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Editorial

In this issue, we are pleased to present a collection of 8 research papers that span a wide spectrum of disciplines, each offering profound insights into complex challenges and innovative solutions that are shaping our world.

The integration of distributed energy resources has brought about a paradigm shift in power systems, accompanied by a myriad of challenges. This pioneering research delves into the intricate dynamics of voltage fluctuations and power losses induced by the proliferation of solar systems and electric vehicle chargers. By introducing a robust methodology centered around Permitted Percentage (PP) allocation, the authors pave the way for enhanced grid resilience and optimized energy management strategies. With the looming surge in electric trucks, the relevance of this model becomes even more pronounced, promising to navigate the evolving landscape of electric transportation seamlessly [1].

Alzheimer's disease, an irreversible neurodegenerative affliction, poses significant challenges in early detection and classification. Leveraging deep learning models, particularly a double-enhanced CNN incorporating attention mechanisms and generative adversarial networks, this study achieves remarkable strides in the accurate classification of Alzheimer's stages. With a stellar performance of 99%, this enhanced model not only surpasses existing approaches but also underscores the potential of AI-driven solutions in revolutionizing healthcare diagnostics [2].

CPR stands as a cornerstone in combating cardiac emergencies, yet its effective administration remains elusive for many. Through the innovative utilization of Azure Kinect DK for body tracking, this study sheds light on the nuanced mechanics of CPR, elucidating the impact of posture variations on its efficacy. By providing quantitative insights into joint angles, this research lays the groundwork for precision CPR training programs, empowering individuals to respond effectively in critical situations [3].

This comprehensive study offers a chronological overview of royal development projects spearheaded by King Rama IX, unravelling their spatial distribution patterns and socio-economic implications. Employing a mixed-methods approach, the research not only highlights the breadth and depth of these initiatives but also underscores their transformative impact on marginalized communities across the nation. Furthermore, the development of a virtual learning platform ensures the dissemination of research findings to diverse audiences, fostering a deeper understanding of Thailand's developmental trajectory [4].

Robo-advisors, emblematic of financial innovation, continue to evolve amidst rapid technological advancements. Drawing on historical data and emerging trends, this study offers strategic recommendations for the robo-advisory industry, emphasizing the integration of AI-driven portfolio optimization and natural language processing capabilities. As the financial landscape undergoes unprecedented transformations, these insights serve as guiding beacons for industry stakeholders navigating the digital frontier [5].

The imperative of data security and privacy in healthcare settings cannot be overstated. Through an in-depth analysis of privacy concerns surrounding eHealth systems, this study underscores the critical need for robust security measures and user awareness initiatives. By engaging medical practitioners in N. Macedonia, the research sheds light on existing challenges and underscores the urgency of addressing usability concerns to bolster trust in eHealth technologies [6].

Addressing the dual imperatives of sustainability and infrastructure development, this study proposes innovative solutions for road pavement construction utilizing waste materials and novel fabrication techniques. By leveraging waste engine oil, recycled concrete aggregate, and Buton Rock Asphalt, the research offers a cost-effective and eco-friendly alternative for road infrastructure, catering to light to medium-traffic loads while minimizing environmental impact [7].

Against the backdrop of global efforts towards sustainable development, Malaysia emerges as a key player in shaping regional energy landscapes through its renewable energy policies. This paper provides a comprehensive analysis of Malaysia's renewable energy framework, highlighting its implications for regional energy security and cooperation. As Malaysia strides towards a greener future, its endeavours reverberate across Southeast Asia, fostering collaboration and sustainability [8].

In conclusion, the diverse array of research presented in this issue underscores the interdisciplinary nature of contemporary challenges and the transformative potential of innovative solutions. We extend our gratitude to the authors, reviewers, and readers whose contributions continue to enrich scholarly discourse and inspire progress across myriad domains.

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Optimal Engagement of Residential Battery Storage to Alleviate Grid Upgrades Caused by EVs and Solar Systems

Rafi Zahedi[*,1], Amirhossein Ahmadian[1], Chen Zhang[1], Shashank Narayana Gowda[1], Kourosh SedghiSigarchi[2], Rajit Gadh[1]

[1] *Smart Grid Energy Research Center, University of California, Los Angeles, Los Angeles, 90095, USA*

[2] *ECE Department, California State University, Northridge, Northridge, 91330, USA*

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ABSTRACT

The integration of distributed energy resources has ushered in a host of complex challenges, significantly impacting power quality in distribution networks. This work studies these challenges, exploring issues such as voltage fluctuations and escalating power losses caused by the integration of solar systems and electric vehicle (EV) chargers. We present a robust methodology focused on mitigating voltage deviations and power losses, emphasizing the allocation of a Permitted Percentage (PP) of battery-based solar systems within residential areas endowed with storage capabilities.

A key facet of this research lies in its adaptability to the changing landscape of electric transportation. With the rapid increase of electric trucks on the horizon, our proposed model gains relevance. By tactically deploying PP to oversee the charging and discharging of batteries within residential solar systems, utilities are poised not only to assist with grid resilience but also to cater to the upcoming demands spurred by the advent of new EVs, notably trucks.

To validate the efficacy of our proposed model, rigorous simulations were conducted using the IEEE 33-bus distribution network as a designed testbed. Leveraging advanced Particle Swarm Optimization techniques, we have deciphered the optimal charging and discharging commands issued by utilities to energy storage systems. The outcomes of these simulations help us understand the transformative potential of various PP allocations, shedding light on the balance between non-battery-based and battery-based solar residences. This research underscores the need for carefully crafted approaches in navigating the complexities of modern grid dynamics amid the anticipated increase in electric vehicles.

1. Introduction

High penetration of distributed energy resources (DER), such as solar systems could result in power quality issues on the distribution network [1,2]. This will be impacted more severely as the number of Electric Vehicles (EVs) grows [3].

Moreover, the emergence of electric trucks introduces distinct challenges and prospects for the distribution network. As highlighted in [4,5], if utilities neglect the increasing prevalence of electric trucks, the distribution network experiences notable voltage fluctuations. They suggested that with an increase in charging loads, there's a heightened probability for upgrades needed for the distribution lines offering an expensive and time-consuming solution with extensive planning to implement [4]. However, strategies for utilities to bear the costs remains an open-ended important question. Furthermore, a high penetration of Non-Battery-Based Solar Residence (NBBSR) elevates the likelihood of voltage fluctuations on distribution lines, particularly when a significant amount of solar power is injected into the feeders

In accordance with FERC Order 2222, regulatory bodies in the United States have been actively promoting the integration and adoption of various Distributed Energy Resources (DERs). This regulatory framework also facilitates the development of models for aggregated resource participation, enabling Behind-the-Meter (BTM) assets such as BTM Battery Energy Storage Systems (BESS) to provide a comprehensive range of power system services for which they possess the technical qualifications [6].

[*]Corresponding Author: Rafi Zahedi, rafi73@g.ucla.edu

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Moreover, in the context of bring-your-own-device business models, utility customers who are also energy producers, such as residential households, are increasingly investing in Battery-Based Solar Residence (BBSR) systems. These prosumers often utilize only a fraction of their storage capacity. In such scenarios, prosumers may consider sharing their unused storage capacity with third parties [7,8]. Additionally, through Energy-Storage-as-a-Service Arrangements, developers or utilities assume the initial costs associated with BBSR systems and subsequently own and manage these systems in return for a fee [9,10]. Both of these aforementioned business models enable utilities to expand the adoption of BBSR systems and exercise varying degrees of ownership and management as needed. For instance, New York ISO has designed a model that will let DERs such as BBSRs provide services to consumers, utilities, and the wholesale energy market to mainly ensure bulk power reliability and accessibility to all grid parties. However, they have not prioritized the power quality problems relating to the high penetration of NBBSR and EVs [11]. To mitigate the power quality challenges caused by DERs including EVs and solar systems, [12,13] provide more in-depth discussion. They suggested that utilizing storage systems could be potentially more cost-effective and merit more investigation for power quality and voltage deviation issues.

To underscore the importance of this study, a unique optimization approach is introduced and assessed within the context of the IEEE 33-bus system.

This approach aims to enhance the power quality of the grid, specifically focusing on mitigating active power losses and voltage deviations, all without the need for additional infrastructure upgrades such as storage systems, and the incorporation of new energy resources. To reduce the number of deciding factors without sacrificing its general applicability, the IEEE 33-bus system is divided into seven distinct sectors. Within each sector, there are multiple instances of two types of solar systems: BBSR and NBBSR. Notably, only NBBSR is authorized to supply solar energy to the grid, but a designated Permitted Percentage (PP) of the BBSR capacity is allocated to enable the utility to access it through charging and discharging commands as needed. Through exploration of various combinations of BBSR battery PPs and different ratios of NBBSR and BBSR at each bus, the study identifies the optimal charging and discharging commands from the grid for the existing storage capacity within each sector. This approach empowers utilities to determine the necessary PP levels by engaging in negotiations with BBSRs, taking into account the actual NBBSR and BBSR ratio and their desired power quality standards.

The remainder of this paper is categorized into four sections. In Section 2, details of the proposed methodology is investigated. A multi-objective optimization model is formulated in Section 3. The whole optimization flowchart is also introduced in this Section. The test case is analyzed in Section 4, and the results are demonstrated. Finally, the major contributions of the present work discussed in Section 5.

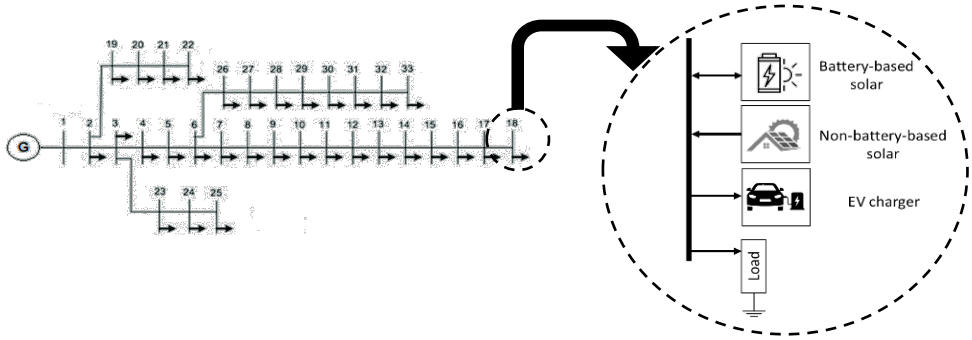

Figure 1: A typical structure of the Bus arrangement used in this study

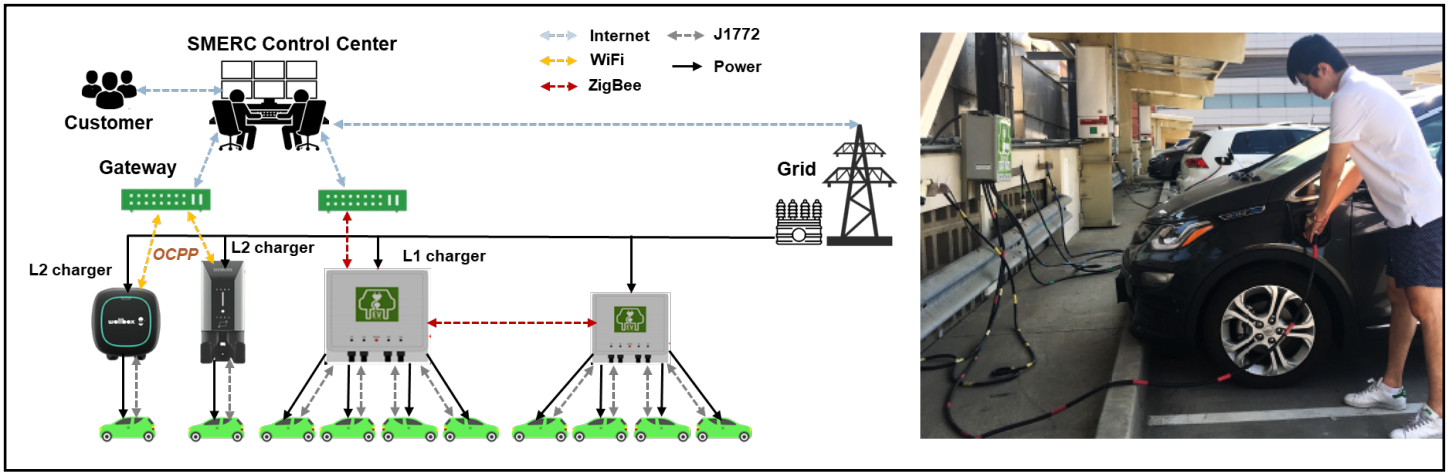

Figure 2: UCLA Smart Grid Energy Research Center charger network architecture

2. System Model

EV energy usage data was gathered from UCLA Smart Grid Energy Research Center charging station as illustrated in Figure 2. The parking structure has different level 1 and 2 chargers. The level 1 chargers talk among themselves and the gateway via ZigBee, and level 2 chargers talk to the gateway via OCPP.

The primary objective of this study is to address the challenges posed by the increasing adoption of EV chargers and solar systems within distribution networks, specifically targeting power losses and deviations in bus voltage. To achieve this goal, the proposed model has been developed in accordance with the IEEE-33 bus radial distribution standard based on [14]. It is assumed throughout this study that every residential dwelling connected to each bus incorporates a solar power generation system. Figure 1 presents an overview of the distribution system encompassing all buses adhering to the IEEE-33 [15] bus standard, encompassing EV chargers, two types of solar systems (BBSR and NBBSR), as well as residential load. Additionally, we introduce the concept of "PP," denoting a percentage of BBSR's capacity that utilities can employ to issue charging and discharging commands to/from the grid as needed.

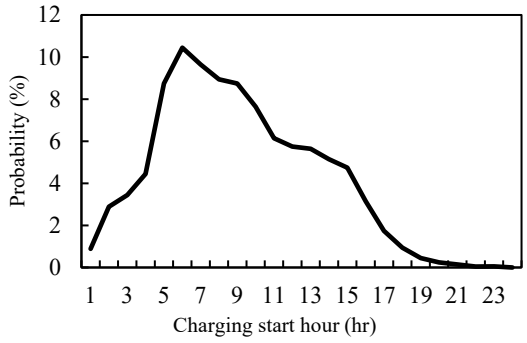

Figure 3: Distribution of the charging start hour for weekdays

Figure 3 shows our assumption on the average distribution of a charging start hour during weekdays, derived from [16].

Batteries serve as short-term energy storage devices and are commonly utilized in conjunction with solar systems, referred to as BBSR [17]. Furthermore, the energy available for each bus can be determined using the following calculation [17]:

$$E_{BT,max} = \beta \times N_{User} \times E_{BT,user} \quad (1)$$

where β, N_{User}, and $E_{BT,user}$ represent the PP of BBSR's capacity, number of residential houses per each bus, nominal storage capacity of each BBSR (kWh), respectively. Additionally, for each time interval, the calculation of available energy per bus is as follows [17]:

$$E_{BT,i}(t) = E_{BT,i}(t-1) + \sum_{t=1}^{T} P_{BT(t)} \cdot \Delta(t) \quad (2)$$

where T, $E_{BT,i}$ (kWh) and $P_{BT,i}$ (kW) are number of hours of operation, the stored energy, and the dispatched power from the utility determined by the optimization algorithm at time interval t for bus i. Finally, the state of charge of BBSR's batteries (SOC_{BT}) calculated as [17]:

$$SOC_{BT,i}(t) = 100 \times \frac{E_{BT,i}(t)}{E_{BT,max}} \quad (3)$$

3. Proposed Methodology

The proposed approach is designed to reduce the total active power loss and voltage deviations over a 24-hour operational period, enabling the utility to implement optimal charging and discharging commands through Particle Swarm Optimization (PSO). Figure 4 illustrates the flowchart outlining this methodology [14].

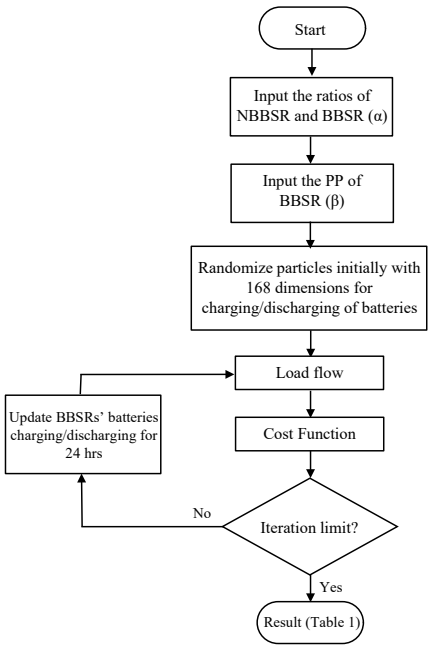

Figure 4: Flowchart of overall proposed optimization procedure

3.1. Cost Function

The cost function in this study can be expressed as the weighted combination of both active power loss and voltage deviation. Active power loss represents the amount of energy dissipated as heat in the distribution network, while voltage deviation measures the deviation of bus voltages from their nominal values. Voltage deviation exceeding a limit can affect electric equipment's lifetime and trigger the protection relays. They can be represented as follows [15]:

$$P_{loss} = \sum_{t=1}^{T} \sum_{k=1}^{N} I_{t,k}^2 R_{t,k} \quad (4)$$

$$V_{dev} = \sum_{t=1}^{T} \sum_{k=1}^{N} |V_{rated} - V_{t,k}| \quad (5)$$

$$\text{Cost Function} = \min\left(w_1 . P_{loss} + w_2 . V_{dev}\right) \quad (6)$$

where V_{rated}, V_K , V_{dev}, I_K , R_K , P_{Loss} , T and N are rated voltage, the voltage of each bus, sum of all buses' voltage deviation, feeder current loading, line resistance, total active power loss, the total number of hours of operation and the total number of lines in the radial distribution network, respectively.

3.2. Particle Swarm Optimization

PSO is an optimization technique that was created by Kennedy and Eberhart [15]. It is inspired by the behavior of bird flocking and fish schooling. PSO is composed of a set of particles that make up a group. Each particle searches its local space to find the local minimum or maximum. The velocity and position of each particle can be updated according to its best experience and the best experience of its neighbors [15]. The variables of each PSO's particle are important factors to guarantee the optimal solution [16]. Using a revolutionary optimization algorithm for a high number of variables can entail significant drawbacks, including the potential for high computational costs and the curse of dimensionality, where the exponential growth in search space makes efficient exploration challenging. Additionally, understanding algorithm behavior and diagnosing issues can be harder, leading to overfitting, generalization problems, and difficulty in visualizing the optimization landscape. Finally, there's an increased risk of premature convergence to suboptimal solutions, making optimization in high-dimensional spaces particularly challenging.

The application of PSO in this study involves optimizing the charging and discharging commands of residential battery storage systems within the distribution network. PSO is employed to find the optimal values for parameters that govern the charging and discharging process, ensuring the reduction of active power losses and voltage deviations. Specifically, the PSO algorithm iteratively refines the charging and discharging commands based on the performance metrics defined by the cost function, converging towards an optimal solution that minimizes power losses and maintains grid voltage stability.

In distribution systems, the number of buses can be relatively high, which leads to weak optimization results. In this study, the IEEE-33 bus has been subdivided into seven sectors, as depicted in Figure 5, to effectively address the challenge posed by a high number of variables. This partitioning of the area is based on presumed demographic conditions and charging demands. Therefore, the charging/discharging command can be strategically allocated to each of these sectors to reduce the number of decision variables for the optimization algorithm (see Figure 5).

3.3. Load Flow

The backward/forward sweep method is used for load flow. The backward/forward sweep is an iterative method in which, at each iteration two computational stages are performed. It is one of the most effective methods for load flow of radial distribution systems [18]. The backward/forward sweep method was chosen for its effectiveness in analyzing radial distribution systems. This method allows for an iterative calculation of currents and voltages, starting from the load buses and moving towards the substation and vice versa. Its suitability for radial systems simplifies the load flow analysis, and its step-by-step approach facilitates understanding.

Below's a brief overview of how the backward/forward sweep load flow method works:

Backward Sweep:

- Start from the load buses (the farthest points from the substation) and work your way back toward the substation.
- At each load bus, calculate the current injected into the bus by the load.
- Use Kirchhoff's Current Law to calculate the current leaving the bus toward the substation.

Forward Sweep:

- Start from the substation and move outward to the load buses.
- At each bus (except the substation), calculate the current entering the bus based on the current calculated in the backward sweep.
- Use Ohm's Law to calculate the voltage at each bus based on the current and the impedance (resistance and reactance) of the transmission lines and transformers.

Active power consumption per bus is the variable for this method in each iteration, which is obtained from the following equations

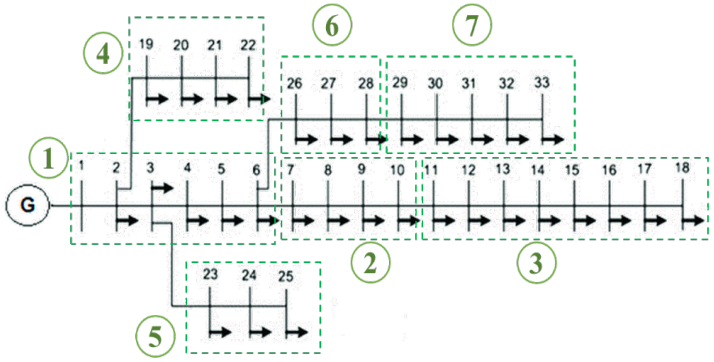

Figure 5: Modified IEEE-33 bus with 7 sectors

$$P_{Load,i}(t) = P_{T,Solar,i}(t) + P_{EV,i}(t) + P_{Res,i}(t) \quad (7)$$

$$P_{T,Solar,i}(t) = \alpha \times N_{B,i} \times P_{Solar,i}(t) \quad (8)$$

$$\alpha = \frac{N_{NBBSR}}{N_{NBBSR} + N_{BBSR}} \quad (9)$$

where $P_{Load,i}$, $P_{T,Solar,i}$, $P_{Solar,i}$, $P_{EV,i}$, $P_{Res,i}$, α, $N_{B,i}$, N_{NBBSR}, and N_{BBSR} are load, total generated solar energy by NBBSR, generated solar per NBBSR unit, EV load, residential load, proportion coefficient, number of residences, number of NBBSR, and the number of BBSR at bus i, respectively.

4. Results

The IEEE-33 bus radial distribution system has been meticulously implemented as the test case using MATLAB 2022b, comprising 33 buses and an intricate network of 32 distribution lines. These lines exhibit varying current-carrying capabilities, with lines connecting node-1 to node-9 accommodating robust capacities of 400 A, while the remaining lines exhibit 200 A capacity. In this meticulously crafted system, the combined losses in active and reactive power are quantified at 281.58 kW and 187.95 kVAR, respectively. It's imperative to note that the baseline voltage is standardized at 11 KV.

The empirical foundation for this research derives from real-world data collected from the UCLA charging station, particularly focusing on EV charging behaviors. Furthermore, solar energy generation patterns for each NBBSR have been meticulously modeled, drawing inspiration from the empirical distributions captured in Figure 6. This data stems from the UCLA 35 kW solar plant, albeit downscaled to a maximum of 10 kWs to align with the research's temporal requirements. Complementing this, the EV load distribution per individual bus is aptly visualized in Figure 7, providing a granular perspective on energy consumption patterns.

The implementation of seven distinct control sectors is a pivotal aspect of this study. Remarkably, this strategic segmentation substantially reduces the number of optimization variables from an initial count of 768 (32 buses × 24 hours) down to 168 (7 sectors × 24 hours). It is essential to note that the number of residences for every bus is the same and equal to 92.

Through the deployment of the PSO algorithm, a comprehensive exploration of various combinations of the optimization parameters α and β is undertaken. The outcomes of this rigorous experimentation are shown in Figure 8, where it is observed that that an insightful pattern emerges. Voltage deviations from the nominal values and power losses exhibit decreasing trends with the progressive augmentation of β for each α. Moreover, the cost function showcases a dynamic response, reducing as α escalates from 0% to 80% and then increasing as α surpasses the 80%. Also, figure 8 indicates that the lowest cost function happens where α equals 70% and β equals 30%.

The numerical values for 77 evaluated combinations of α and β are summarized in Table 1. To show the significance of these findings, it should be noted that the cost function for an unoptimized network is 80. Notably, the achieved cost functions marked improvements in voltage stability and substantial reductions in power loss across the distribution network.

In alignment with the study's objectives, voltage limits within an acceptable range are strategically set at ±10% of the nominal voltage, as articulated in [19].

In radial distribution networks, the end bus of each branch usually faces the highest voltage drop. To evaluate the proposed methodology's efficacy, the voltage profiles of buses 18 and 33, which are the end bus of their own branches are analyzed. Figure 9 illustrates the voltage profiles of buses 18, representing the end buses of their branches. The profiles correspond to the configuration where α equals 70% and β equals 30%, achieving the lowest cost function as highlighted in Table 1. As seen in Figure 9, the proposed methodology consistently meets the specified voltage limits, showcasing its effectiveness in maintaining grid stability. While in other scenarios the voltage profile violates the 10% deviation. A similar pattern is observed in Figure 10 for the voltage profiles of bus 33, reinforcing the robustness of our approach in different scenarios.

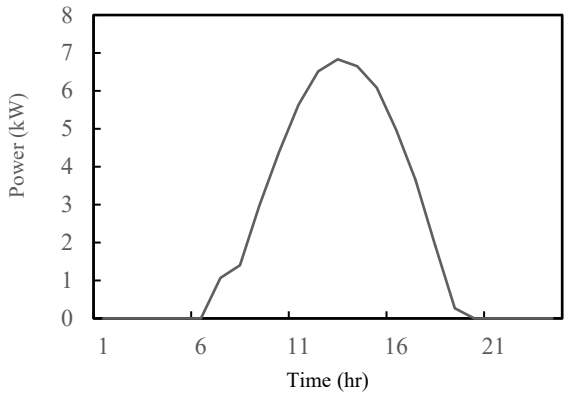

Figure 6: Generated solar

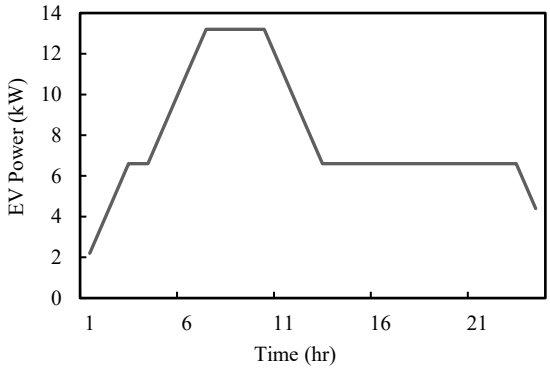

Figure 7: EV load per bus

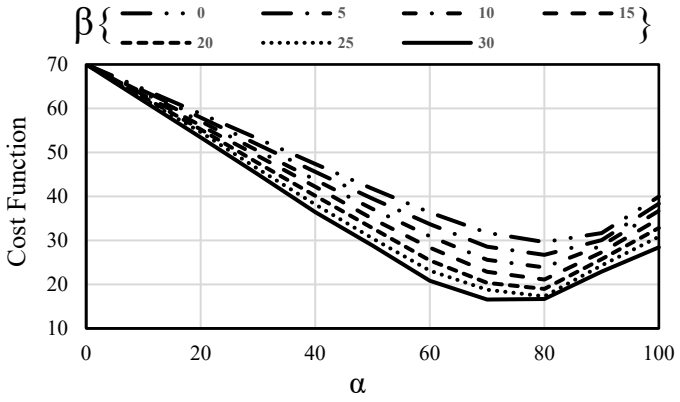

Figure 8: Cost Function value for different combination

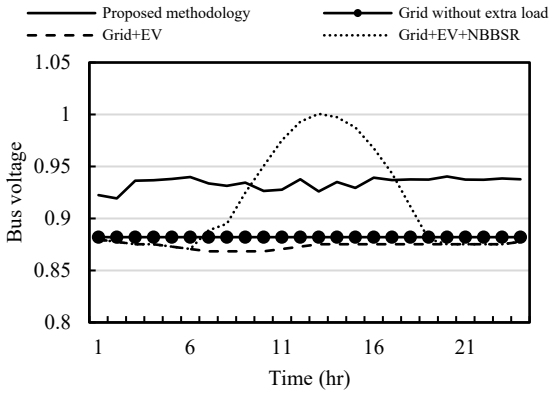

Figure 9: Bus 18 voltage for different scenarios during 24 hr of operation

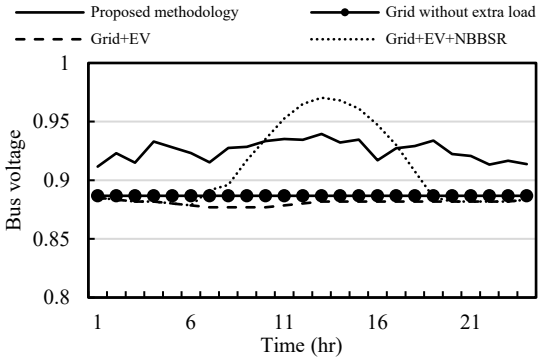

Figure 10: Bus 33 voltage for different scenarios during 24 hr of operation

Table 1 provides numerical values of Figure 8 for various combinations of α and β, showcasing the impact of these parameters on voltage stability, power losses, and the overall cost function. Table 2 further compares the proposed methodology with alternative scenarios. It provides a comprehensive comparative analysis among the proposed methodology with α set at 70% and β at 30% and alternative scenarios, considering key metrics such as total active power loss, average voltage deviation across all 33 buses, and cost function values.

The outcomes of our analysis reveal remarkable improvements in various performance metrics. Specifically, we observe a substantial 47.8% reduction in active power losses when compared to Grid without extra loads. Furthermore, the reduction in active power loss is a notable 53.2% compared with the Grid+EV scenario. Also, the proposed methodology registers a commendable 33.6% decrease in active power losses in comparison with GRID+EV+NBBSR scenario. These findings underscore the remarkable efficacy of our proposed methodology in enhancing the overall efficiency of the distribution network.

Table 1: Cost Function (equation 6) for different combination of α and β

α \ β	0%	5%	10%	15%	20%	25%	30%
0%	70.01663	70.01663	70.01663	70.01663	70.01663	70.01663	70.01663
10%	64.44564	63.98924	63.53546	63.09185	62.60636	62.22017	61.70375
20%	58.81144	57.91499	57.07909	56.09525	55.22481	54.61636	53.40737
30%	53.11391	51.76321	50.36399	49.20472	47.59238	46.2408	45.02529
40%	47.39317	45.58555	43.77159	42.20241	40.14026	38.16705	36.43257
50%	41.75065	39.50142	37.14781	34.90428	32.78993	30.47759	28.8417
60%	36.36633	33.71627	30.93126	28.34218	25.45428	23.10252	20.82519
70%	31.73868	28.55686	25.57219	22.87464	20.36441	18.78012	**16.55407**
80%	29.62956	26.71179	23.85455	21.09941	18.96617	17.28412	16.66144
90%	31.67723	30.07172	28.833	27.30397	25.7509	24.32898	22.90161
100%	39.96917	38.34332	36.70755	34.89518	32.83336	30.8411	28.44189

Table 2: Comparison between the proposed methodology and other scenarios for 24 hr of operation

	Grid without extra load	**Grid+EV**	**GRID+EV+NBBSR**	**Proposed methodology**
Active power loss (kW)	6758.1	7541.6	5314.7	3527.4
Average voltage deviation (%)	6.99	7.41	5.33	4.34
Cost function	26.5094	28.6454	21.1694	16.55407

Our analysis demonstrates an impressive average voltage deviation reduction of 37.9% when contrasted with the Grid without extra loads. The Grid+EV scenario also benefits significantly, with a 41.4% reduction in average voltage deviation. Also, the proposed methodology can achieve 18.6% reduction in average voltage deviation of GRID+EV+NBBSR scenario. These results highlight the transformative potential of our approach in achieving enhanced grid performance and reliability across various scenarios.

The results are striking, revealing a substantial 37.55% reduction in the cost function when compared to Grid without extra loads, a remarkable 42.21% decrease relative to the Grid+EV scenario, and a noteworthy 21.8% deduction in comparison with the GRID+EV+NBBSR scenario.

5. Conclusion

In this study, we have presented an innovative approach to enhance grid power quality without extensive infrastructure upgrades. Our focus was on mitigating active power losses and reducing voltage deviations, critical for ensuring a reliable and stable distribution network. Utilizing the widely recognized IEEE 33-bus system as our testing ground, we explored various scenarios involving PP of BBSR and different ratios of NBBSR to BBSR at each bus. Through optimization, we determined efficient charging and discharging commands, minimizing the need for costly modifications.

Our research demonstrated that several combinations effectively met voltage drop limitations, highlighting the potential for utilities to proactively address challenges posed by DERs. Additionally, electric trucks, while environmentally promising, pose unique charging infrastructure challenges. Our methodology offers a solution by optimizing charging commands, reducing strain on local grids, minimizing disruptions, enhancing electric truck operations, and ensuring overall grid stability. This adaptable approach stands as a strategic tool for utilities and fleet operators, fostering efficiency and sustainability in the face of evolving energy demands.

The outcome of preventing the unnecessary upgrade of the grid from this study not only minimizes power losses and stabilizes the grid but also plays a pivotal role in reducing carbon emissions, particularly in regions where the energy grid relies on a mix of fossil fuels. Implementing the proposed methodology encourages both BBSRs and NBBSRs to expand their solar capacity. The promotion of renewable energy integration, coupled with the optimized utilization of resources, underscores the study's commitment to sustainable practices.

For future works, a notable suggestion involves analyzing the integration of heavy-duty electric vehicles into the grid and exploring the feasibility of utilizing distributed solar generation to meet their charging requirements. This direction addresses the evolving landscape of electric transportation, focusing on the unique challenges posed by heavy-duty electric vehicles and proposing a sustainable approach through the utilization of solar energy.

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Double-Enhanced Convolutional Neural Network for Multi-Stage Classification of Alzheimer's Disease

Pui Ching Wong*, Shahrum Shah Abdullah, Mohd Ibrahim Shapiai

Department of Electronic System Engineering, Malaysia–Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia (UTM), 54100, Kuala Lumpur, Malaysia

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ABSTRACT

Being known as an irreversible neurodegenerative disease which has no cure to date, detection and classification of Alzheimer's disease (AD) in its early stages is significant so that the deterioration process can be slowed down. Generally, AD can be classified into three major stages, ranging from the "normal control" stage with no symptoms shown, the "mild cognitive impairment (MCI)" stage with minor symptoms, and the AD stage which depicts major and serious symptoms. Due to its generative features, MCI patients tend to easily progress to the AD stage if appropriate diagnosis and prevention measures are not taken. However, it is difficult to accurately identify and diagnose the MCI stage due to its mild and insignificant symptoms that often lead to misdiagnosis. In other words, the classification of multiple stages of AD has been a challenge for medical professionals. Thus, deep learning models like convolutional neural networks (CNN) have been popularly utilized to overcome this challenge. Nevertheless, they are still limited by the issue of limited medical images and their weak feature representation ability. In this study, a double-enhanced CNN model is proposed by incorporating an attention module and a generative adversarial network (GAN) to classify magnetic resonance imaging (MRI) brain images into 3 classes of AD. MRI images are obtained from the Open Access Series of Imaging Studies (OASIS) database and four experiments are done in this study to observe the classification performance of the enhanced model. From the results obtained, it can be observed that the enhanced CNN model with GAN and attention module has achieved the best performance of 99% as compared to the other models. Hence, this study has shown that the double-enhanced CNN model has effectively boosted the performance of the deep learning model and overcame the challenge in the multi-stage classification of AD.

1. Introduction

This paper is an extension work originally presented at the 2023 IEEE International Conference on Artificial Intelligence in Engineering and Technology (IICAIET) [1]. It has been extended and improved in terms of its model for the multi-stage classification of Alzheimer's disease (AD). Following the trend of improved performance obtained from single-enhanced convolutional neural network (CNN) models, this study proposes a double-enhanced CNN model by incorporating an attention module together with a generative adversarial network (GAN) for further improvement over existing methods.

