitive in the digital transformation era. IIUM utilizes the Business Model Canvas to develop a visual framework which depicts its essential operational operations. The university uses eight essential components which detail its capability to deliver stakeholder value through Key Partners and Key Activities combined with Value Propositions and Customer Relationships and Customer segments and required key resources within Channels and Revenue Streams and Cost Structure systems.

Key Partners
·Alumni
·Schools and Agents
·Industry partners (internships, research, innovation)
·Government agencies
Parents and Donors
-Global Islamic Universities & Research Institutions
e.g., International Islamic University Islamabad (IIUI), Al-Azhar University (Egypt), Hamad Bin Khalifa University (Qatar), Universitas Islam Indonesia (UII)

Key Activities
· Teaching & Learning (digitally enhanced, blended, hybrid)
· Research & Development (R&D)
· Faculty digital training and upskilling
Community engagement and student services

Key Resources
·Academic and non-academic staff
·Student services division
·Buildings, labs, media production tools
LMS platform (e.g., iTa'leem) and mobile apps

Value Proportions
· Offer broad academic disciplines: health sciences, arts, business, law, education, etc.
· Humanized, values-based education (Islamic)
· Entrepreneurial and industry-ready graduates
· High institutional reputation and research impact
Islamic – Garden of Knowledge & Virtue, Rahmatan lil alamin

Customer Relationships
· Roadshows and open days (online/offline)
Alumni engagement platforms.
· Digital campus.

Channels
·On-campus (blended/hybrid delivery)
·IIUM LMS and mobile applications
Social media, Telegram, YouTube
· Digital campus.

Customer Segments
· Local students
· International students
· Industry partners/ employers
· Working professionals (lifelong learners)
· Alumni (continuing education)
Donors and funding partners

Cost Structure
·Staff and faculty salaries
·Student services operational cost
·Maintenance of digital infrastructure (cloud, labs, Wi-Fi)
·Content development and LMS platform fees
·Staff digital training and upskilling
Cybersecurity and compliance costs

Revenue Streams
·Tuition (on-campus and online)
·Research grants and industry-sponsored projects
·Endowments, waqf contributions
·Consultancy and community training programs
Government and international education funding

Fig. 6. Initial IIUM University-of-Tomorrow (UoT) Business Model, using BMC framework

Value Proposition Canvas

A complete Value Proposition Canvas (VPC) examines the ways IIUM designs its offerings to match stakeholder expectations and resolve their problems and satisfy their ambitions with their main stakeholder groups. The three segments in the VPC structure separate the diverse needs and motivations associated with the university's primary customer groups.
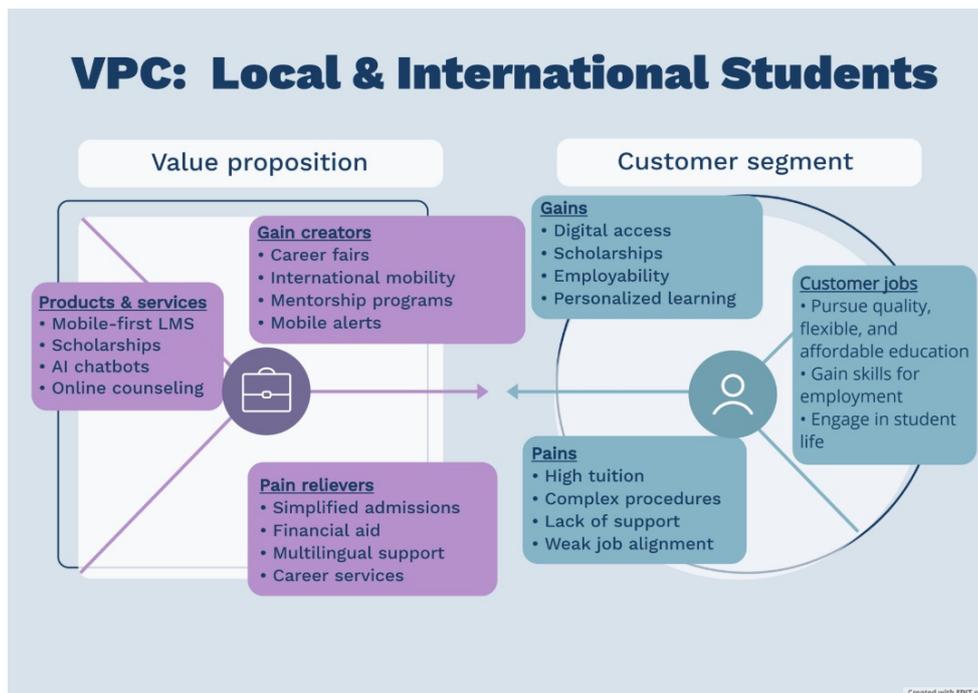
Fig. 7. VPC Local & International Students

Local & International Students

This sector comprises the fundamental student base of IIUM which expects more than standard classroom teaching. The present-day student requests adaptable learning opportunities based in digital platforms combined with career-centered curricula. The value proposition for this academic group highlights IIUM's capability to conduct mobile-oriented learning and personalized educational support together with globally esteemed credentials through micro-credentials. Through this segment the institution solves students' problems related to funding needs and maze-like university processes and bureaucratic systems by providing career support along with tuition aid and instant learning progress reports that align with its value-centered education philosophy.
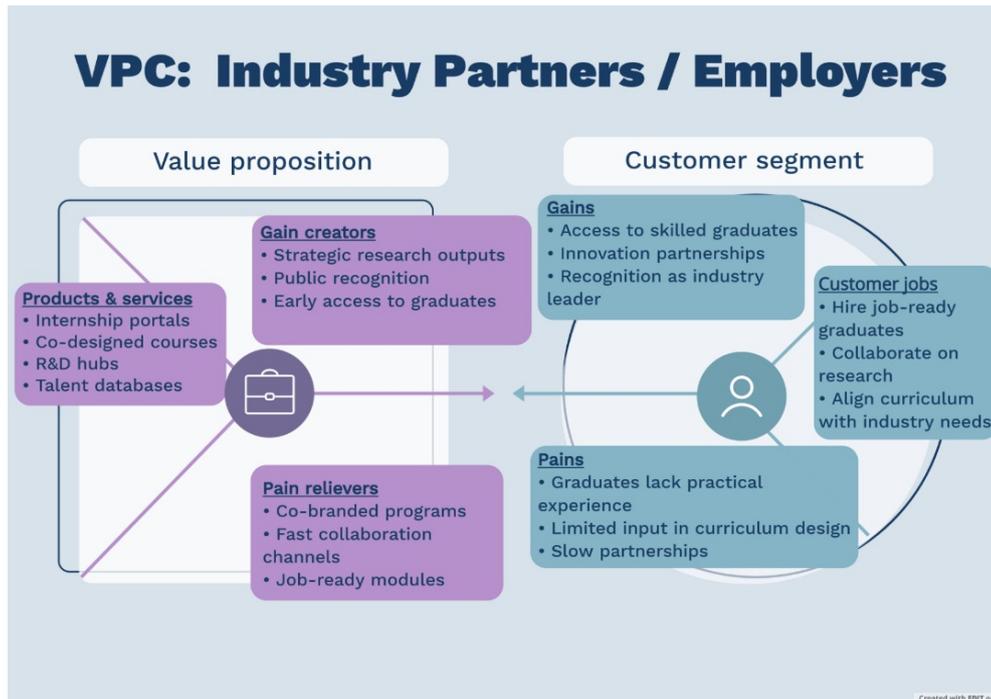
Fig. 8. VPC Industry Partners / Employers

Industry Partners / Employers

The members of the industry fulfill critical responsibilities by helping improve both curriculum content and job readiness of graduates. The VPC demonstrates IIUM's dedication to achieving academic-industry partnership enhancement by developing co-designed learning curricula and research relationships as well as talent development pathways. IIUM undertakes initiatives to meet industry demands about graduate practical experience and curriculum development so it can establish itself as an active partner in workforce preparation. The gain creators—such as early access to graduates, public recognition, and research commercialization—support long-term, mutually beneficial engagement.

Fig. 9. VPC Working Professionals

Working Professionals

The customer base comprises people who need flexible learning programs to upskill or reskill or progress their careers. The VPC for lifelong learners at IIUM provides self-paced micro-credential programs together with professional coaching and continuous professional development (CPD) pathways and modular educational opportunities. Time-efficiency together with cost-effectiveness and acknowledgment issues find specific solutions through this segment t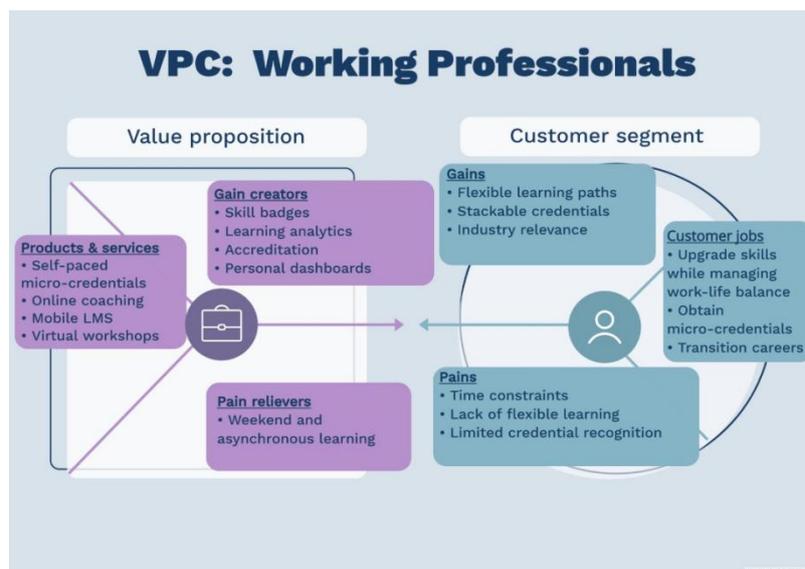hat provides adaptable digital infrastructure and customizable learning control systems. Through this segment IIUM expands its educational range along with revenue sources to support the national aims of lifelong learning and adaptable workforce development.
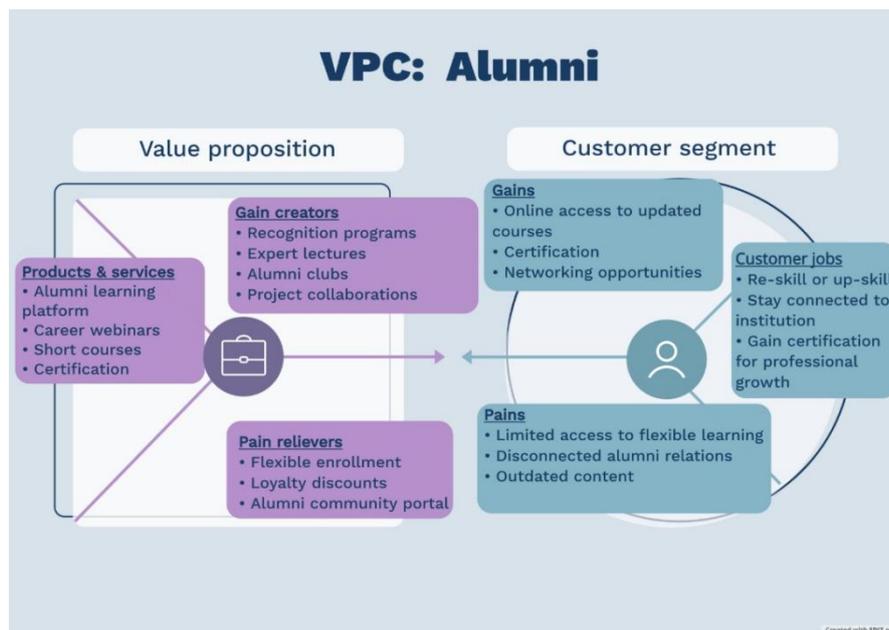
Fig. 10. VPC Alumni

Alumni

The alumni of IIUM serves as brand ambassadors while continuing their learning and collaboration throughout their lives. Through ongoing educational programs and networking services and certification programs the VPC segment develops alumni engagement profiles. Main steps in response to alumni discontent about old material and weak university connections include transforming entry policies for loyal graduates and enabling flexible learning opportunities and access and expert lecture series events. The initiatives establish and maintain alumni connections which strengthens both the university's professional network while developing a worldwide support system based on mutual values.
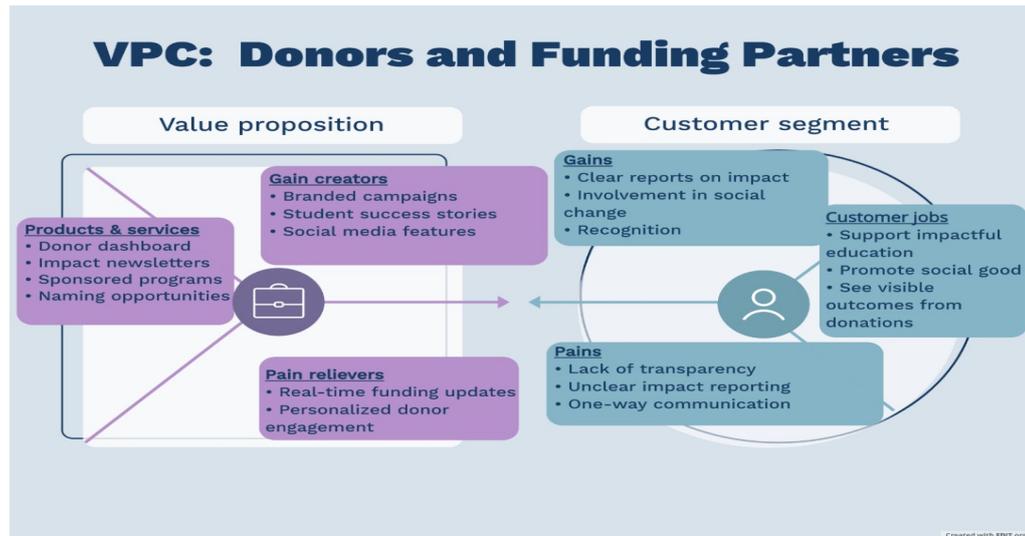
Fig. 11. VPC Donors and Funding Partners

Donors and Funding Partners

This part of supporters comprises philanthropic contributors as well as waqf sponsors and institutional supporters who require organizational transparency while seeking social impact and strategic investment opportunities. The VPC for donors and funding partners demonstrates IIUM's ability to match donor objectives with community results by using impact tracking systems and person-made engagement together with value-driven promotional initiatives. The institution uses pain relievers through real-time funding reports and clear communication channels to deliver relief and gain creators such as named sponsorships and student success stories and recognition events to demonstrate IIUM's mission-driven status and measurable societal value.

