E-ISSN : 2614-8404
P-ISSN : 2776-3234

JISA

(JURNAL INFORMATIKA dan SAINS)

VOL 8 No 1
June

Managed by :
Program Studi Teknik Informatika
UNIVERSITAS TRILOGI

2025

e-ISSN: 2614-8404
p-ISSN:2776-3234

JISA
(Jurnal Informatika dan Sains)

Volume 8, Edition 1, June 2025

e-ISSN: 2614-8404
p-ISSN:2776-3234

Managed by:
Program Studi Teknik Informatika
Universitas Trilogi

JISA	Vol : 8	Ed :1	Page : 001-111	Jakarta, Jun 2025	e-ISSN: 2614-8404	p-ISSN: 2776-3234

e-ISSN: 2614-8404
p-ISSN:2776-3234

JISA
(Jurnal Informatika dan Sains)

Volume 8, Edition 1, June 2025

Editorial Address
Fakultas Sains Teknik dan Desain Lantai 3
Jalan Taman Makam Pahlawan No. 1, Kalibata, Pancoran, RT.4/RW.4, Duren Tiga, Pancoran, Kota Jakarta Selatan, Daerah Khusus Ibukota Jakarta 12760Telp :(021) 798001

Managed by:
Program Studi Teknik Informatika
Universitas Trilogi

JISA	Vol : 8	Ed :1	Page : 001-111	Jakarta, Jun 2024	e-ISSN: 2614-8404	p-ISSN: 2776-3234

e-ISSN: 2614-8404
p-ISSN:2776-3234

Table of Content

e-ISSN: 2614-8404
p-ISSN:2776-3234

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Literature Review Study on the Implementation of Convolutional Neural Network for Lung Medical Images Segmentation and Classification

Joko Riyono[1*)], Supriyadi[2], Christina Eni Pujiastuti[3], Sofia Debi Puspa[4], Aina Latifa Riyana Putri[5]
[1,2,3,4]Program Studi Teknik Mesin, Fakultas Teknologi Industri, Universitas Trisakti
[5]Program Studi Sains Data, Fakultas Informatika, Telkom University
Email: [1]jokoriyono@trisakti.ac.id, [2]supri@trisakti.ac.id, [3]christina.eni@trisakti.ac.id ,
[4]sofia.debi.puspa@trisakti.ac.id,[5]ainaqp@telkomuniversity.ac.id

Abstract – Medical image processing has become an essential aspect of healthcare, enabling accurate disease diagnosis and monitoring through advanced technologies. One of the most widely used methods in this domain is the Convolutional Neural Network (CNN), which has demonstrated high effectiveness in segmentation and classification tasks, particularly for chest X-ray images used in diagnosing lung-related diseases. This study aims to evaluate and analyze various CNN architectures implemented in lung X-ray imaging through a Systematic Literature Review (SLR) approach. The research explores the application, accuracy, challenges, and future opportunities of CNN-based models such as VGG, ResNet, AlexNet, and GoogLeNet. A total of 15 relevant studies published between 2019 and 2023 were selected after applying rigorous inclusion and exclusion criteria. The findings indicate that CNN architectures significantly enhance the accuracy of lung disease detection and support both segmentation and classification tasks. However, challenges such as dataset variability, model generalization, and ethical implications remain. This review provides comprehensive insights into CNN applications in medical imaging, emphasizing their potential and highlighting areas for further research.

Keywords – *CNN architecture, CNN, medical imaging, lung*

I. INTRODUCTION

Imagery is a visual representation of objects in the real world in the form of two dimensions. Mathematically, the image or *Image.* It can be described as a two-dimensional function (x,y), where x and y represent the coordinates in dimensional space, and the amplitude (f) on each coordinate pair (x,y) depicts the intensity in the image. In a digital image, a number of elements are composed of what are known as pixels or grayness values. Each pixel has a different position (coordinates) as a representation of the brightness or color level at that location. Pixel intensity can be expressed in the form of discrete values that typically range from 0 to 255. This value represents different levels of brightness or color in the image, where 0 represents black and 255 represents white. These pixel intensities are stored in digital images and processed in various image processing processes, such as contrast enhancement, quality improvement, object segmentation, and image analysis.