As AD has been known as a progressive brain disorder that is still incurable to date, its early detection and diagnosis have been identified as a significant step by medical professionals [2]. Appropriate treatments can help to alleviate the deterioration process of AD even though it is impossible to fully cure an Alzheimer's patient. World Health Organization (WHO) [3] has reported that AD is the seventh leading cause of death globally and there are currently more than 55 million affected individuals worldwide. Thus, numerous research has been done in this field throughout the years to alleviate the condition [4]. Accurate classification and diagnosis of the disease are important as they can help doctors to effectively provide suitable treatments for slowing down the deterioration process so that patients will be able to continue their daily life as usual [2]. However, it is not easy to classify and diagnose the stages of AD accurately due to the complexity of medical images and the ambiguity among the stages [5].

Generally, there are three major stages of Alzheimer's, which range from the normal control (NC) stage with no symptoms, mild

*Corresponding Author: Pui Ching Wong, puiching1997@graduate.utm.my

cognitive impairment (MCI) with slight or mild symptoms, and the AD stage with serious and major symptoms. The challenge in classifying between these multiple stages is the difficulty in identifying the MCI stage which consists of faint symptoms that are hardly noticed [6]. However, there is a need to accurately identify and classify this prodromal stage of AD as the symptoms might worsen over time and progress to the next serious stage of AD [7]. Existing studies have shown that multi-stage classification is more difficult to detect than binary classification which only comprises two distinct stages, NC and AD. Thus, deep learning classification models have been utilized to efficiently aid medical practitioners in the classification and diagnosis of medical images [8, 9].

In [10], the authors used a type of CNN model known as the Siamese CNN to classify multiple dementia stages. Similarly, authors in [11] and [12] also applied different types of CNN models, such as VGG-16, AlexNet, ResNet-18, and GoogleNet for the classification of MRI scans into their respective stages. Aside from the CNN model which is well-known for its great ability to learn from raw images and classify them accurately [13], other types of deep learning models have been utilized as well. For instance, in [14] and [15], the authors applied recurrent neural networks (RNN) for the classification task due to the model's ability to solve the issue of incomplete feature extraction. On the other hand, authors in [16] used a long short-term memory (LSTM) model for multi-stage classification, while in [17], the authors utilized a GAN for image enhancement and classification tasks. All these studies that utilized various types of deep learning networks have proven that these models can effectively classify and diagnose AD stages accurately.

Nevertheless, deep learning models generally require large amounts of data for training and learning image features [18]. Hence, the complexity and limited availability of medical images have appeared to be a challenge for AD classification recently. Magnetic resonance imaging (MRI) brain images of AD patients, which are commonly used to visualize the inside of the human brain and observe any abnormalities, have a complex structure that requires much experience, time, and professionalism for analysis [5]. Besides, they are also available in limited amounts due to the privacy protection of patients' data, leading to insufficient data for research purposes. Thus, classification models have been enhanced with data augmentation models recently to overcome this limitation. For instance, CNN models are being enhanced by incorporating a GAN model for dataset expansion before the classification task. Authors in [17], [19], and [20] have shown examples of state-of-the-art studies that applied single-enhanced CNN models using GAN for their research to overcome this challenge.

However, another issue in CNN models has arisen, which affects the accuracy of AD classification tasks. The lack of adaptive channel weighting in CNN models has been identified recently and this leads to the inability of the model to effectively learn significant features from MRI brain images to accurately classify AD [21]. Thus, to solve this issue, the CNN model needs to be enhanced using an attention module to improve its feature representation ability. The attention module is a type of enhancement module that can identify regions of interest (ROIs) in an image and apply attention to them [22]. Using the information provided by the attention module, the CNN model will be able to focus on learning the features significant to each stage of Alzheimer's, and then accurately classify them. In [23] and [24], the authors presented studies that applied a single enhanced CNN model using an attention module in their works and achieved improved results. Thus, this study aims to propose a double-enhanced CNN classification model to overcome the mentioned challenges.

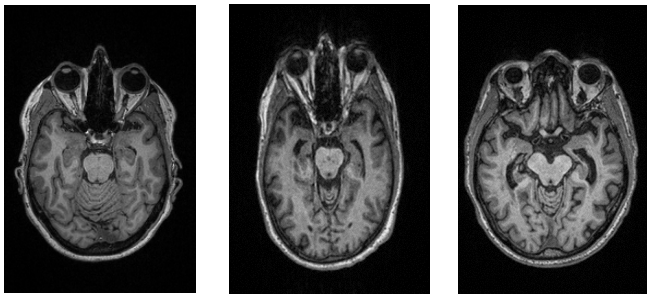
2. Methodology

2.1. Dataset

In this study, MRI data required for training the deep learning model to perform AD classification are obtained from the Open Access Series of Imaging Studies (OASIS) database (https://www.oasis-brains.org/)[25]. The OASIS database is a publicly open-access database on medical imaging which is commonly used for research purposes. Since a multi-class classification task of Alzheimer's disease (AD) is carried out in this study, MRI data from three different classes are collected for experiment purposes. For each class, namely the normal control (NC), mild cognitive impairment (MCI), and Alzheimer's disease (AD) classes respectively, 100 subjects each are collected to maintain a balanced dataset. Table 1 shows the demographic and clinical characteristics of the MRI data collected from the OASIS database. As seen from the table, the subjects are chosen based on a clinical dementia rating (CDR) score, where certain ranges of CDR represent different classes of AD. Moreover, all the MRI images collected are standardized by using only T1-weighted MRI sequences scanned with a 3 Tesla scanner. Figure 1 shows examples of MRI data collected from the OASIS database.

Table 1: Clinical and Demographic Characteristics of MRI Data

Classes	**AD**	**MCI**	**NC**
Number of subjects	100	100	100
CDR score	CDR > 2	0.5 < CDR < 1	CDR = 0
Gender	Males and females		
Age	65 years old < Age < 74 years old		
MRI sequence	T1-weighted		
Scanner type	3 Tesla scanner		



(a) NC class (b) MCI class (c) AD class

Figure 1: Example of MRI data collected from the OASIS database

2.2. Proposed Methodology

The proposed methodology for this study is an enhanced CNN model with an attention module and GAN model. It is proposed to enhance and improve the performance of the CNN model in the multi-class classification task of diagnosing AD. Figure 2 shows the overall flowchart of the proposed methodology. Firstly, the GAN model will be trained using the MRI dataset collected to expand the dataset. Then, the expanded dataset will be inputted to the CNN model with an attention module incorporated for training and validation. The attention module will be responsible for identifying the significant features and regions of interest (ROIs) that correspond to each stage of AD. With this information, the CNN model will undergo training to learn and classify MRI images into the respective 3 stages of AD. After training, the trained CNN model will be validated with an unseen set of MRI data to validate its performance and generalizability. Since there are generally 2 phases in this proposed methodology, the MRI dataset collected is distributed into 2 sets, namely training and validation, as shown in Table 2. From the 300 subjects collected from the OASIS database, a total of 3000 MRI slice images are included as the dataset for this study after filtering and choosing only the slices with significant information. Then, the dataset is split into two subsets of training and validation with a ratio of 8:2.

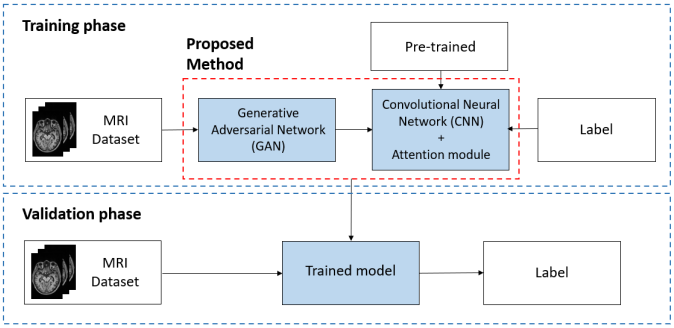


Figure 2: Overall flowchart of proposed method

Table 2: Distribution of MRI Data for Training and Validation

Classes	AD	MCI	NC	Total
Training	800	800	800	2400
Validation	200	200	200	600

2.3. Convolutional Neural Network (CNN)

In this study, a pre-trained convolutional neural network (CNN) is used to learn and classify MRI images into 3 classes, namely NC, MCI, and AD. CNN is a type of deep neural network popularly used for image analysis and classification tasks due to its powerful ability in feature extraction and learning discriminative representations from raw data [26]. Its architecture is illustrated and shown in Figure 3.

However, current trends show that transfer learning is often being used together with CNN models recently for better training experience and performance [27]. Transfer learning can aid CNN models by providing better start value and asymptote, as there is no need to train a model from scratch. This is because the CNN models have been previously trained using ImageNet, a large dataset with millions of images [28], and thus, pre-trained models have been equipped with the optimum parameters for the best training results. With just some fine-tuning, the CNN model can be easily reused for other tasks, such as for AD diagnosis in this case.

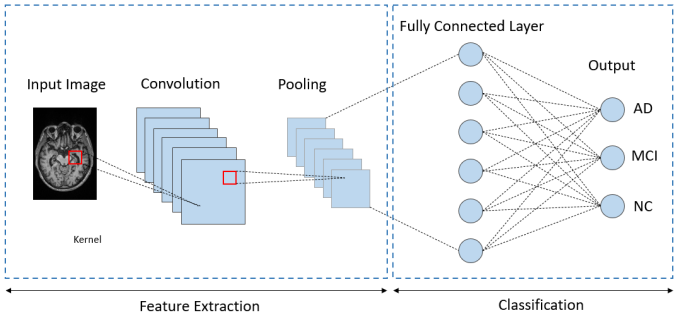


Figure 3: CNN architecture [26]

Since there are numerous types of pre-trained CNN models available, this study has chosen to utilize a ResNet-18 model for the multi-stage classification task of AD. Due to its network architecture that uses skip connections and residual blocks, it can support many convolutional layers, enable smoother gradient flow, and solve the issue of vanishing gradients [29]. Figure 4 shows its network architecture.

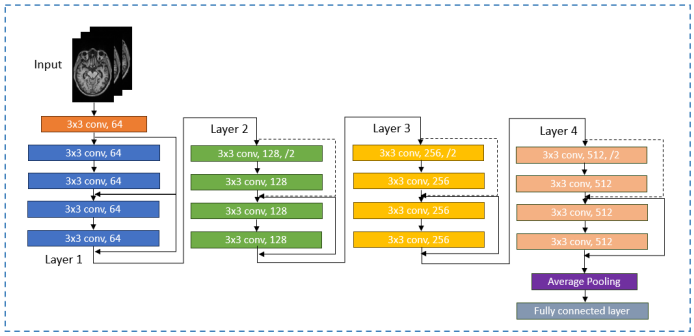


Figure 4: ResNet-18 network architecture [29]

2.4. Attention Module

Adapted from [1], the attention module is a popularly used enhancement module recently in deep learning applications due to its ability to aid in a network's feature representation power. It has been successfully applied and used in various fields such as computer vision and natural language processing (NLP) [30]. The main characteristic of the attention module is that it can help to strengthen the feature extraction ability of a CNN model, and thus enhance the model's analysis and classification performance. Since it is a computer-aided mechanism inspired by the human beings' visualization system [31], the attention module can easily recognize which regions are significant and carry important information in an image, just like the ability of the human eye. Then, it will help the deep learning model to concentrate on learning the important information only by applying focus on these regions of interest (ROIs), such as assigning a higher degree of importance to them. Thus, during training, the CNN model will be

able to learn better as they can focus on the important regions only instead of learning from the whole image which contains abundant information.

In this study, a type of attention module known as self-attention is incorporated into the CNN model for the multi-stage classification of AD. Among the various types of attention modules available, self-attention is chosen due to its characteristics that can learn global or long-range dependencies. It can help in addressing the problem of computational inefficiency brought on by CNN's limited ability that only perform local operations. Thus, it is incorporated into the CNN model to enhance its feature-capturing ability [24]. Figure 5 shows the structure of the self-attention module.

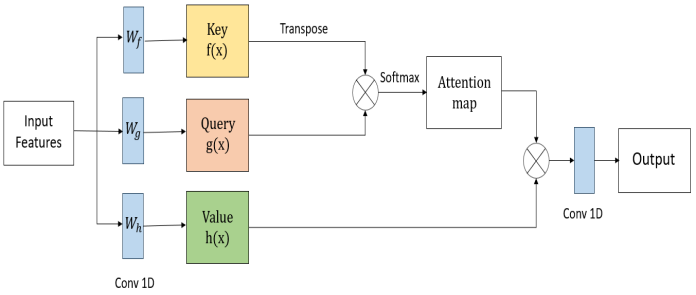


Figure 5: Self-attention module [24]

To help the CNN model capture global information efficiently, the self-attention module maps a key, query, and value to the input. The key and the value are the extracted features from the input MRI images, while the query determines the significant features to be learnt by CNN. As shown in Figure 5, the key, query, and value are transformed into vectors by using a 1x1x1 convolution filter labelled with Wf, Wg, and Wh respectively. After the transformations, they are represented as shown in (1), (2), and (3):

$$Key = f(x) = W_f x \quad (1)$$

$$Query = g(x) = W_g x \quad (2)$$

$$Value = h(x) = W_h x \quad (3)$$

As shown from (1), (2), and (3), the $x \in R^{C\,x\,N}$ represents the features from the original feature map, where C is the number of channels and N is the number of locations of features respectively. Then, the self-attention map $a_{i,j}$ is calculated as below:

$$a_{i,j} = \frac{\exp\left(f(x_i)^T g(x_j)\right)}{\sum_{i=1}^{N} \exp\left(f(x_i)^T g(x_j)\right)} \quad (4)$$

, where $a_{i,j}$ denotes the degree of attention of the model on the i-th region during the synthesis of the j-th region. Following this, the output of the self-attention module is represented by O_j, where $O = (O_1, O_2, \ldots O_j, O_N) \in R^{C\,x\,N}$, and

$$O_j = W_v \left(\sum_{i=1}^{N} a_{i,j} h(x_i) \right) \quad (5)$$

A 1x1x1 convolutional filter is again used to reduce the number of channels of the final output for standardization and memory efficiency as shown in Figure 5.

2.5. Generative Adversarial Network (GAN)

As shown in the overall methodology flowchart in Figure 2, MRI data will first be inputted into a Generative Adversarial Network (GAN) model before they are used to train the CNN model for multi-class classification of AD. GAN is a type of unsupervised deep neural network popularly used for data augmentation and expansion tasks due to its progressive nature. Introduced in [32], the author had proven that it is able to generate realistic and high-quality samples by applying the knowledge from learning the probability distribution of input variables. Thus, it has been increasingly used in recent studies that faced the problem of insufficient data, such as in this research domain where MRI images of Alzheimer's patients are always in limited quantity [17, 19, 33]. Figure 6 shows the structure of a GAN model.

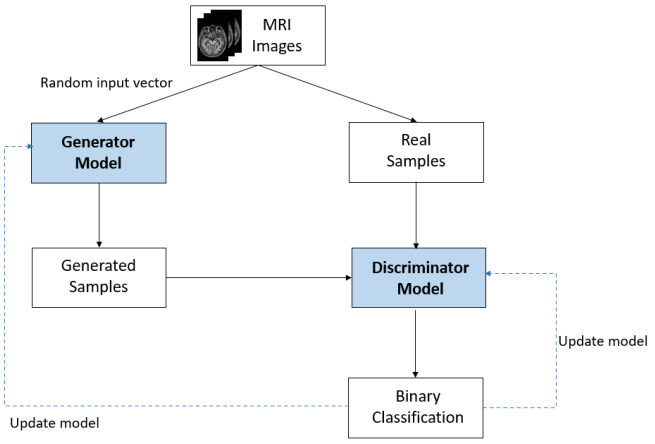


Figure 6: GAN model structure

From Figure 6, it can be seen that there are generally 2 network models in a GAN, which are the generator and discriminator models respectively. The generator model typically generates new samples based on the received random input vector and then passes them to the discriminator model for the following step. On the other hand, the discriminator model receives the real MRI images from the input as well as the generated samples from the generator model. It then compares them and distinguishes the generated samples from the real ones. Both models will continuously update and improve their models to achieve a point of equilibrium where the discriminator can no longer distinguish generated samples from the real data. Equation (6) shows the loss function of the GAN where both the generator and discriminator models will continuously learn until they achieve the goal of maximizing the number of real-looking sample images.

$$\min_G \max_D \; V(D, G) = \mathbb{E}x{\sim}p_{\text{data}}(x) \log D(x) + \mathbb{E}z{\sim}p_z(z) \log (1 - D(G(z))) \quad (6)$$

2.6. Experiment Setup

In this study, four experiments are carried out to verify and observe the difference in the models' performances when classifying MRI images into multiple stages of AD. Table 3 shows the model used for each experiment and the differences between them. Experiment I is done using only the CNN model without applying any enhancements. Experiment II utilizes an enhanced

CNN with an attention module, while a GAN-enhanced CNN model is utilized for Experiment III. Lastly, the proposed enhanced model in this study, which is the CNN enhanced with attention module and GAN is applied in Experiment IV.

Table 3: Four experiments done in this study

Experiment	CNN model	Enhanced with attention module	Enhanced with GAN model
I	/	X	X
II	/	/	X
III	/	X	/
IV	/	/	/

In Experiments I to IV, each of the models is developed using PyTorch, the Python-based deep learning framework and trained using the graphics processing unit (GPU). The hyperparameters used for the models' training are tabulated in Table 4. To avoid bias, the same amount of MRI data as shown in Table 2 is applied for models' training and validation. However, for Experiments III and IV which involve the enhancement using the GAN model, the amount of data used for the multi-stage classification task is later increased due to the addition of generated MRI data samples by GAN, which will be further explained in the results and discussion section below.

Table 4: Training hyperparameters used in Experiments I to IV

Hyperparameters	GAN model	CNN model
MRI image size	64 x 64 x 3	224 x 224 x 3
Epoch	100	100
Batch size	64	8
Learning rate	0.0002	0.0001
Optimizer	Adam optimizer	Adam optimizer
Loss function	Binary cross entropy	Categorical cross-entropy

2.7. Performance Evaluation

After training the models in Experiments I to IV, their performances are measured and evaluated for comparison purposes. It is required to observe the differences in performances of the various combinations of models used in the four experiments so that the best model can be identified. It is also to validate whether the proposed model can perform as desired to achieve the objective of this study. Thus, a few performance metrics are used to evaluate and measure the performance of the 4 different models in the multi-stage classification task of AD. Equations (7) to (10) show the four types of evaluation metrics used in this study together with their method of calculations. The accuracy, precision, recall, and F1-score of the four models used in Experiments I to IV are calculated and tabulated in the results section for performance evaluation. Based on Equations (7) to (10), it can be seen that the metrics are calculated by using the true and false positives and negatives obtained from the classification tasks.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (7)$$

$$Precision = \frac{TP}{TP + FP} \quad (8)$$

$$Recall = \frac{TP}{TP + FN} \quad (9)$$

$$F1 - score = \frac{2\ x\ Precision\ x\ Recall}{Precision + Recall} \quad (10)$$

3. Result and Discussion

After carrying out four experiments by using four different combinations of models to verify the proposed methodology, all the results are tabulated as shown in Table 5. The table shows the performance of the models in terms of performance metrics such as accuracy, precision, recall, and f1-score. The different models used in the four experiments are listed below:

a) Experiment I: CNN model only
b) Experiment II: Enhanced CNN model with attention module only
c) Experiment III: Enhanced CNN model with GAN only
d) Experiment IV: Enhanced CNN model with attention module and GAN model

For each experiment, the CNN model is trained to classify MRI images into different stages of AD using the same number of data as shown in Table 2 to avoid bias. However, for experiments III and IV which involve the usage of GAN, the MRI dataset is expanded before being inputted into the classification model. Figure 7 shows the results from training the GAN model using MRI images obtained from the OASIS database. As shown in the figure, the grid image on the left illustrates the real MRI images from the MRI dataset, while the grid image on the right shows the fake MRI images that are generated by the GAN model. Thus, from the figure, it can be seen that the fake images look quite similar to the real images with most of the image features accurately generated by the GAN after learning them during model training. For Experiments III and IV, the generated MRI images output by the GAN model are added to the original MRI dataset before the CNN models are trained for multi-stage classification tasks. In both experiments, 160 generated MRI sample images were added to the original dataset, accounting for a total of 960 MRI images used for the CNN classification task.

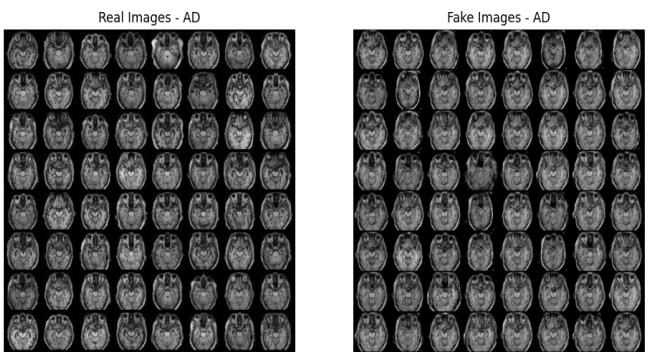


Figure 7: Comparison between real and generated images by GAN

Table 5 shows the complete summary of the results obtained from the multi-stage classification task of AD in terms of accuracy, precision, recall, and f1-score for Experiments I to IV. On the other hand, Table 6 shows a comparison between the performances of the four experiments, focusing on the accuracy metrics. Hence, it can be seen that in general, the results obtained from Experiment I such as the accuracy, precision, recall, and f1-score have the lowest values among the 4 experiments. This is because a basic CNN model without any enhancement is used for classification in Experiment I. Experiments II and III apply a single enhancement to the CNN models, and a slight increase in the performance metrics' results is seen. For instance, the training accuracy has improved from 95% in Experiment I to 98% in Experiment II, while the f1-score has improved from 90% in Experiment I to 96% in Experiment III.

Following this, a more remarkable improvement in the results can be observed from Experiment IV which utilized a double-enhanced CNN model, as proposed in this study. From Table 5, the enhanced CNN model with attention module and GAN model has managed to output the highest accuracy at 99% during training and 92% during validation. These can also be validated from the accuracy and loss graphs that are shown in Figures 8 and 9 respectively. From Figure 8, it can be seen that the accuracy achieved by the proposed model matches the results tabulated in Tables 5 and 6, while in Figure 9, the model loss during training precisely decreases until approximately zero as the number of training epochs increases. However, a slight limitation can be observed from the graphs, which is the presence of some overfitting in the model training, as the validation performance is generally lower than the training results.

Nevertheless, great improvements in the other performance metrics such as precision, recall, and f1-score in Experiment IV can be clearly observed in Table 5 as well. The results suggest that the proposed double-enhanced CNN model achieved the highest performance as compared to the other 3 models in the other experiments. Thus, from the tables and graphs shown, it can be concluded that the classification model's performance significantly improved when a double-enhanced CNN model with both attention module and GAN is utilized, as proposed.

Table 5: Results of performance metrics obtained from Experiments I to IV

	Accuracy	Precision	Recall	F1-Score
Experiment I				
Training	0.9580	0.9017	0.9020	0.9018
Validation	0.8786	0.8384	0.8369	0.8357
Experiment II				
Training	0.9817	0.9587	0.9587	0.9587
Validation	0.8917	0.8752	0.8746	0.8726
Experiment III				
Training	0.9743	0.9604	0.9604	0.9604
Validation	0.8983	0.8796	0.8803	0.8788
Experiment IV				
Training	0.9906	0.9636	0.9636	0.9636
Validation	0.9200	0.8838	0.8828	0.8809

Table 6: Comparison of accuracies obtained from different models

Experiment	Model	Accuracy
Experiment I	CNN only	0.9580
Experiment II	CNN + Attention	0.9817
Experiment III	CNN + GAN	0.9743
Experiment IV	CNN + Attention + GAN	0.9906

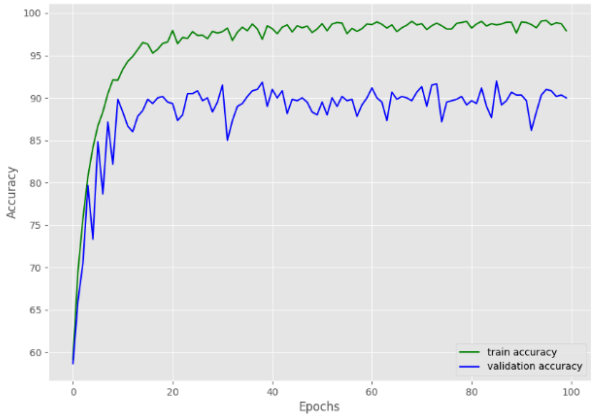


Figure 8: Accuracy graph of the proposed model obtained from Experiment IV

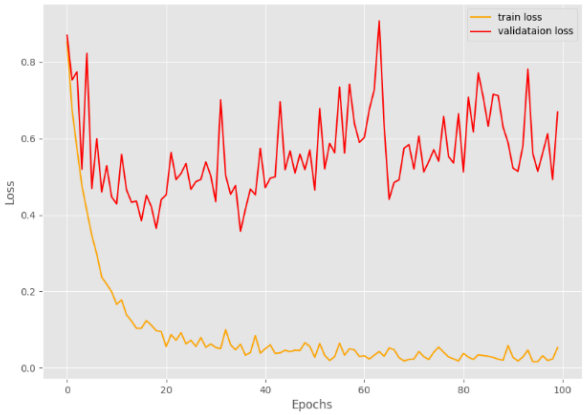


Figure 9: Loss graph of the proposed model obtained from Experiment IV

4. Conclusion

In a nutshell, the results achieved in this study as discussed in the previous section have validated and proved that the proposed objective has been achieved successfully. A double-enhanced CNN model using an attention module and a GAN model has resulted in an improved multi-stage classification performance of Alzheimer's disease, where an accuracy as high as 99% had been achieved. As compared with unenhanced or only single-enhanced CNN models, the classification performance of this double-enhanced model is clearly improved and is the highest among the others. Thus, the significance of the double-enhanced CNN model is proved as it can appropriately solve the challenge in the multi-stage classification of AD, where the MCI stage is difficult to identify, and the issue of limited medical images available. Hence, the findings obtained in this study can significantly contribute to

this research domain by verifying the importance of a double-enhanced classification model for the multi-stage classification of AD. Lastly, future research directions may involve improving the stability of the GAN model for better samples, enhancing the generalization ability of the CNN model to overcome overfitting issues, and trying to incorporate other types of enhancement modules for better classification performance.

Conflict of Interest

The authors declare no conflict of interest.

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Analysis of Components and Effects of Chest Compression Posture using CPR Training System

Taiki Yamakami*, Akinori Minaduki

Kushiro Public University, Economics, Minaduki Lab, Kushiro City,085-8585, Japan

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ABSTRACT

Cardiopulmonary resuscitation (hereafter CPR) is a life-saving procedure to combat our day-to-day risks of cardiac arrest. However, there are a few citizens who can accurately carry out CPR by encountering the scene of the cardiac arrest of others, and there are many unclear parts on the methods such as the correct attitude of CPR, and the condition which lacks the clear scientific reason becomes a problem. This study aims to investigate the lever arm of CPR (cardiopulmonary resuscitation) by Body tracking using Azure Kinect DK to determine the lever arm of CPR (cardiopulmonary resuscitation) by Body tracking. As a movement toward this goal, this time we analyzed the effect of hand up/down changes in CPR posture on CPR and posture from a clear numerical value of joint angle.

1. Introduction

Cardiopulmonary resuscitation (hereafter CPR) is a life-saving procedure to combat our day-to-day risks of cardiac arrest. However, there are a few citizens who can accurately carry out CPR by encountering the scene of the cardiac arrest of others, and there are many unclear parts on the methods such as the correct attitude of CPR, and the condition which lacks the clear scientific reason becomes a problem. CPR Training Posture Analysis Simulator (hereafter CPR Training System) developed in this study visualized the posture of the upper and lower extremities during chest compression in CPR from two frontal and lateral directions using Azure Kinect DK. The development of a posture-conscious CPR training system allowed objective assessment of posture and compression (including decompression) during chest compressions [1],[2]. CPR training system is aimed at the public to disseminate the practical education and training of CPR, and at the same time, to pursue the proper postural shape of CPR position with many unknown parts based on the training record data accumulated through the experiment.

As an approach to elucidate the appropriate posture to perform chest compressions during CPR, which has not been elucidated in previous studies, CPR posture is divided into parts, and the appropriate posture with scientific evidence is analyzed for each part. In this study, we analyzed the effects of CPR postural hand placement and the relation between CPR postures and the number of compressions and muscle strength and muscle mass.

2. Current Status of the Scientific Basis for CPR Attitudes

Currently, it is recommended as an appropriate attitude for CPR by JRC Resuscitation Guideline (Medical Shoin) [3], which is supervised by the Japanese Resuscitation Council, as shown in Figure 1.

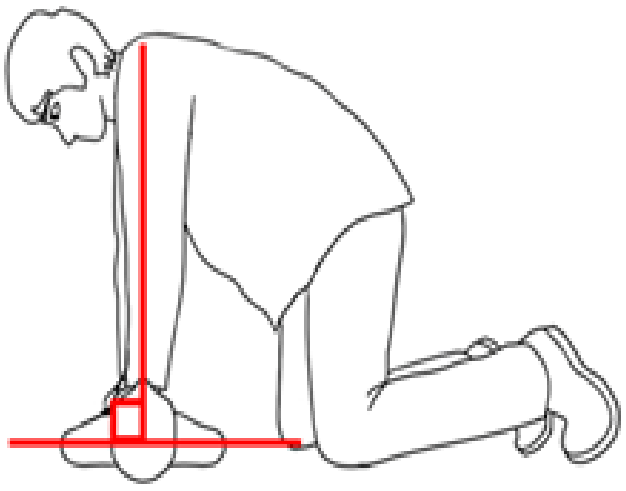

Figure 1: Basic position of CPR (image diagram)

*T. Yamakami, Kushiro Public University, Kushiro City, Hokkaido, Japan, s202103@kpu.kushiro-pu.ac.jp

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Some of the methods of the guideline include those with less certainty of the scientific basis, and the appropriate attitude of CPR remains to be elucidated.

3. Developing NUI Applications for CPR Training

Azure Kinect DK (Kinect) used as an input-sensing sensor device for postural changes in the body during CPR training is an input sensor device for NUI (Natural User Interface connected to Windows PC [4]. Extracting postural movements (shapes; kata) during CPR training and developing a decision-algorithm requires that the entire body is input-detected and user-interfaced when performing CPR. Therefore, in this study, a Kinect was used to develop a training system that implemented a NUI application using Kinect to extract the variations of parts (elbow, shoulder, etc.) from the whole body by capturing the whole body at the time of CPR training to detect the whole-body input, and to make correct and incorrect judgments of the shape of CPR's postures.

4. System Interface Overview

In the interface, we developed an analyzable system to visualize and analyze subjects' training attitudes in AR (augmented reality) representation, and the processing which relied on the anatomical knowledge [5],[6] was carried out on Body Tracking detection data of Kinect. Therefore, this system can be used to determine the correct (or incorrect) position of CPR without wearable devices, which are required by motion capture etc.

As shown in Figure 2, the frontal Kinect display interface derived detection and assessment of the left and right elbow and shoulder in real time and displayed a point transform (100-point method) to make it easier for trainees to recognize.

Comment labels are displayed according to the condition of each joint, and arrow marker interfaces point to incorrect postures and are displayed relative to where they should be corrected.

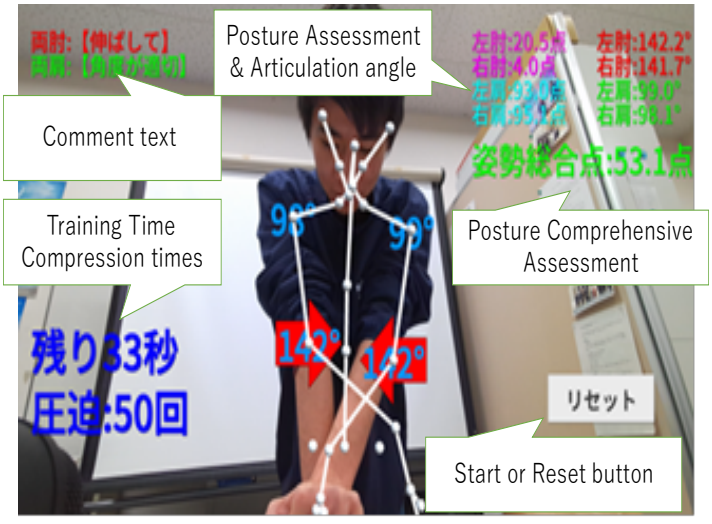

Figure 2: AR representation of the front Kinect.

In the lateral Kinect display interface as in Figure 3, detection and assessment of the chest (thorax), navel (abdomen), and buttock were performed in real time to display the number of points and comments as well as the interface of arrow markers in the direction to be modified. These interfaces have been implemented as NUI applications using the game engines Unity.

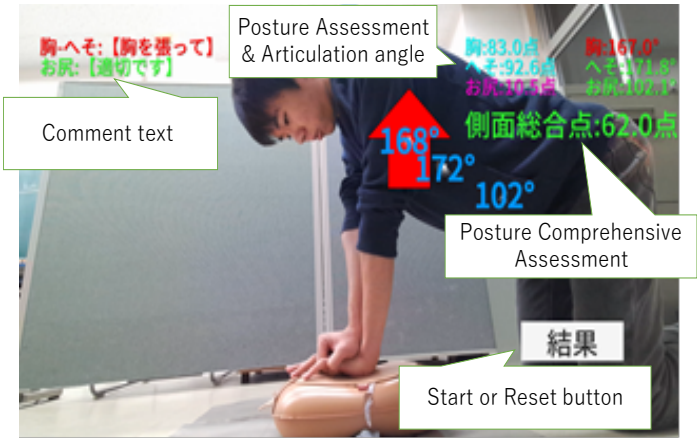

Figure 3: AR representation of Kinect on the side.

5. Correlation Between the Coefficient Processing of the Number of Compressions and the Postural Total Point

As mentioned above, the counting process of the number of compressions implemented in this system detects a total of two clicker sounds during compression and decompression when a CPR training doll is compressed to an appropriate depth using a single-directed microphone, and counts the number of compressions. This clicker sound has a difference in sound pressure between when the sound pressure has reached an appropriate depth and when the sound pressure has not reached an appropriate depth. Using this difference, only an appropriate sound pressure (mean 77.9dB) is recognized as the number of compressions.

A positive correlation between the number of compressions and the postural score has been demonstrated in a previous study in a poor laboratory.

Training time is 1 min. A countdown of the remaining time of training is displayed at the bottom left of the screen. As for the number of times of compression, two clicker sounds (metallic sounds) generated when CPR training doll is compressed and decompressed to an appropriate depth (about 5 centimeters) are detected by a single directional microphone, and the number of times of compression is counted as one time by two clicker sounds.

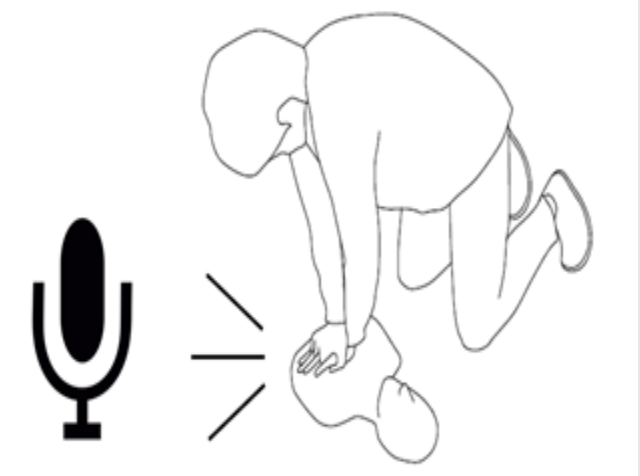

Figure 4: Sound pressure recognition of the number of compressions and image of counting processing.