6. CONDUCT VALIDATION OF INITIAL BUSINESS MODEL & KEY FINDINGS

The initial Business Model (BM) for IIUM's University-of-Tomorrow (UoT) received validation through interviews and feedback sessions directed at key Customer Segments (CS) 8 of respondents for each different CS such as Local & International students, Industry partners and employers, Working professionals (lifelong learners), Alumni, Donors and funding partners. The evaluation aimed to verify whether the suggested value propositions and key activities together with delivery approaches were appropriate and executable. A semi-structured session led the dialogue when investigating value propositions combined with channels based on the nine BMC blocks. Analyzed responses by identifying recurring patterns which identified the major problems and user preferences. An evaluation process utilized the collected feedback to modify the first BM until it matched the university's directives as well as stakeholder objectives.

Validation Summary Table

Table 1: Validation Summary Table

Customer Segment	Key Needs Identified	Feedback Insights	Model Adjustments
Local & International Students	Flexible, affordable, and mobile-first learning with career-focused outcomes	Desire for real-time academic tracking, AI support, and better user experience	Enhanced chatbot features, UI improvement, mobile notification integration
Industry Partners / Employers	Access to job-ready graduates, involvement in curriculum, and collaborative R&D	Support for co-designed programs, but need faster engagement processes	Created fast-track collaboration pathways and co-branded curriculum options
Working Professionals (Lifelong Learners)	Modular, certified learning paths that can fit around professional schedules	Positive response to online credentials and asynchronous delivery	Expanded self-paced course catalog and weekend workshop formats
Alumni (Continuing Education)	Opportunities for professional development and stronger institutional connection	Appreciation for alumni-focused webinars and loyalty discounts	Added alumni portal features, recognition programs, and professional certificates
Donors and Funding Partners	Transparent reporting, social impact, & meaningful engagement opportunities	Interest in personalized communication and evidence of student impact	Developed donor dashboard with custom reports and periodic impact stories

The Validation Summary Table records findings from five main customer groups who participated in developing the UoT business model for IIUM. The model refinement was directed by specific needs and expectations of five distinct customer segments which included students as one of the segments of 12 respondents. Students including both national and international participants told researchers that adaptability together with affordable education costs and immediate academic support were essential needs. The implemented changes to mobile interface structures and AI chatbots functionality along with academic notification enhancements came from user feedback. The industry partners requested quicker collaboration tools and curriculum influence, so the college launched co-branded educational programs and simplified its partnership process. The interest from lifelong learners in modular and self-paced learning systems caused the institution to create more weekend classes and asynchronous micro-credentials. An engagement platform for alumni came into existence alongside new professional development programs which were developed by analyzing alumni feedback. The drive for transparency from donors led to the establishment of donor dashboards and individualized impact reporting systems. Through this validation process the business model maintained its user-focused nature and its relevance to concrete needs shared by every target group.

7. VALIDATED BUSINESS MODEL – BMC FRAMEWORK

The validated Business Model Canvas (BMC) for IIUM's University-of-Tomorrow (UoT) incorporates essential stakeholder feedback and follows both national policy requirements as well as worldwide digital transformation standards.

- **Customer Segments**

  IIUM's UoT business model serves diverse customer segments including local and international students, lifelong learners, alumni, underprivileged and war-torn region students, communities (both global and local), academic staff, industry partners, and government agencies. Each segment presents distinct needs ranging from accessible education to collaborative innovation and ethical talent development.

- **Value Proposition**

  The value proposition centers on delivering holistic, values-based education through flexible, modular, and digitally enabled platforms tailored to each customer segment (CS). For local and international students, IIUM offers personalized learning via AI-guided systems, micro-credentials, and real-world problem-solving opportunities to enhance employability. For lifelong learners and working professionals, the model provides upskilling through stackable, flexible courses aligned with industry demand. For industry partners and employers, IIUM delivers job-ready graduates with ethical grounding and practical competencies. Donors and funding partners are offered transparent, impact-driven initiatives such as waqf-linked innovation programs. All offerings are embedded within Islamic ethical frameworks to produce globally competent, spiritually grounded, and socially responsible individuals.

- **Channels**

  IIUM utilizes an integrated digital campus (DC) as its central delivery channel, supported by mobile-first platforms, cloud-based systems, and LMS-integrated environments. The digital campus provides unified access to learning resources, academic services, communication tools, and collaboration features across departments and global partners. Key functions of the digital campus include real-time academic tracking, virtual classrooms, AI-enabled advising, administrative self-services, and portals for alumni and industry interaction. These ensure that students, educators, and external stakeholders have seamless access to personalized education and institutional engagement, regardless of location or time.

- **Customer Relationships**

  IIUM nurtures strong customer relationships through personalized learning journeys, academic advising, AI-driven support systems, digital feedback loops, mentorship programs, and an actively engaged alumni network. These relationships extend lifelong learning and continuous support to stakeholders.

- **Revenue Streams**

  IIUM generates revenue through tuition and program fees, micro-credential offerings, research commercialization, consultancy services, grants, and philanthropic contributions such as waqf and zakat. Additional income streams may emerge from collaborative ventures with industry and government bodies.

- **Key Resources**

  The model relies on academic talent, digital infrastructure (including cloud and LMS platforms), AI and data analytics capabilities, content creation studios, partnerships, and its Islamic educational content identity. These resources support innovation, delivery, and institutional resilience.

- **Key Activities**

  Core activities include digital content development, curriculum modularization, platform and infrastructure management, stakeholder engagement, and academic-industry collaborative research. The institution also prioritizes community outreach, social entrepreneurship, and internationalization efforts.

- **Key Partners**

  IIUM partners with EdTech firms, accreditation bodies, ministries, global universities, private industries, and Islamic development organizations. These include government entities from under-developed and conflict-affected nations, who sponsor and support student mobility and institutional collaborations.

- **Cost Structure**

  Key costs involve cloud service subscriptions, cybersecurity and governance, faculty digital skill development, content production, platform maintenance, marketing, and partnership coordination. Investments are also directed toward accessibility enhancements for underserved and international learners.

7.1. Transform from cost-center to profit center

To support IIUM's transformation from a cost center to a profit center, the following strategic digital initiatives are recommended. These initiatives aim to generate sustainable revenue while aligning with IIUM's mission, digital capabilities, and academic excellence:

a) IIUM Micro-Credential & Lifelong Learning Marketplace

Develop and commercialize a digital platform offering industry-aligned micro-credentials, professional certificates, and modular short courses. These offerings can target working professionals, international learners, and alumni, generating revenue through flexible online programs while enhancing IIUM's global educational outreach.

b) Digital Waqf Innovation Platform

Create a centralized digital waqf and endowment management system that enables global donors and alumni to contribute to strategic projects. This fintech-based waqf model can include real-time dashboards, AI-driven transparency tools, and impact reporting—enhancing trust and attracting sustainable philanthropic funding for research, scholarships, and infrastructure.

c) IIUM EdTech-as-a-Service (EaaS) Hub

Establish IIUM as a regional provider of Islamic digital education tools and consulting services. This initiative could involve licensing custom-built platforms (e.g., LMS, AI chatbots for student support), offering content development services for partner universities, and monetizing IIUM's expertise in integrating Islamic values into digital education frameworks

7.2. Environmental Map (EM)

The Environmental Map identifies four key external factors influencing IIUM's transformation into the UoT:

Table 2: Environmental Map Table

External Factor	Description	Supporting Literature
Market Forces	Increasing demand for flexible, skills-based, and digitally delivered education options across borders; competition for international students	World Economic Forum (2020); Economic Planning Unit (2021)
Key Trends	Widespread adoption of AI and EdTech in learning, rising prominence of micro-credentials, and alignment with national policies like MyDigital and 4IR	Ministry of Science, Technology, and Innovation (2021); PwC (n.d.); Osterwalder & Pigneur (2010)
Industry Forces	Heightened expectations from industries for job-ready graduates, emphasis on applied research, and rising calls for curriculum co-design	Ministry of Entrepreneur Development and Cooperatives (2020); Ahmad & Ramli (2022)
Macro-Economic Forces	Budget constraints, widening digital divide, NEP 2030 directives for inclusive entrepreneurship, and post-pandemic educational recovery challenges.	Ministry of Entrepreneur Development and Cooperatives (2020); UNESCO (2020)

Through the Environmental Map, IIUM gains strategic visibility into external transformation factors at work. Higher education institutions now operate in a competitive zone as market forces show that educational institutions should present flexible digital learning programs with international relevancy to draw and maintain their student population. IIUM must expedite its digital transformation based on key education trends of AI adoption and EdTech development as well as MyDigital national strategy initiatives. Industry forces underline the necessity for universities to create learning experiences jointly with industries because they demand graduates who possess job-readiness alongside practical and entrepreneurship abilities. IIUM must refine its operations because macro-economic conditions include COVID-19 recovery requirements and financing limitations together with sustainability targets. The UoT model equips IIUM to stay sustainable by analyzing these four substantial areas.
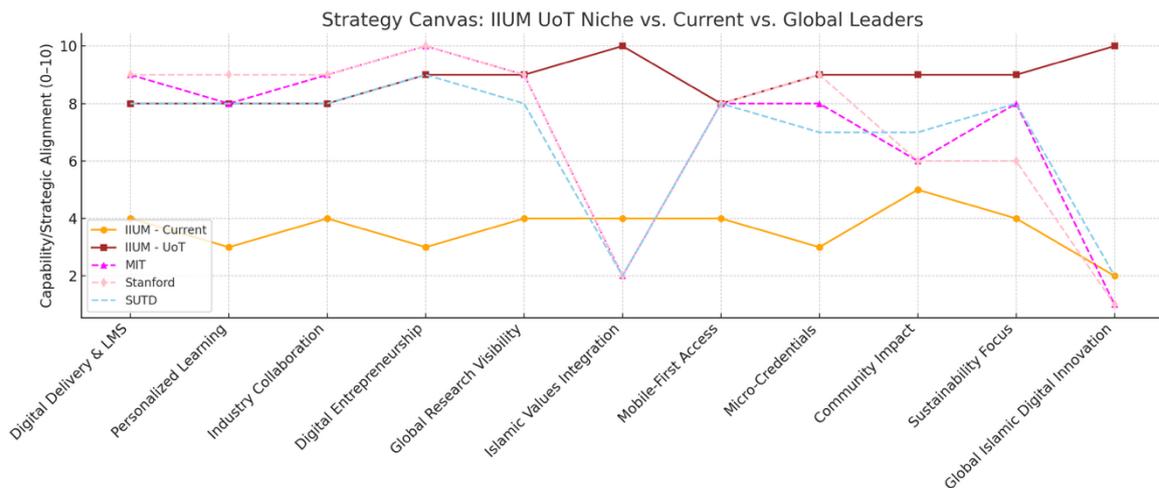
7.3. Strategy Canvas

Fig. 12. Strategy Canvas: IIUM current vs. UoT vs. MIT, Stanford University, and SUTD

The updated Strategy Canvas illustrates a comparative assessment of IIUM's current digital capabilities, its envisioned University-of-Tomorrow (UoT) model, and global benchmark institutions such as MIT, Stanford, and SUTD. The analysis spans across eleven strategic dimensions, including digital delivery, personalized learning, research visibility, mobile access, and a newly introduced dimension - Global Islamic Digital Innovation. While global leaders consistently score high in areas like digital entrepreneurship and industry collaboration, they register notably low in dimensions related to Islamic values and faith-integrated digital ecosystems.

In contrast, IIUM UoT is positioned to lead in two distinctive areas: Islamic Values Integration and Global Islamic Digital Innovation. These dimensions represent IIUM's strategic niche, offering a unique value proposition that aligns advanced digital transformation with Islamic ethics, heritage, and global community impact. This differentiation sets IIUM apart as the only institution among the comparators that fuses technology, values-based education, and transnational Islamic collaboration. By emphasizing this niche, IIUM UoT not only strengthens its global relevance but also fulfills its mission to serve as a digitally empowered institution grounded in the philosophy of *rahmatan lil-'alamin*.

The Strategy Canvas Fig. 12 compares:

a) IIUM's Current Organization vs. University-of-Tomorrow (UoT)

b) IIUM UoT vs. Industry Leaders i.e. MIT, Singapore University of Technology and Design.

Table 3: Strategy Canvas Table

Strategic Factor	IIUM – Current	IIUM – UoT	MIT	Stanford	SUTD
Digital Delivery & LMS	4	8	9	9	8
Personalized Learning	3	8	8	9	8
Industry Collaboration	4	8	9	9	8
Digital Entrepreneurship	3	9	10	10	9
Global Research Visibility	4	9	9	9	8
Islamic Values Integration	4	10	2	2	2
Mobile-First Access	4	8	8	8	8
Micro-Credentials	3	9	8	9	7
Community Impact	5	9	6	6	7
Sustainability Focus	4	9	8	6	8
Global Islamic Digital Innovation	2	10	1	1	2

The updated Strategy Canvas Table highlights IIUM's strategic transformation from its current digital profile to the envisioned University-of-Tomorrow (UoT), benchmarked against leading global institutions such as MIT, Stanford, and SUTD. While global institutions demonstrate high capability across conventional metrics like digital delivery, research visibility, and entrepreneurship, they lack emphasis in areas such as Islamic values integration and digital innovation from an Islamic worldview. IIUM UoT distinguishes itself by excelling in these two strategic domains, notably Islamic Values Integration and Global Islamic Digital Innovation - both scoring 10. These dimensions represent IIUM's "purple cow" or niche capabilities, where it leads globally by aligning digital transformation with the philosophy of *Tawḥīd* and the mission of *rahmatan lil-'alamin*. These niche areas support IIUM's differentiation as a values-driven, future-ready institution that advances inclusive, ethical, and faith-based digital education in the Muslim world and beyond. The table serves as a strategic benchmarking tool to guide DISP implementation and validate IIUM's unique position in the global higher education landscape.