Digital image processing is concerned with converting images into digital formats and processing them using digital computers. Digital image analysis is related to the description and introduction of the content of the digital image. The input of an image analysis process is the digital image and as an output, the digital image produces a description of the image in symbolic form. Image processing is of course carried out for various purposes such as increasing contrast, increasing brightness, image rotation, image fading, and removal [1]. *Noise*, segmentation or separation of objects from their background, extraction of features for the sake of analysis, and artistic effects such as giving the effect as if an image was drawn with a pencil.

Image processing has been applied in various studies which identified rice diseases with one of the methods in digital image processing, namely CNN-BiGRU. Another study was also conducted for the detection of fire smoke in wild forests from synthetic smoke imagery using the Faster R-CNN method [2][3],[4].

Image processing can be used in various fields such as research on fire smoke, license plate detection, plant disease detection, and others. Image processing is also of course possible to be applied in the medical world because image in the medical world itself is a fundamental need used in monitoring and determining disease diagnosis. As in lung disease, which generally has similar symptoms, a supporting procedure is usually needed in determining the diagnosis which is usually done through a chest X-ray examination procedure.

Segmentation and Classification in digital image processing are two different things. Segmentation is a process in image processing to separate objects in an image into several regions based on the difference in the grayness value of an image without labeling a specific category. Meanwhile, image classification is the process of giving certain labels or categories to all images. Both play an equal role in image analysis to achieve certain goals such as object recognition.

One of the methods in digital image processing that can be used in segmentation and classification is *Convolutional Neural Network (CNN). Convolutional Neural Network (CNN)* has evolved in the analysis of medical images performed and provides greater opportunities for radiologists to perform detection and

e-ISSN: 2614-8404
p-ISSN: 2776-3234

diagnosis with a high degree of accuracy by adopting topological mapping that has been optimized within its convolutional layer to extract important features from medical images at each stage, ultimately improving the model's suitability with the expected results. With this concept, CNN has significantly improved the diagnostic and analytical capabilities of medical images [5].

Convolutional neural networks (CNNs) are a type of classification algorithm in the deep learning domain that is capable of receiving images as input [6]. CNN is a good method to identify elements or objects in an image so that computers can learn and distinguish the images from each other. The structure of CNN consists of several main architectures, namely *Input*, *feature learning* and *classification* [7]. *Convolutional Neural Network (CNN)* has different types of architectures such as VGG-16 CNN, Res-Net CNN, Alex-Net CNN, Google-Net, COVID-Nets, and others [8].

The implementation of the CNN architecture has been tested in several studies related to the medical world, especially the implementation of lung medical imaging. An example of a study that has been conducted by for the detection of Covid-19 from an X-ray image using nine CNN architectures namely AlexNet, GoogleNet, ResNet-50, Se-ResNet-50, DenseNet121, Inception V4, Inception ResNetV2, ResNeXt-50, and Se-ResNeXt-50 and results in a level of accuracy achieved on the model [9].*pre-trained* Se-ResNeXt-50 with the highest classification accuracy of 99.32% for binary class and 97.55% for *multi-class* among all models *pre-trained.* Another study was conducted to classify skin cancer with the VGG-16 architecture and produced an accuracy of 99.70%, [10]. *Loss* 0,0055, *precision* 0,9975, *Recall* 0,9975.

Since the accuracy and performance vary across different CNN architectures, this study employs a Systematic Literature Review (SLR) to examine and evaluate the implementation of various CNN architectures in processing lung X-ray images. The research aims to identify the role of CNN in segmentation and classification tasks related to lung diseases based on imaging data, as well as to analyze the challenges encountered in applying these CNN architectures.

II. RESEARCH METHODOLOGY

To conduct a literature review regarding the implementation of various Convolutional Neural Network (CNN) architectures for lung X-ray imaging, this study adopts a Systematic Literature Review (SLR) method. A good literature review requires a well-defined search strategy and selection criteria to ensure that the collected studies are relevant and of high quality. In this case, the SLR was carried out through several stages in the search strategy and selection criteria, as follows:

1. Determine keywords appropriate to the topic, such as "CNN," "Convolutional Neural Network," "X-ray," "medical imaging," "radiology," "chest radiograph," "lung disease," and specific CNN architecture names such as "VGG," "ResNet," "AlexNet," and "GoogLeNet."
2. Selecting a research-appropriate database from relevant sources can include Science Direct, IEEE Xplore, Google Scholar, Scopus, and Springer.
3. Create a Search Query that includes the keywords that have been identified. For example, "(CNN OR Convolutional Neural Network) AND (X-ray OR medical imaging) AND (VGG OR ResNet OR AlexNet OR GoogLeNet) AND (lung disease OR pneumonia)."
4. Using search filters to narrow down search results based on research publications in the range of 2019 - 2023 with the type of journal and conference documents in Indonesian and English.
5. Use a search query on a predefined database and log the search results.