6. Relationship Between Compression Posture and Hand Placement (Hand Shape)

The training features of NUI application developed in this study can capture the trainees' own CPR postures and learn the correct CPR training while modifying their own postures. Conventional studies using this system have analyzed the position and angulation of the elbow, shoulder, lower back, and chest from the front and side using this feature, and have investigated the basic form (shape; kata) of the position to perform CPR. One of the key elements of CPR that has not been analyzed so far is how to place the hand (hand kata). Traditionally, there have been no evidence-based findings referring to the effect of CPR on the efficacy of hand kata, and it has not been elucidated what effect the hand kata has on CPR's posturing.

On the other hand, when CPR training is practiced, trainees are carefully concerned about the hand part, and trainees have also been seen to change the placement and compilation method in the middle of training.

Therefore, the kata of the hand, which is considered to be a critical site when performing CPR training, was analyzed from two perspectives, namely, the postural total point from the training system (front and side) and the exercise load (increased pulse volume), on the effect of the upper and lower changes of the dominant hand, as shown in Figure 5. CPR has a high exercise load, and even a 1-min training using the system requires a substantial amount of exercise. It is said that it takes an average of 8 minutes for an ambulance to arrive at the scene when encountering a scene of cardiac arrest and performing critical care activities. Considering that laypersons perform CPR for more than 8-10 minutes before delivering a cardiac arrest treatment to the ambulance, it is crucial to reduce the exercise load more.

7. Experimental Methods and Overview

The experiments were conducted in February 2023 for the first experiment with 30 people (18-24 years old) and in May to June 2023 for the second experiment with 33 people (18-23 years old) in total for two times. The experimental methods are outlined in Figure 5 (the first experiment) and Table 1 (the second experiment) below.

7.1. Overview of the first experiment

In the first study, we analyzed whether there is a change in postural and exercise loads by changing the kata of the hand during CPR training.

1. Blood pressure and pulse measurement
2. CPR training with the dominant hand on top (1)
3. Blood pressure and pulse measurement
4. Rest (at least 10 minutes)
5. Blood pressure and pulse measurement
6. CPR training with the dominant hand down (2)
7. Blood pressure and pulse measurement

Figure 5: Experiment Method and Procedure for the First Experiment

For Figure 5 ①, ③, ⑤, and ⑦, the increase and decrease of pulse was used as an index of exercise volume, so blood pressure and pulse were measured before and after CPR training. Pre-and post-training pulse rates were compared, and their increments were analyzed by determining differences between those with the dominant hand up and down to determine which exercise dose was more reduced. In ② and ⑥ of Figure 5, training using CPR training system was carried out, and postural total points were analyzed from the front and side in the training of ① and ② in which the dominant hand was changed. In Figure 5 ④, the pulse rate at rest was used as a reference, and a break of more than 10 minutes was set for the purpose of lowering the increase in the pulse by the training performed with the first handedness.

Figure 6: First experiment (The Screen Shows AR of Kinect)

7.2. Outline of the Second Experiment

The effectiveness of the result on the positioning method of the hand in CPR which was proven by the first experiment was verified. The newly conducted experiment (the second experiment) for verification was conducted from May to June 2023 with 33 subjects (18-23 years old). In the second experiment, the body composition, back muscle strength, and grip strength of the subjects were newly measured in addition to the survey on the method of hand placement, and various factors were examined for analyzing CPR postures. The experimental methods and procedures performed in the second experiment are as shown in Table 1 below.

Table 1: Methods and Outline of the Second Experiment

Test days	Experimental items
Day 1 **(Measurement of standard data)**	**①Measurement of blood pressure and pulse at rest** **②Measurement of body weight and muscle mass (body composition monitor)** **③Grip strength measurement**
Day 2 **(Experimental day ①)**	**①CPR training with handedness** **②Measurement of blood pressure and pulse rate after training**
Day 3 **(Experimental Day ②)**	**①CPR training with a dominant hand** **②Measurement of blood pressure and pulse rate after training**

Measurements of physical data, such as blood pressure and pulse measurements, were performed under supervision by nurse-qualified medical personnel. As a cautionary note in measuring blood pressure and pulse, it was noticed that exercise and meal within 2 hours before measurement should be refrained, that the arm in the measurement is used in principle of the same person's arm, and that the number rise due to tension similar to white coat hypertension in the measurement should be sufficiently considered. Changes from the first experiment and additional experimental items are described below.

The first change in the experimental method was the experimental method in which the trainee changed the upper and lower of the dominant hand in the first experiment, experienced the training twice in a day, sandwiched a break between the training to handle the pulse, and returned the pulse to the normal value. In this regard, in the second experiment, by dividing the experiment into three days (experimental day ② performed after 1 week), such as various reference values measurement days (resting blood pressure and pulse, grip strength, and body composition data), experimental days ① (CPR training with the dominant hand down), and experimental days ② (CPR training with the dominant hand up), the pulse values at rest and after the training were acquired more precisely than those in the first experiment.

As the second change point of the experimental method, the case in which the dominant hand was put up was carried out first in the first experiment, therefore, in the second experiment, the training in which the dominant hand was put down was carried out first in the second experiment, and whether the change occurs in the experimental result of the first experiment by changing the order was verified, and the result in the first experiment was confirmed. As a change point of the third point of the experimental method, the dominant hand was investigated by the questionnaire in the first experiment, and the chapman test was used for the discrimination of the dominant hand in the second experiment.

The chapman test is a test of the method which chooses and answers the question of 13 items from 3 choices of right hand, both hands and left hand. It is converted to 1 point in the right hand, 2 points in the both hands, 3 points in the left hand, and the discrimination of the dominant hand is carried out by the total point in all 13 items. The questions of the Chapman test actually used in the experiment are as described in Figure 7 below. The calculation method of the total score is right-handed 13~17 points, both-handed 18~32 points, and left-handed 33~39 points.

Q1 Which hand writes letters?
Q2 Which hand uses a screwdriver?
Q3 Which hand uses a bottle opener?
Q4 Which hand throws a ball?
Q5 Which hand uses a hammer?
Q6 Which hand uses a toothbrush?
Q7 Which hand holds a match?
Q8 Which hand uses an eraser?
Q9 Which hand uses a scissors?
Q10 Which hand uses a racket?
Q11 Which hand paints?
Q12 Which hand mixes the paint?
Q13 Which shoulder is on the catcher's side when you hit the ball?

Figure 7: Chapman Test Question

In the second experiment, a total of 11 items (14 items) including grip strength, back muscle strength, muscle mass (both arms, both legs, and trunk), body fat percentage, height, weight, difference in centroid position according to gender, sitting height, opening knee, positional relationship of the site after the knee, and head position were measured and observed before the experiment. The second experiment was conducted with the above changes and new experimental items added.

Figure 8: Second Expariment (The Screen Shows AR of Kinect)

8. Results of the First Experiment

The developed CPR training system is capable of objectively assessing correct postures during CPR. In the first experiment, in order to investigate the correct posture in chest compressions, the authors noticed the kata of the hand to perform compressions. In this study, we comparatively analyzed the changes in postural assessment points, number of compressions, and exercise loads in CPR training system to determine the effects of hand kata on CPR in the correct posture, and derived statistical outcomes from each relation. Table 2 shows the results of the first experiment with 30 subjects.

The mean was calculated for each postural total score in the frontal and lateral systems and for the increase and decrease of the pulse before and after training, and the significance probability was determined by Wilcoxon signed rank test for the difference between the means.

Table 2: Experimental Results of the First Experiment

	1st	2nd	Difference	P-value	significant difference
Average of Pulse Difference	9.8/m	13.4/m	3.6	P<0.05	○
Average of side score	68.1 pt	59.9 pt	8.4	P<0.01	○
Average of front score	80.1 pt	74.0 pt	6.1	P<0.1	△

As shown in Table 2, there were significant differences in the means of CPR training between the first (training with the dominant hand up) and the second (training with the dominant

hand down) in the two items of the pulse and the postural total points of the lateral system. And, the result that it showed the significance tendency was obtained, though the significance could not be confirmed on posture total point of the frontal system. As shown in Table 2, there was an average difference of 3.6 movements for the pulse, an average difference of 8.2 points for the lateral posture total point, and an average difference of 6.1 points for the frontal posture total point.

These findings demonstrate that a good CPR can be performed when the dominant hand is placed above, compared with when the dominant hand is placed below. This finding suggests that the dominant hand must be raised as a CPR hand kata as an early experiment to elucidate the optimal kata of CPR.

9. New Challenges from the Results of The First Experiment

Though the result obtained in the first experiment was good, it is necessary to reexamine the effect of the order of the training on various items and the effect on blood pressure and pulse [7], because the training for the dominant hand is carried out before and the training for the dominant hand is changed under, and because the training was carried out twice in the same day. As items that need to be verified, it is necessary to confirm that a significant difference in postural score and pulse could have been generated by the experimental method of performing training when the dominant hand is advanced, followed by training when the dominant hand is changed to the lower hand.

As for the postural total point, the exercise load by the training is large, so if the training is carried out during the same day, the fatigue by the first training, etc. seems to have an effect on the second training. On the other hand, for the second training, since the trainee is also experiencing the training once, it is possible that the trainee learns and corrects the posture, and therefore there is a possibility that the total posture point on the front side tends to increase more easily than the first training. Blood pressure and pulse were also performed after the first training until the pulse was lowered to the same level as normal, but because the first training and the second training were performed on the same day, it was speculated that fatigue might be influenced during the second training.

To obtain more accurate data, it was necessary to test the results of the first experiment by changing the training sequence and taking measures such as taking each training on different days.

10. Results of the Second Experiment

The results revealed by the second experiment, which was conducted as the development of the first experiment, are described below. One of the objectives of the second experiment is the verification of the experimental results that "the dominant hand should be put up" on the proper hand placement obtained by the first experiment. Detailed figures are summarized in Table 3. In conclusion, the results of the second experiment were similar to those of the first experiment. Wilcoxon's signed rank test was performed on the total postural total points (frontal and lateral) and the amount of motion (increase in pulse) obtained in the experiment for a total of two training sessions in which the upper and lower dominant hands were changed, revealing a significant difference in the difference between means.

This result verified the result that "the dominant hand should be placed in CPR position" obtained in the first test. Table 3 shows the results of the second experiment. In the first experiment, we compared the postural total points of the pulse and the lateral system, which were found to be significantly different. The first CPR training was performed with the dominant hand down and the second CPR training with the dominant hand up. The test method is Wilcoxon signed rank test.

Table 3: Results of the Second Experiment

	1st	2nd	Difference	P-value	significant difference
Average of Pulse Difference	13.5/m	5.2/m	8.3	P＜0.01	○
Average of side score	62.8 pt	70.0 pt	7.2	P＜0.05	○
Average of front score	73.4 pt	81.5 pt	8.1	P＜0.1	△

The mean increase/decrease in pulse was 13.5 for the first training and 5.2 for the second training. The difference in each mean was 8.3 times, and the significance probability for this difference was found to be significant because the P value was 0.00061 and P<0.01.

The average of posture total point in the side system became 62.8 points in the first time average and 70.0 points in the second time average, and the difference became 7.2 points. The probability of significance for this difference was found to be significantly different from P<0.05, with a P value of 0.045.

In the first experiment, the average of postural total points in the frontal system which showed an extremely high significance tendency was 73.4 points in the first time, and 81.5 points in the second time, and the difference became 8.1 points. For this difference, the significance probability became P value of 0.1, so no significant difference could be identified, but it showed a significant trend.

In addition, the results of the Chapman test performed in the second experiment showed that 26 of 33 trainees (78.8%) fell into right-handedness, 7 (21.1%) fell into left-handedness, and 0 were double-handers.

The following hypothesis was obtained as an observation result of two experiments carried out in this study:

In the first, it became clear that it was important to place the dominant hand as a kata of CPR's hand "above", but it was considered that there might be a difference according to the mastery level. For inexperienced persons and trainees whose CPR had difficulty, the hand (particularly the wrist) was painful or the force transmission was unstable when the dominant hand was placed on the top, because the force (muscle force) of only the dominant hand was to be applied. Based on these observations, we believe that it is important to grasp the base of the palm of the

upper hand so that it is touched on the back of the lower hand as a grasping method for making the dominant hand up.

Second, there is a problem with the need to keep the fingers of the lower hand in close contact. It appeared that the lower hand's palmar base could be focused on the sternum, and compressed at a single point without dispersing the force, by allowing the fingers of the lower hand to be floated by the hand grasping from above, rather than by placing the entire hand on chest compressions. However, this finding is also influenced by sex differences and individuality of muscle mass and body weight, so further analysis will be advanced in the future.

Third, the normality of the frontal total point and the number of compressions was confirmed for the values derived by this system. However, because of the problem of the number of experimental samples in this study and the necessity of examining the effects of sex differences, nonparametric methods were used in the present experiment.

11. New Findings from the Second Experiment

As a result of the new analysis and examination in the second experiment, it was newly proven that the effect of up and down of the dominant hand on the number of compressions, the change of up and down of the dominant hand during chest compressions had an effect on the quality of compressions (appropriate depth and position). As shown in Table 4, the mean number of compressions counted on the system differed by 16.6 in the first and second training sessions, and the results of the tests showed that the differences were significant.

The results reveal the importance of superior handedness in terms of providing adequate compression.

Table 4: Difference in Mean Number of Compressions and Test Results

	1st	2nd	Difference	P-value	significant difference
Average number of compressions	84.2	100.8	16.6	P<0.01	○

12. Correlations Between Muscle Strength and Muscle Mass of Body Components and CPR

As an item newly analyzed in the second experiment, there is the effect of muscle force and muscle quantity which are the component of the body on CPR. The muscle force analyzed in this study is 3 items of back muscle force and left and right-hand grip strength, and the muscle quantity is 4 items of left and right arm, whole-body and trunk division.

As a result of the analysis of the second experiment, it was proven that there was a positive correlation between muscle force and muscle quantity and compression frequency only when the dominant hand was raised. The correlations were high in three items: back muscle strength (correlation coefficient: 0.497), left handgrip strength (0.559), and right handgrip strength (0.452), whose correlation coefficients ranged from 0.4 to 0.7. Four items, including total body muscle mass (0.339), trunk muscle mass (0.338), right arm muscle mass (0.315), and left arm muscle mass (0.269), corresponded to correlation coefficients between 0.2 and 0.4, which were considered to be somewhat correlated.

From this finding, it was clarified that the handedness was important in order to utilize muscle force and muscle quantity in CPR. In addition, as new observations, trainees whose muscle strength and muscle mass did not reach a certain standard were unable to compress to an appropriate depth during compression, and they were found to have a scene in which the clicker sound did not sound. In the future, we will conduct experiments focusing on the values of muscle strength and muscle mass, and aim to elucidate the minimum necessary muscle strength and muscle mass for performing CPR.

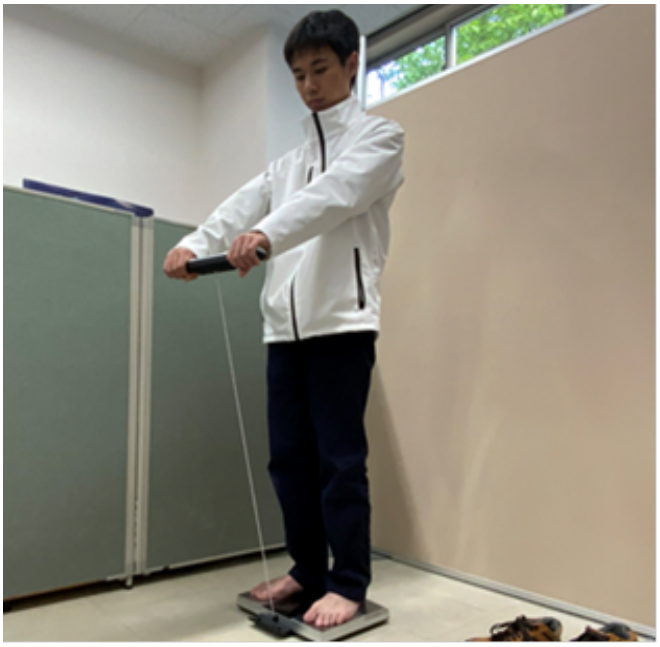

Figure 9: Measurement of Muscle Mass in the Trunk and Right and Left Arms

13. Challenges in the Second Experiment

In the second experiment, the results of the experiment proved that the dominant hand had to be placed on the top, which was found in the first experiment. On the other hand, for katas in other parts of the hands other than kata, in the second experiment, it remained in the observation record of the posture and the stage of data measurement.

In the future, based on the results of the second experiment, after extracting the items to be newly elucidated, the experiment will be conducted according to the extracted items. The items to be tested in future experiments are the positional relation of the knee on the ground in CPR posture and the effect of the position of the head on CPR posture.

14. Threshold-Derived Joint Angles of CPR Training Systems

In CPR training system which analyzes CPR posture, the objective evaluation is carried out on the basis of the value of the joint angle during the training, when the posture total point is derived. For the purpose of elucidating the more precise numerical value of this joint angle, the third experiment was carried out for 68 persons (18-21-year-old) in July, 2023.

15. Third Experiment: Analysis of Joint Angles

In the third experiment, which aimed to analyze the joint angles of CPR, the number of samples acquired is approximately 3500 compressions. For each compression detection, the joint angles of the upper and lower extremities were recorded in the system, and a total of seven joint angles were statistically analyzed to derive a threshold of appropriate joint angles during compression. Angle thresholds take into account the points implemented in the system and use interquartile ranges.

We judged it reasonable to use an interquartile range, which is the median 50% of the data, as the reasons for using the interquartile range are all normality of the joint angle data, and the use of a range of minimum to maximum values as a threshold is dangerous to include outliers.

There was a total of 4 observation points of elbow (left/right) and shoulder (left/right) for the joint angle of the upper extremity, and the results of each analysis (mean, median, maximum, and minimum) and the interquartile range (angle threshold) were shown in Table 5 below.

Table 5: Analytical Results of Upper Limb Angle

	mean	median	max	min	Angle threshold
Left Elbow	152.1°	152.5°	180.0°	100.8°	145.3° ～ 159.8°
Right Elbow	153.4°	152.8°	180.0°	100.1°	146.1° ～ 161.4°
Left Shoulder	109.9°	110.3°	170.6°	88.6°	105.6° ～ 113.7°
Right Shoulder	106.9°	106.2°	144.1°	88.4°	102.5° ～ 110.4°

Regarding the joint angle of the lower extremities, the results of each analysis were as shown in Table 6, according to three observation points in total: chest, navel, and buttock. From the result of this experiment, the range of joint angle which can be called appropriate chest compression posture was proven. In addition, all the data obtained in the experiment had normality.

Table 6: Analytical Results of Leg Angle

	mean	median	max	min	Angle threshold
Chest	171.1°	171.5°	179.9°	150.3°	168.7° ～ 174.0°
Navel	170.6°	170.9°	180.0°	141.6°	167.8° ～ 173.7°
Buttocks	104.6°	102.0°	137.8°	63.7°	99.0° ～ 107.7°

16. Results of the Third Experiment

Experiments performed in this study revealed angles of individual joints in CPR postures. Though chest compressions were traditionally the weather of compressing the heart, the analysis of trainee compression in this experiment revealed the distribution of joint angles when performing appropriate compressions, and there was a discovery that the interquartile range of the angles was converged within 15 degrees for all joints.

Since previous studies have revealed correlations between muscle mass and muscle, this study has demonstrated that posture and muscle mass and strength are components that affect CPR. In the future, it is considered that this test will be a great step in the review of conventional posture score (assessment) derivation algorithms in the elucidation of the appropriate posture of CPR.

17. Appropriate Joint Angle and Systematic Implementation of CPR Postures

Implementation of the system using joint angle thresholds derived by this study was completed in August 2023.

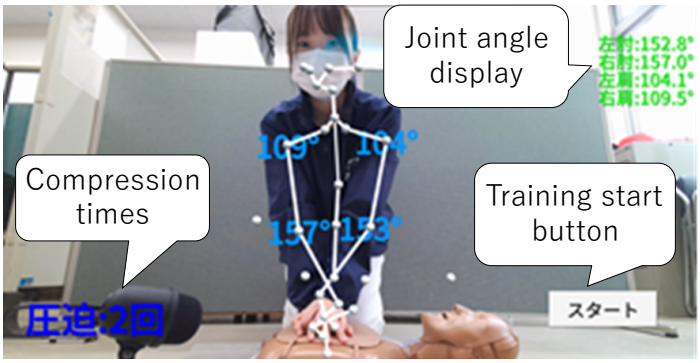

Figure 10: Attitude Analysis System with New Angle Threshold Implemented (Front)

In addition, CPR training system will be a new stage, and CPR training system will be further upgraded by conducting experiments with healthcare professionals such as paramedics and nurses who are professional professionals in critical care settings.

Figure 11: Training at the Aikoku Branch of the Kushiro City Central Fire Department (Imaging Cooperation: Kushiro City Fire Department)

As of September 2023, we have been conducting experiments and posture analysis with the cooperation of professionals such as paramedics, nurses, assistant nurses, and mobility rescuers, with a total of approximately 30 members from the JSDF, the Maritime Guard Agency (Japan Coast Guard), and the Kushiro City Fire Department.

Figure 12: Training at the JMSDF Supply Ship Masyu
(Photography Cooperation: Maritime Self-Defense Force and Ground Self-Defense Force of the Ministry of Defense)

By analyzing the attitudes of professionals, we believe that it will be possible to advance CPR training system that has been developed for lay people to a professional system that can also be used by people in life-saving settings.

Figure 13: Training at Kushiro Air Base of the Japan Coast Guard
(Collaboration on photography: Japan Coast Guard)

To continue the analytical study of CPR postures based on joint angles, and to seek the introduction of artificial intelligence (AI) as the development of this system in the future. In the assumption at present, it aims at the establishment of the new posture evaluation method using the neural network.

18. Development of an AI System for CPR Posture Evaluation

This research, which clarified the effects of partial posture changes on compression and analyzed posture as a clear numerical value of joint angle, realized the development of a new system to derive CPR posture evaluation by AI technology (neural network) as a new stage. The AI system for CPR posture evaluation was developed for the purpose of analysis considering the connectivity of the human body and the individuality of the trainee, which has been a problem in the posture evaluation of conventional CPR training systems. The data learned in implementing these posture evaluations are the training data of 101 trainees and approximately 4,700 training sessions accumulated in the experiments conducted in this study. The training data refers to the joint angle values during compression detected by voice recognition during training using the CPR training system. It was found that the training data for each joint had normal differences. The trainees consisted of 68 general public and 33 lifesaving professionals (medical and emergency scene workers).

As shown in Figure 14, the numerical values of each joint angle obtained during training using the CPR training system when the appropriate pressure is detected by voice are processed for posture evaluation by the AI. The CPR training system and the CPR posture evaluation AI system are connected by a socket to enable prompt provision of feedback after training.

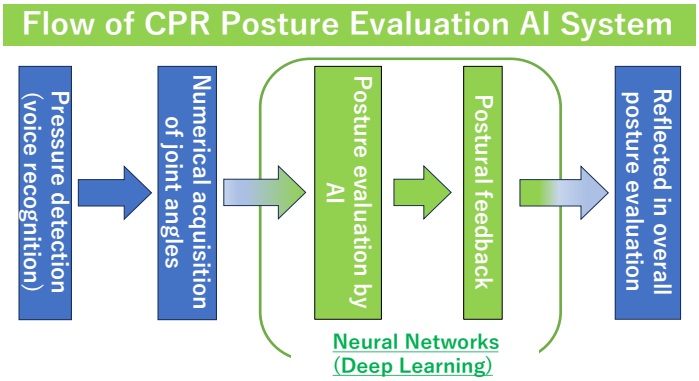

Figure 14: Flow of CPR Posture Evaluation AI System

19. Feedback on Posture

In the CPR training system, the evaluation was derived based on the numerical values of joint angles and referred to the preset threshold values. On the other hand, in the new system, which is a multi-layer learning system with neural networks, it provides feedback (postural feedback) on the characteristics of the trainee's CPR posture and weaknesses and vulnerabilities during CPR.

20. Conclusion

In this study, attention was paid to the hand performing chest compressions as an early study to elucidate the proper posture (shape; kata) of CPR, and the effect of the change of the upper and lower handedness on the whole CPR posture was elucidated from the values such as postural total point of the training system, exercise load (increase of pulse), and the number of compressions. In conclusion, the results of the experiment revealed that placing the dominant hand on top resulted in excellent results for both postural composite point and exercise load. It is also considered that there were great achievements in terms of clarifying the correlations between CPR and muscle strength and muscle mass, and extracting the components that seem to affect CPR. And, the precise numerical value of the joint angle of CPR position was analyzed by the third test, and it seems to become a big step for the elucidation of the kata of the appropriate CPR as well as stepping up the future CPR training system research to the next stage.

By demonstrating previously unexplained joint angles in CPR postures on a scientific basis, we are convinced that training can be established that allows the implementation of continuous CPR over a prolonged period of time without the use of wasteful forces by compressing them in an appropriate posture, even in the presence of body disparities. In the next stage of the study, the posture in CPR is extracted using the parts constituting the posture as elements, and how each part brings about the change in CPR posture and compression frequency, and what kind of catastrophe exists for each part in order to reduce the motion quantity are elucidated. Further experiments will elucidate not only the effects of one site, but also the effects of a particular site on adjacent sites, and the effects of a particular site on overall posture.

This study is a steady study to elucidate the unknown attitude of life saving methods related to the forefront of human life saving called CPR.

We hope that this study will be a step-in saving people who have suffered a cardiac arrest, and we will definitely clarify the appropriate attitudes of CPR. Cardiac arrest is a constant risk-of-being, while CPR may be able to control it.

This study will be developed in the future so that more human life can be saved by the elucidation of the appropriate CPR attitude.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgement

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Figure 15: Pulse and Blood Pressure Measurement by Medical Personnel Supervision

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Spatial Distribution Patterns of the Royal Development Projects Initiated by King Rama 9th of Thailand

Puntip Jongkroy, Ponthip Limlahapun*

Geography Department, Kasetsart University, Bangkok, 10900, Thailand

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ABSTRACT

The study aimed to create a chronological overview of the royal development projects initiated by King Rama IX and to analyze their spatial distribution patterns. The research used a mixed-methods approach, combining quantitative and qualitative data collection methods such as obtaining data from relevant offices, internet research, and field observations. Data analysis involved descriptive statistics and content analysis across three dimensions as temporal, spatial, and disciplinary. The findings were visualized using digital mapping, tables, and diagrams. The analysis revealed that over King Rama IX's seven-decade reign, there was a strong focus on improving the lives of marginalized populations in areas with limited development opportunities and services. The research specifically aimed to 1) present the timeline of changes in the number of royal development projects and 2) analyze the spatial distribution patterns of these projects. The minor objectives included analyzing the patterns of the projects and their spatial distribution. The spatial distribution of the royal development projects was found to be extensive, covering various regions of the country from north to south. However, while there was comprehensive information on the projects, there was no centralized spatial database. Online data accessibility provided a flexible way for users to access project information based on their interests. Additionally, a virtual learning platform was developed to engage younger generations and present the research findings in a more engaging and accessible manner.

1. Introduction

The current polarization of ideas in society, exacerbated by political differences, has widened the generation gap in thinking. This divide has expanded beyond political matters to include challenges to the monarchy, often seen on platforms like Twitter, Facebook, and Instagram. While there is a growing demand for democratic change, actions against the monarchy, especially considering King Rama IX's contributions, based on distorted data from unreliable sources, unfairly undermine one of the country's key institutions. This research focuses on analyzing data related to King Rama IX's royal duties over his seven-decade reign, particularly emphasizing the Royal Development Projects initiated. Quantitative methods were used to analyze the spatial distribution patterns of these projects, with the findings presented through maps, tables, graphs, and diagrams. This study, along with a related project titled "Development Web Spatial Database System of the Royal Projects under the Inspiration of King Rama 9th" [1], which employs web-based GIS for easy retrieval and comprehension, aims to accurately showcase the late King's contributions. The data were categorized into two main types: those with identifiable locations (e.g., reservoir development projects, road construction, schools, hospitals) and those without (e.g., scholarships, public health initiatives, facilities, utilities, conservation and reforestation efforts). To process the data, three approaches were employed which are geocoding to reference coordinate locations using Python in Jupyter and Anaconda, creating project locations as points using QGIS (an open-source GIS software) and storing geospatial data using GeoServer and Openlayers. Additionally, a website was developed using HTML and PHP to integrate the web-based system, enabling users to visualize project information on a map [2] and access detailed project data without needing to install software.

2. Research Materials and Methods

2.1. Scope of Study

Quantitative and qualitative data collection and analysis methods.

*Corresponding Author: Ponthip Limlahapun, thip.limlahapun@gmail.com

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- Spatial dimension: Thailand and analyzed at the provincial and the regional levels. The six geographic regions and their respective provinces under study are 21 provinces and 1 metropolis in the Central Region, 9 provinces in the Northern Region, 7 provinces in the Eastern Region, 20 provinces in the Northeastern Region, 14 provinces in the Southern Region, and 5 provinces in the Western Region.
- Temporal dimension : The changes in the number of the royal development projects throughout the 70 years of the late King's reign from 1946 when he ascended to the throne to 2016, the year of his passing. The changes were divided into 7 periods of 10 years each: from 1946-1956 through to 2007-2016, and illustrated with diagrams.
- Disciplinary dimension : The disciplinary focus was divided into two major issues in harmony with the research objectives as timeline of the project development based on changes in the number of the royal projects in each decade of the reign classified provincially by the project type. The spatial distribution of the projects in each province and each region was analyzed by comparing the number of the projects to 100,000 population on the provincial and the regional. For the demographic and urbanization perspective, the researchers analyzed the level of urbanization, population density, and the average population growth rate. Finally, the constraint to development from the physical perspective was scrutinized through topography and infrastructures.

These concepts were grouped into eight categories by the Office of the Royal Development Project Board (ORDPB) to be summarized into "the project pattern" in three major groups, as follows. Development projects on resources and the environment (water supply source projects and other environmental and resource projects). Sectoral development projects (agricultural projects; socio-economic project consisting of occupational support, public health, social and educational projects; and infrastructure projects, namely, those involving transportation and communication). Other development projects (projects with integrated concepts or agricultural projects based on the late King's New Theory) [3].

Software and techniques utilized primarily on spatial web-based application. During the web development phase, the focus was on effectively managing data, handling backend operations, and ensuring a user-friendly interface. The system preparation was divided into four main components, namely geocoding, geospatial server setup, database management, and web development.

Geocoding, a notable aspect of this process included restructuring more than 4,500 project records in MS Excel to facilitate streamlined location searches [4]. This required the conversion of address text into geographic coordinates (latitude and longitude) [5], facilitating accurate mapping of locations. While users typically engaged through a Google web browser without the requirement for additional software installation or programming proficiency, the scale of data prompted the adoption of a scripted approach to simultaneously locate multiple locations. The Anaconda and Jupyter environment were set up to execute Python programming for acquiring geocoordinates [6].

GeoServer, a freely available geospatial server environment, is utilized for storing spatial data in diverse formats such as geopackage, shapefile, image, PostGIS, among others. It operates seamlessly on the Windows operating system or functions as a web server service.

General databases such as MySQL and MS Access lack spatial capabilities. Instead, project information was stored using PostGIS, PostgreSQL, and PgAdmin software [7-9]. The developed system incorporates interactive time-series data on an annual basis. Hence, project information was loaded into PostgreSQL and organized based on the dates when the projects were initiated.

Geoserver and web elements were incorporated to provide users with project information presented in spatial and non-spatial formats [10]. Additionally, interactive time-series maps and virtual learning platforms were integrated to enrich user engagement and enhance comprehension of the data.

2.2. Literature Reviews

Analysis on the spatial distribution pattern is part of the spatial process analyses that focuses on the dynamic locational decision-making for land use activities. In [11], the authors highlighted human geographer's interests in people and places that are key to understanding of natural and human-made geographic phenomenon. In this regard, distribution, diffusion, and interaction are the main subsections of the concepts of interaction, communication, and movement on the earth surface. Similarly, in [12], the authors described spatial distribution as the starting point for analyzing the structured content of place that distinguishes geography from other sciences. Common elements to analyze spatial distributions are density, dispersion, and pattern. In [13], the author aims to describe the regular distribution of objects in space. By observing spatial arrangement of research objects across the earth the three properties of distribution: density, concentration, and pattern can be analyzed. For the purpose of the analysis of spatial distribution pattern, the spatial geometric arrangement of interested objects involved two features: 1) the data for the number of projects in each administrative division are depicted by polygons; and 2) quantitative data across an area or surface are illustrated with various shades of color. The research conceptual framework is presented in Figure 1.

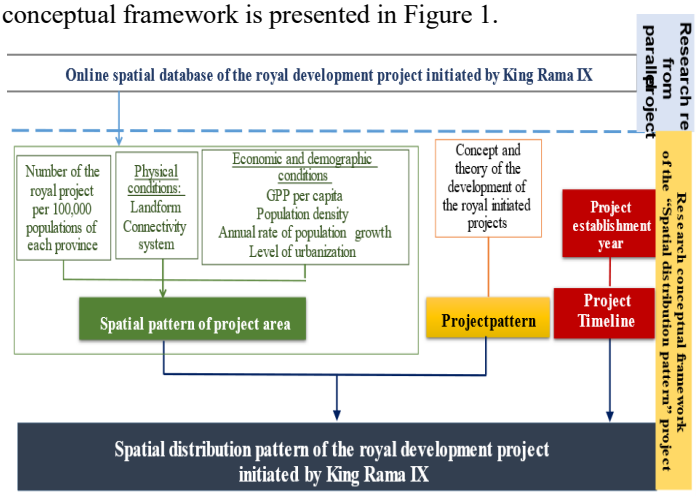


Figure 1: The Research Conceptual Framework (Source: by Authors)

The challenge with spatial data lies in accurately locating all the projects. Traditional techniques for converting address text to geographic coordinates using ArcGIS software are not suitable for Thai addresses. Instead, the Geocoding Application Interface (Geocoding API) from Google is utilized to convert text addresses into geographic coordinates, represented as latitude and longitude [14]. To streamline this process, a custom-written program is employed to handle multiple records simultaneously, eliminating the need for manual searches through Google. This automated approach improves efficiency and accuracy in geocoding a large volume of project records.

In summary, this research project was designed to transform the number of projects and the spatial data on provinces and regions into the ordinal scale. Indices and criteria used in the spatial ordering were set for five issues. They were the spatial ordering of project distribution per 100,000 population in each province of each region; the ordering by economic index (per capital income); the ordering of population and urbanization (annual average of population growth rate, level of urbanization, and population density). Five levels of ordering and interpretation were set including the summary of the overall development level in each province, as shown in Table 1.

Table 1: Development Level

Number of projects per capital	Economic index	Population and urbanization indices			Level
	GPP per capita (USD/ year) [1]	Average annual growth rate (%)[2]	% of urban population[3]	Population density (per sq.km.) [4]	Interpretation
Very few (0.08-5.69)	Low (<1,045)	Contracted (<0.00)	Low-very low (<30%)	Low-very low (<100)	Low
Few (5.70-11.30)	Middle-low (1,046-4,125)	Low (0.00-0.34)	Moderate (30.1-40%)	Low (101-250)	Slightly low
Moderate (11.31-16.91)	Middle (4,126-8,431)	Moderate (0.35-1.00)	Slightly high (40.1-60%)	Moderate (201-500)	Moderate
Slightly large (16.92-22.52)	Middle-high (8,432-12,735)	Slightly high (1.01-2.00)	High (60.1-80%)	Slightly high (501-1,000)	Slightly high
Large (22.53-28.13)	High (>12,735)	High (>2.00)	Very high (>80%)	High-very high (>1,000)	High

Remarks: [1]Applied from the criteria of national development level according to the World Bank's average income per capita [15]..; [2]Classified by the maximum and minimum values from research results; [3]Applied from the United Nations' guideline on urbanization classification [16].;[4]Applied from CIESIN's criteria (Center for International Earth Science Information Network [17].

The developed website integrates virtual learning platforms [18] aimed at involving younger generations in comprehending the vision and concepts driving project development. This includes knowledge about the philosophy and theories of His Majesty King Bhumibol Adulyadej's reign, focusing on projects like the Sufficiency Economy, the Chai Pattana Aerator, a floating buoy that rotates slowly to pump oxygen into wastewater, and Soil Development. These initiatives aim to address issues such as soil acidity, saline soil, vetiver grass, and the prevention of soil erosion and degradation.