To ensure effective implementation of the University-of-Tomorrow (UoT) model, IIUM adopts the Skills Framework for the Information Age (SFIA) to guide digital talent development and capability mapping across the institution, especially within the Information Technology Division (ITD). SFIA enables IIUM to align roles and responsibilities with clearly defined competencies across areas such as cybersecurity, service design, data analytics, and digital strategy. By incorporating SFIA, IIUM ensures that ITD staff possess the necessary skills at appropriate responsibility levels to support emerging digital initiatives, foster continuous professional growth, and maintain operational excellence in alignment with national frameworks such as MAMPU and the ICT Strategic Plan.

8. CONCLUSION AND FUTURE WORKS

This paper addressed the complex challenges faced by the International Islamic University Malaysia (IIUM) in maintaining relevance amidst digital disruption, evolving learner demands, and institutional inefficiencies. Key customer segments—such as students, academic staff, industry partners, and donors—face critical pains including fragmented digital services, lack of personalized learning, and limited real-world application of knowledge. Their key jobs-to-be-done include

accessing flexible education, receiving ethical and industry-aligned learning experiences, and engaging in meaningful, lifelong learning pathways. To address these needs, this study developed a validated conceptual business model for the University-of-Tomorrow (UoT) at IIUM, grounded in Design Thinking methodology and supported by the BMC, VPC, EM, and Strategy Canvas frameworks. A distinct strength of the UoT model is its alignment with IIUM's foundational values, particularly its commitment to nurturing holistic, ethical, and globally competent individuals. Rooted in tawhidic epistemology and guided by ummatic excellence, the model integrates spiritual, intellectual, and professional development through humanized education and digital innovation.

The proposed UoT model presents several "purple cow" differentiators that act as effective pain relievers and gain creators across segments. These include mobile-first digital delivery, modular micro-credential pathways, AI-enabled academic support, and the integration of Islamic values into digital learning environments. Furthermore, the model introduces innovative funding mechanisms such as waqf-based research investment and establishes global Islamic digital innovation as a strategic niche. These features collectively position IIUM as a digitally empowered, ethically grounded, and globally relevant higher education institution. The model not only strengthens IIUM's competitive position but also offers a scalable and contextually adaptable framework for other institutions seeking digital transformation.

Future work will focus on developing a comprehensive Digital Implementation Strategic Plan (DISP) that will operationalize the UoT business model. The DISP will detail the necessary digital infrastructure, governance structures, human capital development, delivery phases, and risk mitigation frameworks required to transition from IIUM's current business model to its envisioned UoT. It will also include performance metrics, stakeholder engagement protocols, and mechanisms for continuous evaluation. Further empirical validation through stakeholder surveys, system testing, and benchmarking will help refine the model and ensure long-term institutional sustainability and national policy alignment. This conceptual UoT BM offers viable options for decision makers & planners to consider, adopt or adapt in enhancing & innovate their own organizations.

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AI FROM AN ISLAMIC PERSPECTIVE

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ABSTRACT: This paper explores Artificial Intelligence (AI) from an Islamic ethical perspective by drawing upon the Qur'an, classical tafsir, and contemporary scholarship. Rather than treating AI solely as a technological or theological issue, the paper highlights how Islamic principles—justice, accountability, remembrance (dhikr), reflection (fikr), and gratitude (shukr)—can guide the ethical development and use of AI. Using a descriptive research design, the study synthesizes global concerns about AI, including bias, manipulation, and autonomy, with Islamic teachings on morality, responsibility, and societal well-being. The objective is to propose a framework that integrates AI ethics with Islamic epistemology, offering guidance for Muslims and contributing to broader discussions on responsible AI.

KEY WORDS: *Artificial Intelligence, Islamic perspective, Muslim society*

1. INTRODUCTION

Artificial Intelligence (AI) is a technology that is constantly encountered in our lives, and it is a force that we should actively engage with rather than disregard. As a widespread influence, AI has the potential to significantly impact various sectors of our lives, including the economy, politics, society, education, and future generations. As Muslims and members of Muslim society, we must prepare for these changes. We should understand how AI will shape our world. This chapter will discuss how the teachings of the Quran can guide us in navigating the complexities of AI. It is our responsibility to manage and control AI, not just for the betterment of humanity in general but also to bring us closer to Allah. This sentiment is also echoed by secular institutions, with the European Union recently introducing legislation to regulate and manage AI. This study therefore focuses on the ethical dimension of AI, examining how Islamic sources provide a framework to navigate its challenges. The objectives are threefold: (1) to analyze contemporary global concerns about AI; (2) to critically examine Islamic principles from the Qur'an and classical tafsir that relate to knowledge, ethics, and responsibility; and (3) to integrate these insights into a practical ethical framework for AI from an Islamic perspective.

2. PROBLEM STATEMENTS

As mentioned in the book, "Muslim Societies in Post-normal Times," with the introduction of social media, communication and information sharing between North and South and East and West have become more accessible thanks to sites like Facebook, WhatsApp, Twitter, and many more. In addition to uniting individuals,

social media also separates and shatters them. Artificial Intelligence (AI) starts as process automation, which is commonly observed in retail and industry. However, it can potentially become a crucial component of finance, manufacturing, advanced medical technology, and even warfare.

As Artificial Intelligence (AI) becomes more advanced, more issues and problems will occasionally occur. There's also AI in social media. If we do not handle social media correctly, it will take us to a dangerous zone. Tristan Harris, a former Google ethical designer, says during his interview for the Documentary on Netflix, "The Social Dilemma," "If something is a tool, it's just sitting there, waiting patiently." If something isn't a tool, it expects something from you. It tempts you, manipulates you, and desires things from you. We have progressed from a tool-based technological environment to a technical environment utilized for addiction and manipulation. Social media is not a technology waiting to be used. The media serves a purpose and has its own way of manipulating your psychology" (The Social Dilemma, 2020).

According to Stephen Hawking, we are about to enter a more hazardous era in human history. He was worried about the potentially dangerous effects of brilliant artificial Intelligence (AI). Thus, it is imperative that each individual, community, and nation—develop a sense of direction, including knowing where we are going, being aware of the possible outcomes of the actions we take right now, and appreciating the financial and environmental costs of the decisions we make. In the Muslim world, arguably, social justice issues, economic inequality, unemployment, the environment, and technological and cultural upheaval are more pressing and urgent than elsewhere (Hawking et al., 2014).

Geoffrey Hinton, generally regarded as the "godfather of AI," has resigned from Google and plans to warn the public about the perils of the technology he has long backed. Hinton argues that computer intelligence can amass far more knowledge than any one biological agent. He intends to warn the world about the possible threat of artificial Intelligence, which he believes is approaching faster than anticipated. According to The New York Times, Hinton resigned from Google to publicly communicate his concerns about artificial Intelligence's perils. He added that he finds solace in the conventional justification that someone else would if he did not do it.

Elon Musk warns about Metaverse/AI. He shares some of the significant concerns related to Artificial Intelligence (AI). The development of Artificial Intelligence (AI) must be monitored so that it is safe to use. Otherwise, Artificial Intelligence (AI) would be far more dangerous than nuclear war. There should be rules and regulations regarding such advanced systems due to the potential threats that may arise. Professor of AI, Prof Stuart Russell, said, "AI does good things, but allowing AI to choose to kill humans will be devastating to our security and freedom. We have an opportunity to prevent the future from becoming dangerous, but the window to act is closing fast."

According to the article "The Clash of Artificial and Natural Intelligences: Will It Impoverish Wisdom?" by Prof Osman Bakar, other than AI, there are Natural Intelligence (NI) and Prophetic Intelligence (PI). Natural Intelligence (NI) refers to the aspect of a human being that encompasses all cognitive faculties, both physical and non-physical, along with their functions and activities in gathering and

organizing information to process knowledge and understand the complexities of human language. In Islamic civilization, this concept of NI is represented by the term 'aql,' typically translated as intellect or reason. Meanwhile, Prophetic Intelligence (PI) represents the highest level of Intelligence achievable by the human mind. Al-Farabi, a Muslim philosopher from 870 CE–950 CE, equates this extraordinary Intelligence with the group of individuals historically referred to as prophets. Within Islam, the term used for a prophet is "nabiy."

While global voices such as Stephen Hawking, Geoffrey Hinton, and Elon Musk highlight the existential and ethical risks of AI, these concerns resonate with Islamic teachings that emphasize accountability, justice, and the safeguarding of humanity. Rather than treating these as two separate discourses, this paper positions Islamic perspectives as complementary to, and sometimes corrective of, secular AI ethics.

3. DESCRIPTIVE RESEARCH

This study adopts a descriptive research design, which focuses on systematically portraying a phenomenon as it exists, rather than manipulating variables or testing causal relationships. According to Creswell (2014), descriptive research is particularly valuable in studies that aim to understand current practices, issues, or contexts without altering them. Its purpose is to provide a clear picture of a situation through qualitative and interpretive accounts.

This paper adopts a qualitative descriptive research design based on library research. Primary sources include the Qur'an, tafsir literature (e.g., Ibn Kathir, Al-Tabari, Al-Qurtubi), and classical Islamic scholarship. Secondary sources consist of contemporary AI ethics literature, policy reports, and peer-reviewed studies. The analysis employs thematic mapping: identifying major AI concerns (e.g., manipulation, bias, militarization, autonomy) and examining how Islamic principles provide ethical guidance. This interpretive approach enables a holistic framework that integrates modern AI debates with Islamic epistemology.

3.1. AI Issues and Global Concerns

Descriptive research allows us to highlight pressing ethical, social, and economic concerns raised by AI. Scholars and scientists have consistently warned about the potential dangers of AI if left uncontrolled. Stephen Hawking argued that humanity is entering a more hazardous era due to the unpredictable consequences of advanced AI systems (Hawking et al., 2014). Geoffrey Hinton, often called the "godfather of AI," also resigned from Google to publicly voice concerns about the uncontrolled growth of AI (The New York Times, 2023, as cited in Noordin & Zailan, 2023). Similarly, Elon Musk has described AI as potentially more dangerous than nuclear weapons if not properly regulated (Russell, 2019).

These warnings highlight the urgent need for ethical frameworks that go beyond secular regulations such as the European Union's AI legislation. Descriptive research is well-suited to documenting these concerns while simultaneously contrasting them with Islamic principles that emphasize justice, mercy, and moral responsibility.

3.2. Methodology

This study employs a **qualitative descriptive research design** to explore the intersection between **Artificial Intelligence (AI)** and **Islamic teachings.** The

descriptive approach is appropriate for this study because the objective is not to test a hypothesis or measure variables but to provide a detailed account of existing issues and perspectives related to AI from an Islamic worldview (Creswell, 2014).

Research Design

The research is conceptual in nature and relies on **descriptive and interpretive methods**. It seeks to synthesize contemporary concerns about AI with ethical and spiritual insights derived from the Qur'an, Sunnah, and Islamic scholarship. The methodology is rooted in library-based research, where primary and secondary sources are systematically reviewed, analyzed, and integrated.

3.2.1. Sources of Data

The study draws upon two main categories of sources:

1. **Islamic Sources**: The Qur'an, tafsir literature (e.g., Ibn Kathir, Al-Tabari, Al-Qurtubi), and writings of classical and contemporary Muslim scholars such as Al-Ghazali, Al-Attas, and Al-Faruqi. These sources provide ethical, spiritual, and epistemological principles relevant to technology and knowledge.

2. **Contemporary Literature**: Works by scientists, ethicists, and policymakers addressing the risks and opportunities of AI, including warnings from Stephen Hawking, Geoffrey Hinton, and Elon Musk, as well as regulatory efforts such as those from the European Union. Academic literature on AI ethics and postnormal times (e.g., Sardar, 2019) also informs this study.

3.3. Analytical Approach

The analysis follows a **thematic descriptive method,** where issues identified in the contemporary discourse on AI (e.g., ethical risks, manipulation, social disruption, warfare) are mapped against corresponding Islamic concepts. Qur'anic narratives, such as Prophet Sulaiman's understanding of the languages of birds and ants (Surah An-Naml 27:16–19), are interpreted as ethical metaphors that provide guidance for developing AI responsibly.

The study also applies the principles of **zikir (remembrance), fikir (reflection), and syukur (gratitude)** as overarching themes for evaluating the use of AI. By applying these themes, the research ensures that technological development remains aligned with Islamic values of justice, mercy, and moral responsibility.

3.4. Quranic Approach between 'Aqli and Spiritual

(Surah Aal-e-Imran, Verses 190 & 191)

إِنَّ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ وَاخْتِلَافِ اللَّيْلِ وَالنَّهَارِ لَآيَاتٍ لِّأُولِي الْأَلْبَابِ

Verily! In the creation of the heavens and the earth, and in the alternation of night and day, there are indeed signs for men of understanding.

الَّذِينَ يَذْكُرُونَ اللَّهَ قِيَامًا وَقُعُودًا وَعَلَىٰ جُنُوبِهِمْ وَيَتَفَكَّرُونَ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ رَبَّنَا مَا خَلَقْتَ هَٰذَا بَاطِلًا سُبْحَانَكَ فَقِنَا عَذَابَ النَّارِ

Those who remember Allah (always, and in prayers) standing, sitting, and lying down on their sides, and think deeply about the creation of the heavens and the earth, (saying): "Our Lord! You have not created (all) this without purpose; glory to You! (Exalted be You above all that they associate with You as partners). Give us salvation from the torment of the Fire.

1. **Dhikr,** characterized by 'Ulul Albab. Encouraging to think about the relationship between the physical world and its Creator.

2. **Fikr,** Cognitive skills are needed to understand the nature of the subject. Questioning thought-provoking questions about behavior, laws, systems, and others that lead to the recognition of the greatness of God.

3. **Shukr.** Syukur to Allah and his surroundings. Think positively about using science by subjecting its application to the protection of religious human life.

3.4.1. Mind & Thinking

In the Qur'an:

1. The word 'aql is mentioned in the Qur'an 49 times.
2. The word "Afala Ta'qilun" (don't you use your mind?) 24 times;
3. The word "Afala Ya'qilun" (do they not use their intellect?) 22 times;
4. The word "Afala Ta'lamun" (don't you know?) 36 times;
5. The word "Afala Ya'lamun" (do they not know?) 91 times;
6. The word "Afala Tatafakkarun" (don't you think?) 3 times;
7. The word "Afala yatafakkarun" (do they not think) 91 times;
8. The word "Afala Tadrusun" (did you not learn) twice.

Source: Article "Agama dan kehidupan manusia modern" by muddasir dasir

3.5. Artificial Intelligence and Quranic Approach

3.5.1. Artificial Intelligence: Pure and Safe

From Surah An-Naml, Verse 1:

<div dir="rtl">

طس تِلْكَ آيَاتُ الْقُرْآنِ وَكِتَابٍ مُّبِينٍ

</div>

Ta-Sin. [These letters are one of the miracles of the Quran, and none but Allah (Alone) knows their meanings]. These are the Verses of the Quran, and (it is) a Book (that makes things) clear. (English- Mohsin Khan)

"Tha-sin" is a combination of letters that appears at the beginning of several Surahs (chapters) in the Quran. Many scholars of Tafsir (Quranic exegesis) have concluded that "only Allah knows its meaning, as it is not possible for there to be words in the Quran that have no meaning, even if they consist of letters without apparent significance." However, some scholars have attributed meanings to it. They suggest that the letter "Tha" signifies "Thayyib" or "Thaher," which means excellent and pure, respectively. The letter "Siin" is seen as an indication of the phrase "Salim," which means safe or complete. With these letters, our Prophet

Muhammad (peace be upon him) is called "the one who is good, pure, and safe." This is mentioned in the Quran, which is a clear book. (Tafsir Al Azhar)

The Artificial Intelligence that we want should be pure and safe for humanity. It is not going to be harmful to the Muslim ummah in particular and humanity in general.

3.5.2. Artificial Intelligent and Language of Bird

In Surah An-Naml, Verse 16:

وَوَرِثَ سُلَيْمَانُ دَاوُودَ وَقَالَ يَا أَيُّهَا النَّاسُ عُلِّمْنَا مَنطِقَ الطَّيْرِ وَأُوتِينَا مِن كُلِّ شَيْءٍ إِنَّ هَٰذَا لَهُوَ الْفَضْلُ الْمُبِينُ

And Sulaiman (Solomon) inherited (the knowledge of) Dawud (David). He said: "O mankind! We have been taught the language of birds, and on us have been bestowed all things. This, verily, is an evident grace (from Allah)." (English - Mohsin Khan)

Allah s.w.t asked us to learn the language of birds. The way in which the bird can fly long distances with the aerodynamic pattern is known as Intelligence, which leads the bird flock. In Surah An-Naml (27:16), Prophet Sulaiman is described as understanding the "language of birds." Classical tafsir (Ibn Kathir, Al-Tabari) interprets this as a divine gift symbolizing wisdom, communication, and knowledge of creation. While not referring to technology in a literal sense, this narrative highlights the importance of learning from nature and expanding human understanding responsibly. In the AI context, it can be seen as a metaphor for developing technologies that enhance communication and knowledge-sharing without violating ethical boundaries.

3.5.3. Artificial Intelligent and Language of Ant

Surah An-Naml, Verse 18 & 19:

حَتَّىٰ إِذَا أَتَوْا عَلَىٰ وَادِ النَّمْلِ قَالَتْ نَمْلَةٌ يَا أَيُّهَا النَّمْلُ ادْخُلُوا مَسَاكِنَكُمْ لَا يَحْطِمَنَّكُمْ سُلَيْمَانُ وَجُنُودُهُ وَهُمْ لَا يَشْعُرُونَ

فَتَبَسَّمَ ضَاحِكًا مِّن قَوْلِهَا وَقَالَ رَبِّ أَوْزِعْنِي أَنْ أَشْكُرَ نِعْمَتَكَ الَّتِي أَنْعَمْتَ عَلَيَّ وَعَلَىٰ وَالِدَيَّ وَأَنْ أَعْمَلَ صَالِحًا تَرْضَاهُ وَأَدْخِلْنِي بِرَحْمَتِكَ فِي عِبَادِكَ الصَّالِحِينَ

And when they came across a valley of ants, an ant warned, "O ants! Go quickly into your homes so Solomon and his armies do not crush you unknowingly." So he [Sulaiman (Solomon)] smiled, amused at her speech, and said: "My Lord! Inspire and bestow upon me the power and ability that I may be grateful for Your Favours which You have bestowed on me and on my parents, and that I may do righteous good deeds that will please You and admit me by Your Mercy among Your righteous slaves. (English - Mohsin Khan)

Artificial intelligence also existed among the ants, such as when the servant of the ant could bring the food to the queen, how the ants made the underground tunnel, and how they could find the food everywhere they communicated. And here in Surah An-Naml verses 18 and 19, Prophet Muhammad SAW understood the conversation between the leader of Ant and others Ant.

3.5.4. Artificial Intelligence: Observation and Data Collection

Surah An-Naml, Verse 22:

<div dir="rtl">فَمَكَثَ غَيْرَ بَعِيدٍ فَقَالَ أَحَطتُ بِمَا لَمْ تُحِطْ بِهِ وَجِئْتُكَ مِن سَبَإٍ بِنَبَإٍ يَقِينٍ</div>

But the hoopoe stayed not long; he (came up and) said: "I have grasped (the knowledge of a thing) which you have not grasped, and I have come to you from Saba' (Sheba) with trustworthy news. (English - Mohsin Khan)

In the Story of hoopoe or Hud-hud, the birds are flying from Baitul Muqaddis or Jerusalem to South country, which is Yaman; the bird managed to observe another country with another leader so the capabilities of Hoppoe or Hud-hud recognized by Allah s.w.t and the birds itself communicate with Prophet Sulaiman A.S and Prophet understand it brings another dimension of other countries and the story continue with how Prophet Sulaiman AS deals with the Queen Balqis.

In Surah An-Naml (27:22), the Qur'an describes how the hoopoe (Hudhud) returned to Prophet Sulaiman with news from the land of Sheba. Classical tafsir, such as Al-Qurtubi and Al-Razi, highlight that the bird did not simply deliver information but brought naba' yaqīn—certain and trustworthy news. The emphasis here is on careful observation, verification, and the delivery of accurate knowledge.

Applied to AI ethics, this episode serves as a metaphor for data collection and information integrity. Just as the hoopoe was valued for providing reliable intelligence, AI systems must ensure accuracy, transparency, and accountability in the way they process and disseminate information. In an era of misinformation and data manipulation, this Qur'anic lesson underscores the ethical imperative of amanah (trustworthiness) in the design and use of AI.

3.5.5. Artificial Intelligence: In the Name of Allah, the Most Beneficent, the Most Merciful

Surah An-Naml, Verse 30:

<div dir="rtl">إِنَّهُ مِن سُلَيْمَانَ وَإِنَّهُ بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ</div>

Verily! It is from Sulaiman (Solomon), and verily! It (reads): In the Name of Allah, the Most Beneficent, the Most Merciful; (English - Mohsin Khan)

The theme of Surah An-Naml talks about Artificial Intelligence, when Prophet Sulaiman sent a letter to the Queen of Sheba, it began with the phrase *Bismillāh al-Raḥmān al-Raḥīm* (Surah An-Naml, 27:30). Classical tafsir, including Ibn Kathir, emphasize that opening with the Divine Names of mercy and compassion sets the tone for justice, peace, and ethical engagement. This reflects the Qur'anic principle that all actions should be rooted in mercy.

From an AI perspective, this serves as a guiding principle that technological systems must prioritize compassion, social good, and the well-being of humanity. Just as Sulaiman's leadership was framed by mercy, AI development should be guided by values of empathy, inclusivity, and protection of the vulnerable. In doing so, Islamic ethics extend contemporary AI principles (such as fairness and

accountability) by grounding them in a transcendent moral order that emphasizes divine compassion.

3.5.6. Artificial Intelligence: Knowledge from Allah

Surah An-Naml, Verse 42:

فَلَمَّا جَاءَتْ قِيلَ أَهَٰكَذَا عَرْشُكِ قَالَتْ كَأَنَّهُ هُوَ وَأُوتِينَا الْعِلْمَ مِن قَبْلِهَا وَكُنَّا مُسْلِمِينَ

So when she came, it was said (to her): "Is your throne like this?" She said: "(It is) as though it were the same." And [Sulaiman (Solomon) said]: "Knowledge was bestowed on us before her, and we were submitted to Allah (in Islam as Muslims before her)." (English - Mohsin Khan)

Allah is the one who created all Intelligence of other beings, human beings, and animals. All knowledge is from Allah s.w.t. We discover the knowledge of Allah s.w.t. The main Creator of Knowledge is Allah s.w.t. The Queen of Sheba's recognition of Sulaiman's wisdom leads her to acknowledge that knowledge was bestowed upon him before her arrival. Tafsir works highlight that this verse underscores Allah as the ultimate source of knowledge.

In the AI context, this narrative serves as a reminder that all human discoveries, including technological innovations, are ultimately gifts from Allah. Ethical AI development must therefore be accompanied by humility and acknowledgment of divine providence. This perspective challenges secular narratives of human mastery, reorienting technology as a trust (*amanah*) rather than a possession.

3.5.7. Artificial Intelligence: Virtual Reality, Augmented Reality, And Mixed Reality

Surah An-Naml, Verse 44:

قِيلَ لَهَا ادْخُلِي الصَّرْحَ فَلَمَّا رَأَتْهُ حَسِبَتْهُ لُجَّةً وَكَشَفَتْ عَن سَاقَيْهَا قَالَ إِنَّهُ صَرْحٌ مُّمَرَّدٌ مِّن قَوَارِيرَ قَالَتْ رَبِّ إِنِّي ظَلَمْتُ نَفْسِي وَأَسْلَمْتُ مَعَ سُلَيْمَانَ لِلَّهِ رَبِّ الْعَالَمِينَ

It was said to her: "Enter As-Sarh" [(a glass surface with water underneath it) or a palace], but when she saw it, she thought it was a pool, and she (tucked up her clothes) uncovering her legs, Sulaiman (Solomon) said: "Verily, it is Sarh [(a glass surface with water underneath it) or a palace] paved smooth with slab of glass." She said: "My Lord! Verily, I have wronged myself, and I submit (in Islam, together with Sulaiman (Solomon), to Allah, the Lord of the 'Alamin (mankind, jinns and all that exists)." (English - Mohsin Khan)

When Balqis entered the throne of Sulaiman, she thought it was water, so she tucked up her clothes to avoid getting wet. It is not water; it is just a technology that, like virtual reality or mixed reality or maybe augmented reality, existed during that time. If not technology, to be safe, we called it mukjizat. But if technology were implemented during Prophet Sulaiman AS, it would already be more advanced than what we have now.

3.5.8. Artificial Intelligence: Syukur Not Kufur

Surah an-Naml verses 39 and 40:

قَالَ عِفْرِيتٌ مِّنَ ٱلْجِنِّ أَنَا۠ ءَاتِيكَ بِهِۦ قَبْلَ أَن تَقُومَ مِن مَّقَامِكَ ۖ وَإِنِّى عَلَيْهِ لَقَوِىٌّ أَمِينٌ (39) قَالَ ٱلَّذِى عِندَهُۥ عِلْمٌ مِّنَ ٱلْكِتَٰبِ أَنَا۠ ءَاتِيكَ بِهِۦ قَبْلَ أَن يَرْتَدَّ إِلَيْكَ طَرْفُكَ ۚ فَلَمَّا رَءَاهُ مُسْتَقِرًّا عِندَهُۥ قَالَ هَٰذَا مِنْ فَضْلِ رَبِّى لِيَبْلُوَنِىٓ ءَأَشْكُرُ أَمْ أَكْفُرُ ۖ وَمَن شَكَرَ فَإِنَّمَا يَشْكُرُ لِنَفْسِهِۦ ۖ وَمَن كَفَرَ فَإِنَّ رَبِّى غَنِىٌّ كَرِيمٌ (40)

"Said an 'Ifrit of the Jinns: "I will bring it to thee before thou rise from thy council: I have full strength for the purpose and may be trusted. One who knew the book: "I will bring it to thee within the twinkling of an eye!" Then, when (Solomon) saw it placed firmly before him, he said: "This is by the Grace of my Lord! - To test whether I am grateful or ungrateful! And if any is grateful, truly his gratitude is (a gain) for his soul; but if any is ungrateful, truly my Lord is Free of all Needs, Supreme in Honour!"

Allah tells us that technology should be utilized to syukur to Him, not for disobedience or unbelief. Allah describes the account of Prophet Sulaiman, who used technology to bring the throne of Balqis to him in Surah Al-Qalam. According to the Quran, an Ifrit from the Jinn brought the throne before Prophet Sulaiman could even stand up, whereas a person believing in the Book (Kitab) could bring it quickly. This demonstrates that a faithful human being's technology is superior to the Jinn's. Human capacities result from faith in Allah and obedience to the book's teachings.

As a result, the goal of technology like Artificial Intelligence should not be solely to increase commercialization or financial gain. Instead, they should be used to draw us closer to Allah, convey thanks, and avoid disobedience. All our endeavors are built on the Book (Kitab). The concept of Maqasid Tech (technological goals) is based on thankfulness (Syukur), not unbelief (Kufur). By incorporating technology that aligns with Taqwa, we can harness its potential to promote positive behavior and enhance our relationship with Allah.

4. AI AND ISLAMIC PERSPECTIVE

From an Islamic worldview, Artificial Intelligence (AI) integration must be guided by ethical, spiritual, and epistemological principles rooted in the Qur'an and Sunnah. The development and application of AI should not merely serve utilitarian or material purposes but must align with higher objectives of human well-being, divine consciousness, and moral responsibility.

Firstly, AI systems and their usage should reflect the holistic Islamic values of Zikir (remembrance), Fikir (reflection), and Syukur (gratitude). These three elements are deeply intertwined in Surah Al-Imran (3:190–191), where believers are praised for reflecting on the creation of the heavens and the earth while remembering Allah and expressing gratitude. According to Tafsir Ibn Kathir, these verses emphasize the integration of intellectual reflection (fikir) with spiritual remembrance (zikir) and thankfulness (syukur) as signs of proper understanding and piety (Ibn Kathir, 2003).

Secondly, the ethical foundation of AI in Islam can be linked to the concept of Thasiin, drawn from Surah An-Naml (27:1), where the mysterious letters "Ṭā Sīn" open the surah. Some scholars, like Al-Razi and Al-Qurtubi, interpret such letters as signs pointing to the miraculous nature of the Qur'an and the importance of purity and guidance. By extension, AI should be Thayyib (good), Thaher (pure), and Salim (safe)—qualities that promote ethical use and ensure societal benefit (Al-Qurtubi, Tafsir al-Jami' li Ahkam al-Qur'an). Moreover, the story of Prophet Sulaiman in

Surah An-Naml (27:16, 22) demonstrates an advanced understanding of the languages of birds and ants. This signifies the value Islam places on inter-species communication and knowledge. Contemporary scholars such as Al-Attas (1995) have emphasized that all knowledge must lead to the recognition of divine purpose. AI, similarly, should be designed to bridge communication gaps across disciplines, systems, and beings in ways that reflect tawhidic knowledge.