3. Results

3.1. Timeline of Changes in the Number of the Royal Development Projects

Quantitative data analysis together with the temporal dimension indicated that 42% of the royal development projects were carried out in the fourth decade of the late King's reign (1977-1986). Only a small number of these projects (0.3%-20%) took place in other decades. It can be argued that the royal development projects were concentrated mostly Table 1. Criteria to summarize "level of area" for spatial pattern analysis of projects with multi-faceted factor displayed with the radar graph. in the fourth decade, especially the water supply source development projects—when as many as 93% of them were implemented. In the fourth decade of the late King's reign, Thailand was in the 4th and 5th National Socio-economic Development Plans. It was also the period of economic transition for Thailand, from an agricultural country to one of the newly industrialized countries. Discovery of natural gas in the Gulf of Thailand had spurred economic growth especially in manufacturing and urban infrastructure system. At the same time, remote rural areas had no accessibility to such development (Figure 2). Moreover, the 4th decade of the late King's reign saw the world in turmoil from the oil crisis that negatively impacted people's lives. Development of the royal development projects, then, put the emphasis primarily on water supply source for the agricultural sector followed by the promotions of occupation, society, and education, as well as other projects such as the New Theory for agriculture or those with integrated activities within the same project. These projects were found mainly outside the metropolitan area.

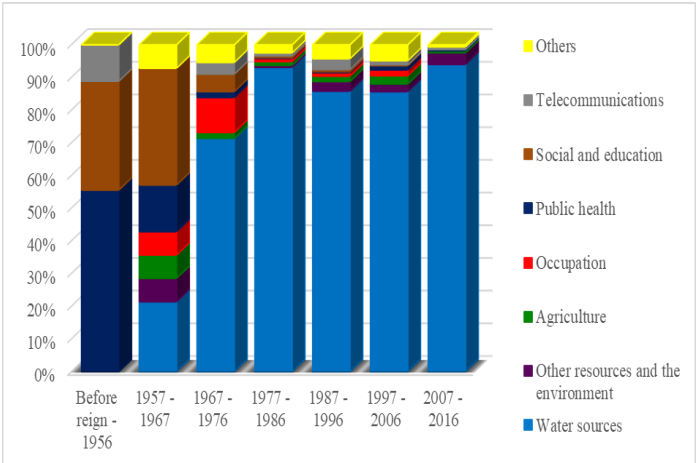


Figure 2: Comparing the Proportion of the Royal Development Projects by Decades of His Reign (Source: by Authors)

Towards the end of the 4th decade, the "Royal Development Center" had been inaugurated in every region. Each center is the hub of efficient coordination and dis-semination of all the royal development projects throughout the regions, supported by numerous experimental projects King Rama IX had established on the grounds of the Chitralada Rahotan Royal Residence. The inauguration of these regional centers and the acceleration of the experimental pilot projects truly laid the strong foundation and the

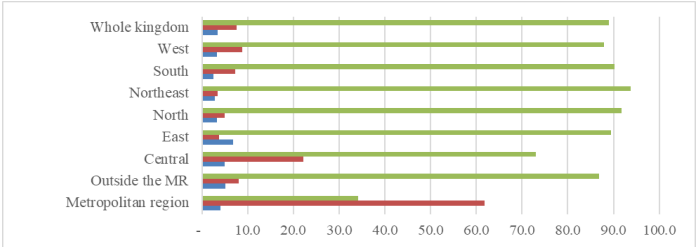
manifestation of sustainable progress of the royal development projects. Features of the above-mentioned development projects were different from the previous three decades that mainly involved projects focusing on people's quality of life, first in the capital and eventually diffused to other regions, specifically to the West and the North. However, the issues regarding the King's health particularly in the last three decades of His reign (5th-7th decades) saw a sharp drop in the number of new projects. These mainly involved transportation and communication, resources and the environment, and public health. Such projects were the direct act in response to the dilapidated natural resources and the environment from industrial development and urbanization. It should be pointed out that development projects concerning transportation and communication had markedly increased in the 5th decade of His reign (1987-1996) with the continuation of infrastructure system development to support urbanization in Thailand from the previous decades. In the latter part of His reign, the area of the royal development projects had been scattering in almost every province of the country, with the metropolitan area taking the backseat. Projects concerning flood mitigation in the metropolis were initiated in the 6th decade but none in the 7th decade. Overall, it is clear that in all the decades of King Rama IX's reign, the royal development projects all aimed at fighting poverty in both urban and rural areas, with great emphasis on the most underprivileged groups in remote rural areas.

3.2. Spatial distribution pattern of the royal development project

- Pattern of the royal development project.

From the three groups of the royal development projects, namely, projects on re-sources and the environment, regional-based development projects, and other projects, it was found that 88.9% of them involved resources and the environment. Among these were mainly for water supply source--the major pattern of the royal development project that could be found in every region, especially in the North. Overall, the distribution of the royal development projects, as illustrated in Figure 3, could be summarized in two patterns.

The first pattern was based on the development concept for resources and the environment. Almost all of the projects in this pattern involved water supply source development and were established in almost every region in Thailand, except in the metropolitan area known as Bangkok Metropolitan Region (BMR) (comprising of Bangkok Metropolis or Krung Thep Maha Nakhon and its 5 vicinity provinces: Nonthaburi, Pathum Thani, Samut Prakarn, Samut Sakhon, and Nakhon Pathom provinces). Nevertheless, differences in the pattern of regional development concept were discovered. In this regard, the North, the Northeast, and the South had well over 90% of all the projects whereas the East, the West, and the Central, with the exception of BMR had 80.1-90%. Overall, only 40-80% of all the projects in the Central Region (including BMR) involved resources and the environment. The second pattern was based on various sectoral project development concepts and was found to cover as much as 60% of all the projects. In this pattern, the development project for resources and the environment was not the major concept as found in other regions of the country. This second pattern was found specifically in the metropolitan area, consisting of Bangkok Metropolis and the surrounding five provinces.



	Metropolitan region	Outside the MR	Central	East	North	Northeast	South	West	Whole kingdom
Resources and the environment	34.2	86.8	73.0	89.4	91.7	93.8	90.2	87.9	88.9
Sectoral development projects	61.8	8.0	22.1	3.7	5.0	3.4	7.3	8.8	7.6
Other concepts	4.0	5.2	4.9	6.9	3.3	2.8	2.5	3.3	3.5

Figure 3: Percentages of the Royal Development Project, Categorized by the Major Development Concept in Each Region in Thailand (Source: by Authors)

- Spatial pattern of the royal development project

Results from spatial distribution analysis of the 2,738 royal development projects in Thailand on the regional basis albeit the total number of projects, the project density per area, or the number of projects per capita—clearly showed the dominance of the North as a major development target with 838 projects or 31% of all the projects in the country. The project density in the North was 9 per 1,000 square kilometers (higher than the national average of 5:1,000 sq.km.) with the highest project numbers per capita of 13.25 per 100,000 population whereas other regions had less than 6 projects per capita. When the data on the number of projects per 100,000 population in each province were depicted in the spatial distribution map of the royal development project, it was found that the province with the highest number of projects per capita was Mae Hong Son in the North (28.11 projects), followed by Narathiwat in the South (25.98 projects). These two provinces had the highest project density, as shown in Figure 4.

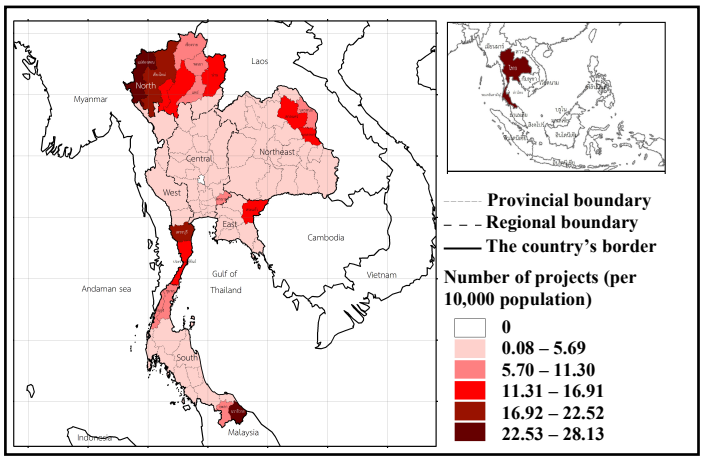


Figure 4: The Spatial Distribution of the Royal Development Project in Thailand, by Province (Source: by Authors)

Results of the spatial pattern analysis in terms of the economic, demographic, and urbanization perspectives together with the number of projects per 100,000 population as illustrated in the radar chart (Figures 5 and 6) could be interpreted into the findings on the regional and provincial spatial pattern (showing the selected provinces with the highest number of project per capita in each region only), as follows. The regional perspective, it was found that the North, a target area for the royal development project, is mostly mountainous interspersed with hills, valleys, and

intermontane basins. Steep areas are headwaters of numerous rivers and creeks. On the socio-economic condition, its population had "middle to low income" which was the lowest income level found in Thailand; its economic base was mixed, its population density was "low", its average annual population growth rate was "low", and its urbanization was "moderate". In fact, the North is the only region experiencing population contraction with six out of nine provinces having lost their population in recent years which was similar or lower than almost every region in Thailand. The provincial perspective, the two provinces with the highest number of projects per capita in the country, classified as the "high" level were Mae Hong Son (28.11 projects) and Narathiwat (25.98 projects). The socio-economic conditions in almost all dimensions of these two provinces were in the "low-lowest" levels in comparison to other provinces in their respective region. Direct fieldwork survey in Mae Hong Son, with the highest number of projects in the country, indicated that most of the royal development projects were in remote areas and far from the provincial center. Its population had limited infrastructure system in both public utility and public facility.

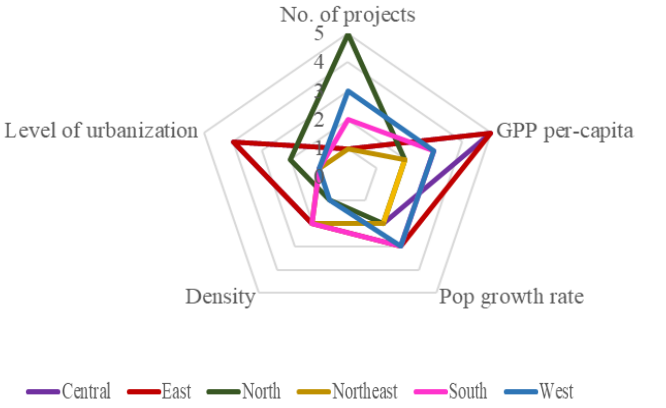


Figure 5: Economic, Demographic, and Urbanization Conditions Scrutinized Together with the Number of Projects Per Capita at the Regional Level.

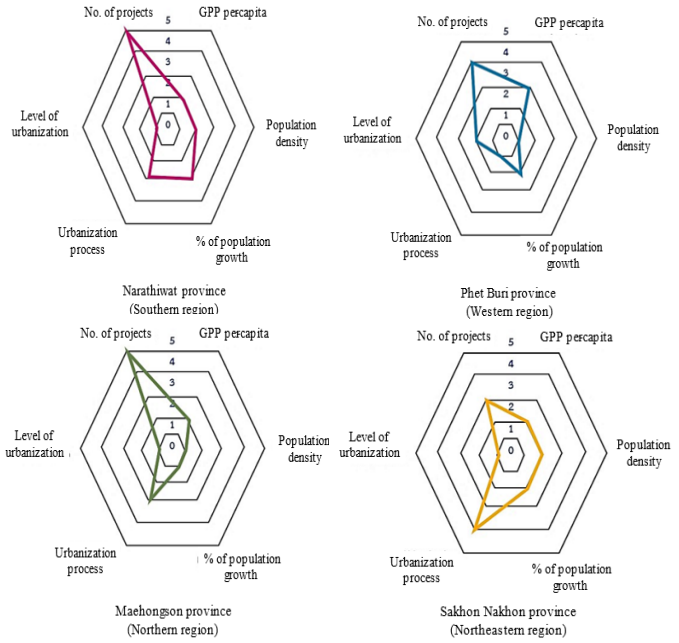


Figure 6: Economic, Demographic, and Urbanization Conditions Scrutinized Together with the Number of Projects Per Capita at the Provincial Level.

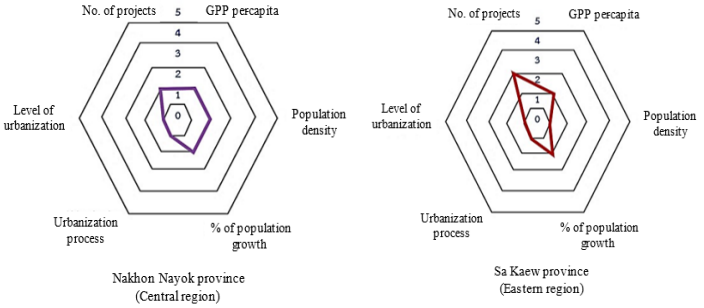


Figure 6 (Cont.): Economic, Demographic, and Urbanization Conditions Scrutinized Together with the Number of Projects Per Capita at the Provincial Level.

3.3. Web development

The web component is intended to enable the sharing of data and information. Data is organized by project types and provinces. The web development is dynamic and comprehensive, incorporating complex web applications that present detailed project information in an interactive and user-friendly manner. An example of this is the virtual learning platform depicted in Figure 7. The website can be accessed at [19].

Figure 7: Virtual Learning Platform (a Sample of Methods to Address Soil Acidity

4. Discussions

The spatial distribution of the royal development projects in the seven decades of His reign could be summarized into two major parts: timeline, and spatial patterns of the distribution of royal development projects in all regions of Thailand during the past seven decades of His reign.

4.1. Timeline of the Royal Development Projects

The distribution of the 2,738 projects were mostly initiated in the fourth decade of His reign (1977-1986) when Thailand was in the process of laying down the infrastructure that was the foundation of national development to become a newly industrialized country. The fourth decade saw a complete inauguration of all types of development project, but the focus was on water supply source development. This focus - in reality, was the core pattern that could be found in every decade of His reign. Moreover, it was also found that most of the projects were distributed in remote regions, far from the capital city. The overall findings in terms of timeline of the royal development projects throughout seven decades of His reign indicated that His Majesty

aimed his efforts at alleviating poverty and hardship in remote areas where the poorest poor reside and at the water source development that benefits particularly those in agricultural sector. This was likely the same as a couple of Ayoo's suggestions on poverty reduction strategies in developing countries. To alleviate poverty, the author [20] recommended stimulating inclusive economic growth, economic and institutional reforms, promoting microfinance institutions and programs, improving the marketing systems, and cash and income transfer programs.

4.2. Spatial Distribution Pattern of the Royal Development Project

Analysis based on the regional perspective indicated that pattern of most of the royal development projects focused on the development of 'resources and the environment' particularly water supply source development which accounted for more than 80% of all the projects. The largest concentration of these projects was found in the North-the only region where the number of projects per capita was classified as "high". The findings noted his focus on water source development which aligns with the concepts explored in the study on water allocation management during scarcity [21]. Setting aside the search for feasible study of applying a bankruptcy approach to water allocation management under scarcity, the authors also pointed out the prominent of the scarcity of water resource that decision makers should focus. This is because it dealt closely with the most vulnerable households, especially those in remote areas.

Regarding the spatial pattern of the North as a development target, it was found that this region had the lowest average income per capita, low population density, and low population growth rate in comparison to other regions. At the same time, its level of urbanization was "moderate" (lower than the Central and the East that were at "high level", but higher than the Northeast, the South, and the West which were at the "low level"). Thus, it could be argued that King Rama IX placed the first priority on the neediest area – where the majority of the most vulnerable group resided.

However, projects concerning rural livelihood and agricultural society such as those for water supply source, agriculture, the environment, occupational development, and other aspects had a random spatial pattern. That is to say that although the projects were distributed in every region but in each region the royal development projects would be concentrating only in selected provinces where poverty and hardship in life were their common problem issues.

From the provincial perspective, the royal development projects could be found primarily in provinces with very low level of urbanization but contained the highest number of projects per capita in each region. As seen in the provinces with the highest number of projects per capital of each region, all had the lowest level of development in almost all aspects (income level, average annual population growth rate, population density, or level of urbanization).

In the end, it can be concluded that targeting the royal development projects on water supply sources and putting focus on remote areas highlighted the uniqueness of what was known as the King's Philosophy. In reference [22], the authors observed that the unique philosophy was a practice that took into account the geographical, economical, and social contexts of each area inclusively. Problem solving strategies were designed not only in a holistic way but also with the focus on building the sense of belonging of local people in order to achieve three ultimate goals: survival, self-reliance, and sustainability.

5. Conclusions

The research findings on the timeline of the royal development projects and the above-mentioned spatial distribution patterns clearly indicated that almost half of the royal projects initiated in the fourth decade of His reign (1977-1986) when Thailand was in the process of the infrastructure installation that was the foundation of national development to become a newly industrialized country. Regardless of the year, King Rama IX placed the highest emphasis on alleviating poverty and raising marginal people's livelihood through the development of water supply sources.

In relation to the spatial distribution patterns, it was found that most of the royal development projects focused on the development of 'resources and the environment' particularly water supply source development which accounted for more than 80% of all the projects. The largest concentration of these projects was found in Northern Thailand where not only the number of projects per capita was classified as "high" but also where the most vulnerable inhabitants lived. Apart from the problems of poverty, destituteness, and disparity in the chance for development; it should be pointed out that hardship in everyday life and inadequate infrastructure system all acted as the pull factor for the initiation of the royal development project as well.

6. Recommendations

The above-mentioned findings clearly echo the royal grace of King Rama IX whose primary intention was to raise life quality of the impoverished. His effort as well as those of the Royal Family resulted in almost 5,000 royal development projects 2,738 of which were initiated within the seven decades of His reign, averaging 40 projects annually that are unparalleled amongst monarchies the world over. His royal grace be-stowed upon the nation should be appreciated and commemorated. Relevant agencies should expedite dissemination of correct information both academically and in-depth in response to false accusation and fake news appearing in Thai society lately that had reached parts of society especially among the youths.

Furthermore, the findings clearly pointed out that most of the royal development projects were found in provinces with low to slightly low level of economic, demographic, and urbanization conditions. Such projects have benefitted communities in remote areas with poor accessibility. Field surveys conducted in various provinces still found the royal development projects in remote areas that had there been without them they would have been in a much worse condition than at present. The social gap and economic disparity between urban areas and remote rural areas would have been far greater than what it is today. Nonetheless, many royal development project areas visited on field surveys in 2022 were found to be dilapidated and poorly maintained. Therefore, relevant agencies should expedite the rejuvenation of these project areas so that they will continue to effectively raise the quality of life of the underprivileged and impoverished.

Conflict of Interest

The authors declare no conflict of interest.

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Revolutionizing Robo-Advisors: Unveiling Global Financial Markets, AI-Driven Innovations, and Technological Landscapes for Enhanced Investment Decisions

Marco I. Bonelli*, [1], Jiahao Liu[2]

[1]*Dr. Vishwanath Karad MIT World Peace University, Pune, 411038, India*

[2] *Judge Business School, University of Cambridge, Cambridge, CB2 1AG, United Kingdom*

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ABSTRACT

Robo-advisors, fundamental to the financial services sector, have undergone substantial technological metamorphosis. Innovations in artificial intelligence, blockchain, cloud technology, augmented reality, and virtual reality have reshaped the financial industry's landscape. As automated investment solutions, robo-advisors are on the brink of further technological evolution. This comprehensive research amalgamates historical data, behavioral insights, and emerging market trends to provide technology-centric recommendations for the robo-advisory industry. Emphasizing the significance of a global perspective, the study explores the adoption of full-scale optimization in portfolio construction and the integration of digital twin capabilities. It delves into the burgeoning realm of Natural Language Processing facilitated by AI-driven chatbots in financial technology companies. These recommendations stand as pivotal pillars for steering the ongoing technological advancements of robo-advisors in the ever-evolving landscape of the financial sector.

1. Introduction

This paper extends work originally presented in 2023 at the 9th International Conference on Virtual Reality (ICVR 2023), held on May 14th, 2023, in Xianyang, China. Investors today leverage robo-advisors as powerful tools for efficient portfolio management. This is particularly beneficial for small investors navigating the complexities of crafting tailored investment strategies. Operating on sophisticated algorithms, robo-advisors autonomously oversee investment portfolios, increasing the likelihood of attaining financial goals.

Beyond portfolio management, these digital platforms extend their support to investors by providing a spectrum of financial planning services, ranging from budgeting and debt management to comprehensive retirement planning. This holistic approach empowers businesses to cultivate sustainable financial models, fortifying their overall financial health.

The emergence of robo-advisors signifies a transformative shift in investment advisory, offering a cost-effective alternative to traditional human advisors. Originating as fintech startups post the global financial crisis, robo-advisors have surged in popularity, with established financial institutions like Charles Schwab and BlackRock integrating robo-advisory services into their portfolios. Major players, including Bank of America and Wells Fargo, have also introduced their automated advisory services.

The United States dominates the robo-advisory market, hosting over 200 robo-advisors and commanding 57% of global robo-advisory investments as of 2017. With assets exceeding $400 billion in 2018 and an impressive annual growth rate of approximately 30%, projections indicate that by 2023, assets overseen by robo-advisors in the US will approach $1.5 trillion. Vanguard, Schwab Intelligent Portfolios, and Betterment stand out as major players by assets under management [1]. While the US leads, robo-advisory services are gaining traction globally. Europe hosts over 70 robo-advisors, with five managing assets exceeding €100 million. In Asia, particularly in developing markets, the proliferation of robo-advisors is propelled by a growing middle class and robust technological connectivity.

This study navigates through the industry's history, emerging trends, strengths, and weaknesses, pinpointing potential areas for growth. It posits three key predictions: a shift from Modern Portfolio Theory towards Full-Scale Optimization, the integration of Digital Twin capabilities to harness user data, and the

*Corresponding Author: Marco I. Bonelli, Mibonelli6@gmail.com

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development of Natural Language Processing to elevate the user experience. These insights encapsulate the evolving landscape of robo-advisory services, positioning them for sustained global growth and innovation.

2. Literature Review

In recent years, the landscape of the financial services sector has been marked by a profound and dynamic transformation propelled by the integration of cutting-edge technologies, notably artificial intelligence (AI) [2-5]. This technological wave has seen the rise of robo-advisors as a pivotal force, fundamentally reshaping investment management and financial planning services, as highlighted by a study by Deloitte [6].

Nevertheless, while the preceding introduction offers a glimpse into this transformative landscape, it only scratches the surface of a multidimensional tableau. This study sets sail to delve into the complexities of robo-advisors on a global scale, focusing on their evolutionary journey and technological advancements. In this exploration, it aims to shed light on the disparities observed in the worldwide automated investment advisory sphere while acknowledging, for example an emerging market like India's with significantly higher growth, anticipated to reach a notable 8.5% annually. [1].

Guided by a central research question resonating across scholarly discourse—"Amid the AI surge, how can robo-advisors ascend to new frontiers, and what fault lines underlie the landscape of robo-advisory services globally?"[4], [7-11]—this intellectual exploration aspires to unearth insights that shed light on potential advancements and bridge the gaps awaiting in the realm of AI-augmented financial guidance and strategy.

2.1. Global Landscape of Robo-Advisors and AI Technology

Robo-advisors have garnered swift global recognition, primarily for their capacity to provide automated and personalized investment solutions, a facet reaffirmed in longitudinal studies [12]. These platforms, driven by intricate algorithms, consider individual risk profiles and financial objectives when creating and managing portfolios [13], [14] even extending to crypto asset allocation [15]. AI, a linchpin of robo-advisory technology, empowers comprehensive data analysis, pattern recognition, and predictive modeling [1]. AI-fueled robo-advisors, both from established institutions and startups, possess the potential to reshape the financial sector, making investment opportunities more accessible and cost-efficient [4], [6], [8], [15], [16]. Notably, robo-advisors provide the capability to incorporate global environmental constraints into stock forecasts [4]. A prevalent challenge in the adoption of advanced AI-powered robo-advisor technology is the lack of trust, a pivotal topic in customer studies globally and within regional markets [3], [8], [10], [11].

2.2. Advancing Technology Through AI

The AI explosion has ushered in new horizons for enhancing robo-advisory capabilities [4], [8]. The incorporation of AI into robo-advisors has unlocked the potential for more precise predictions, streamlined risk assessment, and optimized portfolio management [17]. Techniques such as machine learning, deep learning, and natural language processing have contributed to the refinement of investment strategies and the enhancement of the customer experience [11]. By harnessing the capabilities of AI, robo-advisors stand poised to offer more resilient and personalized solutions, ultimately elevating investor satisfaction and engagement [10].

3. Applications, Advantages, and Insights from Behavioral Studies

3.1. Efficient Functioning of Robo-Advisors

Robo-advisors adopt a personalized approach to shaping investment decisions, initiating the creation of individualized investment plans tailored to specific goals and risk preferences. Prospective clients undergo inquiries regarding their investment purpose, horizon, and readiness to endure market fluctuations, enabling robo-advisors to propose plans for various objectives, such as significant expenditures, retirement, income generation, or emergency fund building [18].

To ensure cost-effectiveness, robo-advisors employ online questionnaires to assess clients' needs, investment goals, and risk profiles. Automated algorithms utilize this information to recommend asset allocations across different types of assets, with portfolio optimization typically grounded in Modern Portfolio Theory [19]. The entire process, often completed online without human interaction, ensures efficient portfolio management.

3.2. Cost Optimization and Returns

Retail investors utilizing robo-advisors benefit from significantly lower management fees, typically ranging from 20% to 30% of fees charged by human financial advisors due to automation and scalability [20, 21]. Robo-advisors aim to reduce costs, discouraging fee-inducing practices like excessive trading. Studies indicate a substantial reduction in average retail investor expense ratios, leading to significant savings and reinvestment opportunities [22].

Utilizing passively managed ETFs, robo-advisors offer less expensive and transparent fee structures, empowering clients to determine costs easily. Research indicates that robo-advisors in the US have outperformed popular mutual funds and major equity indices in value-weighted returns between 2016 and 2019, emphasizing their cost-effectiveness and potential for better risk-adjusted returns [24].

3.3. Behavioral Impact on Retail Investors

Robo-advisors play a crucial role in mitigating behavioral biases, such as under-diversification, overtrading, and herd mentality, prevalent among retail investors [25-27]. These platforms, driven by algorithms, craft portfolios tailored to individual objectives and risk tolerance, effectively addressing concerns related to behavioral biases [28].

Research highlights that robo-advisors effectively counter under-diversification, reducing portfolio volatility and enhancing performance. The services act as a shield against behavioral biases associated with DIY investment approaches, providing a more disciplined investment strategy. While not entirely immune to biases, robo-advisors contribute to countering behavioral pitfalls such as the disposition effect, rank effect, and trend-chasing, ensuring more rational investment decisions [29]."

3.4. Current State of the Industry

Robo-advisory services are poised for a robust Compound Annual Growth Rate (CAGR) of 40% from 2021 to 2026, emphasizing the steady expansion of this sector. The industry is witnessing a shift toward advanced portfolio strategies, integrating artificial intelligence (AI) and machine learning to align with the ongoing wave of financial digitization [30, 31]. Hybrid robo-advisors, combining human and automated advice, dominate the sector, reflecting the enduring demand for human involvement in portfolio management [32].

The Covid-19 pandemic underscored the resilience of robo-advisors, with certain platforms doubling their client base during lockdowns. Platforms equipped with advanced technology showcased their ability to withstand market shocks, attracting a larger clientele [30]. Notable performers during volatile market conditions included Wealth Front, Morgan Stanley Inflation Conscious, and Personal Capital, emphasizing the appeal of robo-advisory services in navigating challenging economic landscapes.

4. Research Study

The Web-Based Research Design study revolves around gathering data from the Internet concerning global financial indicators. Information regarding financial markets was systematically collected using platforms like statista.com. Additionally, the study involved employing Google Trends to gauge the level of interest in financial technology, as outlined by Vasylchenko and Bonelli in 2023 [33]-[36]. The data collection process also encompassed obtaining comprehensive insights into the most popular global Robo-Advisors and AI-driven solutions.

4.1. Analysis Key Aspects:

During our analysis, we focused on evaluating the following key aspects:

1) Obtaining a comprehensive global perspective of the financial markets, both on a global scale.
2) Investigating the status of technology within the global landscape of Robo-Advisors.
3) Exploring opportunities for enhancing technology through the implementation of AI-driven solutions.
4) Exploring the status of technology within the global landscape of Robo-Advisors.

Statista [7], the publisher of financial data, allowed us to collect data about the global perspective of the financial market within the context of India. That includes key points of financial market development, actual financial data about market volume worldwide, and forecasts for India until 2030.

In the first stage, information about the most frequently mentioned robo-advisors online was filtered [37-45]. About 70 international Robo-Advisors (Advisors who work worldwide, in many countries) lists were formed. For each Robo-Advisor, data about user count, capitalization of assets managed by, and interest data about search requests about Advisors were collected.

The Betterment Robo-Advisor, serving 775,000 customers with assets totaling $36 billion, was chosen as the benchmark for comparing relative measures with other advisors. Operating globally, with its headquarters in the US, this data was utilized to compute the relative interest in other advisors worldwide, incorporating the average Google Trend values for Robo-Advisors [36]. The tools advisors use to help investors through Finance Advisors, Robo Advisors, and AI trading were classified into the next categories.

Table 1: Advisor tools

Tool Category	Definition
Risk Assessment and Profiling	Robo-advisors collect information about an investor's risk tolerance, investment goals, and financial situation to create personalized investment profiles.
Portfolio Creation	Based on the investor's profile, robo-advisors automatically build diversified portfolios using various asset classes like stocks, bonds, and alternative investments.
Asset Allocation	Robo-advisors use algorithms to determine the optimal distribution of assets in the portfolio based on the investor's risk profile and market conditions.
Rebalancing	Robo-advisors monitor the portfolio and periodically adjust the allocation to maintain the desired balance as market conditions change.
Tax Efficiency	Some robo-advisors optimize investment decisions for tax efficiency, including strategies like tax-loss harvesting to minimize capital gains taxes.
Goal-Based Investing	Robo-advisors help investors set specific financial goals, such as retirement or buying a home, and create investment strategies tailored to those goals.
Automated Trading	Many robo-advisors automatically execute trades based on pre-defined investment strategies and market conditions.
Cost Optimization	Robo-advisors often build portfolios using low-cost exchange-traded funds (ETFs) or index funds, aiming to minimize investment expenses.
Diversification	Robo-advisors ensure that portfolios are well-diversified across various assets to reduce risk and enhance returns.
Continuous Monitoring	They continuously monitor the portfolio's performance and provide updates and notifications to investors.
Education and Insights	Robo-advisors offer educational resources and insights to help investors understand their investments and make informed decisions.
User-Friendly Interfaces	Many robo-advisors provide easy-to-use online platforms and mobile apps for investors to track their portfolios, make changes, and access information.
Savings and Investing Automation	Some robo-advisors allow users to automate regular contributions to their investment accounts, helping investors save and invest consistently over time.

Accessibility	Robo-advisors make investing accessible by offering lower account minimums compared to traditional financial advisors.
Personalized Recommendations	They provide recommendations for additional investments or adjustments based on changing market conditions and the investor's goals.
Behavioral Finance Strategies	Certain robo-advisors incorporate behavioral finance principles to help investors stay disciplined and avoid emotional decisions.
Financial Planning	Some robo-advisors offer comprehensive financial planning services, including retirement planning, estate planning, and goal tracking.
Transparency	Many robo-advisors provide transparent fee structures, allowing investors to see exactly how much they are paying for the service.
Customer Support	Although automated, robo-advisors often offer customer support through various channels to assist with account-related queries.

4.2. Exploring opportunities for enhancing technology through the implementation of AI-driven solutions.

Advisor tools and AI Enhancement options were collected in the next table [37-50]. The next conjoint of these papers was summarized in Table 2 [36].

Table 2: AI Enhancement

AI Enhancement	Description
Advanced-Data Analysis	AI analyzes extensive financial data from various sources to identify patterns and insights for informed investment strategies.
Predictive Modeling	AI creates predictive models using historical data to estimate future market movements, enabling more accurate investment decisions.
Natural Language Processing (NLP)	NLP technology helps robo-advisors understand text-based information, such as news and social media, to assess market sentiment.
Personalized Recommendations	AI analyzes individual investor profiles, preferences, and risk tolerance to provide highly tailored investment recommendations.
Dynamic Asset Allocation	AI algorithms adjust asset allocations in real time based on changing market conditions to keep portfolios aligned with goals.
Behavioral Finance Analysis	AI studies investor behavior patterns and biases, offering strategies to avoid behavioral pitfalls and make rational decisions.
Automated Tax Optimization	AI optimizes tax-related decisions, like tax-loss harvesting, to minimize tax liabilities and enhance after-tax returns.
Risk Assessment and Management	AI performs advanced risk analysis beyond traditional metrics to provide accurate risk assessments and effective risk management.
Alternative Data Utilization	AI processes unconventional data sources to gain insights into potential investment opportunities, enhancing decision-making.
Portfolio Stress Testing	AI simulates the impact of market scenarios on portfolios, helping investors understand potential performance under different conditions.
Market Timing	AI identifies potential entry and exit points by analyzing technical indicators and historical trends to enhance investment timing.
Real-time Alerts	AI generates real-time alerts for significant market events or changes, keeping investors informed of potential adjustments.
Natural Language Interaction	AI-enabled interfaces offer conversational interactions, allowing users to engage with the platform using natural language.
Fraud Detection	AI identifies unusual patterns in account activity, detecting potentially fraudulent activities and enhancing security.
Continuous Learning	AI systems learn from interactions and continuously improve recommendations and strategies based on feedback and outcomes.
Market Sentiment Analysis	AI analyzes social media and news to gauge market sentiment, incorporating sentiment analysis into investment decisions.
Deep Learning for Complex Analysis	AI techniques like deep learning analyze intricate financial models and predict complex outcomes for more accurate decisions.
Cognitive Computing	AI processes unstructured data, making sense of diverse information sources and enhancing decision-making capabilities.
Enhanced User Experience	AI-driven interfaces offer personalized dashboards, interactive visualizations, and user-centric features, enhancing the investor experience.

Google Trends used search engine data to determine interest in finding interesting information during the last year. Developer reports were used to determine the actual number of users and assets under management. Sometimes, if user data was not accessible, Google Play market data were used to determine the current count of users for applications.

These are the worldwide robo-advisor list used for this study: Capital One Investing, Schwab Intelligent Portfolios, Etoro, Marcus Invest, TD Ameritrade Essential Portfolios, XM Group,

Ally Invest, Fidelity Go, SoFi Invest, E*TRADE Core Portfolios, Acorns, Charles Schwab Intelligent Portfolios, DBS, FxPro, Morgan Stanley Access Investing, Betterment, Interactive Brokers, Wealthfront, M1 Finance, Fundrise, Plus500, Nutmeg, Ellevest, Syfe, StashAway, OCBCBank, Merrill Guided Investing, Kristal.AI, Titan Invest, SigFig, CitiWealthBuilder, Modern Advisor, BMO Smartfolio, MSCI, FutureAdvisor, FP Markets, Qtrade Guided Portfolios, Empower/Personal Capital, Endowus, CI Direct, and Axos Invest [36].

4.3. Research Methodology and Evaluation

In our pursuit of understanding the global robo-advisor landscape, we used Google Trends and developers' reports to assess user interest and metrics. The study, anchored in a worldwide robo-advisor list featuring major players like Capital One Investing and Schwab Intelligent Portfolios, formed the basis of our approach. Our analysis covered 94.7% of the global robo-advisor market, excluding smaller Indian players. We curated robo-advisor lists, explored AI roles, and utilized Google Trends for global and Indian insights on popularity and enhancements [36].

4.4. Interest Measures

To complete our quantitative analysis, we took advantage of the power of Google Trends, recognizing its dominance as the predominant search engine globally, capturing approximately 96-98% of search requests. This expansive coverage allowed us to gain insights into the worldwide interest trends related to robo-advisors, offering a perspective on the evolving landscape of financial technology.