In addition, AI must aim to promote righteousness and good deeds, in line with Surah An-Naml (27:19), where Prophet Sulaiman supplicates for the ability to perform righteous actions pleasing to Allah. As mentioned in Tafsir Al-Mazhari, this reflects the Prophet's deep sense of responsibility and desire to use his power for good. AI should reflect this ethos by being a tool that fosters ethical conduct and communal well-being.

The attribute of care and compassion is also central, as seen in Surah An-Naml (27:30), where Prophet Sulaiman's letter begins with "Bismillahirrahmanirrahim"— invoking Allah's names of mercy and compassion. Al-Ghazali (1997) emphasized that divine names such as Ar-Rahman and Ar-Rahim guide ethical behavior. Thus, AI systems must be constructed to reflect mercy, empathy, and social responsibility values. Moreover, the Qur'an acknowledges the efficiency and dynamism in task execution through the servant who swiftly brought the Queen's throne (27:40–42). Classical scholars like Al-Tabari describe this event as a manifestation of knowledge and speed used for righteous objectives. Similarly, AI should be fast and efficient but grounded in wisdom and ethical limits.

In economic and social contexts, the Qur'an reminds us that Allah is the ultimate provider (Surah Al-Jumu'ah, 62:11). This teaches humility and warns against an over-reliance on technological systems. As emphasized by Nasr (1993), Islamic epistemology always centers on the Creator as the source of sustenance and knowledge. AI must also aim to guide humanity toward gratitude (syukur) and away from ingratitude (kufr), as highlighted in Surah An-Naml (27:14). According to Tafsir Ibn Ashur, the verse criticizes the arrogance of those who deny truth despite recognizing it, which can be seen in the blind pursuit of power and technology. AI should be a means to recognize the signs of Allah, not obscure them.

Finally, the story of the Queen of Sheba's submission in Surah An-Naml (27:44) reminds us that all knowledge must lead to submission to Allah (rabbil-'alamin). After witnessing a sign, her recognition of the divine truth demonstrates that technological marvels should point to more profound spiritual truths. As Al-Faruqi (1982) argued, Islamic knowledge must ultimately lead to transformation and submission (Islamization of Knowledge). In summary, an Islamic perspective on AI envisions a model that is ethically grounded, spiritually conscious, and oriented towards the betterment of humanity. Such an approach ensures that AI becomes a means of enhancing not just Intelligence but also iman (faith), 'amal (action), and Ihsan (excellence).

Artificial intelligence raises complex ethical questions concerning justice, accountability, and human well-being. While contemporary frameworks such as UNESCO's Recommendation on the Ethics of AI (2021) and IEEE's Ethically Aligned Design (2020) stress fairness, transparency, and accountability, Islamic teachings offer a complementary and transcendent ethical foundation.

Islamic ethics are rooted in the Qur'an, Sunnah, and the objectives of the Shari'ah (maqasid al-shari'ah), which emphasize the preservation of religion, life, intellect, lineage, and property. These principles align with and enrich global AI ethics by grounding them in divine accountability and human dignity. For example, the principle of 'adl (justice) resonates with fairness in AI systems, while amanah (trustworthiness) corresponds to accountability and reliability in data-driven technologies. Similarly, rahmah (compassion) calls for designing AI that safeguards the vulnerable and promotes social good.

By integrating these values, Islamic ethics move beyond technical guidelines to offer a holistic vision of AI as a trust (amanah) that must serve humanity responsibly. This perspective ensures that technological advancement is not divorced from moral reflection but is guided by humility, gratitude, and accountability before God. In this way, Islam contributes to shaping a balanced framework for AI ethics—one that combines modern principles of transparency and inclusivity with spiritual and moral guidance that upholds truth, justice, and mercy.

5. CONCLUSION

This study has explored artificial intelligence through the lens of Qur'anic narratives, classical tafsir, and Islamic ethical principles. By examining global AI concerns alongside Islamic teachings, it becomes evident that both traditions share common values such as justice, accountability, and compassion. However, Islam enriches the discussion by grounding ethics in *maqasid al-shari'ah* and the recognition of divine accountability.

To move from abstract ideals to practical application, we propose the following Islamic Ethical Guidelines for AI:

1. **Non-Maleficence (*la darar wa la dirar*)**
   AI must not inflict harm, directly or indirectly. Systems should be evaluated for potential misuse, bias, or unintended consequences that may endanger individuals or communities.

2. **Justice (*'adl*)**
   AI design and deployment must ensure fairness, inclusivity, and the protection of human dignity. Bias and discrimination must be actively identified and mitigated.

3. **Trustworthiness (*amanah*)**
   As with the Qur'anic hoopoe that delivered reliable information, AI must maintain integrity in data handling, decision-making, and accountability mechanisms.

4. **Transparency and Truth (*haqq*)**
   Reflecting the lesson of Sulaiman's palace of glass, AI systems must avoid deception. They should provide explainable outcomes that allow users to distinguish perception from reality.

5. **Compassion and Mercy (*rahmah*)**
   Inspired by the invocation of *Bismillāh al-Raḥmān al-Raḥīm*, AI development must prioritize human well-being, especially protect vulnerable groups and promoting social good.

6. **Gratitude and Humility (*shukr, tawadu'*)**
   Like Sulaiman's gratitude for the throne's miraculous transfer, developers and users must approach AI with humility, recognizing it as a trust from Allah and resisting arrogance or misuse of power.

Taken together, these guidelines provide a holistic framework that complements contemporary AI ethics while offering unique insights rooted in Islamic values. They call for technological progress that is not only innovative but also responsible, transparent, and compassionate. By integrating *maqasid al-shari'ah* into global AI discourse, Islamic ethics contribute to shaping a future where AI serves as a means for justice, mercy, and human flourishing.

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AN INTELLIGENT SYSTEM TO IDENTIFY FAKE VIDEOS ON ONLINE SOCIAL NETWORKS USING MACHINE LEARNING

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ABSTRACT: Advances in emerging technologies have led to the wide dissemination of fake videos on online social networks. This research employs the hybrid machine learning and deep learning algorithms to recognise video forgery on social media. This research presents a hybrid deep learning and machine learning approach for detecting manipulated videos. The proposed model employs the OpenCV deep neural network (DNN) face detector to locate facial regions in video frames, after which a pretrained ResNet50 convolutional neural network is applied to extract deep features, and a Support Vector Machine (SVM) is used to classify authentic and fake content in a binary fashion. The model was trained and evaluated on a dataset of publicly available 128 short-form videos gathered from TikTok and Facebook platforms. The five-fold stratified cross-validation results generated an average accuracy of 89.1%, precision of 87.6%, recall of 96.1%, F1-score of 91.5%, and an AUC of 0.95 for the SVM model. Furthermore, the comparative analyses showed that SVM outperformed Logistic Regression, Random Forest, Gradient Boosting, and K-Nearest Neighbour classifiers. The findings demonstrate that combining automated face detection with deep feature extraction and classical machine learning significantly improves fake-video detection and contributes to preserving authenticity in digital communication.

KEY WORDS: *Network security, Social Networks, Machine learning, Fake Videos, ResNet50*

1. INTRODUCTION

The ability of a machine to perform cognitive tasks like perception, learning, reasoning, and problem-solving that are completed by humans is referred to as artificial intelligence. AI speech, vision, and thinking teams need to function at least as effectively as human ones (Markauskaite et al., 2024). Currently, artificial intelligence (AI) is widely employed across various industries, offering significant technological benefits to organizations that extensively utilize it. The potential of AI is to increase value of the banking sector by 50% (Christensen, 2021) and the retail sector by $600 billion (Donepud, 2019) when compared to conventional analytic techniques. Furthermore, research revealed that higher percentage rise in potential income in logistics and transportation due to the adoption of AI (Kuberkar & Singhal, 2020; Yaiprasert & Hidayanto, 2024).

AI systems employ machine learning (ML) that can acquire knowledge autonomously and continually improve. The practice of ML includes designing programs that can access data and learn autonomously. To begin the learning process, one must gather observations or data, such as examples, personal experiences, or instruction, to identify patterns and improve decision-making in the future. The main aim is for computers to gain knowledge independently and adjust their actions as necessary, without depending on humans (Sarker, 2021). Deep learning in machine learning focuses on constructing models for intricate datasets that involve creating relationships using multiple-level representational learning approaches. Higher-level concept and functionalities are expressed concerning those at a lesser level in a deep architecture. Most of these models are based on unsupervised learnt representations (Ahmed et al., 2023). The phrase "deep-fake" originates from the concepts "deep learning" and "fake". Deep neural networks have made it easier and faster to fabricate realistic-looking fake photos and videos. It is a method whereby someone's video or image is modified by another person's image by using deep learning (Mitra et al., 2021). Deep neural network-based encoders, which are commonly employed in picture compression, impose a compressed version of the original input by creating a bottleneck in the network. More advanced encoders have made it possible to compress high-quality images, which reduces the computing power required for deep-fake jobs. To produce deep fakes, two auto-encoders are trained. The deep-fake image is created by reconstructing the target image using the decoder of the source image. This yields an image of the target that contains elements of the source image. The characteristics of the source picture are learned by the first auto-encoder, the attributes of the target image are learned by the second encoder, and the settings of the two encoders are shared (Khalil & Maged, 2021). Nowadays, social networking networks are a multipurpose tool utilised for telemarketing, business, education and regrettably, illicit activity. Users usually use social media to communicate with colleagues and peers who share their interests. It also acts as a channel for client communication, and the information it gathers could help identify new trends in business insights. Social media is a major aspect of contemporary living. Social media users post news, videos, and thoughts about a wide range of activities on Facebook, WhatsApp, Instagram, Twitter, and other online networks. Even though many individuals enjoy using social media, many dishonest activities could lead users to believe misleading information, such as rumours or fake news (Islam et al, 2020).

The methods used in creating deepfake videos are either the target's real video is used as the source, in which case the target is manipulated to say and do things they have never done before, or the target's face is replaced with a video of someone else. This has prompted the creation of fake videos which are almost real and hard to tell the difference between them and the original ones (Botha & Pieterse, 2020). They have become paramount due to their ability to spread fake news, sway opinions, instigate social and political unrest. Hence, this research presents a robust and intelligent model suitable for detecting fake video clips on different social media platforms. The rise in the proliferation of doctored videos via the internet has augmented the necessity to have effective detection systems that can maintain the authenticity of visual data. Although numerous deep learning approaches have been created to identify deepfakes, most of them do not cope with variability in video quality, lighting, and motion in the real world, and their end-to-

end training is very expensive. These problems may have the propensity to limit the scale of their operations and application to social media data, which is brief, compressed, and exceedingly diverse.

This paper introduces a hybrid detection system to overcome these limitations, which is a fusion of deep feature and classical machine learning classification. The model unites representational power of a trained ResNet50 model and efficiency of a Support Vector Machine (SVM) classifier. This balanced structure gives a boost to the detecting power incurring less computation price which is more adaptive to the dynamism of the online video materials. The emphasis on the short format and user-created videos of TikTok and Facebook enables the research to bring a realistic and varied dataset, which represents the actual complexity of social media settings. Therefore, this approach is capable of achieving a lightweight and yet very efficient model to locate manipulated videos and protect digital authenticity. The purpose of this work is to optimise the chances of detecting fake videos and contribute to preventing the spread of false information, protecting individuals' rights to privacy and maintaining the credibility of visuals disseminated on social media. The remaining part of the paper is structured as follows: in Section 2, the literature review is provided. Section 3 provides methods and approaches, and Section 4 provides findings and analysis. Section 5 is the conclusion and potential future research directions.

2. RELATED WORKS

The growing availability of artificial intelligence products has facilitated the ability of even non-experts to generate and share fake content, such as manipulated videos, content and fabricated news. As social media becomes more essential for accessing important information, the danger of deepfakes sharing misleading information is increasing (Jing & Murugesan, 2021). Authentic face-swapping effects are achieved in media using AI software like FaceApp, AgingBooth, and others. Through swapping, it is possible to change facial structure, hairstyle, sex, age and other factors (Yavuzkiliç et al., 2021). The mass distribution of such distorted media brings up severe issues touching on misinformation, privacy, and online trust. Consequently, detecting falsified video content has become an urgent

research priority given society's growing reliance on social media for communication and information exchange. Even though some studies have examined deepfake detection methods, few studies have examined deepfake detection specifically in the context of social-media-based video datasets, which are characterised by compression artefacts, varied lighting, and other user-induced variations that present special detection problems. Recent research on fake media detection varies across learning paradigms and data types. This section reviews key developments within these categories and situates the contribution of the current study. Although numerous studies have proposed deepfake detection systems, relatively few have targeted social-media-based videos, where compression artifacts, spontaneous lighting, and short duration complicate analysis. The manufacturing of deepfakes frequently fails to maintain temporal consistency between frames, and several works have leveraged this limitation to design detection models (Sabir et al., 2019).

2.1. Machine Learning Approaches

Machine learning (ML) techniques have been widely applicable and used to identify deepfakes by analysing frame-level data and classifying it based on labelled data (Altaei, 2023; Hamza et al, 2022). These techniques typically involve two processes, that is, discrimination feature extraction and classification. Features extracted can be hand-crafted, like edge descriptors, motion vectors, or texture patterns, or high-level features, which are the output of tested deep networks. Support Vector Machines (SVM), Logistic Regression (LR), Decision Trees, Random Forest (RF), Gradient Boosting, and K-Nearest Neighbours (KNN) are some of the classifiers that have been used to differentiate between authentic and cheated content (Alemerien and Al-Mahadin, 2025; Suryani et al, 2025). As an example, (Kharbat et al, 2019) used SVM regression to detect videos containing fake content. The conventional edge feature detectors were used to train the model to find counterfeit videos. Moreover, other scholars had conducted an extensive survey of various deepfake recognition systems based on ML and found that there are still primary issues, such as the imbalanced distribution of classes, overfitting, and low generalisation across datasets (Rana et al. 2022). Moreover, another researcher did a study to investigate the use of ensemble models (RF and Gradient Boosting) to detect fake content; the experimental findings showed that the ensemble models offer higher detection accuracy and recall compared to single-model models (Ali et al., 2024).

2.2. Deep Learning Approaches

The deep learning (DL) methods performed a bit differently from ML; DL architectures learn spatial and temporal features directly from video data without the need for manual feature engineering. These models employ convolutional and recurrent neural networks to detect inconsistencies that arise during manipulation. The process of creating fake videos usually involves altering real video to depict fabricated actions and generating highly realistic results that are difficult to detect (Botha & Pieterse, 2020).

Over the years, several DL studies have attempted to address these challenges; the study conducted by Sabir et al. (2019) used spatio-temporal relations between frames and observed that fake videos tend to have temporal discontinuities. The autoencoder-decoder pipeline employed by Khalil and Maged (2021) recreates the target frames and reveals the differences between real and fake videos. Moreover, Elhassan et al. (2022) developed the DFT-MF model which is a CNN based model that utilises mouth region motion to identify abnormal lip synchronisation. On the same note, Yadav and Salmani (2019) examined Generative Adversarial Networks (GANs) in which the generator creates counterfeit content, and the discriminator identifies it.

Other modern DL works are Lewis et al. (2020), the authors combined spatial, spectral and temporal images with a multimodal CNN architecture, Deressa et al. (2024), the authors combined CNN and vision transformer modules to align pixels sequentially and Aymen and Hussein (2024), the authors used discrete wavelet transforms and CNNs to detect forgery at the frame level. In addition, El-Gayar et al. (2024) suggested a graph neural network based on video-level deepfake detection, whereas Ismail et al. (2021a, 2021b) used YOLO and YOLOv2 as the architectures on the image of precisely face localisation and manipulation detection.

Moreover, Mitra et al. (2021) and Malathi (2023) created CNN-based classifiers with the help of XceptionNet, InceptionV3, and ResNet50 with high accuracy to detect fake frames. Guera and Delp (2018) used CNN and RNN models, whereby convolutional layers obtained features, and recurrent layers modelled temporal variations, which resulted in high accuracy. Amerini et al. (2019) proposed an optical flow based approach that compares changes between two successive frames and discovered that VGG16 was superior to ResNet50 in detecting inconsistency on a frame-by-frame basis. Nguyen et al. (2022) also applied autoencoders to predict encoding and decoding mechanisms during generating and detecting manipulated videos.

Despite the high performance of the DL models, they can be characterised by high requirements in computational resources and voluminous, high-quality datasets. According to the research conducted by Amerini et al. (2019), the accuracy of ResNet50 was only 76% in certain cases, which demonstrates that deep learning does not necessarily provide high accuracy, particularly social-media videos that have compression artefacts.

2.3. Hybrid Approaches

Combining the representational power of deep neural networks and efficiency of machine learning classifiers, hybrid models represent a new approach to machine learning. Such frameworks use pretrained CNNs like ResNet, VGG or Inception to extract features and use the final classification with classical algorithms like SVM, Logistic Regression or Gradient Boosting. Ahmed et al. (2023) proved that the integration of CNN-generated embeddings and SVM enhanced the classification on small datasets. To achieve a high rate of accuracy of more than 86% on benchmark videos, Alzurfi and Altaei (2025) introduced a hybrid system that employed CNN-extracted features and a series of ML classifiers. Short-form content on social media is particularly well-placed in hybrid approaches due to their balanced accuracy in detection and computational efficiency. The present study adheres to this paradigm when applying a ResNet50-SVM model that has been trained on videos on social-media and collected through cross-validation. This composite system manages drawbacks of both pure ML and DL models, providing a high-performing and lightweight architecture to be deployed in practise.

2.4. Datasets Used in Prior Studies

The available literature is based on well-organised benchmark datasets, including FaceForensics++, DeepFake Detection Challenge (DFDC), and Celeb-DF (AbdElfattah et al., 2025), which consists of high-resolution face-centric clips under controlled circumstances. Although these datasets are helpful in benchmarking, they are not realistic in view of the diversity, compression artefact, and lighting anomalies of social-media videos created by users (Khan et al., 2023). According to Dadkhah et al., 2023, the models that are trained on only such datasets are poor when they are tested on real-life content on platforms such as Tik Tok and Facebook. The current study aims to address this shortcoming by coming up with a new dataset of 128 short-form videos, which were gathered on TikTok and Facebook, consisting of 78 real and 50 fake samples. These videos are between 5 to 30 seconds, and this is what is characteristic of social-media. There was extraction of frames, annotation of the frames and classification into real and

fake directories which offered realistic basis on assessing the performance of detection under real online circumstances.

2.5. Summary and Identified Gap

The literature reviewed has shown that there has been a significant advance in using machine learning, deep learning, and hybrid-based architectures in detecting deepfakes. However, key gaps persist. The majority of models rely on high-quality benchmark videos instead of social-media videos. Deep learning systems are also associated with high computational cost and inability to generalise. Machine learning classifiers are efficient but mostly use handcrafted or pre-extracted features and do not reflect temporal dynamics. Compromise Hybrid frameworks are a promising middle ground involving CNN-based feature extraction and classical ML classification. Based on this observation, the current research will develop a hybrid ResNet50-SVM model that will be trained and evaluated on a novel Tik Tok and Facebook dataset to create an effective and stable fake-video detector that applies in real-life social-media scenarios.

3. METHODOLOGY

This paper proposes a hybrid architecture that combines deep learning and machine learning models in detecting manipulated videos. As illustrated in Fig. 1, the workflow consists of five steps namely, dataset collection, preprocessing and face detection, deep feature extraction, machine learning classification, and experimental evaluation. The architecture uses deep neural representations of ResNet50 and the discriminative ability of a Support Vector Machine (SVM) classifier to identify visual irregularities associated with fake content.

3.1. Dataset Collection

The data used in this paper was a manual collection of publicly available short-form videos on Tik Tok and Facebook two widely used platforms where real and fake content is postponed in the same degree. These platforms were selected based on the idea that the dataset should consist of real-world diversity and the dynamism of social media videos. The number of short-form videos collected was 128 representing 78 real and 50 fake clips. The videos were of between 5 and 30 seconds, which is common with social media posts. With the openCV library, every video was broken down into still image frames with a fixed sampling rate. The count of the extracted frames per video varied between 2 and 220 and the median count was around 15, and the total number of annotated frames was around 2,440 because of the difference in the video duration and motion activity. Each frame had all its dimensions shrunk to 224 x 224 pixels and saved as JPEG files. The frames were put on two directories RealFrames (around 1,490 images) and FakeFrames (around 950 images).

    a) Annotation and Verification: Two reviewers independently checked each video and assigned labels to them. A video was regarded to have been faked in case it presented two or more signs of manipulation including facial boundary artefacts, lip movements that were asynchronous, irregular blinking, or uneven illumination and texture. The disagreements that arose among reviewers were solved by discussing the issues, and Cohen, Kappa (k = 0.91) was obtained, which means a high level of inter-rater reliability.

b) Video-Level Organisation: The difference in the number of frames per video was significant, hence the dataset was processed at video level rather than frame level. Frame embeddings were summarised so that short and long videos have the same contribution in the model training.

c) Ethical Implications: The videos were all publicly available, and any personal identifiable information (such as the usernames, captions or comments) was removed prior to processing. The data was gathered exclusively to be used in academic research.

3.2. Data Preprocessing and Face Detection

Preprocessing has been done so that it will be uniform, improve the image, and concentrate on areas of the face that are the most vulnerable to manipulations. OpenCV was used to deconstruct each video into still frames. Face location in each frame was done by a Deep Neural Network (DNN)-based face detector, which was developed based on the Single Shot Multibox Detector (SSD) architecture, and used a ResNet backbone. The identified faces were cropped, rescaled to 224 x 224 pixels, and brought to the [0,1] interval to make them uniform in their light and size. Histogram equalisation and denoising philtres were used in order to increase contrast and decrease artefacts and make the picture more visual. This preprocessing made sure that the extracted facial regions had enough visual fidelity to be used in extracting features later.

3.3. Deep Feature Extraction Using ResNet50

Deep feature extraction involved a pretrained ResNet50 model which was trained on ImageNet dataset. The last connected classification layer was eliminated and features were obtained out of the penultimate global average pooling layer, which generated a 2048-dimensional feature vector per frame. The architecture of the ResNet50 was chosen due to its depth, residual connexions, and demonstrated capability to represent hierarchical features- low-level pixel irregularities and high-level semantic inconsistency, which is typical of deepfake videos. The weights of the model were not trained (no fine-tuning) and it was possible to use the pretrained network as a feature extractor only. This approach gave consistent and non-selective representations and minimised computational expenses. For each video, all frame-level embeddings were averaged to create one representation vector, which captured the overall spatio-temporal properties of it.
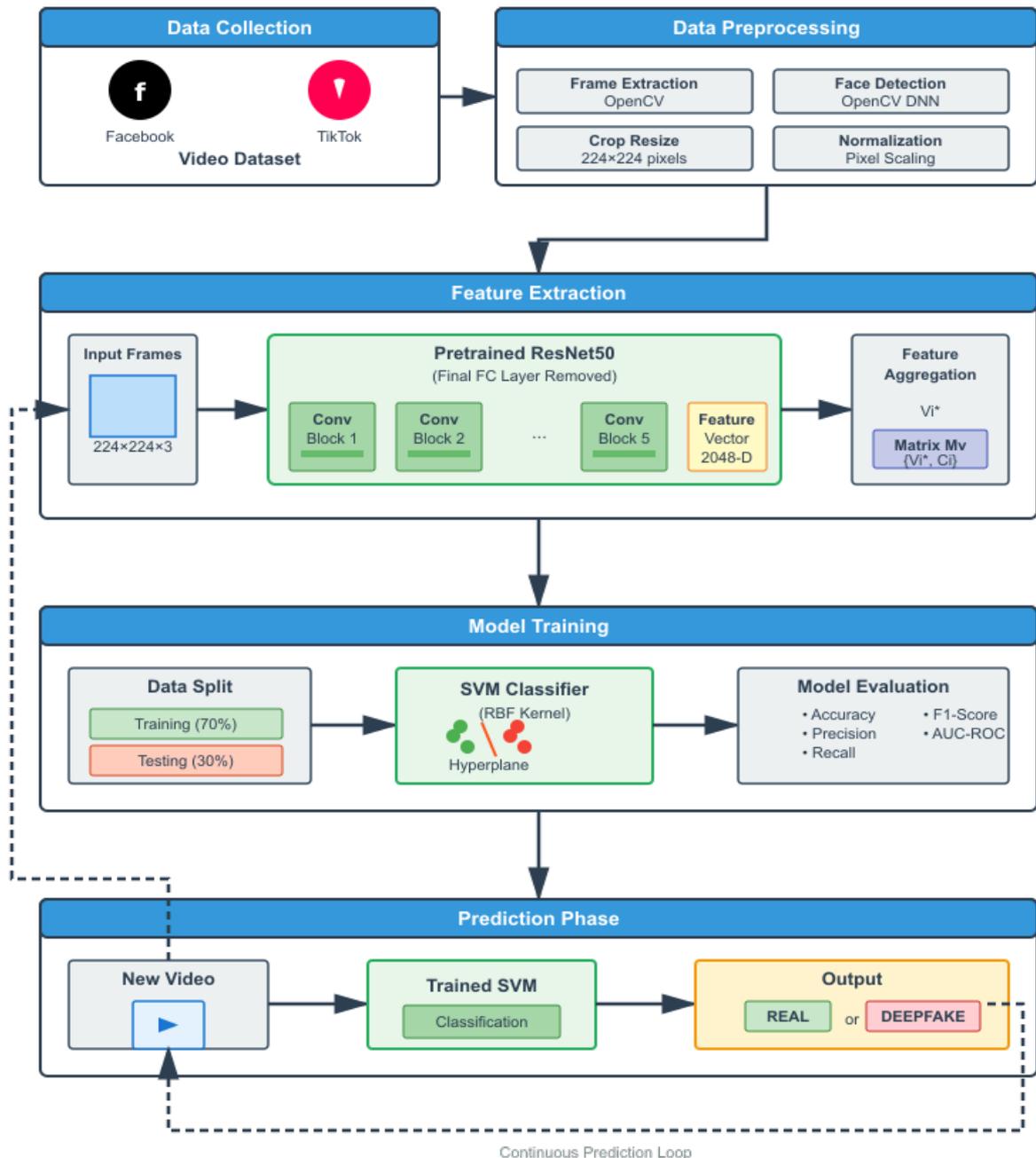
Fig. 1. Fake Video Detection Model

3.4. Machine Learning Classification

Stratified sampling was used to divide the aggregate feature matrix into training (70%) and a testing (30%) sample to ensure there was an equal number of classes in the real and fake videos. Classification was based on a Support Vector Machine (SVM) classifier using a Radial basis function (RBF) kernel. The model was selected as it is useful in processing high-dimensional, nonlinear feature spaces based on deep networks and due to its good generalisation on rather small

datasets. The penalty constant C and kernels coefficient g that have been hyperparameterized were optimised with grid search and five-fold cross-validation. This made sure that the boundaries of classification were as high as possible with a minimum overfitting. When making an inference new videos were processed through the same feature extraction pipeline and the trained SVM generated binary predictions on whether the video was real or fake. The general workflow of the suggested model is described in Algorithm 1. It begins by decoding frames of every video and identifying areas of faces to analyse them. The faces are preprocessed and then subjected to the ResNet50 model to get the deep feature representations and the same is summed up into a single feature vector per video. With the help of these vectors, an SVM classifier is trained to recognise real and fake videos. New videos are subjected to the same procedure during testing and the trained model estimates their authenticity.