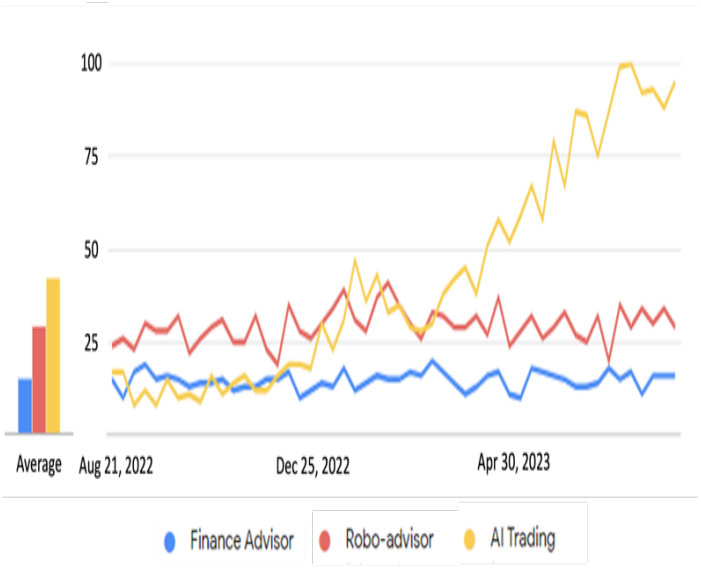

Figure 1: Interest Over Time

Figure 1, titled "Interest Over Time," illustrates the frequency of searches for key terms such as "Finance Advisor," "Robo Advisor," and "AI Trading" over the past year.

The data derived from Google Trends serves as a valuable tool for monitoring and comparing the popularity of specific search queries, enabling a dynamic understanding of user preferences and interests in the financial technology domain [36].

5. Findings

5.1. Global perspective of the financial market

In Figure 2, we present a comprehensive overview of the global financial services sector, revealing a projected market value of around $31 billion based on insights from a report by BLinC Invest [51]. This figure encapsulates the expansive scope and economic significance of the financial services industry on a global scale. The forecasted trajectory of the market points towards a notable growth trend, with an anticipated annual growth rate of 6.8%. Notable is the growth in emerging markets like India, which is over double the rate compared to the average overall growth rate [51]. This projection underscores the sector's resilience and its capacity to evolve, signaling opportunities for expansion and innovation within the financial services domain. Analyzing these projected values provides crucial insights into the dynamic nature of the global financial landscape, setting the stage for strategic considerations and potential advancements in the industry.

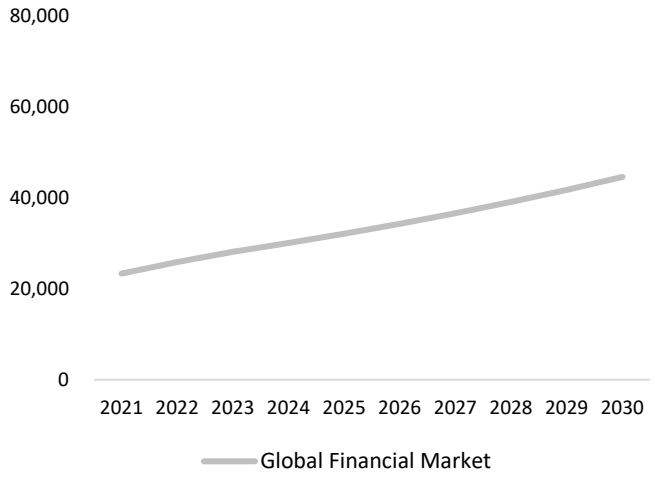

Figure 2: Global Financial Markets: Statista (2023)

5.2. Investigating the status of technology within the global landscape of Robo-Advisors

Our investigation reveals a global landscape of robo-advisors, where the most influential players collectively command 94.7% of the world's assets. To discern their prominence, we utilized assets under management as the benchmark for ranking these advisors. This criterion was selected to accommodate the diverse nature of advisors catering to a myriad of customer segments.

Figure 3, as depicted in our research [36], visually underscores the dominance of these major global advisors and serves as a key reference point for understanding their significance in the industry.

The diverse clientele of these Robo-Advisors spans a wide spectrum of needs and preferences, encompassing various categories such as Individual Investors, Quick Traders, International Funds, Banks and Institutions, Retirement Planners, Novice Investors, Ethical and Socially Responsible Investors, High-Net-Worth Individuals, Young Investors, Passive Investors, Digital Natives, Small Businesses, Educational Savings, Real Estate Investors, Customized Portfolios, Tax-Efficient Investors, Conservative Investors, Alternative Investments.

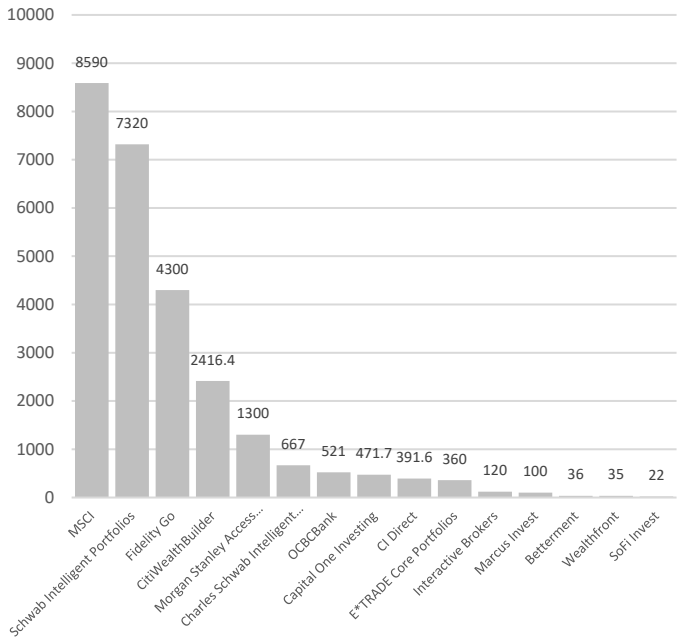

Figure 3: Highlights the dominance of the most influential global advisors [36].

5.3. Exploring Opportunities for Enhancing Technology through AI-Driven Solutions

In our quest to advance technology within the financial sector, we conducted a thorough examination of AI-driven solutions, shedding light on significant trends and user preferences. Figure 4 visually represents the evolving landscape of AI trading and its intersection with user interests, serving as a compelling testament to the comprehensive analysis [36].

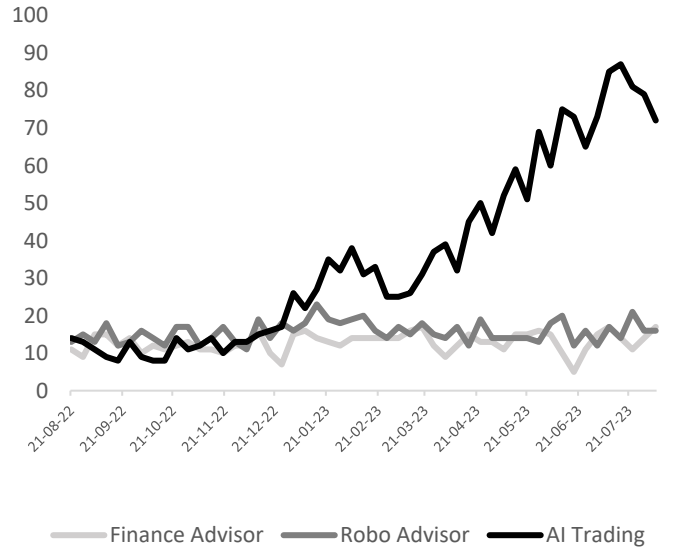

Figure 4: Illustrates the trend in the interest surrounding AI trading [36].

Figure 4 offers valuable insights into the dynamic preferences surrounding AI trading and financial advisory services. The depicted global trends showcase a consistent pattern; however, a closer examination reveals intriguing nuances.

The data indicates a noticeable divergence in the level of interest between Finance Advisors and Robo-Advisors. Finance Advisors command a notable interest score of 12.8 points, while Robo-Advisors register at 15.6 points. This suggests a preference for the automated and technologically driven approach of Robo-Advisors, even when faced with the typically higher costs associated with traditional Finance Advisors[36].

A noteworthy disparity emerges when specifically examining the interest in AI trading. Globally, AI trading garners a considerable interest score of 9.3 points, surpassing the interest in Robo-Advisors at 3 points. This signifies a distinct global enthusiasm for AI-driven trading solutions, potentially fueled by the allure of sophisticated algorithms and data-driven decision-making processes.

In summary, the trends illustrated in Figure 4 underscore the increasing prominence of AI trading in the financial technology landscape. The global preference for Robo-Advisors over traditional Finance Advisors, combined with the growing interest in AI trading, indicates a notable shift toward technologically advanced solutions in the financial advisory realm [36]. These insights not only mirror current user preferences but also provide valuable foresight into the trajectory of AI-driven financial services in the future (see Fig. 4 for illustration)

6. Development of Robo-Advisory Services

6.1. Full-Scale Optimization

The initial research focus revolves around the investment strategies employed by robo-advisors to serve their clients. Given the saturation within this sub-sector, the remaining robo-advisors face the imperative of distinguishing themselves from their competitors to both attract assets and maintain customer loyalty, thus heralding the anticipation of evolving investment methodologies [29].

Modern Portfolio Theory (MPT), initially embraced within this subsector, offered a well-established, Nobel Prize-backed approach known for its safety and appeal to investors seeking automated investment solutions. MPT is grounded in mean-variance analysis, striving to maximize expected returns while minimizing associated risks [52].

At its core, MPT employs mean-variance analysis, an approach that aims to strike a balance between maximizing expected returns and minimizing associated risks. Mathematically, it is represented as follows:

$$CapRp = \sum i = 1nwi * Ri \quad (1)$$

$$\sigma p^2 = \sum i = 1n \sum j = 1n\, wi * wj * \sigma i * \sigma j * \rho ij \quad (2)$$

Here, Rp represents the expected portfolio return, wi signifies the weight of each asset in the portfolio, Ri is the expected return of each asset, σi denotes the standard deviation of each asset, ρij reflects the correlation between assets i and j, and σp is the standard deviation of the portfolio.

While MPT has been a valuable tool, the robo-advisory landscape has evolved, revealing its limitations. These limitations include an overreliance on data inputs, an undue concentration in

specific asset classes, and the assumption of normal asset return distributions, which can be problematic in the presence of extreme returns.

Rather than shifting towards entirely new strategies, numerous firms are instead choosing to enhance the existing MPT investment framework, thus giving rise to the phenomenon known as the "Multidimensional Improvement of Modern Portfolio Theory" [29].

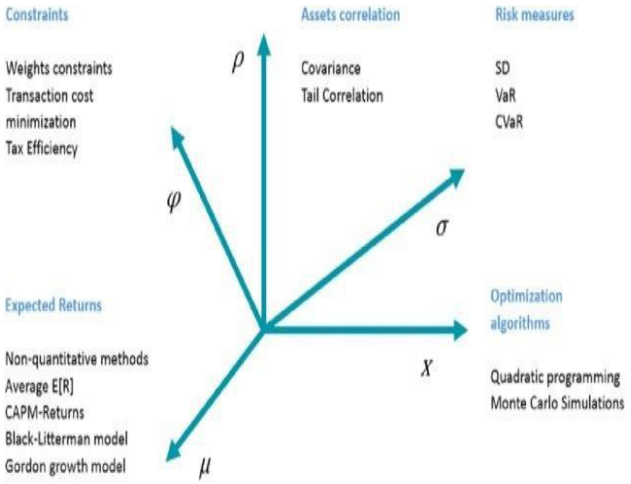

Figure 5: Many robo-advisory firms are adopting the Multidimensional Improvement of Modern Portfolio Theory, which incorporates additional factors, inputs, methods, and considerations in the newer portfolio models [53].

Figure 5 offers a summary of the multidimensional improvement of Modern Portfolio Theory (MPT), although it does not encompass all the methodologies currently being implemented by robo-advisors [29].

To overcome the limitations inherent in Modern Portfolio Theory (MPT), an advanced approach known as the "Multidimensional Improvement of Modern Portfolio Theory" (MPT+) has emerged. MPT+ goes beyond the traditional MPT framework by considering a broader array of factors, inputs, methods, and considerations in portfolio models. This extended framework is designed to overcome some of the constraints associated with MPT [53].

The MPT+ introduces an alternative formula for portfolio optimization:

$$Rp = \sum i = 1nwi * Ri - \lambda * \sum i = 1nwi * Ai \quad (3)$$

$$\sigma p^2 = \sum i = 1n \sum j = 1nwi * wj * \sigma ij \quad (4)$$

In this formula, Ai represents alternative risk measures, and λ is a risk aversion parameter. By incorporating these additional risk measures, MPT+ offers a more nuanced approach to portfolio optimization, effectively addressing the limitations of traditional MPT [53]

As the robo-advisory landscape evolves, a growing disparity emerges between conventional investment strategies and newer, academically validated approaches. Modern Portfolio Theory (MPT), while widely adopted, reveals limitations such as data reliance, estimation errors, and over-concentration in specific asset classes within portfolios. It assumes normal asset return distributions, neglecting "fat tails" observed in empirical evidence, and overlooks crucial factors like time horizon and diverse financial circumstances [54-55].

MPT's reliance on quadratic utility presents further challenges, assuming uniform emotions towards market volatility and an inaccurate representation of investor utility changes with wealth accumulation [4]. Alternative utility functions have been proposed, acknowledging that wealth benefits increase with growth, investors prefer upward market volatility, and relative risk aversion remains constant. Despite advantages, some argue these functions may oversimplify preferences, suggesting S-shaped or kinked utility functions for a more accurate representation [54-55].

Addressing these limitations, advanced strategies like Full-Scale Optimization, Risk Parity, Scenario Optimization, and Risk Parity with Skewness Risk have been introduced. Schwab Intelligent Portfolios has already implemented Full-Scale Optimization, showcasing practical advancements in the robo-advisory sector. Research suggests firms adopting these methodologies attract higher client investment levels [56].

As the robo-advisory sector evolves, these advanced strategies are poised to play a crucial role in meeting diverse investor preferences and optimizing portfolio performance. Particularly, the Multidimensional Improvement of Modern Portfolio Theory (MPT+) has gained traction, providing a more comprehensive and adaptable approach compared to traditional MPT, incorporating various risk measures, and accommodating different asset return distributions [57].

6.2. Digital Twin

Within the evolving landscape of robo-advisory, a new frontier emerges with the exploration of Digital Twin capabilities (Figure 6). This concept introduces the prospect of creating a virtual replica of the user's environment, a digital twin that serves as the foundation for personalized advice delivered by robo-advisors [58]. It should be underscored that this approach remains speculative, warranting thorough regulatory examination to establish trust in the responsible use of consumer data.

The envisioned integration of Digital Twin capabilities into robo-advisor software marks a theoretical leap. Data extracted within the virtual environment shapes a digital replica. This conceptual duplicate becomes a tool for robo-advisors to tailor advice, utilizing insights gleaned from the user's simulated surroundings [42].

The process can be summarized as:

$$Digital\ Twin\ Creation: DT = f(Data)$$

Where DT represents the digital twin, and Data signifies the data collected from the user's environment.

Digital twins hold promise in delivering more personalized recommendations compared to current robo-advisors. These replicas dynamically adapt guidance based on evolving client circumstances. For instance, if a client publicly shares on social media that they've become a parent, the robo-advisor could promptly suggest a college savings plan. As the software accumulates data, the digital twin's understanding of the client's financial situation becomes more comprehensive, enabling

adjustments to their financial strategies [58]. The recommendations can be quantified as:

$$Recommendations = g(Client\ Data))$$

where recommendations denote advice from the digital twin, and Client Data represents data from the client's virtual environment.

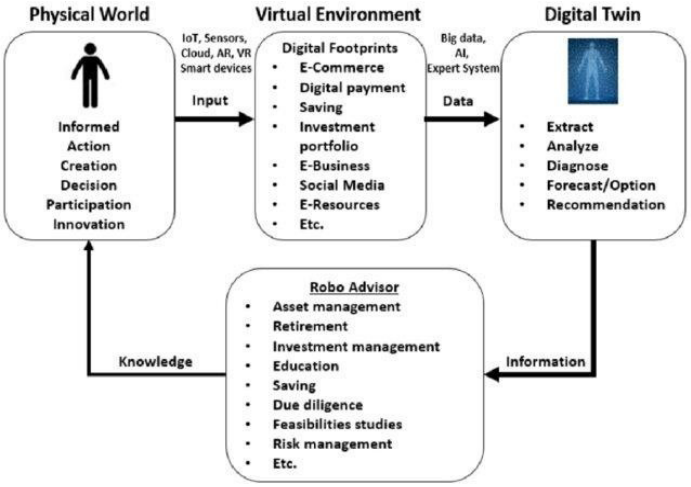

Figure 6: The integration of Digital Twin capabilities into robo-advisor software is a theoretical approach that involves creating a digital replica of the user's environment. The data collected from the virtual environment would be used to create the digital twin, which the robo-advisor could then use to provide advice to the real user [58].

Leveraging insights from the digital twin, the robo-advisor can offer a spectrum of recommendations, including adjusting the client's portfolio, providing guidance on insurance, suggesting new accounts, and delivering insights on significant purchases. Additionally, the robo-advisor can anticipate both near-term and long-term scenarios and recommend appropriate actions.

The digital nature of robo-advisors provides higher accessibility for clients with internet connectivity, a notable advantage over traditional human advisors. However, integrating digital twins into robo-advisory services poses challenges and risks, requiring robust data security measures to handle substantial volumes of sensitive client information and build trust in the technology[58].

6.3. Natural Language Processing

Natural Language Processing (NLP), a cornerstone of Artificial Intelligence (AI), is a crucial force bridging human language and machine comprehension. Rooted in Computational Linguistics, NLP enables machines to understand and manipulate human language, evolving beyond traditional predefined instructions [59].

The rise of Machine Learning and AI signifies a transformative era, empowering machines to make nuanced decisions based on real-time contextual information. This shift is evident in technologies like voice-activated virtual assistants (e.g., Alexa, Google Home), showcasing NLP's role in enhancing human-machine interactions [59].

Figure 7 illustrates NLP's profound impact on the financial landscape. Sourced from Analytics Vidhya, it exemplifies NLP's transformative role in refining communication between users and robo-advisors, shaping the financial services landscape.

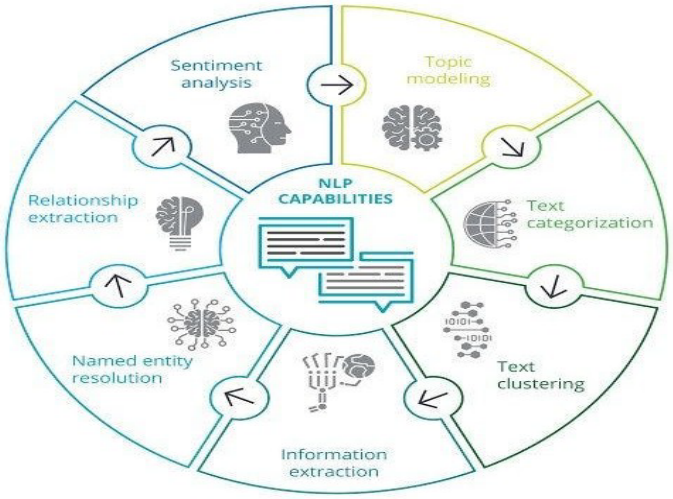

Figure 7: The impact of NLP within the financial industry and robo advisers is palpable and far-reaching, as exemplified in the above figure scenarios (Source: Analytics Vidhya)

In the financial realm, grappling with time-consuming methods for document retrieval and extracting insights from vast, unstructured data has been a persistent challenge for decades. The intricate nature of unstructured data makes analysis and deciphering a formidable task. However, the emergence of Natural Language Processing (NLP) revolutionized this landscape, delivering unprecedented efficiency and accuracy [60].

NLP, prized for its innate ability to discern patterns within unstructured data, provides a profound advantage to financial institutions and, more recently, robo-advisers. Its applications span text classification, information retrieval, natural language generation, and natural language understanding. These capabilities collectively yield streamlined and powerful results, establishing NLP as an indispensable tool for automating numerous processes within the financial sector, particularly benefiting robo-advisers [61].

Robo-advisors in finance leverage Natural Language Processing (NLP) for significant enhancements:

1. **Personalized Customer Care:** NLP-powered chatbots serve as 24/7 personal clerks for clients. They efficiently manage repetitive tasks and provide financial advice, aiding clients in saving, on-time payments, and overdraft prevention.
2. **Automated Trading Platforms:** NLP is vital for high-frequency trading in robo-advisors. It enables the analysis of data, including news and press releases, to identify trading patterns. These tools operate almost in real-time, aiding brokers in validating trading decisions.
3. **Monitor Investor's Sentiment:** NLP tools track mentions of companies and assess sentiment in news coverage. Understanding the tone of news articles provides valuable insights into investor perceptions.
4. **Upgrade Quality of Analyst Reporting:** NLP enhances analyst reporting by swiftly accessing relevant information. This enables analysts to create more detailed reports and offer superior advice.

5. **Easier Data Retrieval:** Robo-advisors use NLP to implement conversational interfaces, allowing effortless searches within vast internal databases, even for complex queries.

These advancements in robo-advisors are powered by the capabilities of NLP, contributing to efficiency and effectiveness in various financial processes. That can be quantified as follows:

Let:

- ***PC:*** *Personalized Customer Care efficiency.*
- ***ATP****: Efficiency in Automated Trading Platforms.*
- ***MCS****: Monitoring Company Sentiment.*
- ***UQAR****: Upgrade in Quality of Analyst Reporting.*
- ***EDR****: Easier Data Retrieval.*

And:

- ***Total Benefits (TB)*** *= PC + ATP + MCS + UQAR + EDR*

Quantitative Representation:

$$TB = PC + ATP + MCS + UQAR + EDRbg$$

Where:

- **PC** is measured as the percentage increase in the efficiency of customer care and financial advice provided.
- **ATP** is quantified as the percentage improvement in trading efficiency.
- **MCS** is evaluated based on the accuracy of sentiment analysis and its impact on investment decisions.
- **UQAR** is expressed as the percentage increase in the quality of analyst reporting.
- **EDR** is assessed as the percentage reduction in the time required for data retrieval and its impact on decision-making processes.

By assigning values to each of these components, the overall benefits of implementing NLP in their robo-advisory services can be accurately quantified.

In [62], the authors underscores the potential of reciprocal conversations between human and robo advisors through AI chatbots to foster trust and enhance the perceived relationship between clients and RA firms. By investing in NLP technology on their platforms, RA companies can significantly enhance the user experience and cultivate customer loyalty. AI chatbots bring a conversational element that can potentially increase the likelihood of clients adhering to the portfolio guidance provided by robo-advisors, improve investors' perceptions of the investment firm, and create a more positive and engaging experience for customers [62].

Furthermore, AI chatbots enable investors to obtain more personalized portfolio recommendations based on customer data. However, the preference for conversationalist RAs over non-conversational ones does raise potential ethical implications, as investors might be inclined to follow suboptimal investment decisions [62]. In [56], the athors delves into the advantages of AI-powered consultants for enhancing decision-making in businesses. It highlights the introduction of psychological barriers and emphasizes the potential risks associated with imbuing robo-counselors with social design elements to make them appear more human-like.

7. Regulating Robo-Advisors: Navigating Legal and Regulatory Frontiers

The rise of robo-advisors, internet-based advisory services driven by algorithms, has revolutionized the financial landscape, offering cost-effective solutions compared to traditional advisors. However, the unique client-machine interaction raises intricate legal questions, challenging regulators globally. This section explores the regulatory aspects surrounding robo-advisors, emphasizing their distinctive nature and the responses of major regulatory bodies [63].

Regulators, especially in major jurisdictions, grapple with adapting existing frameworks to address the peculiarities of robo-advisory services. While the European Union's financial intermediary framework is seen as broadly applicable, the challenge lies in interpreting these rules without stifling innovation. Globally, regulators are cautious, often opting for a conservative stance. For instance, the U.S. Securities and Exchange Commission (SEC) issued guidance cautioning investors against sole reliance on robo-advisors, highlighting the need for individual research. Meanwhile, the Financial Industry Regulatory Authority (FINRA) in the U.S. expressed concerns about the adequacy of robo-advisor advice, emphasizing the importance of human intervention [64].

7.1. Elements of Robo-Advisory Regulation:

a. **Ongoing Duties, Compliance, and Authorization:** The regulation of robo-advisors involves authorization by national regulators, aligning with the traditional framework for financial intermediaries. However, the challenge lies in ensuring that robo-advisors comply with ongoing duties and standards of care, particularly concerning communication with clients. Regulatory bodies globally, including the U.S. SEC and the Australian Securities and Investments Commission (ASIC), have issued guidance emphasizing the need for disclosure and investor protection [64].

b. **Collective Fallibility and Market Failure:** Concerns surrounding market stability and systemic risks due to the collective decision-making processes of robo-advisors have been raised. While robo-advisors are yet to achieve a market share that poses a threat to systemic stability, regulators must be vigilant. The potential for instantaneous reactions during market crises and the risk of market distortions due to uniform advice patterns are areas where future regulatory focus may be warranted.

This section addresses concerns about the effectiveness of communication between robo-advisors and clients and delves into the need for a standard of investor protection equivalent to that for human advisors. It emphasizes that while robo-advisors need not be flawless, they should provide a similar level of investor protection as their human counterparts. The importance of recourse options for clients in case of flawed advice and the role of regulatory mechanisms in preventing or responding to such instances are underscored.

As robo-advisors continue to gain prominence, the regulatory landscape must evolve to accommodate their unique characteristics. While current frameworks offer a foundation, thoughtful interpretation, and adjustments are crucial to ensure a level playing field. Balancing innovation with investor protection remains a key challenge for regulators globally, urging ongoing dialogue and adaptability in the face of a dynamic financial landscape [63].

In conclusion, the regulatory framework for robo-advisors requires careful calibration to meet the evolving dynamics of the financial landscape. This section advocates for an investor protection standard akin to that applied to human advisors, recognizing the importance of addressing communication concerns and ensuring recourse options for clients. As the prominence of robo-advisors continues to grow, a nuanced and adaptable regulatory approach is paramount. Striking a balance between fostering innovation and safeguarding investor interests stands as an ongoing challenge, urging regulators to engage in continuous dialogue and adaptability. This proactive stance will contribute to the sustainable development of robo-advisory services in a rapidly changing financial ecosystem.

8. Pros and Cons of Robo-advisors

8.1. Pros

1. **Lower Costs** Robo-advisors tend to have lower costs than traditional financial advisors because they operate more efficiently, reducing the workload of human advisors.
2. **Automated Investing** Robo-advisors can automatically manage the investment portfolios of businesses, streamlining the investment process for enterprises and saving time.
3. **Efficient Financial Planning** Robo-advisors can offer a more efficient financial planning process, aiding businesses in achieving their financial goals.

8.2. Cons

1. **Lack of Personalization** Robo-advisors may not offer services as personalized as human consultants, potentially falling short of fully meeting the specific needs of businesses.
2. **Risk Management** Robo- advisors may not provide sufficient expertise in risk management strategies for enterprises, necessitating additional support in this domain.
3. **Lack of Emotional Connection** Robo- advisors may struggle to establish the same level of emotional connection as human consultants, which may result in a diminished human element in the consulting services offered to businesses.

As a result, robo-advisors can undoubtedly assist investors in constructing a more efficient business model, particularly in areas such as financial planning, investment, and risk management. However, they may encounter limitations when it comes to addressing their specific needs, and the absence of the human factor can potentially reduce the emotional connection in the consulting services provided.

9. Conclusive Remarks

In conclusion, this comprehensive analysis, rooted in the exploration of technological advancements within the robo-advisory sector, integrates insights from academia, industry reports, and emerging trends. The primary goal is to offer a technically grounded perspective that informs practical decision-making in a competitive landscape.

The recommendations emerging from this study herald a new era in robo-advisory technology. First and foremost, the adoption of advanced portfolio management methodologies, like Full-Scale Optimization (FSO), is pivotal for robo-advisory firms to gain a distinctive edge. Second, the incorporation of digital twin capabilities offers a future where ultra-personalized services are tailored to each unique client. Lastly, the infusion of Natural Language Processing (NLP) into robo-advisor software promises substantial enhancements in customer satisfaction, portfolio guidance adherence, and client-advisor relationships.

These implications reverberate across the spectrum of industry stakeholders, guiding firms, regulators, and investors. Firms can employ these technical recommendations to initiate conversations and explore the potential of integrating these technologies. Regulators responsible for oversight, must vigilantly monitor the development of these trends as robo-advisors evolve. For investors, this research provides a valuable framework to assess prospective platforms.

In the realm of research, our web-based design incorporated data gathered from platforms like statista.com, Google Trends, and developer reports. This study delved into key aspects, encompassing a global perspective of financial markets, an investigation into the status of technology within the global landscape of Robo-Advisors, and an exploration of opportunities for enhancing technology through the implementation of AI-driven solutions.

The pathway for future research extends towards delving into alternative investment strategies like Risk Parity, Scenario Optimization, and Risk Parity with Skewness Risk, as well as their adaptability within the robo-advisory sub-sector. Further studies can delve into the enduring impact of AI chatbots on the intricacies of the client-robo-advisor relationship, particularly as the younger generation inherits wealth and navigates its utilization.

While this study aims to offer technical insights, it encounters certain limitations. The availability of pertinent data points and the relatively nascent nature of the robo-advisory sector may constrain the breadth of current academic research. Nevertheless, this research sets the stage for technical innovation and paves the way for future explorations and advancements within the robo-advisory sub-sector.

Conflict of Interest

The authors declare no conflict of interest.

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Exploring Current Challenges on Security and Privacy in an Operational eHealth Information System

Viktor Denkovski[*, 1], Irena Stojmenovska[1], Goce Gavrilov[1], Vladimir Radevski[1], Vladimir Trajkovik[2]

[1]*University American College Skopje, School of Computer Science and Information Technology, Skopje, 1000, North Macedonia*

[2]*University "Ss. Cyril and Methodius", Faculty of Computer Science and Engineering, Skopje, 1000, North Macedonia*

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ABSTRACT

Bearing in mind that patient data is extremely sensitive, it is crucial to establish strong protection when the security and privacy of healthcare data are concerned. Prioritizing data security and privacy is essential for the overall healthcare industry in order to maintain the reliability of electronic healthcare (eHealth) information systems. This study explores the gathered data and information from the surveys and interviews by looking at the security and privacy concerns in using eHealth information technologies. The surveys and interviews were performed on the medical practitioners in N. Macedonia. The main goal is to find out how well-informed are the medical practitioners on the already in-place privacy measures that have been implemented by the medical authorities and to assess their attitudes regarding the need for additional improvements of the system. From the executed interviews, eight healthcare professionals participated in a thorough email interview in order to discover security and privacy issues associated with eHealth systems usage. This information served as the groundwork for administrating an online survey, to which 370 medical practitioners responded from primary and secondary healthcare. The findings emphasize how essential it is to promptly address the system usability concerns on the security and privacy procedures that are implemented when using eHealth technologies.

1. Introduction

This paper is an extension of work originally presented at the 2023 IEEE International Mediterranean Conference on Communications and Networking (MeditCom) [1] to highlight how critical it is to promptly tackle system usability issues related to privacy and security protocols while utilizing eHealth technologies. In recent years there have been revolutionary developments concerning the integration of eHealth information technology, changing the delivery of healthcare services, and providing several benefits, such as raised efficiency and improved accessibility to medical data [2, 3]. Technology has shown increased development that has sped up the integration of eHealth systems way above initial expectations. In 2004, the European Union (EU) established the eHealth systems as a national strategy and policy after realizing their crucial role play in today's modernized healthcare [4]. The research and development strategies from the EU are actively supporting the international progress of the eHealth systems promoting non-EU and EU country cooperation [4].

Even before progressing to national projects, the deployment of eHealth systems needs to go under extensive research and testing in order to address the adaptation and ethical concerns [5]. The mere fact that N. Macedonia's eHealth system was initially implemented without following any clear national policies or strategies indicates the need for additional financial support and support from the government to ensure a smooth national integration later on [6, 7].

The main purposes of electronic health systems are making the medical staff's paperwork easier, lowering costs, and raising satisfaction [8]. To enhance the quality of health care services, well-defined workflow procedures and online data exchange between primary and secondary care facilities must be implemented and adopted [9]. Furthermore, using eHealth technologies makes it much simpler to contact medical specialists, especially those who are working in big cities and larger hospitals. This promotes cooperation in overall health care and improves patient accessibility [8].

To increase efficiency in managing patients and saving paperwork, eHealth systems are an essential tool for patient management and data sharing. This involves digitizing,

[*]Corresponding Author: Viktor Denkovski, viktor.denkovski@uacs.edu.mk

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exchanging, and archiving all relevant information [7]. However, worries over the security and privacy of the patient's private medical information are raised by the growing dependencies on digital platforms. Trust maintenance in the health care systems and also guaranteeing the patient's data privacy and security requires safeguarding the patient data from illegal breaches, access, and misuse [10]. In alignment with the regulatory protocols, people must be guaranteed that their data is being secured and that the security of digital data is being considered a top priority in eHealth systems [7].

Per a systematic study in [11], the usage of big data analysis and its applications in the healthcare industry has emerged recently in several studies and research projects. Three modules comprise the health care system's structure, of which, medical practitioners, medical consumers, and health services related to medical treatment, like research and health insurance. Furthermore, although it is still in its early stages, the pharmacy business and shareholders started their analysis of big data even more regularly in order to gain knowledge and an overview of numerous activities related to their sector [12].

By the end of 2021, 22 nations that were already a part of the digital service infrastructure for eHealth systems, began exchanging patient information and electronic prescriptions, indicating that healthcare data digitalization in some EU countries was already at an advanced stadium [13]. According to the World Health Organization (WHO) Regional Office for Europe in [14], research of healthcare big data in the healthcare sector presented vital importance, however, they were not sufficiently explored, and there were only a few methods and arrangements that offered help in this field. Having in mind this assessment, just 13% (six nations) of the EU had integrated national policies and rules in motion for big data in this area, while the private sector controlled just a small portion of this, or just 9% (four nations). The commercial sector would take over and seize the chance to capitalize on the potential of big data analysis in the healthcare industry if the public medical authorities fail to investigate this issue.

As was already pointed out above, big data in healthcare information systems presents several security and privacy issues when it comes to patient medical records. At the top, data centers that house sensitive data possess various levels of security. Because of this, it was unable to directly apply conventional security options and solutions to sizable and diverse data sets [15]. The complexity of security in many software systems that can handle different sources and data formats is compounded by the growing demand for cloud solutions in the healthcare sector [16]. Big data had to be properly maintained for this reason to be made available for data analysis.

Utilizing the accumulated big data for any kind of progress across all industries may present various difficulties. The lifecycle of the data was divided into data, management, and process classification when it comes to those difficulties [17]. The representation of data characteristics (variety, visualization, volume, variability, etc.) was one type of such difficulty. Security and privacy issues presented one of the challenges to be managed, also, issues that arise during data processing (analysis and modeling, data mining and implementation, etc.), and the absence of understanding the data. According to [18], management of big data must be improved by using operations of cleaning, processing, analyzing, securing, and granting access to the data due to its lack of flexibility, scalability, and performance. Furthermore, security and privacy protection were essential for the widespread usage of big data in all areas especially in the healthcare sector. Thus, the privacy and security issues related to the topic at hand were breakdown into categories that address infrastructure security (cloud security DoS attacks, Hadoop), data management (auditing and monitoring, key management, and data provenance), and data privacy (including data anonymization, encryption, and access control) [19]. For instance, considering big data in healthcare, it is crucial to protect sensitive patient data especially when dealing with privacy and security issues. Additionally, in [16] it was illustrated the distinctions between privacy and security issues that arise when dealing with big data, in which the primary security objective is to safeguard the information and not adequate to address privacy issues. In their research, they explain that, while privacy was more dependent on individual management of data (implementing policies to ensure that customer data was being gathered, used, and shared appropriately), security was more concerned with the protection of the data from malicious attacks and acquiring profit from the stolen data.