Algorithm 1: Fake Video Detection

```
Input: V = {V1, V2, ..., Vn}      // Set of social media videos
Output: C ∈ {0, 1}                // 0 = Fake, 1 = Real

1.  Begin
2.  For each video Vi ∈ V:
3.      Extract frames Fi using OpenCV
4.      For each frame f ∈ Fi:
5.          Detect and crop face using OpenCV DNN face detector
6.          Resize to 224×224 and normalize pixel values
7.      End For
8.  End For
9.  Load pretrained ResNet50
10. For each frame f ∈ Fi:
11.     Extract 2048-dimensional feature vector
12. End For
13. Aggregate frame features to obtain Vi*
14. Construct feature matrix Mv = {Vi*, Ci}
15. Split Mv into Train (70%) and Test (30%) sets
16. Initialize SVM classifier with RBF kernel
17. Train SVM using Train set
18. Evaluate on Test set using metrics
19. For each new video Vnew:
20.     Repeat Steps (3-13)
21.     Predict Ŷ = SVM(Vnew)
22.     Display Ŷ
23. End For
24. End
```

---

4. IMPLEMENTATION

This part reports on how the proposed fake video detection framework can be implemented in practise. The entire experiment was carried out on a Google Colab environment to take advantage of the acceleration provided by GPUs to efficiently train the model and make inferences. It was developed based on TensorFlow, Keras, OpenCV, scikit-learn, and NumPy to preprocess data, create models, as well as to evaluate their performance. The data, which has been described in the section 3.1, was short-form videos recorded on Tik Tok and Facebook, comprising both real and faked samples. OpenCV was used to break down each video into

frames and a DNN face detector was used to obtain facial regions. The features Before extracted faces were normalised to a 224 x 224 pixel size and before features extraction. The video dataset in terms of images is shown in Fig. 2, whereas Fig. 3 demonstrates the number of classes of real and fake samples employed in the process of the model training.

Representation of features was done by using a pretrained ResNet50 model that was initialised using ImageNet weights. The last classification layer was then eliminated in order to have the network acting as a pure feature extractor hence producing a 2048-dimensional embedding of every detected face. This made the model both able to predict pixel-level deviations and high-level semantic indicators that define deepfake manipulations. The use of fine-tuning was avoided since ResNet50 actually offered good generalizable features to tell between the real and the altered visual contents. These embeddings were extracted and then trained a SVM classifier that was based on RBF kernel. Optimization of hyperparameters, such as the penalty parameter (C) and kernel coefficient (g) was done using grid search and a five-fold cross-validation to ensure good generalisation and avoid overfitting. The data was divided into training and test set in a ratio of 70:30 in order to have equal representation of the two classes.

Model assessment was based on standard performance measures such as accuracy, precision, recall, F1-score and the area under the receiver operating characteristic curve (AUC). To obtain statistical reliability and reduce bias in the performance reported, a five-fold cross-validation strategy was used. In order to measure the robustness of the hybrid architecture, ResNet50-SVM was compared with other supervised models such as Logistic Regression, K-Nearest Neighbour, Random Forest, and Gradient Boosting models using the same extracted features. The hybrid model was significantly more accurate and recalled and had a better AUC, indicating its suitability in automated recognition of manipulated videos on a variety of social media content. Overall, the practicality of hybridising deep convolutional feature extraction and a classical machine learning classifier to enable efficient and accurate fake video content detection was proven by the implementation.
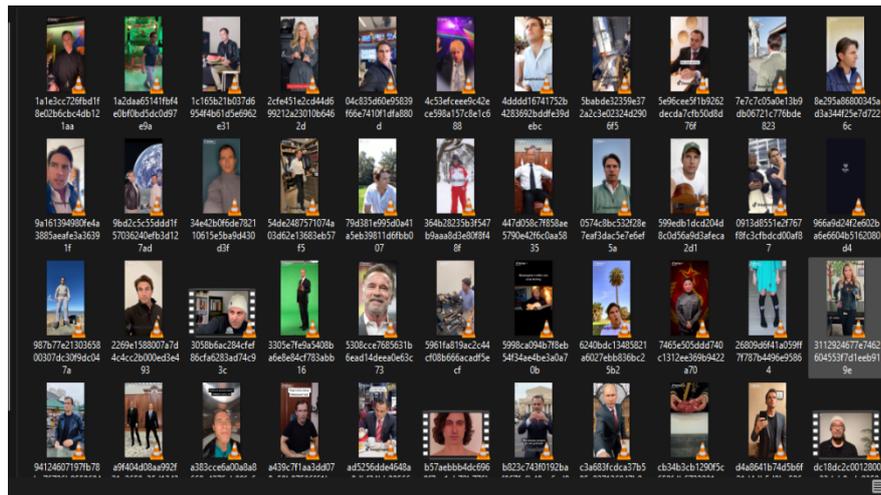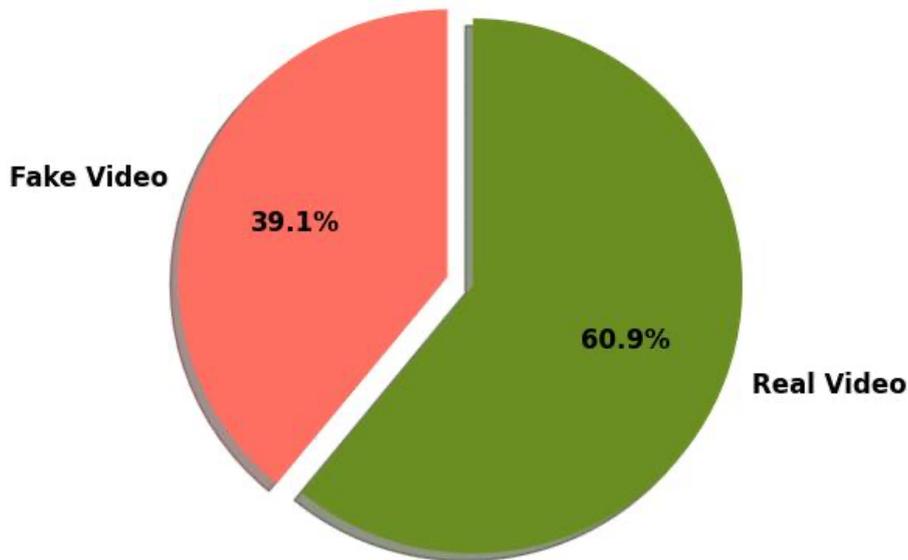
Fig. 2. Sample Images of the Video Dataset

Fig. 3. Class Distribution of Video Dataset

5. RESULT AND DISCUSSION

5.1. Implementation Results

To assess the performance of the hybrid ResNet50-SVM model, several analyses such as the confusion matrix, ROC curve, and visualisation of features through PCA were used to give both quantitative and qualitative information on the classification's capabilities of the hybrid model. The accumulated confusion map (see Fig. 4) demonstrates that the model made correct decisions in 78 fake videos (True Fake) and 96.2 real videos (True Real) and 22 fake videos which were wrongly classified as real (False Real) and 3.8 real videos which were wrongly classified as fake (False Fake). These figures point toward the fact that the classifier has a high accuracy and mostly it identifies the authentic material and false video content, with a minor percentage of misclassifications occurring due to videos containing milder or more realistic manipulations.

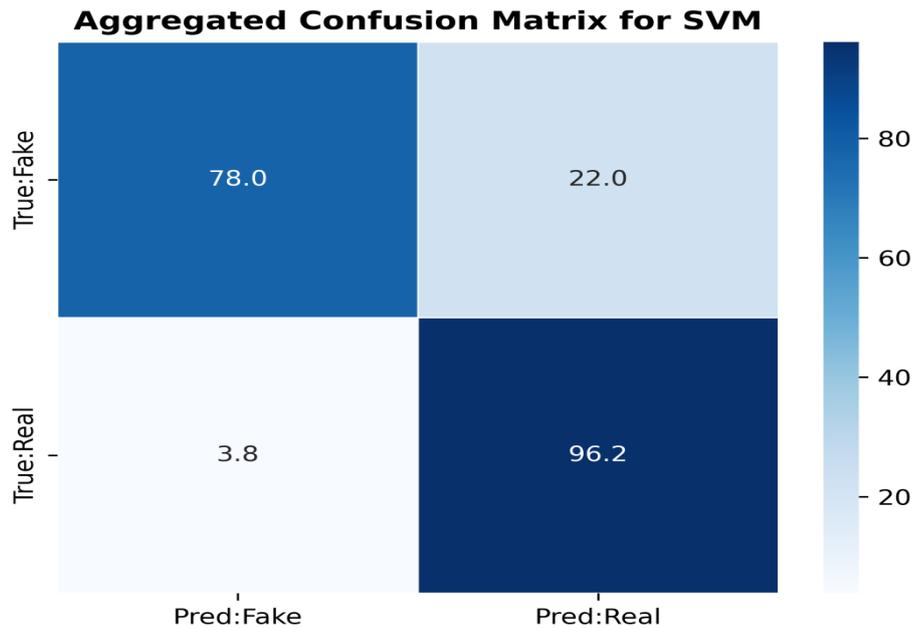**Aggregated Confusion Matrix for SVM**

Fig. 4. Confusion Matrix for SVM

The Receiver Operating Characteristic (ROC) curve (see Fig. 5) also indicates the strength of the model with an AUC of 0.996 that indicates almost perfect separation between authentic and fake videos. This suggests that the classifier has high sensitivity and specificity under varying thresholds, which further substantiates the use of the classifier in real world video authentication activities. Further qualitative support is in the form of a 2D Principal Component Analysis (PCA) projection of the extracted video features (Fig. 6). This projection reveals that fake and real video are separated into different clusters with little overlap which means that features that are learned by ResNet50 are highly discriminative. The fake videos are clustered in focused parts of the feature space which show that they share common features that are not similar to the genuine ones and the real videos are more varied but still show certain patterns that can be separated. The small ratio of overlap is in line with the good classification accuracy, which is a confirmation that the first two principal components hold the most pertinent discriminative information.

Going further with this analysis, a 3D PCA projection (see Fig. 7) shows that the fake and real video features can be further separated into three major components. False videos create compact clusters in particular areas, whereas the real video is presented in various clusters, which means more variation in authentic materials. Such a conspicuous difference in 3D space further illustrates the high classification rate of the SVM model, where the learned feature representations are resilient and discriminative in higher dimensional feature space.
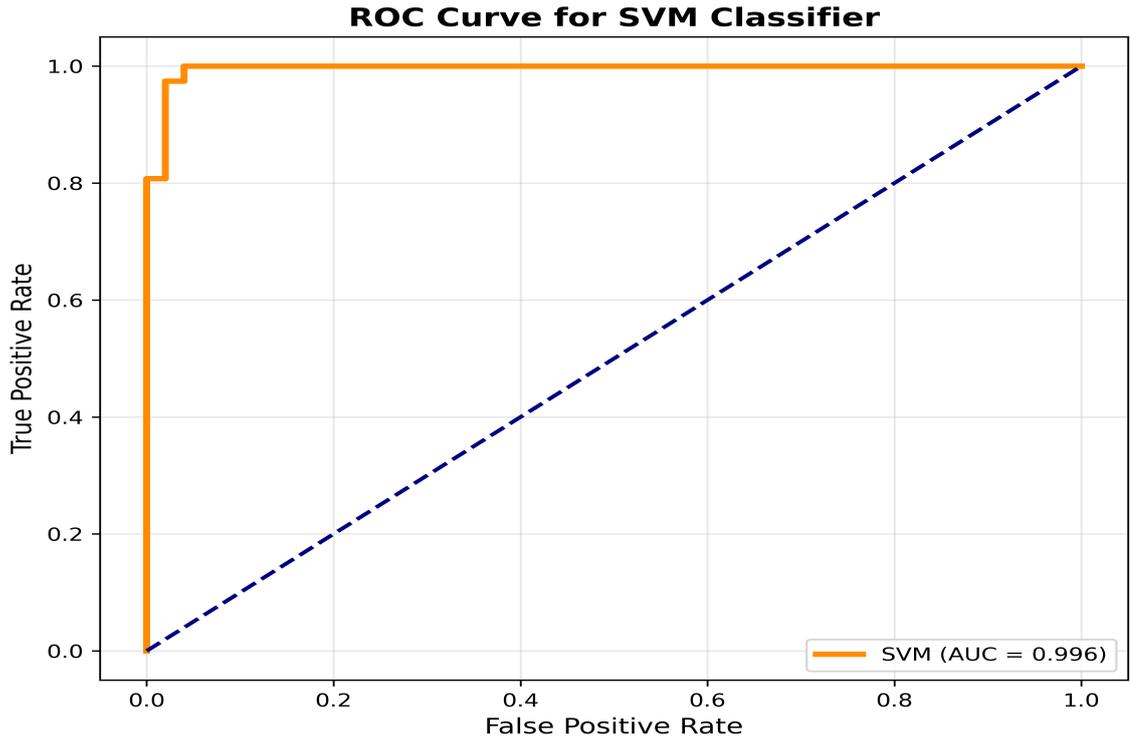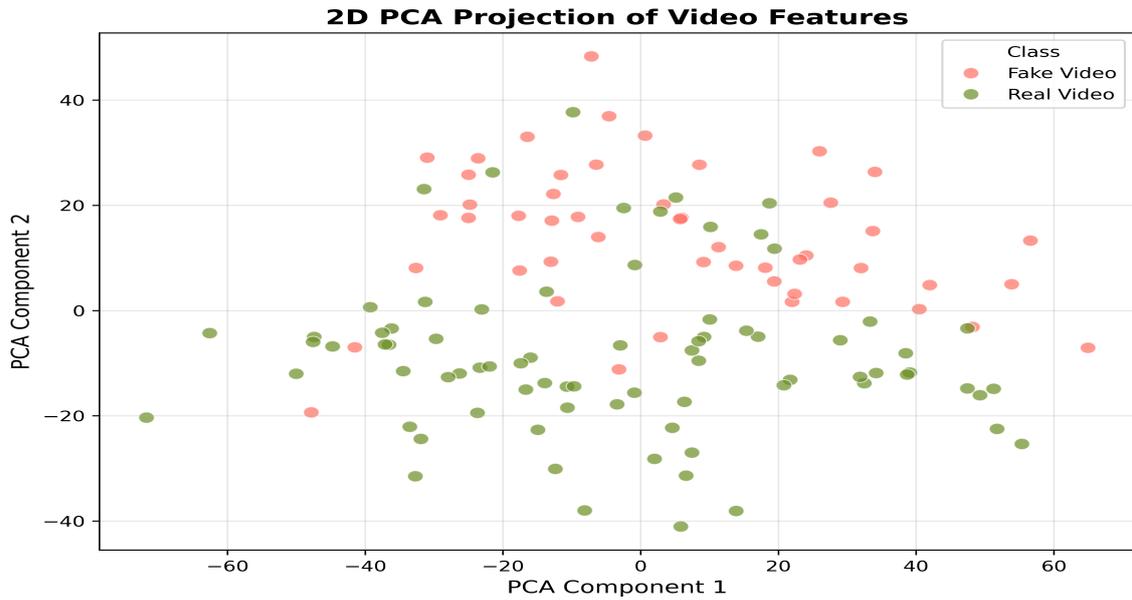
Fig. 5. ROC Curve for the SVM Classifier

Fig. 6. 2D PCA Projection of Video Features
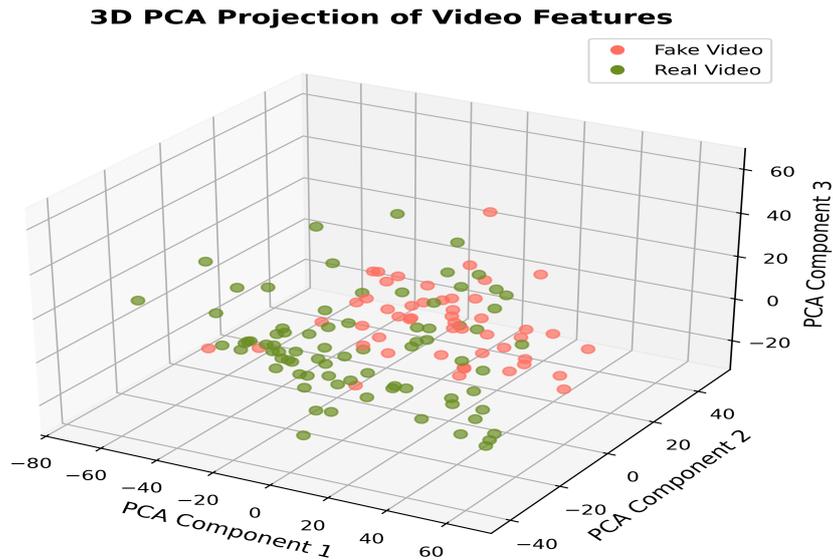
3D PCA Projection of Video Features

Fig. 7. 3D PCA Projection of Video Features

Further examination of misclassified points by 2D PCA (see Fig. 8) indicates that misclassified points fall in areas where the two classes also overlap, especially along particular sets of combinations of the two major components. This indicates that the combinations of features cause some videos to be more challenging to categorise by nature, which can be used to understand the remaining errors in the confusion matrix. Knowledge of these overlapping regions can be used to direct subsequent feature engineering or model refinement to further minimise misclassification. Altogether, these results indicate that the hybrid ResNet50-SVM model is very efficient in differentiating between real and fake videos, has good generalisation, has well-represented features, and can provide clear-cut answers about the origins of the residual classification errors.
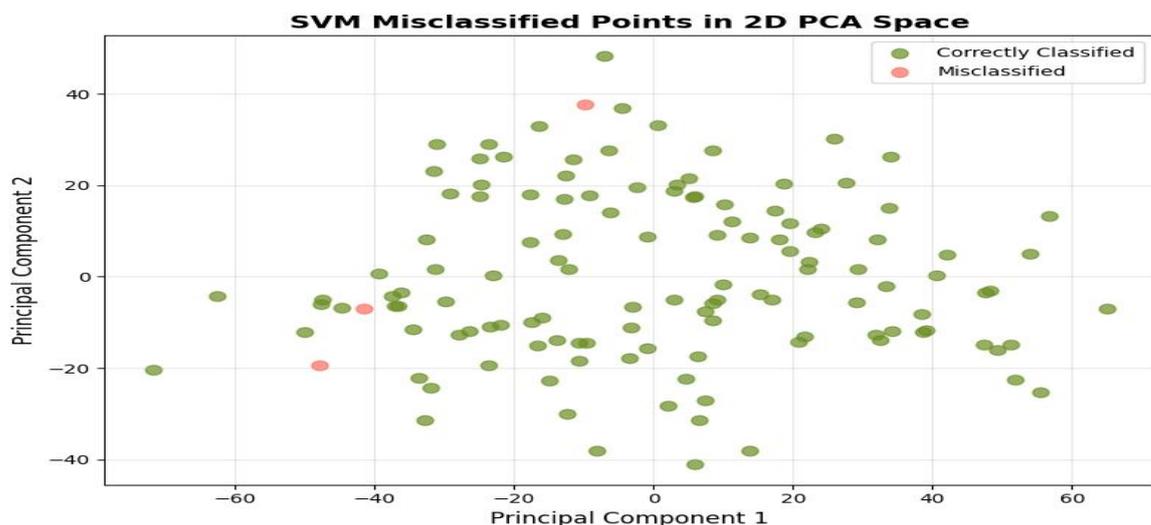

Fig. 8. SVM Misclassified Points

5.2. Comparative Analysis with Baseline Models

In a further attempt to confirm the strength and stability of the hybrid ResNet50-SVM model, other baseline classifiers were tested namely: Random Forest (RF),

Gradient Boosting (GB), K-Nearest Neighbours (KNN), and Logistic Regression (LogReg). Though SVM is the primary classifier of the approach to the methodology in Section 3.4, these other models were also added to the study on comparative grounds, in order to compare SVM with other standard supervised learning methods. Each of the models was trained and evaluated on the same 70:30 stratified portion of the data, and with five-fold cross-validation repeated ten times. Averaging of the performance metrics over the iterations was done to ascertain the statistical reliability and reduce the variability. SVM, Random Forest and Gradient Boosting are compared in Fig. 9. The SVM model has the most balanced performance with a recall of 96.1, F1-score of 91.5 and AUC of 95.2, and are very good at correctly classifying fake videos and separating between classes. Random Forest has better raw accuracy (96.1%), but poorer recall (73.4) and precision (75.3), which means that it has a higher number of misclassified positive samples. Gradient Boosting does average as far as it has gradual yet less pronounced outcomes.

Fig. 10 extends this comparison to include KNN and Logistic Regression. Here, SVM maintains its superior performance across all metrics. KNN, although showing high precision (92.6%), suffers from poor recall (60.3%) and accuracy (72.7%), indicating difficulty capturing all fake videos. Logistic Regression demonstrates consistent performance across metrics and ranks second overall, with accuracy of 83.9%, recall of 88.3%, and AUC of 91.5%. These comparative analyses clearly demonstrate that the hybrid ResNet50–SVM model consistently outperforms classical and ensemble classifiers, providing the best trade-off between precision, recall, and overall discriminative ability for video forgery detection. Fig. 11 shows the interface of the designed web application that will be the front-end platform for real-time fake videos detection. The interface permits the user to add video content and obtain the results of the classification with the best-performing model (SVM). The implementation brings about a cross between model creation and functional application and serves to show the feasibility and functionality of a system in a real-world implementation. The combination of machine learning with an interactive platform allows identifying the full potential of the project regarding data preprocessing, model training, and inference in real-time and interaction with users.
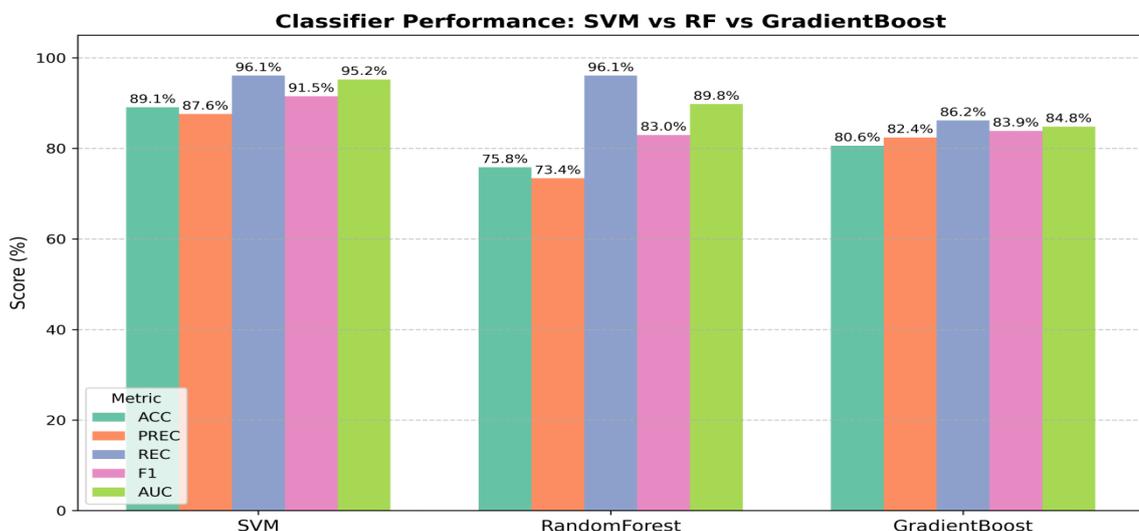
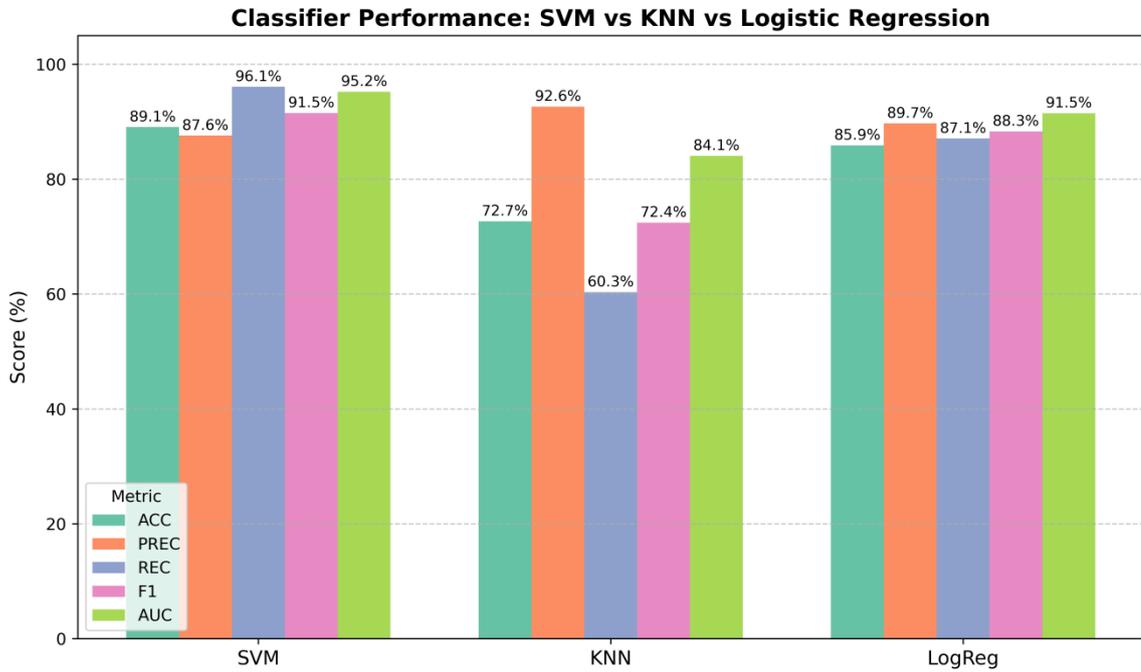Fig. 9. SVM vs Random Forest vs Gradient Boosting performance

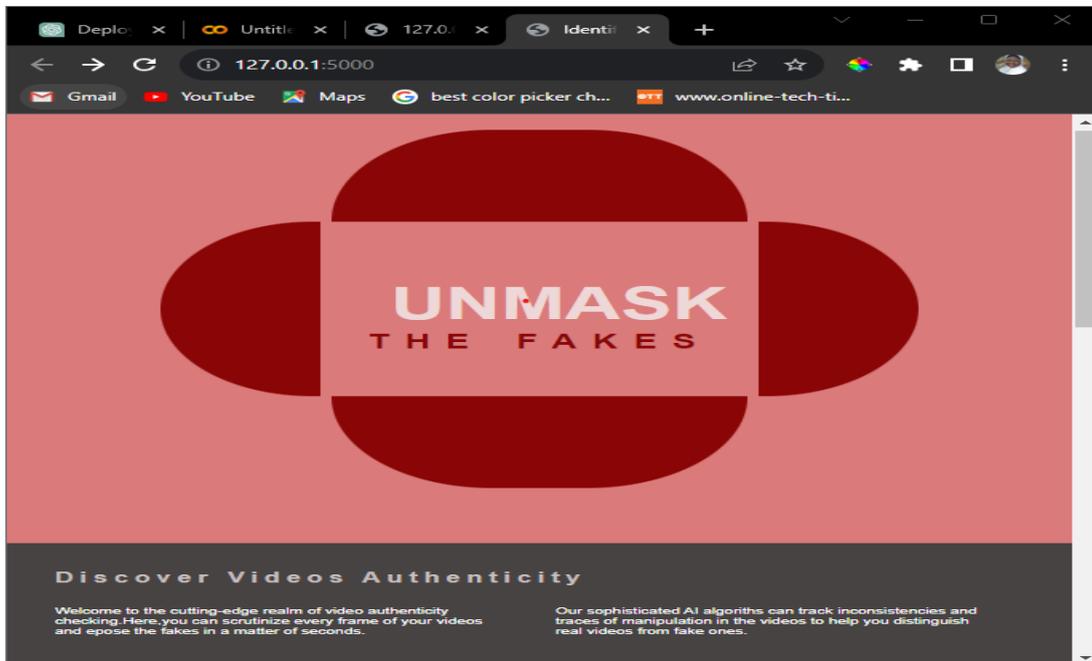Fig. 10. SVM vs KNN vs Logistic Regression performance

Fig. 11. Web Application User Interface

6. CONCLUSION

This study presents a hybrid framework that integrates deep feature extraction using pretrained ResNet50 with a Support Vector Machine SVM classifier for detecting manipulated videos. The framework was evaluated using a curated dataset from TikTok and Facebook, where complex video content was transformed into meaningful feature representations, enabling accurate distinction between real and fake videos. Quantitative analyses, including the confusion matrix, ROC curve, and PCA projections, demonstrated high accuracy, recall, and AUC, while feature visualizations confirmed clear class separation and highlighted regions contributing to residual misclassifications. Comparative evaluation with baseline classifiers, including Random Forest, Gradient Boosting, K-Nearest Neighbours, and Logistic Regression, showed that the SVM model consistently outperformed alternative approaches, providing the best balance between precision, recall, and overall discriminative capability. The successful deployment of the model within a functional web application demonstrates its practical applicability for real-time video verification. These results underscore the effectiveness, robustness, and scalability of combining deep convolutional features with classical machine learning techniques in multimedia forensics, with potential for further improvements through expanded datasets, real-time deployment, and advanced architectures.

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