Data interoperability across primary and secondary healthcare systems was essential for the improvement of the end-user experience when discussing the national eHealth information system. To make it easier to integrate and share data between several platforms, it was crucial to develop common technological standards for data interchange between the primary and secondary healthcare systems. Adoption of common standards could be considered for this purpose, such as DICOM [20] (Digital Imaging and Communications in Medicine), SNOMED CT [21] (designed as a multilingual international core set for electronic clinical data exchange that can be used in Electronic Health Records (HER) systems), and HL7 FHIR [22] (next-generation standard for interoperability developed by Fast Healthcare Interoperability Resources and Health Level 7 to provide efficient and quick health data exchange) [23].

The sensitive patient data that must be legally protected and secured raised concerns when dealing with eHealth systems that monitor all the patient information and data as well as the medical staff who provide healthcare. According to WHO in [14], over 80% of the EU member states have created laws to protect the privacy of sensitive health information, which almost 30% from 2009 to 2016 was raised exponentially. Furthermore, the medical personnel must address additional challenges related to financial difficulties, computer expertise, information technology support, etc. when implementing eHealth systems [24]. In [25] it was pointed out that eHealth systems must have strong privacy and security policies in place to be able to handle these issues. The medical practitioners as the major users of these health systems must be aware of and abide by the established security procedures to reduce the threats associated with the digital transfer and storage of medical data [26].

The dynamic nature of security and privacy in healthcare was highlighted in [27], who additionally point out the significance of current security practice reviews and observation in order to respond to emerging vulnerabilities and threats. The medical staff members must take part in frequent education and awareness

programs in order to be informed about the latest security requirements and best practices. In [28] the focus was put on privacy and security concerns in the era of digital healthcare, emphasizing the need for robust security protocols to manage the issues and challenges posed by the rapid advancements of technology and the expanding amount of data in the healthcare sector. A question was posed on privacy protection and sensitive information, addressing the national data protection laws and the General Data Protection Regulation (GDPR). The topic of discussion was "Is it decently implemented in the medical field?". As a member of the Council of Europe since 2006, N. Macedonia has benefited from the creation of the Convention for Protection of Individuals related to the Automatic Processing of Personal Data, known as Convention 108, and on December 5th, 2019, was made the 37th nation to sign the updated Convention 108+ [29, 30]. The two main objectives of this revised Convention 108+ were to effectively reinforce the Convention's execution and address different issues that may arise from employing the new Information and communication technology. According to the convention, member nations must ensure that the individuals are informed about which and what type of information was being gathered about them, have access to the data, and can make corrections to their data. To keep up with the EU's GDPR, the new law on personal data protection was passed by Macedonian Parliament that went into effect in February 2020 [31, 32]. This law establishes responsibilities for the data processors and controllers to respect and safeguard the individuals' right to privacy. Also, this law regulates the processing of sensitive health information as personal data.

The opinion of the medical practitioners on eHealth technology security and privacy safeguards was the focus of this study. Their familiarity with the security mechanisms in place was evaluated, and possible areas of improvement – specifically, with the "Moj Termin" (My Appointment) system currently operational in N. Macedonia were highlighted. Understanding these problems would enable recommendations to be made to strengthen privacy of patient data and enhance the system's performance. To investigate these privacy and security concerns, the medical practitioners were subjected to a comprehensive email interview and a structured survey to evaluate their awareness of the security protocols and opinions regarding the protection of private medical information. By focusing on the system "Moj Termin", the results from the survey will be used to provide guided suggestions for enhancing the overall security and privacy of health care information systems.

The remaining sections of this research are arranged as follows: The study's tools and methods were detailed in the Materials and Methods section. The Results section includes the study's findings. The Discussion section interprets the survey and interview data and highlights the important findings. The conclusion section summarizes the findings of this research and offers recommendations for the medical authorities, organizations, and various IT bodies, emphasizing the value of providing ongoing education and training for medical practitioners to familiarize them with various privacy and security measures.

2. Materials and Methods

To gain a better grasp of the effect that using eHealth information systems has on the medical practitioners' awareness of the security and privacy of sensitive medical data, indebted e-mail interviews were the initial method used to conduct this research. The e-mail interviews presented an excellent alternative to phone and in-person interviews. Furthermore, the participants who were difficult to get in touch with lived in distant locations, or just didn't have the time because of their jobs may benefit more from this kind of qualitative research [33, 34]. The primary problem with this approach was that, in many cases, the interview participants weren't responsive to their requests to take part in the interview. To avoid this challenge, timed reminders were necessary [33].

Before conducting the e-mail interviews, a set of materials was put together, which included interview questions, a completed and scanned interview permission form, interview instructions, and an invitation to the interview by e-mail. Finally, there were no financial incentives offered as rewards to the study's participants.

The focus of this research was the addressed questions about security and privacy measures of sensitive medical data and the viewpoints of the participants in the context of challenges and difficulties. These questions included:

- What security measures were available to you while handling sensitive eHealth information belonging to the patients?
- What kinds of issues did you encounter when utilizing the eHealth information system "Moj Termin"?
- What features, data, services, etc. do you believe the eHealth information system "Moj Termin" requires?
- How did the administrators of the medical department help you when you first started using this information system "Moj Termin"?
- Which security measures were disposal to you when handling the sensitive data belonging to the patients?

The Interview transcripts were examined, and the questions were reviewed. The data was evaluated and examined to uncover similar statements on issues and concerns related to security and privacy.

An online survey was used in the second technique of this study to include a considerably bigger number of participants for the research relevance and further investigation of the topic at hand. Only the first section of the questionnaire, which included the demographic characteristics of physicians of primary and secondary level, and the third section, which included the issues and challenges were taken into consideration for this study out of the total six sections that the questionnaire was composed of.

Survey of primary and secondary physicians was carried out in N. Macedonia in two-months, between February 7th and April 7th, 2022. Considering the physicians' busy schedules, closed hospitals except in cases of emergency, and the reason that many of them were ill and isolated at home, the medical personnel were difficult to contact during the COVID-19 outbreak.

2.1. Study population

The standardized formula for minimal sample size was used to estimate the minimal sample size for this study to be relevant and achieve its primary goal [35].

$$n = \frac{\frac{z^2\pi(1-\pi)}{e^2}}{1 + \frac{z^2\pi(1-\pi)}{e^2 N}} \quad (1)$$

The formula considers the following factors:

- Sample size (n),
- Population proportion (π),
- Desired confidence level (z),
- Acceptable sampling error (e), and
- Population size (N).

At the time of access, in N. Macedonia were registered 4636 specialists in outpatient clinics, 1793 pharmacists, 1554 general physicians, and 160 gynecologists [36].

Based on the 9386 total population, 370 participants were necessary according to (1) to complete the questionnaire for the study to be relevant with a 95% confidence level and a 5% margin of error. All medical practitioners who worked with or had knowledge of the eHealth system "Moj Termin" usage were eligible to participate in this study. The technical workers at the healthcare facilities, those who had never utilized the eHealth system, and those who had not given informed consent were excluded from the study.

2.2. Statistical analysis

IBM SPSS Statistics version 23.0, a statistical program for the Windows operating system was utilized to examine the collected data [37]. The data analysis's categorical variables were provided as frequencies and percentages. To find any significant link between the variables, a cross-tabulation was performed. Phi and Cramer's V were utilized for calculation of the effect size between the variables, and to test the correlation, the Chi-Square test was used. A two-tailed p-value < 0,05 was considered significant and for the null hypothesis, it was assumed that there would be no relationship between the variables.

3. Results

3.1. Participants' demographic characteristics

3.1.1. Results from in-depth interviews

Between April and September 2020, the study's participants began to receive invitations for interviews, out of which, eight medical practitioners took part in the study (five being primary and three secondary care physicians). The demographic details of those who took part in the interview procedure are displayed in Table 1. They all finished the email interview, and two of them additionally had a follow-up email exchange. The interviews lasted between 20 to 40 minutes (on average) and it took the physicians one to two weeks (8,25 days on average) to respond after they received the invitation.

Table 1: Demographic characteristics of medical practitioners from the in-depth interviews

Characteristics	
Gender – No. (%)	
Male	1 (12,5%)
Female	7 (87,5%)
Age, years – Mean (±SD)	33,8 (±10,5)
Level of Education – No. (%)	
University	6 (75%)
PhD	1 (12,5%)
Other	1 (12,5%)
Profession – No. (%)	
Primary healthcare physician	5 (62,5%)
Specialist	3 (37,5%)
Work experience of primary healthcare physician, years – Mean (±SD)	7,8 (±10,3)
Work experience of specialist, years – Mean (±SD)	5,7 (±4,1)
Experience in patient management before starting to use the eHealth system – No. (%)	3 (37,5%)
No experience in patient management before starting to use the eHealth system – No. (%)	5 (62,5%)

3.1.2. Results from the online survey

As shown in Figure 1, most of the participants who took part in the online survey were from primary healthcare.

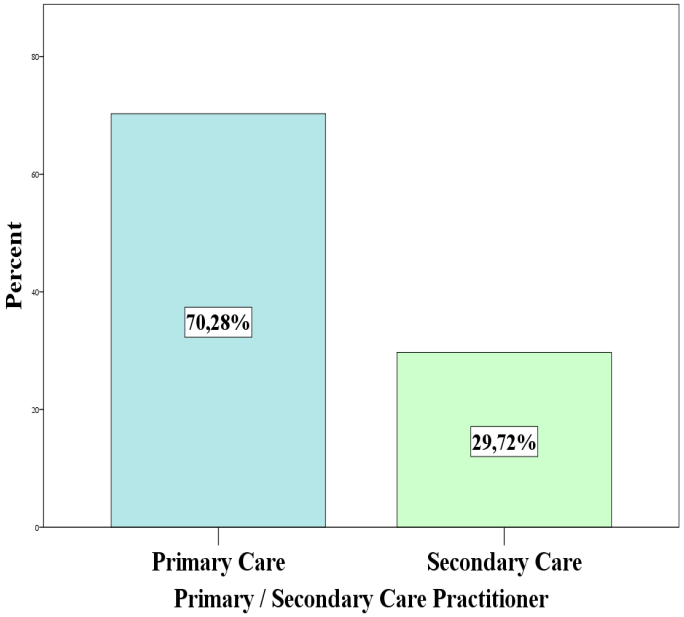

Figure 1: Medical practitioners' distribution within the healthcare sectors

The majority of the medical practitioners who took part in this survey were female, married, and had finished their specialty training as presented in Table 2. Furthermore, it was estimated that the typical medical practitioner had 19 (+/-10,5) years of overall work experience, however, the average years of experience with the eHealth system were estimated to be 7,5 (+/-3,8) years. Finally, as shown in Table 2, most of the participants worked in an urbanized environment.

Table 2: Results from the online survey - Demographic characteristics of medical practitioners

Characteristics	
Age, in years – Mean (±SD)	46,9 (±10,9)
Gender – N (%)	
Female	244 (66,1)
Male	125 (33,9)
Marital status – No. (%)	
Married	314 (84,9)
Unmarried	37 (10,0)
Widowed	17 (4,6)
Other	2 (0,5)
Education – N (%)	
Specialized studies	206 (56,4)
Graduate	123 (33,7)
PhD	19 (5,2)
Postgraduate	16 (4,4)
Other	1 (0,3)
Practitioners' Healthcare Sector – N (%)	
Primary Care	253 (70,3)
Secondary Care	107 (29,7)
Working experience of the medical practitioner, in years – Mean (±SD)	19,1 (±10,5)
Location of the medical facility – N (%)	
Urban Area	321 (87,2)
Rural Area	47 (12,8)
eHealth system patient management experience, in years – Mean (±SD)	7,5 (±3,8)

The distribution of the participants was approximately evenly distributed, with the majority falling within the age range of 28 and 62, as seen in Figure 2.

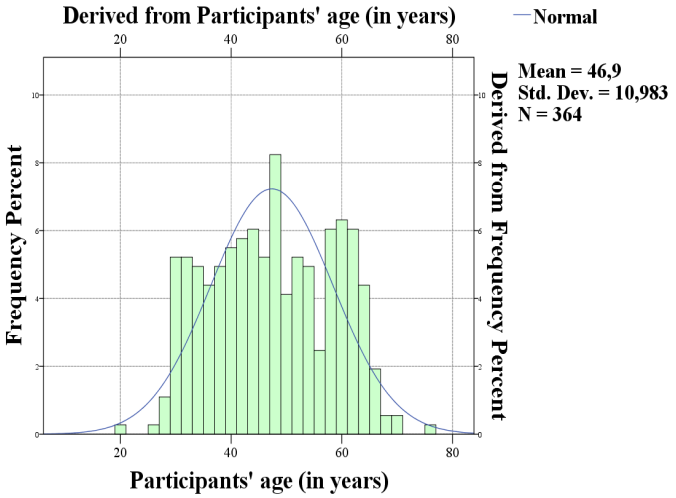

Figure 2: Results from the online survey - Age distribution of the medical practitioners

The specializations of the medical practitioners included in this analysis are shown in Table 3. Of these, the majority were registered as other specialized physicians, followed by general practitioners, and dentists.

Table 3: Medical practitioners' area of expertise

Physician's role		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Gynecologist	21	5,7	6,1	6,1
	Dermatologist	2	,5	,6	6,7
	Dermatologist and venereologist	2	,5	,6	7,3
	Internist	14	3,8	4,1	11,4
	Effectologist	4	1,1	1,2	12,5
	Clinical pharmacologist	1	,3	,3	12,8
	Maxillofacial surgeon	1	,3	,3	13,1
	Neurologist	3	,8	,9	14,0
	Neuropsychiatrist	1	,3	,3	14,3
	Neurosurgeon	1	,3	,3	14,6
	Nuclear medicine	2	,5	,6	15,2
	General Medicine	66	17,8	19,2	34,4
	Orthopedist	3	,8	,9	35,3
	Otorhinolaryngologist	8	2,2	2,3	37,6
	Ophthalmologist	3	,8	,9	38,5
	Pediatrician	21	5,7	6,1	44,6
	Pneumophthisiologist	1	,3	,3	44,9
	Psychiatrist	2	,5	,6	45,5
	Radiologist	2	,5	,6	46,1
	X-ray specialist	1	,3	,3	46,4
	Social medicine	4	1,1	1,2	47,5
	Specialist	13	3,5	3,8	51,3
	Sports medicine	1	,3	,3	51,6
	Dentistry	58	15,7	16,9	68,5
	Transfusiologist	2	,5	,6	69,1
	Urologist	3	,8	,9	70,0
	Physical medicine and rehabilitation	7	1,9	2,0	72,0
	Surgeon - Specialist	5	1,4	1,5	73,5
	Other specialist doctors	91	24,6	26,5	100,0
	Total	343	92,7	100,0	
Missing		27	7,3		
Total		370	100,0		

3.2. Challenges and Issues (Contextual Aspects)

The opinions of the medical practitioners on the challenges and issues they encountered when utilizing the eHealth system are shown in Table 4. The majority of the medical practitioners in this survey reported that throughout their working experience in the eHealth system, they occasionally ran across different persistent technical challenges, nevertheless, this group was closely followed by those who often faced consistent issues. When faced with various technical issues, the majority of the medical practitioners stated they were rarely given assistance or some technical support by the medical authorities. However, 16,1% stated they never received any assistance or support from medical authorities. When the medical practitioners first began using the eHealth information system, the majority of them did not received introduction or explanation of the security and privacy measures that were implemented to protect the sensitive patient medical data and information that was being stored in the eHealth information system. Lastly, the majority of the medical practitioners in this study strongly agreed that the information system required a variety of significant and critical enhancements to the system functionalities. These system functionalities are to be integrated and upgraded to the current implementation based on their working experience with the system and its effectiveness in managing patients.

Table 4: Medical practitioners' opinions on challenges and issues in utilizing the eHealth information system

Context Factors	N (%)
Frequently run into recurring technical issues when using the eHealth system	
Always	54 (14,6)
Very often	123 (33,3)
Sometimes	133 (36,0)
Rarely	48 (13,0)
Never	11 (3,0)
Frequently got assistance or technical support from the medical authorities when faced with technical difficulties	
Always	46 (12,5)
Very often	74 (20,2)
Sometimes	91 (24,8)
Rarely	97 (26,4)
Never	59 (16,1)
Presented with different privacy and security measures to safeguard the patients' sensitive medical data stored in the eHealth system	
To a great extent	53 (14,4)
Somewhat	93 (25,3)
Very little	89 (24,3)
Not at all	132 (36,0)
Significant functional improvements are required for the eHealth system	
Strongly agree	210 (56,9)
Agree	82 (22,2)
Undecided	60 (16,3)
Disagree	14 (3,8)
Strongly disagree	3 (0,8)

Figure 3 presents an introduction to the various security measures implemented concerning the security and privacy protection of the patient's sensitive medical data by the practitioners' gender, distribution within the healthcare sectors, and the location of their medical facility.

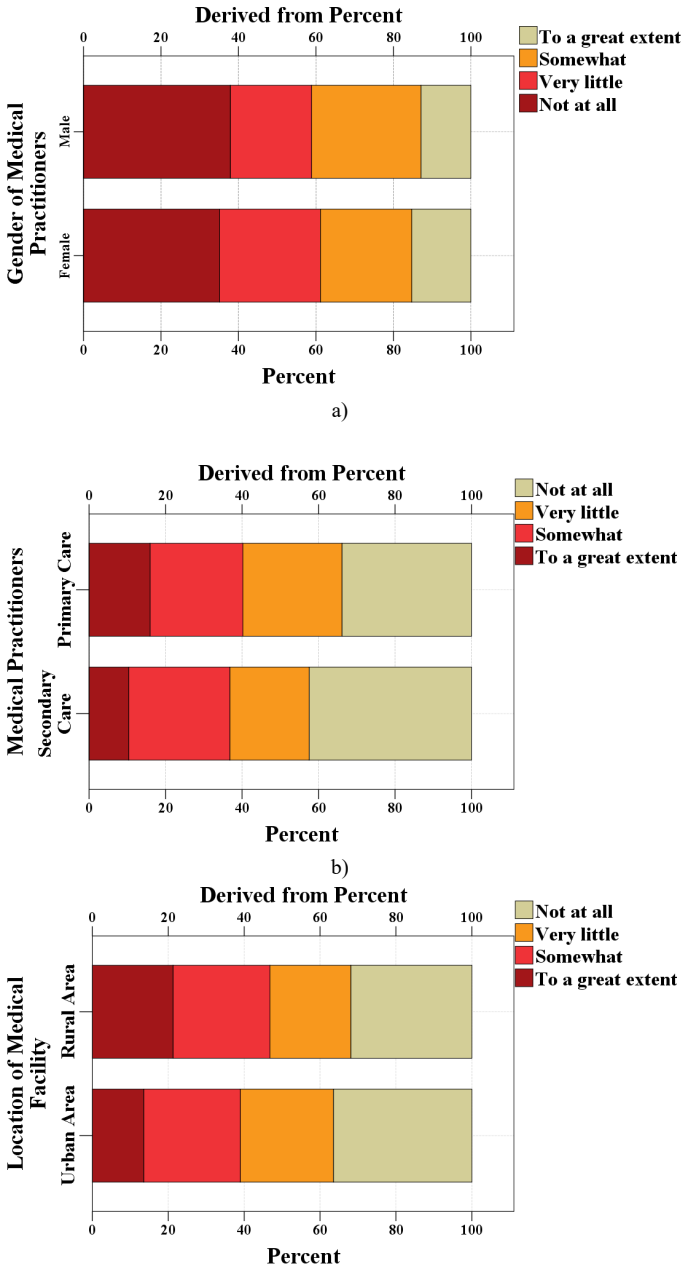

Figure 3: Various privacy and security measures in relation to protecting patients' sensitive medical data presented by a) Practitioners' gender; b) Distribution within the healthcare sectors; and c) Location of their medical facility

A crosstabulation between the variables presented various security measures to safeguard the patients' sensitive medical data stored in the system and often receives technical support and assistance when encountering technical difficulties while working in the system is presented in Table 5. A greater number of the medical practitioners than anticipated did not receive any assistance or support from the medical authorities, nor were they informed of the numerous privacy and security procedures

implemented to safeguard patients' private medical information. The number of medical practitioners who occasionally, frequently, and consistently received assistance and support from the medical authorities was lower than anticipated. Additionally, there was a complete lack of introduction of security protocols regarding the safeguarding of patients' sensitive medical data.

Table 5: Crosstabulation of the variables Often receive assistance and technical support from the medical authorities and Presented with various privacy and security measures

Frequently got assistance or technical support from the medical authorities when faced with technical difficulties		Presented with different privacy and security measures to safeguard the patients' sensitive medical data stored in the eHealth system				
		Not at all	Very little	Somewhat	To a great extent	Total
Never	Count	32	12	6	9	59
	Expected Count	21,2	14,4	15,1	8,3	59,0
Rarely	Count	39	28	23	6	96
	Expected Count	34,5	23,5	24,5	13,5	96,0
Sometimes	Count	28	25	30	7	90
	Expected Count	32,4	22,0	23,0	12,6	90,0
Very often	Count	18	20	24	11	73
	Expected Count	26,3	17,8	18,7	10,2	73,0
Always	Count	14	4	10	18	46
	Expected Count	16,6	11,2	11,8	6,4	46,0
Total	Count	131	89	93	51	364
	Expected Count	131,0	89,0	93,0	51,0	364,0

Certain medical practitioners were somewhat introduced with different security and privacy preferences taken in regard to protecting the patients' sensitive data, however, they never, rarely, or always received any aid and support from the medical authorities when was required. There were more medical practitioners who sometimes and frequently got assistance and support from the medical authorities than expected. They were somewhat introduced to different privacy and security measures that were taken in relation to protecting the sensitive patients' data.

There were certain medical practitioners who rarely and sometimes received assistance and support from the medical authorities than to be expected, that to a great extent were introduced to different privacy and security measures taken in relation to protecting the sensitive patients' medical data. There were more medical practitioners who never, frequently, and always received assistance and support from the medical authorities than to be expected, that to a great extent were introduced with different privacy and security measures taken in relation to protecting the sensitive patients' medical data.

There was a statistically significant difference (X^2=53,194, p=0,000) between the opinions that introduction to different privacy and security measures to safeguard the sensitive medical data of the patients and often received assistance and support from the medical authorities. Since the p-value in this instance was less than the alpha standard value of 0,05, the null hypothesis, which stated that the two variables were independent of each other was rejected. The data indicates that the variables' introduction to different privacy and security measures for the protection of the sensitive data of the patients and frequently receiving assistance and support from the medical authorities were related to one another. The effect of this association was almost moderate (0,221), meaning that the assistance provided by the medical authorities may have had some role in the way in which the medical practitioners answered the given questions. The remaining variables, such as age group, marital status, location of the medical facility, education, gender, employment history, etc., did not reveal any significance of impact on the opinions of the medical practitioners.

4. Discussion

The in-depth interviews and online surveys were the two main research methodologies used in this study to examine the difficulties and concerns related to privacy and security when handling the sensitive information of the patients. The fact that a wide range of medical practitioners with different specialties (Table 3) offered their opinions on the use of the eHealth information system enhanced the level of quality and importance of this research. The government and medical authorities have the responsibility of authorizing the adoption of these eHealth systems without giving any thought to the security integrity of the private medical data of the patients [38]. For comparable eHealth information systems in other developing nations, this study would likewise present relevant data and support the government leaders and medical authorities.

This study was carried out among primary and secondary care practitioners (Table 3) to find out what they thought of the privacy and security features of the system, what was lacking, and what features and services should be enhanced to provide patients with better treatment. The answers to the survey revealed that the experiences of the medical practitioners with the security measures implemented by the medical authorities varied greatly. A significant portion of the survey participants, who believed that the different privacy and security measures were not sufficiently introduced and presented to them, emphasized the needs for improving the awareness and training programs to be initiated more frequently (Table 4). By filling in these knowledge gaps with different training and seminars, the healthcare authorities should ensure that the medical practitioners have the skills required to safeguard and protect the patient's sensitive data and respect the privacy and protection legislation [39].

Data interoperability requirements and protecting the privacy and security of sensitive patient medical data are potential challenges when working with external documents associated with

medical data exchange between primary and secondary care. It may be challenging to integrate the patients' medical data records or other healthcare-related documents into the broader eHealth system since they may be kept in several external systems at various locations. To address this challenge and issue with interoperability, appropriate funding is required for collaboration with external systems and data integration technologies to ensure operational sharing of medical sensitive data. As was already indicated, an additional difficulty was guaranteeing the privacy and security of the patient's medical data because, the system holds the personal data of the patients, such as their insurance information and medical history. Considering this, these various healthcare systems need to implement the necessary safeguards to protect sensitive data from unauthorized access and cyber threats [23].

As an example, across the user experience of patients, medical practitioners, and other end-users may have greatly impacted to the integration of privacy and security measures in the national eHealth information systems. From one perspective, robust security and privacy measures may enhance the trust in the healthcare system and the end-user confidence by providing reassurance that their private medical information is being shielded from unwanted access, disclosure, and use. This would improve the overall user experience as they would be more likely to feel content and at ease in using the eHealth system and its features. On the other hand, inadequate privacy and security measures may lead to unfavorable user experiences because the end-users could be concerned that their private medical information which must remain confidential with implemented safeguards may be compromised or that too strict safety measures would make it impossible for them to access or share their data. This could cause distrust, annoyance, and a reluctance to utilize the eHealth information system [23, 39].

The Law on Health Protection includes regulations for the security of patient data specifically for the healthcare industry. Because of this, the health data is regarded as sensitive information and is given extra protection under Macedonian law. However, there may be several obstacles to effectively implementing and enforcing these regulations and laws in day-to-day life, not just in N. Macedonia, but in any other country. The Macedonian healthcare practitioners must understand their responsibilities under the data privacy laws and take the appropriate safety measures to safeguard the patient's sensitive medical data. The EU has regulations in place to protect individuals' rights when it comes to the gathering and usage of personal sensitive data. These regulations include the General Data Protection Regulation (GDPR) and the Directive on the Protection of Individuals concerning the processing of personal data by adequate authorities, both of which have as their main objectives the prevention, investigation, detection, prosecution, or the implementation of penalties for criminal offenses. For these reasons, all nations, especially N. Macedonia, must ensure that the right policies are implemented to safeguard the rights of the population and that they always remember the ethical principles when handling medical data It meant guarantee that the data was being collected and used openly, that sufficient organizational and technical security measures were being put in place, and that people's consent was being appropriately requested. To ensure that people are not treated unfairly in light of the findings of big data analysis, it was also crucial to address concerns of prejudice and discrimination when analyzing the medical data [29, 30, 31, 32].

This study also assessed the perceptions of medical practitioners on the functionality of the eHealth information system. This was crucial since system updates could enhance both the user experience and the overall security of the system (Table 4). By concentrating on the precise areas where the medical practitioners believe that improvements are necessary, the IT staff can focus their efforts on resolving these issues and with that offering better security measures.

This research adds to the amount of knowledge already available on privacy and security issues in healthcare systems especially in medical information systems. It aligns with the increased focus on patient privacy, data security, and compliance with legal frameworks such as the GDPR and the Health Insurance Portability and Accountability Act (HIPPA). Enhancing the security and privacy of eHealth systems is imperative, so it's crucial to identify useful insights the parties involved may apply to improve eHealth systems [40].

This study has its limitations because it concentrated on the use of the "Moj Termin" eHealth information system that is currently in use in N. Macedonia. Second, there was a lack of a straightforward open discussion between the interviewer and the participants because the in-depth interviews were conducted remotely via e-mail. Thirdly, the online survey sample utilized in this study was restricted to only Macedonian healthcare professionals working in primary and secondary healthcare level, as such, it may not accurately reflect the majority of medical practitioners both inside and outside the nation. Thus, more research is required to examine the boundaries of the various eHealth systems in use in other more developed countries, as well as to find out what many relevant medical and technical professionals think about the issue at hand, which directions should be pursued, and how to provide further upgrades for the eHealth systems to develop properly.

5. Conclusion

The study's findings demonstrate the urgent need for better security and privacy safeguards when medical practitioners utilize the eHealth systems. The healthcare authorities and IT companies must act quickly in response to the recognized difficulties with the eHealth systems, the lack of expertise and knowledge of the current security and privacy standards. By resolving these issues, medical practitioners' confidence in the security of protecting private patient information could be increased. This will eventually aid in the successful integration of the eHealth system technology into the delivery of overall healthcare.

Integrating privacy and security safeguards into the national healthcare and medical information systems may have a substantial impact on how patients, medical practitioners, and other end-users interact with the system. Users would therefore likely feel more satisfied and comfortable utilizing the eHealth information system and its features, which would enhance the user experience. Inadequate privacy and security measures, however, may have the opposite negative effect. End-users may worry that their personal medical data won't be secure, that the security measures in place will be compromised, or that they won't be able

to access or share their data easily because of overly strict regulations and security measures. This could cause mistrust, reluctance, and annoyance to utilize the eHealth system. In consideration of this, integrating sufficient security and privacy features into the system would be essential to maintaining the confidence of the patients. It's also essential to implement this under the relevant regulations. Privacy and security measures should be included in the design and implementation of eHealth systems in a way that creates a balance between the need for data protection, usability and accessibility. The following are some suggestions for a user-centered integration of security and privacy safeguards into national medical information systems, as well as for presenting these ideas as a kind of implementation roadmap: Start a user research project and utilize the results to assist the medical organization in better understanding the user requirements, expectations, and preferences regarding privacy and security safeguards that are in line with those demands; Healthcare organization should involve the users in the design process of privacy and security measures. Through user testing and other feedback sessions, they can ensure that the implemented measures are clear, in line with expectations and requirements, and easy to use; Provide users with accurate and transparent information about the privacy and security safeguards implemented through data usage agreements and privacy policies. This would increase users' trust in the system and increase their level of satisfaction in general; User-friendly authentication techniques, like single log-in or biometric authentication, to provide users with easier, secure system access; and finally, monitor and assess the effectiveness of the privacy and security safeguards that have been put in place to make any necessary adjustments along the road to ensure that they continue to fulfill the requirements and expectations of the end-users.

Conflict of Interest

The authors declare no conflict of interest.

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Buton Rock Asphalt Paving Block Innovation using Waste Engine Oil and Recycled Concrete Aggregate

Sigit Pranowo Hadiwardoyo[1,*], Riana Herlina Lumingkewas[2], Tommy Iduwin[1], Silvanus Nohan Rudrokasworo[1], Darren Matthew[1]

[1]*Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok, 16424, Indonesia*

[2]*Civil Engineering Study Program, Institute Teknologi Indonesia, Tangerang Selatan, 15314, Indonesia*

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ABSTRACT

Road surface coating using concrete paving block cement has been used for a long time. As an aggregate binding agent, asphalt can be made into paving blocks. Utilizing waste in the recycling process is an activity to control the sustainability of natural resources. Waste Engine Oil and Recycled Concrete Aggregate can be used as road pavement materials to reduce the use of new materials. Buton Rock Asphalt is natural asphalt in the form of hard asphalt granules and certain minerals that can be softened by waste engine oil with a content of 15% to increase penetration. The contribution of rock asphalt and used engine oil reduces the use of new asphalt by 67.33%. Furthermore, using recycled concrete aggregate by 24% can reduce the need for new aggregate. The innovation of asphalt paving block fabrication using a Hand-stimulus compactor with Marshall test control has demonstrated suitable performance as a structural material for road pavement. Using a modified rock asphalt mixture as paving blocks reduces construction costs because it does not require heavy equipment. This innovation is only for light to medium-traffic vehicle loads. Laboratory test results show that it is sufficient for this type of traffic.

1. Introduction

The choice of surface layer type on the road pavement structure is adjusted to the road's intended function of serving traffic volumes during its service life. Other problems are excessive axle load, large-scale vehicles, and side channel damage. These problems cause severe damage to most of the road pavement, and the pavement will likely be repaired.

Paving block material can be used as a road surface for low-traffic or medium-traffic, depending on the height of the paving blocks used. The problem in maintaining road surfaces is resurfacing due to increased load on road surfaces, especially on urban roads. Using concrete paving blocks can improve durability, reduce maintenance requirements, and provide pleasing aesthetics for consumers [1]. Road surface maintenance and dismantling work using paving blocks does not require heavy equipment, which can save costs. This material is widely used on residential roads, driveway access roads, sidewalks, garages, and parking lots. In general, the material size is in the form of blocks measuring 200-100-60 mm consisting of crushed stone, stone ash, sand, cement, and water. This material is a precast product produced in a factory, so it provides good dimensional consistency and accuracy in concrete paving blocks [2]. This pavement has become an attractive engineering and economical alternative to flexible asphalt and cement concrete rigid pavement due to its easy and fast placement, ease of maintenance and removal, resistance to movement and damage, durability, and aesthetic surface [3]. Block paving is used worldwide primarily for its resistance to movement, damage, and aesthetic surface. These features result in longer pavement life, reduced maintenance costs, extended replacement cycles, and reduced raw material usage. In addition, block paving eliminates rainwater runoff and saves land, can be produced using local materials and labor, and is recycled [4].

The increasing demand for paving blocks as a construction material has increased the need for cement [5]. The demand for cement as a building material is also in other buildings, so efforts are needed to find alternative solutions without harming durability and other physical characteristics. The cement production process significantly negatively impacts the environment due to producing carbon dioxide emissions [6].

Another building construction material requirement that requires savings is aggregate. Restrictions on stone mining from

*Sigit Pranowo Hadiwardoyo, Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, sigit@eng.ui.ac.id

a quarry are intended to preserve the environment. Therefore, the agency can use recycling methods to meet the needs of building materials, such as aggregate materials. The need for aggregate to form cement concrete and asphalt concrete requires around 60-75% of the concrete volume, and natural resources cannot be produced shortly.

Research on recycled concrete aggregate (RCA) as a substitute for natural aggregate is continuing, even though RCA has different properties from natural aggregate (NA). In RCA, there is mortar that sticks to the aggregate. As a result, water absorption in RCA was higher than in NA and had a lower work capacity [6] [7]. This absorption is a consequence of the cement mortar adhering to the surface. Higher absorption reduces the amount of water available to combine with the cement; this hurts the mechanical properties of RCA, among other disadvantages [8]. However, the use of RCA with certain technologies is something that promises to reduce the environmental impact of the construction sector and preserve natural resources.

RCA can be processed from several types of concrete waste, such as substantial waste from batching plants, building construction demolition waste, etc. Somebody can apply this waste to engineering or building infrastructure as some components have a high resource value and have previously proven technical sustainability of recycled concrete. Recycling technologies have been developed in road pavements to limit the use of new natural aggregates. Reducing concrete waste can reduce the need for landfills for construction waste, where aggregate is the main component of concrete waste, the most significant construction waste [9]. Waste concrete is original concrete from construction, made by separating mortar from stone, which can be reused. One of the main reasons for using RCA in road pavement is to complete construction work in a more environmentally friendly manner. On a global scale, the construction sector contributes to waste, which increases yearly. Therefore, the construction sector can significantly reduce the amount of concrete waste by using aggregate waste as a road pavement mixture [10]. RCA shape variation will occur during mix preparation due to the bonding mortar.

The paving block forming material can be used as an asphalt binder to substitute Portland cement. This method is an alternative for reducing cement demand, even though using asphalt still hurts carbon emissions from the asphalt heating process at a specific temperature. Depending on availability, asphalt can be used as an aggregate binding material to form paving blocks. A choice of asphalt types is available, including oil asphalt and rock asphalt. There are many types of natural asphalt (mainly rock and lake asphalt). One kind of rock asphalt in the form of natural rock asphalt deposits on Buton Island, Indonesia, has been widely used in recent years [11–13]. Buton Rock Asphalt (BRA) contains large reserves of natural rock asphalt with an average asphalt content of 20% [14].

Natural rock asphalt is formed from a process that combines heat, pressure, oxidation, catalysts, and bacteria after hundreds of millions of years of geological changes in rock fractures [15]. As an additional material, BRA effectively increases the temperature sensitivity of the asphalt. Increasing the BRA content decreases the penetration value gradually while the soft point of asphalt gradually increases. By adding BRA to new asphalt, the ductility value decreases rapidly. Meanwhile, the rheological properties of BRA at high temperatures have a positive modifying effect; on the contrary, it hurts crack resistance at low temperatures [16]. In BRA, there is ash content, which can improve the behavior of oil asphalt at high temperatures and has the best modification effect with a significant specific surface area. The optimal modification effect on the recommended particle size is 200 mesh [17]. Adding Rock Asphalt (RA) can significantly improve the performance of petroleum asphalt binder at high temperatures. More details show that higher RA dosage results in better high-temperature performance and shows little adverse effect on the performance of binder and asphalt mixture at low temperatures [18]. Resistance to wheel groove deformation of asphalt mixed with rock asphalt (RA) increases with increasing dosage. However, the effect of BRA dose on variations in groove resistance is smaller than the resistance to water impact and high temperatures [19]. BRA is an excellent modifier due to its low cost and excellent compatibility with petroleum asphalt because BRA and petroleum asphalt are both petroleum derivatives. Many studies have verified the remarkable effects of RA as a modifier in improving the strength, high-temperature stability, aging resistance, and weather resistance of asphalt pavements [20,21]. The BRA-modified asphalt mixture has a much higher durability modulus. The influence of temperature, service time, traffic volume, and loading time on the resistance modulus shows that BRA-modified asphalt mixtures have better performance on these factors than unmodified asphalt mixtures [22]. One of the waste oils that is reused as a rejuvenation material in the road asphalt industry is WEO. This used oil can reduce the viscosity of old asphalt and increase the potency of the asphalt mixture. Using 15% waste engine oil (WEO) as a BRA softener increases BRA utilization. It reduces the use of pure asphalt (oil asphalt) up to 32% of the total weight of BRA-modified asphalt at penetration 60. The study results show that this method can increase BRA utilization and reduce the need for petroleum asphalt [23].

The composition of WEO is very complex, but most of its chemical compounds are low-weight components, such as aromatic solvents, paraffin oils, and polyolefin oils, similar to aromatics in asphalt [24]. Reusing used oil as a rejuvenation material in the road pavement industry can help reduce the amount of used oil waste that becomes B3 waste. This waste is used as a softener or rejuvenator for old asphalt by curing for 24 hours with a certain percentage until the properties of the old asphalt approach those of the new asphalt, especially at the planned penetration value [25]. Previous research found that adding waste oil can increase penetration value, decrease softening point, and decrease ductility and asphalt viscosity, thereby reducing the production temperature and compaction of the asphalt mixture [26–29]. Similar observations have been made on the softening and elasticity properties, so using 50% aged asphalt is relatively helpful in restoring the physical properties [30]. The results show that all types of waste oil can increase anti-aging properties. Because motor oil and asphalt binder are products of petroleum refining, some contractors have investigated blending used motor oil as a potential binder replacement or rejuvenator when joining reclaimed asphalt pavements [31]. Used oil can improve the performance of old asphalt by adding lightweight components. And as a modifier, the influence of WEO on the performance of

various types of asphalt is receiving increasing attention. However, there are drawbacks to using WEO in asphalt mixtures. Some disadvantages are that the viscosity of the used oil is relatively high, causing uneven distribution of the asphalt mixture. In addition, using this softening agent causes a decrease in the elastic properties of asphalt and groove resistance [32].

The main objective of this research is to conduct a study on the design of asphalt paving blocks using BRA, waste concrete aggregate, and waste engine oil. This waste material utilization research aims to determine the combination of aggregate waste utilization in BRA and RCA by including WEO as a softening agent for BRA asphalt. In this way, savings are obtained from the use of new materials. This recycled material is processed to achieve aggregate asphalt mixture performance at certain specifications. The development of waste utilization in this research still refers to previous research by optimizing the performance of the remaining material. Thus, using materials in this way can contribute more to environmental sustainability.

2. Materials

2.1. Asphalt Binder

The asphalt binder in this study consisted of Pen 60/70 quality oil asphalt in the form of new asphalt called fresh asphalt, added with asphalt extracted from Buton Rock Asphalt (BRA). Conventional property tests have been carried out on both types of asphalt; namely, the 25 °C penetration test (ASTM D5) shows the asphalt's consistency in deformation resistance at a temperature of 25 °C. The ductility test (ASTM D113) states the ability of asphalt to deform plastic before it reaches failure. The softening point test (ASTM D36) indicates resistance to high temperatures. The viscosity test (ASTM D4402) shows that material viscosity is related to the ease of mixing the asphalt aggregate at a specific temperature. Asphalt changes its properties when used as a binder. Penetration and ductility values will decrease significantly.

Meanwhile, the soft point value will increase as the time of use increases. These changes are a mechanism for asphalt to achieve the aging process. Therefore, old asphalt will lose its aromatic content and increase the asphaltene content. Generally, asphalt with a low asphaltene content is susceptible and flexible to high temperatures. The properties of BRA are like the properties of old asphalt. The test results can be seen in Table 1.

2.2. Waste engine oil.

The WEO used is often found in car maintenance workshops. This research took material from three car service workshop locations, two of which have the same characteristics. From this place, brownish-black WEO was obtained. The viscosity value at 25 °C is 121-126 cP. WEO is a softening agent for BRA asphalt because BRA granules are stone and have low penetration. Figure 1 shows the change in BRA penetration value by adding WEO. By adding 15% WEO, a penetration value of 60 can be achieved. Furthermore, the BRA that WEO has softened is called Modified BRA.

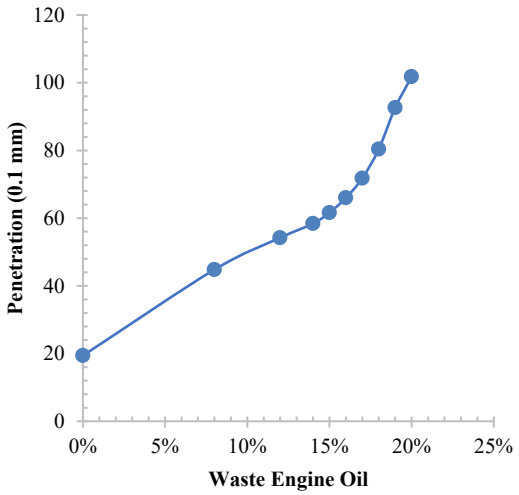


Figure 1: Changes in BRA asphalt penetration values with the addition of WEO

2.3. Aggregate

In this research, three types of aggregate were used; the first was an asphalt concrete mixture using asphalt and a new aggregate. Meanwhile, the second is an asphalt concrete mixture with the addition of BRA. The third type is a mixture of new aggregate, asphalt, BRA, and concrete waste aggregate. It can be a combination of the three types of aggregate with the composition of BRA (13%), RCA (24%), and new aggregate (63%).

The aggregate composition is obtained according to the plan specifications (Figure 2).

Table 1: New Asphalt Pen 60/70 Characteristics.

No.	Type of Testing	Testing Method	Unit	New Asphalt	BRA
1	Penetration at 25 °C	ASTM D-5	0.1 mm	68.2	11.4
2	Softening Point	ASTM-D36	°C	48.3	75.3
3	Flash Point	ASTM D-92	°C	281.4	273.3
4	Ductility at 25 °C	ASTM-D113	cm	102.7	5.43
5	Specific Gravity at 25 °C	ASTM-D70	gr/cm^3	1.07	1.42

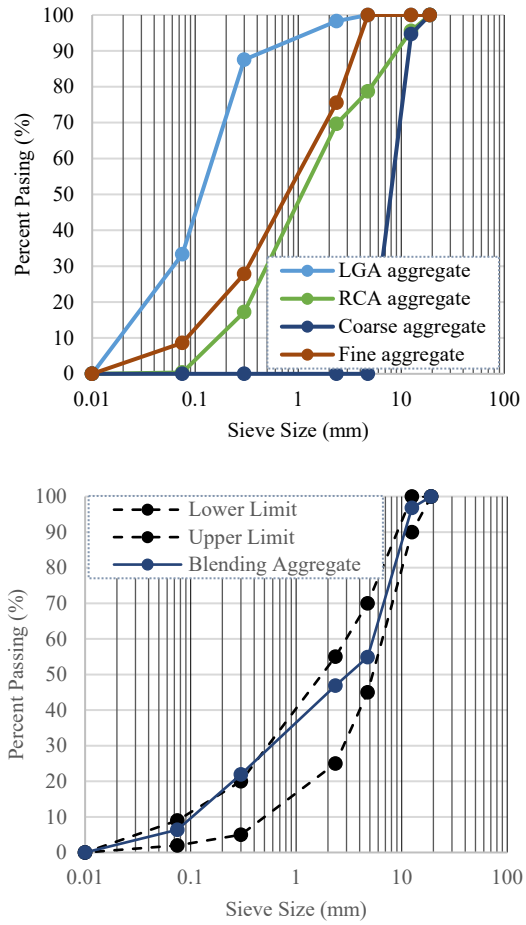


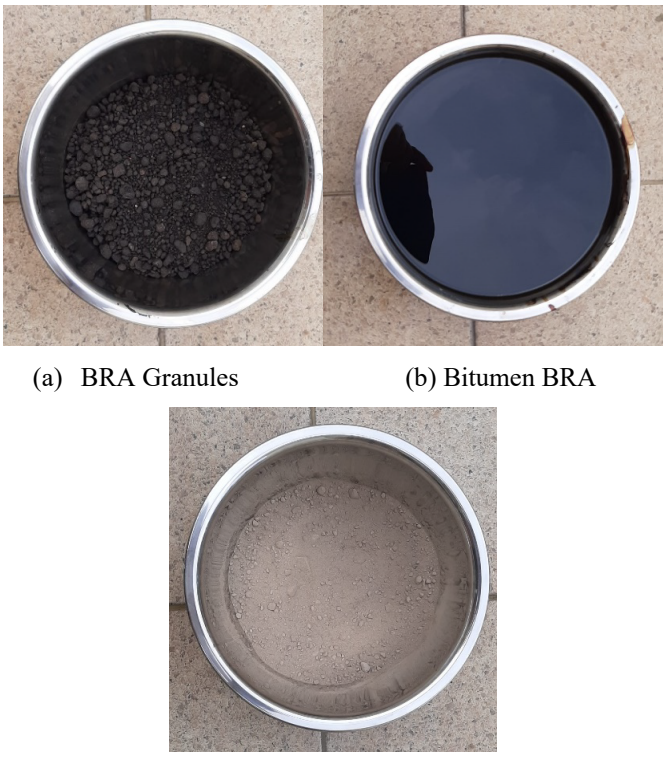
Figure 2: Blending aggregate.

2.4. New Aggregate (NA)

As an asphalt material, BRA has an additional influence on preparing new aggregate. This effect is caused by the fine-grained material contained in BRA. Inspection of aggregates, including fine BRA material, is carried out. The new aggregate is obtained from a stone-crushing company. Testing of aggregate physical properties includes gradation tests passing through a sieve, Los Angeles tests, and specific gravity tests. New aggregate is added to the recycling process to replace changes in aggregate of a particular size due to vehicle loading during service life.

2.5. BRA Extraction

In BRA, there is fine-grained material, and these refined grains can be used as fine aggregate. Before BRA is used as a hot or warm mix material, it is necessary to know the asphalt and fine mineral content. Asphalt and fine minerals are separated through an extraction process using a centrifuge extractor. The results of the extraction test from BRA material are used as a basis for calculations in preparing the asphalt content in the mixture, which is a combination of BRA asphalt and new asphalt, as well as the contribution of BRA mineral ash in the aggregate structure. The results of BRA asphalt extraction consist of BRA granules (a), BRA bitumen (b), and BRA fine granules (c), shown in Figure 3.



(a) BRA Granules (b) Bitumen BRA

(c) BRA fine granules

Figure 3: BRA (bitumen and aggregate) extraction

2.6. RCA

This research used RCA in the asphalt mixture to partially replace the new aggregate. The RCA content as a substitute for new aggregates is calculated based on the composition of the RCA aggregates, so there are limitations to specific amounts. Increasing the amount of RCA in the asphalt concrete mixture can increase the optimum asphalt content. RCA aggregate differs from natural aggregate because it consists of two materials: natural aggregate and embedded cement mortar. Cement mortar causes weaknesses in recycled aggregates, such as lower density and higher absorption, Los Angeles abrasion, and sulfate content [23].

Table 2: Aggregate characteristics.

No.	Type of Testing	Testing Method	Unit	New aggregate.	RCA aggregate
1	Specific Gravity	SNI 1970:2016	gram/cm^3	2.75	2.60
2	Absorption	SNI 1970:2016	%	1.58	1.84
3	Los Angeles abrasion	SNI 2417:2008	%	17.6	23.6

Using RCA particles requires preliminary examination to overcome the problem of the mortar's impact and increase the mixture's performance (especially resistance to moisture damage).

The RCA used in this research was obtained from the batching plant location. Before use, the RCA chunks are crushed with a stone crusher to separate the rock grains from their respective bonds. Next, the rock grains are washed to remove mortar from the surface. The washing process is carried out so that the aggregate does not contain dust or other fine materials. The characteristics of RCA aggregates are shown in Table 2 and Figure 4.

Figure 4: RCA granules before and after the washing process

3. Design Methodology

Asphalt Paving Block (APB) research uses Hot-Mix Asphalt (HMA) specifications for the Asphalt Concrete Wearing Coarse (ACWC) type as the asphalt concrete mixture in the APB. Three kinds of HMA materials are used in this research: a new aggregate asphalt mixture as a control for test results, two asphalt mixtures using BRA, and a third BRA asphalt mixture using recycled RCA aggregate. Preparing this research activity consists of several stages, as described in the flowchart in Figure 5.

From the identification of BRA characteristics, which consists of identifying BRA bitumen, it is separated from the refined grains using an extraction test. The bitumen content of each BRA quarry can vary; in this research, BRA was obtained from the Lawelle location. Another identification of WEO is its viscosity value. Next, the low penetration BRA is softened using WEO. Aggregate identification begins by breaking up Cement Concrete Waste (CCW) to separate the mortar from the aggregate. The user washed the RCA aggregate and the sieve analysis test to determine the composition of the aggregate. Next, the RCA aggregate, new aggregate, and Ash-BRA are mixed with a specific composition based on sieve analysis to meet the technical specifications of Asphalt Concrete Wearing Coarse (ACWC). RCA reduces the use of new aggregate in this asphalt concrete mixture.

The final stage is the formation of this modified BRA asphalt concrete mixture into an APB in specific dimensions, and then tests are carried out to determine its performance.

ACWC-BRA modified hot mixture is carried out by compaction process using a Stemper Compactor in a rectangular mold with a density level equal to the density in the Marshall test. The results of this compaction are tested using two types of tests: the Marshall Standard and the Three-Point Bending tests. Figure 6 shows the test method in this research, where the Marshall sample is obtained from a core drill sample while the three-point bending sample is obtained by cutting the sample. Marshall Stability, flow, and Flexural Stress values measure APB performance.

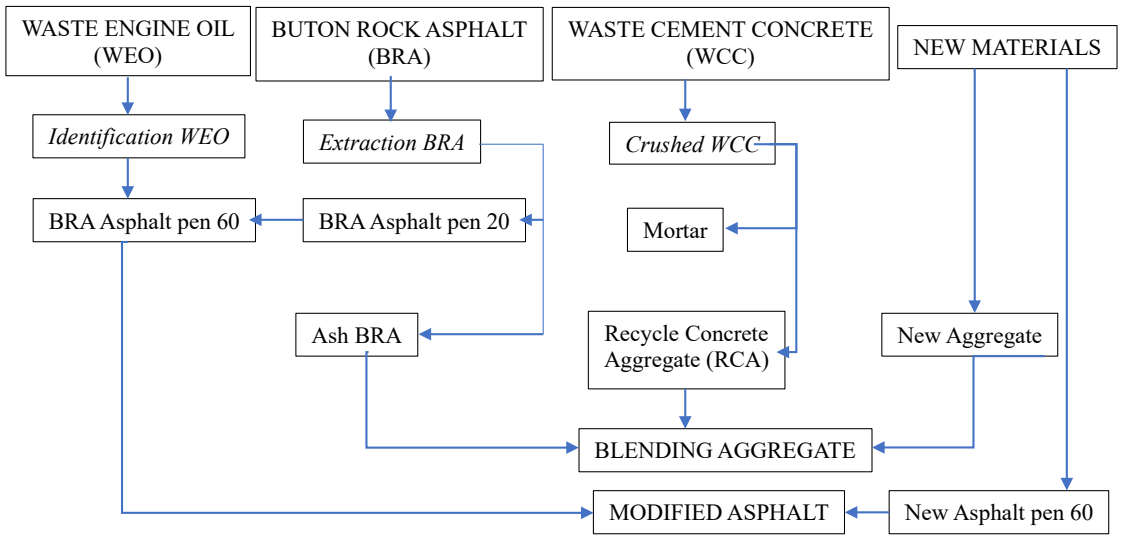


Figure 5: Design Methodology-1

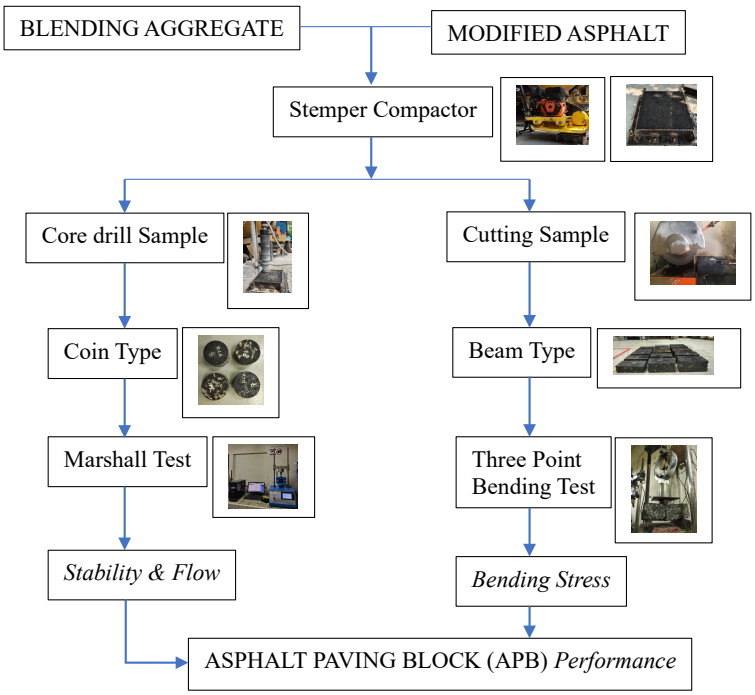


Figure 6: Design Methodology-2

3.1. Viscosity

The results of the asphalt viscosity test are used to determine the ease of mixing and compacting the asphalt aggregate mixture. The viscosity of the mixture of BRA asphalt binder and WEO softener was tested using a Brookfield viscometer according to ASTM D4402 specifications, the amount of torque required to maintain the spindle (62) at a constant speed of 50 revolutions per minute. The viscosity of the entire mixture was also measured at temperatures of 100°C to 160°C. Viscosity testing was carried out on the three types of asphalt, and the results are shown in Figure 7.

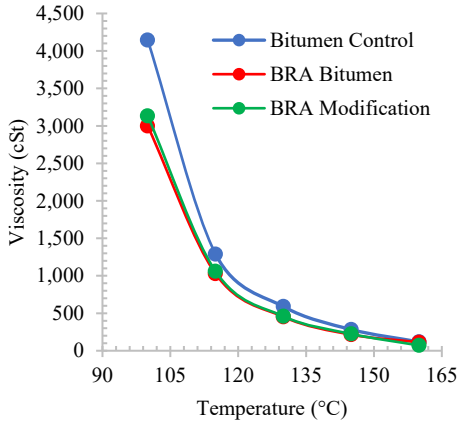


Figure 7: Viscosity test results against temperature changes

This picture shows that the viscosity value of BRA asphalt modified with WEO has increased compared to that of BRA asphalt without WEO. In forming the ACWC mixture, a viscosity value of 280 Cts is required in the compaction process and 170 Cts in the mixing heating process. In this research, the control ACWC required heating the mixture at a temperature of 151 °C and a compaction temperature of 141 °C, while the Modified ACWC BRA required a lower temperature, namely 145 °C for heating and 136 °C for the compaction process. Thus, the use of Modified BRA reduces temperature requirements by 5 °C. This reduction impacts energy savings, although the reduction is still tiny.

3.2. Asphalt-aggregate mixing.

Material preparation starts with washing the RCA aggregate and softening the BRA with used engine oil by placing both in a closed bag for 24 hours. Hot asphalt mixture consists of 3 types: coarse aggregate, medium aggregate, and fine aggregate. The percentage of each type of aggregate is determined based on the results of the aggregate mixing analysis, as shown in Figure 2. Meanwhile, the composition of new asphalt and BRA asphalt is determined based on an analysis of achieving optimum asphalt content. This research was conducted to assess the effect of using BRA and RCA to optimize the use of natural and waste materials, so the percentage of RCA used is quite large.

Next, the mixing process begins by heating the RCA and BRA materials, which have been soaked in used oil for 24 hours. Second, this aggregate is heated to 145 °C, and new pen grade 60/70 asphalt is heated to up to 140 °C and then poured into the BRA+RCA aggregate asphalt mixture. Using RCA requires precise calculations as HMA material for ACWC NA and BRA+WEO materials.

3.3. Asphalt paving block process.

The BRA-Modified APB is compacted using a Hand-Stemper motor with the resulting density level equivalent to compaction in

the Marshall test sample compaction process (Figure 8). The volume of the hot mix asphalt aggregate mixture is calculated from the Marshall density value. This asphalt concrete mixture is divided into three compaction layers to achieve a uniform density level. The compaction temperature is determined as in the Marshall test sample compaction process based on the viscosity value of BRA-Modified asphalt.

Figure 8: Compaction process for forming APB

Cutting the HMA-ACWC mixture into APB form is carried out after the sample temperature drops to 26 °C by opening the mold lock. The APB sample is formed with a width of 100 mm and a length of 200 mm, while there are three types of APB height, namely 60 mm, 80 mm, and 100 mm (Figure 9). The APB height is designed to match the height of the mold with different volumes, but the target is to achieve the same density so that the time and amount of compaction are additional for each thickness size.

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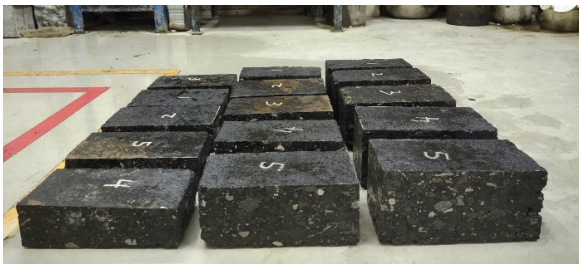


Figure 9: APB thickness sizes are 60 mm, 80 mm, and 100 mm

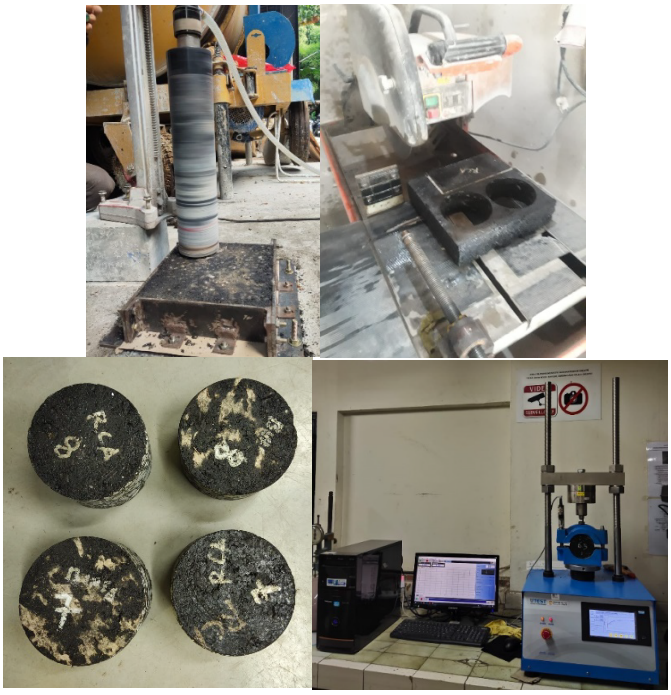


Figure 10: Molding of Marshall test samples from APB samples

Table 3: Marshall Test Results by Compaction Standard

No. Sample	VIM (%)	VMA (%)	VFA (%)	Marshall Stability (kg/cm^2)	Flow (mm)	Density (kg/cm^3)
1	5.93	22.52	73.69	830.52	3.75	2.14
2	6.46	22.97	71.85	773.18	3.85	2.14
3	5.90	22.50	73.78	846.86	3.80	2.18
4	4.22	21.12	80.02	859.33	3.85	2.24
5	4.76	21.57	77.91	858.01	3.90	2.25
Average	5.45	22.13	75.45	833.58	3.83	2.19

Marshal Standard and Immersion tests were carried out in this paving block research, where the specimens were obtained using core drilling in a compactor mold, as in Figure 10. The Marshall test was carried out to control the strength of the asphalt aggregate mixture in the form of paving blocks.

3.4. Marshall Standard and Immersion test

Marshall testing has two test methods in this research, namely standard Marshall testing and immersion Marshall testing. The two tests are differentiated by the time the test object is immersed in a water bath. The standard Marshall test takes ±30 minutes to

soak the test object at a temperature of 60°C, while the Marshall immersion test is carried out for ±24 hours.

The Marshall test results can be obtained from samples from the Marshall test mold (Table 3) and core drill samples from Hand-Stamper compaction (Table 4). Both tests show suitability for determining the Marshall stability value in the APB aggregate asphalt mixture; the stamper compaction method, core drill sample, and Marshall Standard and Immersion tests were carried out.

3.5. Bending Test

The bending test, also known as the bending test, is one of the essential methods in the field of materials mechanics. This test is carried out to evaluate the ability of a material to withstand bending loads until deformation or cracking occurs. APB performance measurements were performed using compression tests on two supports to determine the flexibility value. The bending test (Figure 11) is essential for APB because the aggregate binder for this material is asphalt, which has a flexibility value, so to achieve specific performance, it is necessary to measure the level of flexibility. Table 5 shows the bending test results of samples with different thicknesses, namely 6 cm, 8 cm, and 10 cm.

Figure 11: Bending Test

Table 4: Marshall Test Results by Hand-Stemper Compactor

No. Sample	VIM (%)	VMA (%)	VFA (%)	Marshall Stability (kg/cm^2)	Flow (mm)	Density (kg/cm^3)
1	3.00	19.16	84.32	693.40	3.64	2.04
2	2.65	18.87	85.95	874.91	3.31	2.08
3	3.95	20.85	81.07	827.15	3.41	2.06
4	2.74	19.85	86.18	831.07	3.39	2.07
5	2.62	19.75	86.74	798.37	3.51	2.05
Average	2.99	19.70	84.85	804.98	3.45	2.06

Table 5: APB Bending Test results.

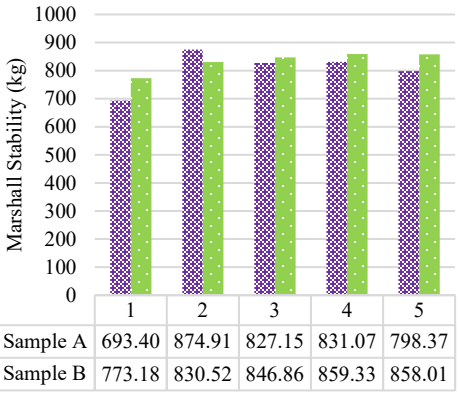
Thickness (cm)	6				
No. Sample	1	2	3	4	5
Density (kg/cm^3)	2.11	2.07	2.06	2.01	2.06
Flexural Strength (MPa)	8.04	6.89	6.89	5.74	6.89
Thickness (cm)	8				
No. Sample	1	2	3	4	5
Density (kg/cm^3)	2.00	1.94	2.01	1.96	1.96
Flexural Strength (MPa)	11.49	9.19	12.64	9.19	10.34
Thickness (cm)	10				
No. Sample	1	2	3	4	5
Density (kg/cm^3)	1.96	2.02	1.97	2.02	1.99
Flexural Strength (MPa)	16.08	20.68	16.08	20.68	18.38

4. Result and Discussion

Using RCA and BRA as BRA-Modified Asphalt Paving Blocks has shown reduced oil asphalt and aggregates as a program for utilizing rock asphalt and recycling cement concrete aggregates. Another study uses simple equipment in the APB-BRA-Modification formation process, so it is necessary to analyze it as described in this section.

4.1. Density evaluation of the Hand-Stemper machine

The BRA-Modified APB performance measurement in this study used the Marshall test. As shown in Figure 12, Sample A is compared with Marshal Standard compaction, and Sample B is compared with Hand-Stemper compaction in the APB printing process. From the five samples, the test results using the Marshall Standard compaction method and the Hand-Stemper compaction method showed differences. However, they were still small, so the five samples showed that the Marshall Stability values were close for the two compaction methods. This research can use this compaction method on this research using the Hand-Stemper can be used in the APB sample compaction process.



	1	2	3	4	5
Sample A	693.40	874.91	827.15	831.07	798.37
Sample B	773.18	830.52	846.86	859.33	858.01

Figure 12: Test results using Marshall and Hand-Stemper compactors.

4.2. Effect of RCA on volumetric characteristics of APB-BRA

Using RCA in APB mixtures can reduce the need for new aggregate. In this study, the amount of RCA reached 24% of the total aggregate demand. As shown in Figure 13, using RCA changes the VIM value to smaller when compared to APB without RCA. This condition also occurs for the VMA value, but the results are the opposite for the VFA value. Figure 14 shows that using RCA in APB increases the need for asphalt binder material. This increase can also be seen from the optimum asphalt content (OPC) value, where OPC without RCA is 7.5% while OPC with RCA is 8% of the total mixture.

4.3. Influence of RCA on Flexural Stress Values

Test measurements on road pavement from asphalt aggregate mixtures use the Marshall Standard and Immersion Test, but Concrete Paving block materials generally use the Compression Test. In this research, the properties of asphalt were used to determine the asphalt paving block material using the Bending Test.

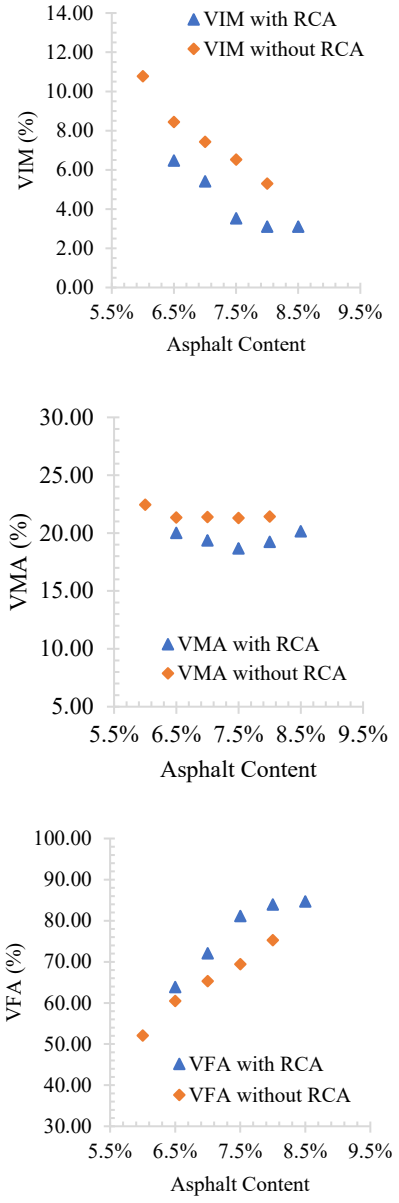


Figure 13: Volumetric characteristics of APB

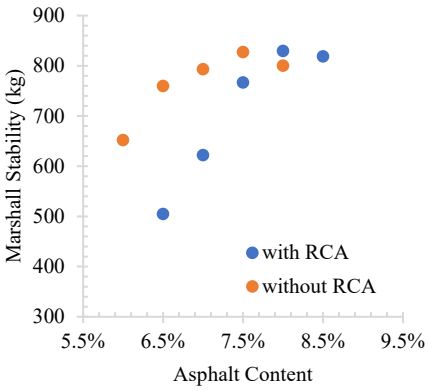


Figure 14: Marshall Stability and Asphalt Content

The effect of using RCA as a substitute for new aggregate material has shown an increase in flexural test values of 23.13% (figure 15). This increase is likely due to mortar in the RCA aggregate, which fills the voids in the aggregate.

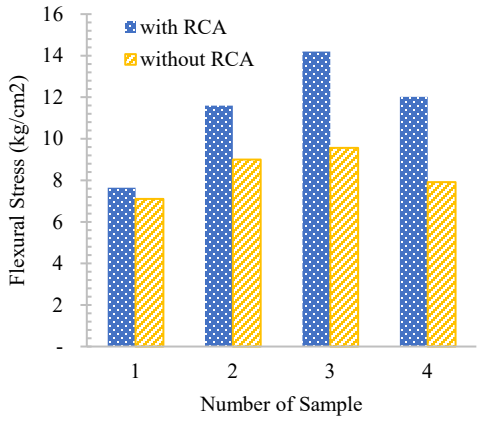


Figure 15: Effect of RCA on flexural strength values

4.4. Volumetric Characteristics of APB-BRA Optimum Asphalt Content

Changes in volumetric characteristics of the APB-BRA material from the influence of temperature and water are shown in Figure 16. The VIM value decreased from 6.06% to 5.28%; there was a decrease of 13%. Likewise, the VMA value decreased by 3%. On the other hand, there was an increase in the VFA value of 4%.

This change shows that the influence of water and soaking at a temperature of 60 °C for 24 hours has changed the volumetric value, decreasing the performance of the APB-BRA mixture.

The effect of water and immersion at a temperature of 60 °C reduces the bond between aggregates by the asphalt binder. This reduced ability of the asphalt binder causes the aggregate to be released from the asphalt, which is called stripping. This kind of process shows the vulnerability of the asphalt aggregate mixture to environmental conditions. This level of vulnerability is measured by comparing samples in submerged and dry conditions.

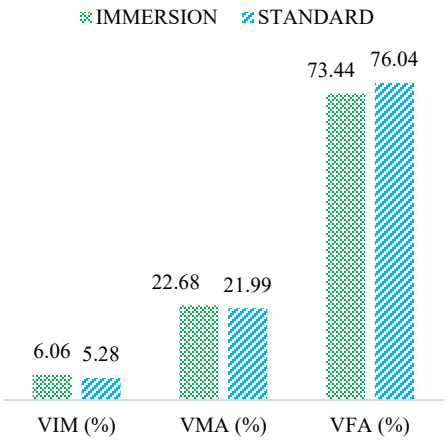


Figure 16: Influence temperature and water on Volumetric Characteristics

The Residue Stability Index (RSI) compares the Marshall stability (MS) value from the immersion test with the dry test. The vulnerability level of APB-BRA in conditions of Optimal Asphalt Content was measured using Standard Marshall and Marshall Immersion tests (Figure 17). The RSI value of 15 samples for this test shows a value of 71.32%. This value is relatively low, so it is still susceptible to the effects of temperature and water.

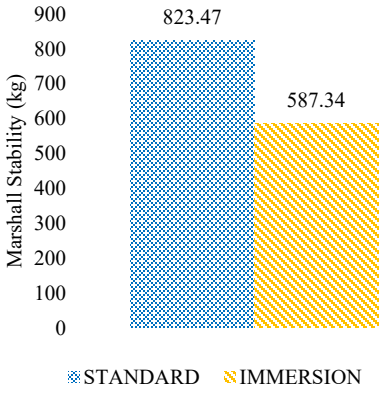


Figure 17: Marshal Standard and Immersion Test Results

4.5. Marshall Stability and Flexural Stress of APB-BRA

Paving Blocks generally use cement concrete, while APB uses asphalt concrete material. The flexible nature of asphalt makes it possible to determine the performance of APB using the Bending Stress test. The test assessed the performance of the asphalt concrete mixture using the Marshall Standard test with test objects with a circular surface and a thickness of 63.5 mm, with Marshall Stability test results. Meanwhile, testing for APB uses a beam with a surface size of 100 mm wide and 63 mm high, with Flexural Stress test results. Both types of testing use a sample density level of between 2.07 – 2.25 kg/cm^3, and the average Marshall test result is 774.56 kg, while for the Bending test, the average is 5.22 kg/cm^2.

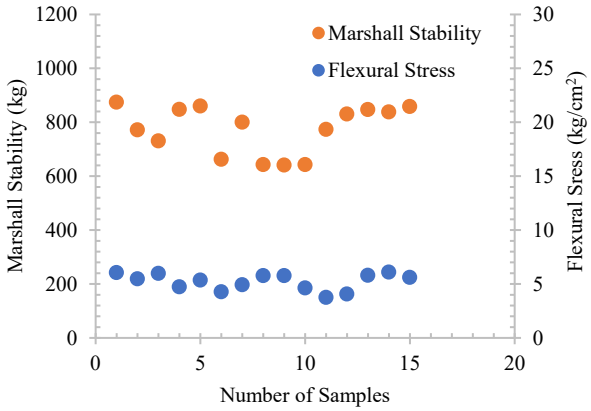


Figure 18: Marshall Standard test and APB-BRA Bending Stress test.

Figure 18 shows the results of the Marshall test and Bending test. Comparing these two test results can help determine targets for achieving APB performance and the performance of asphalt concrete mixtures as a surface layer on pavement structures, which is generally based on the Marshall Stability value.

4.6. Effect of Thickness of APB-BRA on Flexural Stress

In general, testing concrete paving blocks (CPB) using compression tests on paving blocks shows that the thicker the block sample, the decreases the compressive strength value [33]. A similar thing also happened with the flexural stress on APB, an increase in sample thickness showed a slightly reduced flexural stress value, as in Figure 19.

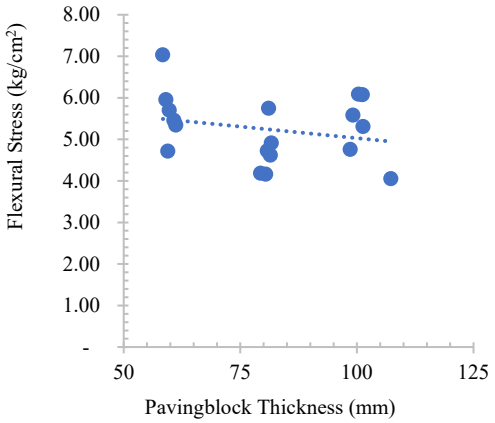


Figure 19: The effect of sample thickness on the Flexural Stress value

Conclusions

This research aims to use RCA to reduce new aggregates and BRA to minimize the use of petroleum asphalt with WEO softener material. This environmental preservation concept is applied to paving blocks as a material for forming road surfaces. In contrast, the Modified APB-BRA process uses simple equipment so small industries can carry it out. Some concluding notes from this research are as follows:

- The incorporation of Recycled Concrete Aggregate (RCA) and Bitumen-Rubber Aggregate (BRA) in the Modified Hot Mix Asphalt (HMA) presents opportunities for cost reduction and environmental conservation initiatives. The table illustrates the proportions of various materials in both Conventional HMA and Modified HMA, showing that RCA contributes 24% and BRA modified contributes 32.67% to the APB-BRA Modified mixture. However, the inclusion of RCA in this study has led to a slight increase of 0.5% in the total weight of the asphalt aggregate mixture (Table 6).

Table 6: Composition Comparison between Conventional Hot Mix Asphalt (HMA) and Modified HMA Incorporating Bitumen-Rubber Aggregate (BRA)

Materials	Content	HMA Conventional	HMA-BRA Modified
New Asphalt	%	100.00	67.33
BRA bitumen	%	-	27.77
WEO	%	-	4.90
New Aggregate	%	100.00	63.00
RCA	%	-	24.00
BRA granules	%	-	13.00

- The test method for APB uses the Bending Test based on the properties of the aggregate asphalt mixture but with Marshall Test control, which is generally the performance measurement for asphalt mixtures on road pavement.
- Innovation in making asphalt paving blocks by utilizing waste material through a recycling process using simple equipment has shown that this solution is better for light-traffic roads, pedestrians, or other facilities.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Malaysia's Renewable Energy Policy and its Impact on ASEAN Countries

WaiYie Leong*[1], LeeSun Heng[2], YuanZhi Leong[2]

[1] *INTI International University, Persiaran Perdana BBN Putra Nilai, 71800 Nilai, Negeri Sembilan*

[2] *Schneider Electric, 50 Kallang Ave, Singapore 339505*

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ABSTRACT

As the global community increasingly shifts its focus towards sustainable development and combating climate change, renewable energy policies have become pivotal in shaping national and regional energy landscapes. Malaysia, as a developing nation with a rapidly growing economy, has recognized the importance of renewable energy sources in achieving its socio-economic goals while addressing environmental concerns. This paper explores Malaysia's renewable energy policy framework and assesses its impact on neighboring countries in the Southeast Asian region. Through a comprehensive analysis of policy measures, incentives, challenges, and achievements, this paper elucidates the significance of Malaysia's renewable energy endeavors in fostering regional energy security, sustainability, and cooperation.

1. Introduction

In the face of global climate change and the need for sustainable development, countries worldwide are increasingly turning towards renewable energy sources. Malaysia, a rapidly developing nation in Southeast Asia, has recognized the importance of renewable energy in its energy transition. The Malaysian government has implemented various policies and initiatives to promote renewable energy adoption, aiming not only to meet domestic energy needs but also to have a positive impact on the region's energy landscape [1-2]. This paper examines Malaysia's renewable energy policy framework and analyzes its impact on neighboring countries in the region.

1.1. Malaysia's Renewable Energy Policy Framework

Malaysia's journey towards renewable energy adoption began with the enactment of the Renewable Energy Act in 2011 [1]. This legislation laid the groundwork for various initiatives aimed at promoting renewable energy development. The key components of Malaysia's renewable energy policy framework include:

A) National Renewable Energy Policy and Action Plan: The Malaysian government formulated a comprehensive National Renewable Energy Policy and Action Plan, outlining targets and strategies for renewable energy deployment. This policy framework provides a roadmap for transitioning towards a more sustainable energy mix [2].

B) Feed-in Tariff (FiT) Mechanism: The FiT mechanism, introduced in 2011, offers attractive tariffs to renewable energy producers, thereby incentivizing investment in solar, biomass, and biogas projects. This policy has stimulated significant growth in renewable energy capacity across Malaysia.

C) Net Energy Metering (NEM) Scheme: The NEM scheme allows renewable energy system owners to offset their electricity bills by exporting excess energy to the grid [3]. This initiative encourages the adoption of rooftop solar systems among residential, commercial, and industrial consumers.

D) Renewable Energy Fund: The government has established a Renewable Energy Fund to support research, development, and deployment of renewable energy technologies [4]. This fund facilitates innovation and capacity building within the renewable energy sector.

The implementation of Malaysia's renewable energy policies has not only transformed its domestic energy landscape but also had significant implications for neighboring countries in the region.

2. Literature Review of Malaysia's Renewable Energy Policy

Malaysia, a country in Southeast Asia, has been actively pursuing renewable energy initiatives to address energy security concerns, reduce dependency on fossil fuels, and mitigate climate

*Corresponding Author: WaiYie Leong, INTI International University, Negeri Sembilan, waiyie@gmail.com

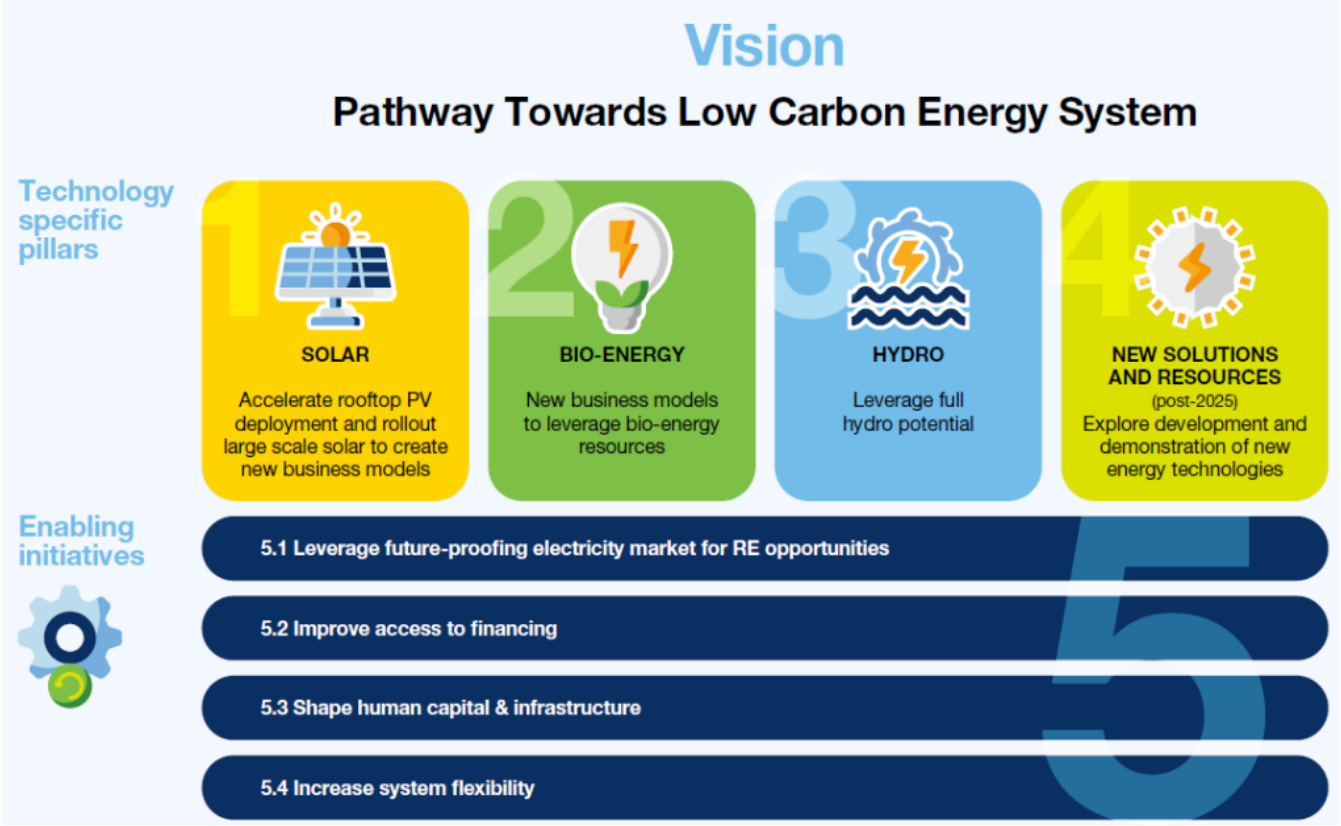

Figure 1: Strategic Plan and Framework for MyRER [1]

change. This section provides a historical overview and literature review of Malaysia's renewable energy policy development and its impact on neighboring countries in the region.

Malaysia's interest in renewable energy dates back to the early 2000s when the government recognized the need for sustainable energy development [1,5]. Key milestones include the establishment of the National Renewable Energy Policy and Action Plan in 2009, which set targets for renewable energy adoption and introduced policy mechanisms such as Feed-in Tariffs (FiT) and Net Energy Metering (NEM). Subsequent revisions and updates to the policy framework have aimed to accelerate renewable energy deployment and attract investment in the sector. Malaysia's renewable energy targets have been incorporated into national development plans, demonstrating the government's commitment to transitioning towards a low-carbon economy.

Numerous studies have examined various aspects of Malaysia's renewable energy policy and its impact on the region. Research has focused on the effectiveness of policy instruments such as FiT and NEM in incentivizing renewable energy investment and deployment. Scholars have also explored the potential of different renewable energy sources, including solar, wind, biomass, and hydro, in Malaysia's energy transition. Assessments of Malaysia's renewable energy market dynamics, investment climate, and regulatory framework have provided insights into the challenges and opportunities facing the sector.

The impact of Malaysia's renewable energy policy extends beyond its borders, influencing regional energy dynamics and cooperation. Enhanced regional energy security is achieved through diversified energy sources and reduced reliance on imported fossil fuels. Economic opportunities arise from cross-border investment and collaboration in renewable energy projects, fostering regional integration and development. Knowledge sharing and technology transfer initiatives contribute to capacity building and sustainable energy development in neighboring countries. Malaysia's leadership in renewable energy policy serves as a model for regional peers, influencing the formulation of renewable energy strategies and policies across Southeast Asia.

Malaysia's renewable energy policy has undergone significant development over the years, shaping the country's energy landscape and influencing regional energy dynamics. Through policy initiatives, incentives, and collaborations, Malaysia has made strides towards a more sustainable and resilient energy future. Continued research and cooperation among regional countries are essential for advancing renewable energy adoption and achieving shared climate and energy goals.

3. MyRER: Malaysia Renewable Energy Roadmap

The Malaysia Renewable Energy Roadmap (MyRER) is a strategic plan developed by the Malaysian government to promote the growth and adoption of renewable energy sources in the country. It aims to diversify Malaysia's energy mix, reduce dependence on fossil fuels, and mitigate the environmental impacts of energy generation.

Key objectives of MyRER typically include:

A) Increasing Renewable Energy Capacity: Setting targets for the installation of renewable energy capacity, such as solar, wind, hydroelectric, biomass, and biogas power plants.

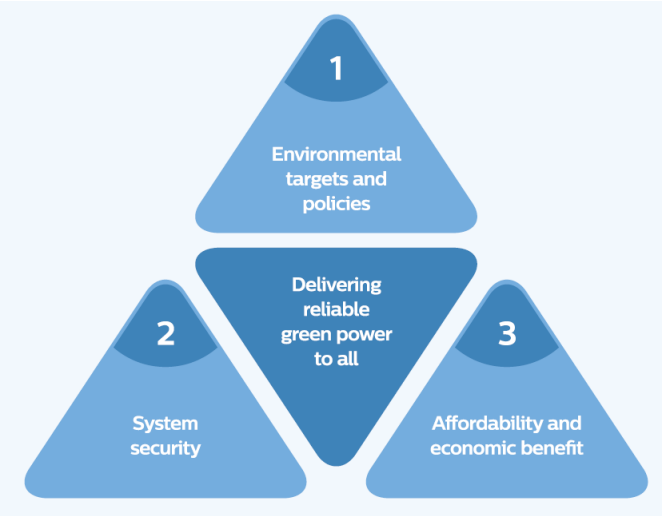

Figure 2: Principles to follow in the pursuit of dependable green power [1]

B) Policy and Regulatory Framework: Developing supportive policies, regulations, and incentives to attract investment in renewable energy projects and streamline approval processes.

C) Infrastructure Development: Investing in the necessary infrastructure, such as grid upgrades and energy storage facilities, to support the integration of renewable energy into the existing power system.

D) Research and Development: Encouraging research and development efforts to improve renewable energy technologies, reduce costs, and enhance efficiency.

E) Capacity Building and Awareness: Providing training programs, workshops, and public awareness campaigns to build capacity and promote the benefits of renewable energy adoption.

F) Collaboration and Partnerships: Fostering collaboration between government agencies, private sector entities, academia, and international organizations to achieve the goals of the roadmap.

MyRER serves as a guiding framework for the Malaysian government and stakeholders in the renewable energy sector to work towards sustainable energy development and achieve national energy security goals. It typically outlines specific targets, timelines, and action plans to monitor progress and ensure the successful implementation of renewable energy initiatives.

4. MyRER: The Milestones and Aspirations

The Malaysia Renewable Energy Roadmap (MyRER) typically outlines a series of milestones and aspirations to guide the country's transition towards a more sustainable and renewable energy future. These milestones and aspirations may vary depending on the specific version or iteration of MyRER, as well as evolving national priorities and goals. However, here are some common milestones and aspirations that could be included:

A) Setting Renewable Energy Targets: Establishing ambitious targets for the deployment of renewable energy capacity in Malaysia, including targets for solar, wind, hydroelectric, biomass, and biogas power generation.

B) Policy and Regulatory Reforms: Implementing policy and regulatory reforms to create a conducive environment for renewable energy investment, such as feed-in tariffs, net metering schemes, renewable energy auctions, and streamlined permitting processes.

C) Infrastructure Development: Investing in grid infrastructure upgrades, energy storage facilities, and smart grid technologies to support the integration of variable renewable energy sources into the electricity grid.

D) Promotion of Solar Energy: Encouraging the widespread adoption of solar photovoltaic (PV) systems, including rooftop solar installations on residential, commercial, and industrial buildings, as well as utility-scale solar farms.

E) Expansion of Wind Power: Identifying and developing suitable sites for wind energy projects, particularly in coastal and high-wind areas, to harness Malaysia's wind energy potential.

F) Hydropower Development: Continuing to develop hydropower projects in a sustainable manner, balancing energy generation with environmental and social considerations.

G) Biomass and Biogas Utilization: Promoting the use of biomass and biogas for electricity generation, industrial processes, and transportation fuels, leveraging Malaysia's abundant agricultural and organic waste resources.

H) Research and Innovation: Investing in research and innovation to drive down the costs of renewable energy technologies, improve efficiency, and address technical challenges.

I) Capacity Building and Education: Providing training programs, workshops, and educational initiatives to build local expertise and raise awareness about the benefits of renewable energy.

J) International Collaboration: Collaborating with international partners, organizations, and experts to share best practices, technology transfer, and financial assistance for renewable energy projects.

K) These milestones and aspirations are typically designed to accelerate the transition towards a more sustainable, low-carbon energy system in Malaysia, while also promoting economic growth, energy security, and environmental stewardship. Regular monitoring and evaluation of progress are essential to ensure that MyRER goals are being met and to make adjustments as needed to stay on track.

5. MyRER: The Strategic Framework

The strategic framework of the Malaysia Renewable Energy Roadmap (MyRER) typically encompasses a comprehensive approach to advancing renewable energy deployment and achieving sustainability goals [1,5]. While the specific details may vary, depending on the version and iteration of MyRER, the

strategic framework generally includes the following key components:

A) Policy and Regulatory Environment: Establishing a supportive policy and regulatory framework that incentivizes investment in renewable energy and facilitates its integration into the energy market [6]. This may include feed-in tariffs, renewable energy quotas, net metering schemes, tax incentives, and streamlined permitting processes.

B) Market Development and Financing: Stimulating market demand for renewable energy through mechanisms such as renewable energy auctions, power purchase agreements (PPAs), green procurement policies, and financial incentives for renewable energy projects [7]. Access to financing, including loans, grants, and venture capital, is also crucial for accelerating renewable energy deployment.

C) Infrastructure and Grid Integration: Investing in grid infrastructure upgrades, energy storage systems, and smart grid technologies to accommodate the variability and intermittency of renewable energy sources [8]. This includes grid expansion to remote areas with high renewable energy potential and implementing grid codes and standards to ensure the reliable and efficient operation of the grid with increased renewable energy penetration.

D) Resource Assessment and Planning: Conducting comprehensive resource assessments to identify and prioritize renewable energy sources, such as solar, wind, hydroelectric, biomass, and biogas, with the greatest potential for development. Long-term energy planning, including scenario analysis and forecasting, is essential for guiding investment decisions and optimizing the mix of renewable energy technologies [9].

E) Technology Innovation and Research: Supporting research, development, and innovation in renewable energy technologies to improve efficiency, reduce costs, and address technical challenges. This includes funding for research institutions, technology demonstration projects, and collaborative R&D initiatives with industry partners.

F) Capacity Building and Human Capital Development: Building local expertise and technical skills in renewable energy development, operation, and maintenance through training programs, education initiatives, and partnerships with academic institutions and industry associations. This includes vocational training, professional certification programs, and knowledge sharing platforms to enhance workforce readiness and competency.

G) Public Awareness and Stakeholder Engagement: Raising awareness among policymakers, businesses, communities, and the general public about the benefits of renewable energy, including environmental sustainability, energy security, job creation, and economic development. Engaging stakeholders through consultations, workshops, and outreach activities fosters support for renewable energy policies and projects.

H) Monitoring, Evaluation, and Review Mechanisms: Establishing robust monitoring, evaluation, and review mechanisms to track progress towards renewable energy targets, assess the effectiveness of policy measures, and

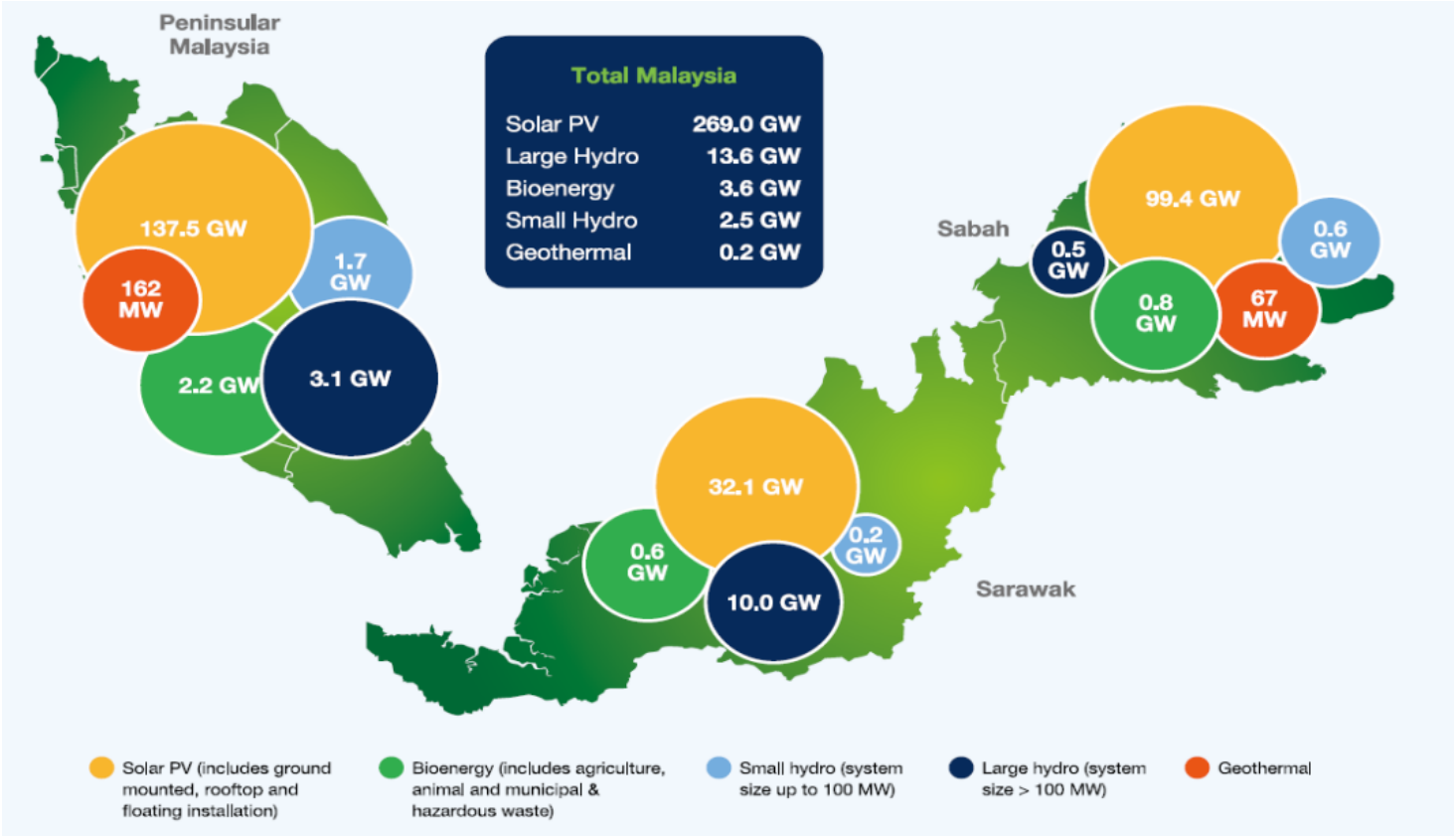

Figure 3: An overview of Malaysia's potential for RE resources [1]

identify areas for improvement. Regular performance monitoring and reporting ensure accountability and enable evidence-based decision-making to optimize the implementation of MyRER initiatives.

By addressing these strategic elements, MyRER aims to create an enabling environment for scaling up renewable energy deployment, driving sustainable economic growth, and mitigating climate change impacts in Malaysia. The strategic framework provides a roadmap for coordinated action by government agencies, private sector stakeholders, civil society organizations, and international partners to achieve shared renewable energy goals and objectives.

6. Growth Of Primary Energy Demand Is Expected To Decline

A decline in the growth of primary energy demand suggests a significant shift in energy consumption trends, typically influenced by various factors:

A) Energy Efficiency Measures: Increased adoption of energy-efficient technologies and practices across sectors like industry, transportation, and buildings can lead to reduced energy consumption per unit of economic output. Investments in energy-efficient appliances, vehicles, and infrastructure contribute to this decline in demand growth.

B) Renewable Energy Integration: The expanding deployment of renewable energy sources such as solar, wind, hydroelectric, and biomass can displace traditional fossil fuels for electricity generation and other energy needs. As renewable energy becomes more competitive and accessible, it can curb the growth of primary energy demand.

C) Economic Changes: Structural shifts in economies, such as a transition towards service-based industries or improvements in industrial processes, can affect energy demand. Economic diversification, coupled with technological advancements, can lead to more energy-efficient production methods and reduced energy intensity.

D) Policy and Regulatory Measures: Government policies and regulations aimed at promoting energy conservation, reducing greenhouse gas emissions, and increasing renewable energy deployment play a crucial role. Measures such as energy efficiency standards, carbon pricing mechanisms, renewable energy targets, and subsidies for clean energy technologies incentivize energy savings and renewable energy adoption.

E) Technological Innovations: Ongoing advancements in energy technologies, including energy storage, smart grids, and electrification of transportation, contribute to the decline in energy demand growth. Innovations in energy management systems, automation, and digitization optimize energy use and improve overall efficiency.

F) Changing Consumer Behavior: Increasing awareness of environmental issues and sustainability, coupled with changing consumer preferences, can drive demand for energy-efficient products and services. Lifestyle changes, such as the adoption of public transportation, cycling, and telecommuting, also contribute to reducing energy demand growth.

G) Global Trends: Global initiatives to address climate change, such as the Paris Agreement, and the growing recognition of the importance of sustainable development influence energy policies and investment decisions. International cooperation and commitments towards decarbonization further accelerate the transition towards cleaner and more efficient energy systems.

H) A decline in the growth of primary energy demand reflects efforts to decouple economic growth from energy consumption, promote sustainable development, and mitigate climate change. However, achieving sustained reductions in energy demand growth requires continued investment, innovation, and policy support across multiple sectors and stakeholders.

7. ASEAN: Increasingly Aggressive Renewable Energy Targets

The Association of Southeast Asian Nations (ASEAN) has indeed been increasingly aggressive in setting renewable energy targets in recent years. This trend reflects the region's commitment to promoting sustainable development, enhancing energy security, and mitigating climate change. Several factors contribute to ASEAN's growing focus on renewable energy [1,5-6]:

A) Energy Security Concerns: ASEAN member states recognize the importance of diversifying their energy sources to reduce dependence on fossil fuels and enhance energy security. Investing in renewable energy helps mitigate risks associated with energy supply disruptions and price volatility [7-8].

B) Climate Change Mitigation: ASEAN countries are vulnerable to the impacts of climate change, including extreme weather events, sea-level rise, and disruption of agricultural systems. By transitioning to renewable energy sources, ASEAN aims to reduce greenhouse gas emissions and contribute to global efforts to limit temperature rise and mitigate climate change impacts.

C) Economic Opportunities: The rapid growth of renewable energy markets presents significant economic opportunities for ASEAN countries. By investing in renewable energy infrastructure and technologies, ASEAN can stimulate job creation, attract investment, and promote industrial development, particularly in the manufacturing and services sectors.

D) Technological Advancements: Advances in renewable energy technologies, coupled with declining costs, have made renewable energy increasingly competitive with conventional fossil fuels. ASEAN member states can leverage these technological advancements to accelerate the deployment of renewable energy projects and achieve their targets cost-effectively[9-10].

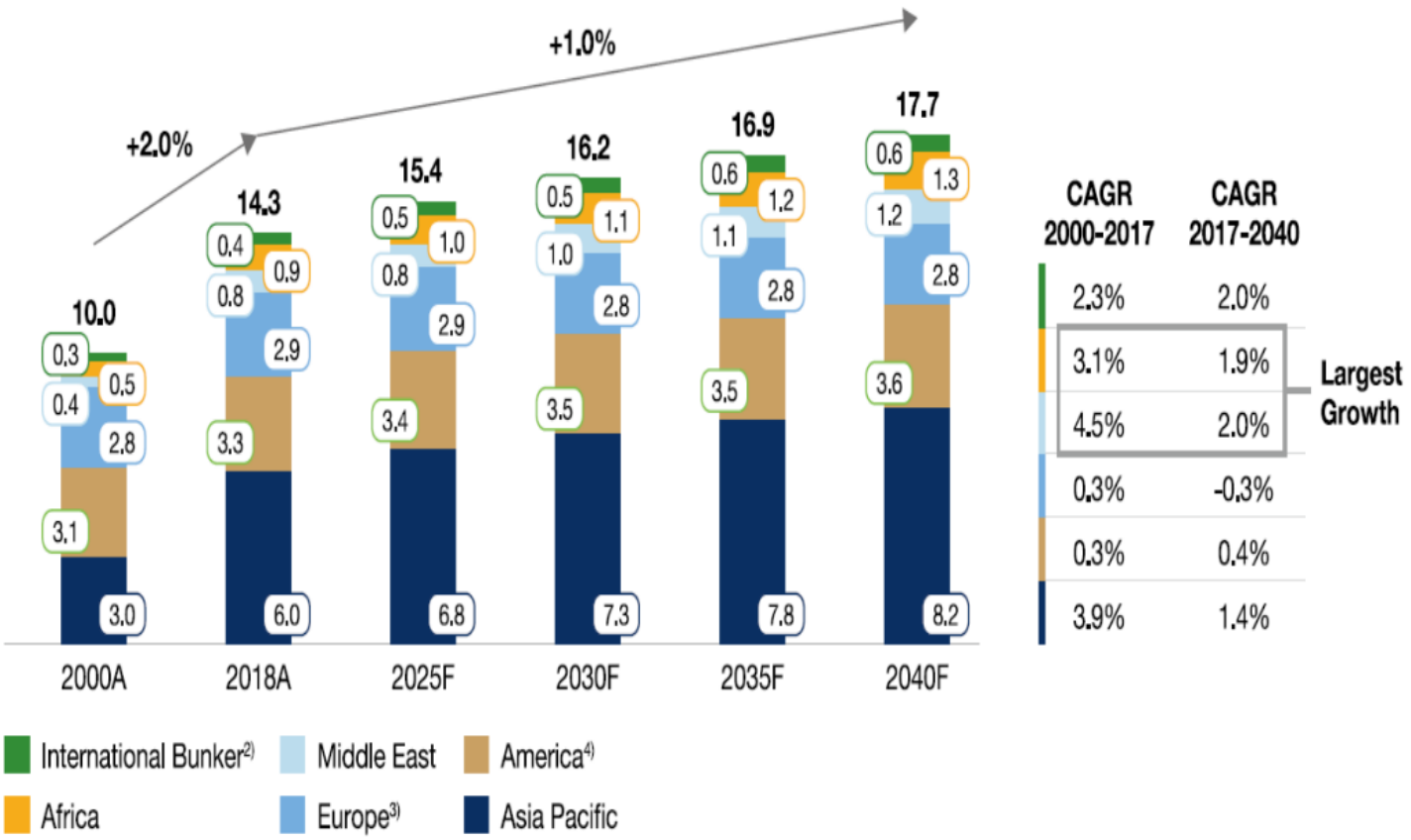

Figure 4: Regional variations in global primary energy demand (IEA New Policies Scenario), 2000–2040F [1]

E) Policy Support and Regional Cooperation: ASEAN has established frameworks and mechanisms to support renewable energy development, including the ASEAN Plan of Action for Energy Cooperation (APAEC) and the ASEAN Centre for Energy (ACE). These initiatives facilitate policy dialogue, capacity building, and knowledge sharing among member states to promote renewable energy deployment.

F) International Commitments: ASEAN member states are signatories to international agreements and initiatives aimed at promoting renewable energy and sustainable development, such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs). Meeting renewable energy targets aligns with ASEAN's broader commitments to these global initiatives [11-12].

	Malaysia	Indonesia	Philippines	Thailand	Vietnam	Singapore
Latest RE policy	MyRER 2035	National Energy Roadmap	Sectoral Energy Plan & Roadmap	Power Development Plan	Power Development Plan	Singapore's Energy Story
Year of latest RE policy	2020	2017	2017	2019	2019	2019
Overall RE targets	31% RE installed capacity by 2025, 40% by 2035	RE installed capacity by 45 GW by 2025, 168 GW by 2050, 31% of national primary energy supply in 2050	RE installed capacity of 20 GW by 2040	33% RE installed capacity by 2037 with RE mix as following • Solar 6 GW • Biomass 5.57 GW • Wind 3 GW • Hydropower 3.3 GW • Biogas 0.6 GW • MSW 0.5 GW	32% RE installed capacity by 2030, 45% by 2050	At least 2 GW of solar by 2030, and energy storage deployment target of 200 MW post 2025

Figure 5: Overview of key ASEAN countries' renewable energy share targets [1]

G) Public Awareness and Support: There is growing public awareness and support for renewable energy across ASEAN countries. Concerns about air pollution, environmental degradation, and the health impacts of fossil fuel combustion have fueled demand for cleaner and more sustainable energy solutions.

ASEAN's increasingly aggressive renewable energy targets underscore the region's commitment to transitioning towards a low-carbon and sustainable energy future. By harnessing the abundant renewable energy resources available in the region and leveraging technological innovations and policy support, ASEAN aims to achieve its renewable energy goals while promoting economic growth, energy security, and environmental sustainability.

8. Conclusions

Malaysia's Renewable Energy Policy has been a significant driver in promoting the adoption of renewable energy sources within the country, with ripple effects impacting neighboring regional countries. The policy framework, encapsulated in initiatives such as the Malaysia Renewable Energy Act and the National Renewable Energy Policy and Action Plan, sets ambitious targets for renewable energy capacity expansion and outlines various mechanisms to incentivize investment and deployment.

One key impact of Malaysia's Renewable Energy Policy on regional countries is the demonstration effect. As Malaysia implements and showcases successful renewable energy projects, it serves as a model for other countries in the region, inspiring them to pursue similar initiatives. This influence is particularly significant for ASEAN member states, given Malaysia's active participation and leadership within the ASEAN community.

Furthermore, Malaysia's efforts in renewable energy development contribute to regional energy security by diversifying the energy mix and reducing reliance on imported fossil fuels. This resilience is especially crucial for countries in Southeast Asia, which face geopolitical and supply chain risks associated with traditional energy sources.

Additionally, Malaysia's growing expertise and capabilities in renewable energy technology and project development offer opportunities for regional collaboration and knowledge exchange. Through partnerships, capacity-building initiatives, and joint ventures, neighboring countries can leverage Malaysia's experience to accelerate their own renewable energy transitions.

Moreover, Malaysia's Renewable Energy Policy contributes to the region's collective efforts in combating climate change. By reducing greenhouse gas emissions and promoting sustainable development practices, Malaysia sets a positive example for regional cooperation on climate action, aligning with international commitments such as the Paris Agreement.

Malaysia's Renewable Energy Policy has a multifaceted impact on regional countries, serving as a catalyst for renewable energy adoption, enhancing energy security, fostering collaboration, and advancing climate mitigation efforts across Southeast Asia. As Malaysia continues to progress in its renewable energy journey, its influence on the region's energy landscape is likely to grow, driving a more sustainable and resilient future for all.

Conflict of Interest

The authors declare no conflict of interest.

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