After following this search strategy and selection criteria, relevant literature was obtained regarding the implementation of various CNN architectures in chest X-ray images. From the entire search process, a total of 21 relevant articles were initially identified. This helps in evaluating the various approaches that have been used in previous research and compiling an informative literature review.

In this digital era, medical image processing has become one of the most important aspects in the field of medical science. Medical image processing technology allows healthcare professionals to diagnose diseases, monitor patient progress, and make informed medical decisions. In this context, the use of Convolutional Neural Network (CNN) architecture has become a growing focus of research. Relevant research questions in this area are of essence in an effort to understand and maximize the potential of CNN architecture in medical image processing.

RQ1 : Can the application of the CNN architecture be used in segmentation as well as classification of medical images?

RQ2 : What is the level of accuracy that can be achieved by using the CNN architecture in the segmentation and/or classification tasks of a lung image?

RQ3 : What are the obstacles and future research opportunities in the implementation of various CNN architectures in lung medical imaging research?

The RQ1 statement is important to uncover CNN's architectural capabilities in supporting two important tasks in medical image processing. RQ2 question highlights effectiveness of CNN in producing accurate results in recognizing or grouping various features in lung images. The RQ3 question aims to evaluate barriers that may arise, such as access to data and hardware complexity, as well as identify opportunities, such as the use of more advanced technologies and cooperation between researchers and medical practitioners, that could advance research in this area.

After applying inclusion and exclusion criteria such as relevance to the research questions, availability of full text, and avoidance of duplicate studies, a final set of 15 articles was selected for in-depth review. In order to answer these questions, this study will conduct a comprehensive literature review of recent works in the domain of medical image processing using the CNN architecture.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

III. FINDING ANALYSIS AND DISCUSSION

In this literature analysis, a number of studies that have been conducted in the field of implementation of various types of architecture on CNN in lung imaging will be investigated to understand and answer the research questions that have been determined. This study aims to identify the use of architecture in segmentation and classification and evaluate the implementation of various CNN architectures in lung imagery. Understanding the existing literature is an important step in guiding our research and making a valuable contribution to scientific understanding. Table 1 contains Research Data found through search strategies and target criteria. The introduction of the entire article is summarized in a table with columns of Authors, Datasets Size, Year, CNN Architecture, and Application Deployments.

Table 1. Relevant Research Data

Author	Dataset Size	Year	CNN Architecture	Application
(Arvind et al., 2023) [11]	944	2023	U-Net	Segmentation
(Aslan, 2022) [12]	2905	2022	Alex-Net	Segmentation
(Ilhan et al., 2023)	100	2023	U-Net	Segmentation
(Chen et al., 2021) [13]	240	2021	Seg-Net	Segmentation
(Xu et al., 2019)	201	2019	CNN	Segmentation
(Salama & Aly, 2022) [14]	746	2022	AlexNet, GoogLeNet, ResNet, VGG16, VGG19, and U-Net	Segmentation and Classification
(Hastomo et al., 2021) [15]	10300	2021	Res-Net 152	Segmentation and Classification
(Hira et al., 2021)	8830	2021	AlexNet, GoogleNet, ResNet-50, Se-ResNet-50, DenseNet121, Inception V4, Inception ResNetV2, ResNeXt-50, and Se-ResNeXt-50)	Segmentation and Classification
(Hastomo et al., 2021)	4000	2021	ResNet-152, InceptionResNet-V2, MobileNet-V2 CNN	Segmentation and Classification
(Mohd Ashhar et al., 2021) [16]	1646	2021	GoogleNet, SqueezeNet, DenseNet, ShuffleNet and MobileNetV2 CNN	Segmentation and Classification
(Alshazly et al., 2021) [17]	4173	2021	CovidResNet dan CovidDenseNet	Segmentation and Classification
(Kusmareni et al., 2022) [18]	566	2022	U-Net	Segmentation
(Astuti, 2021) [19]	135	2021	Mask R-CNN	Segmentation
(Khultsum et al., 2022) [20]	720	2022	Mobile-Net	Klasifikasi
(Yopento et al., 2022) [21]	2217	2022	CNN	Klasifikasi

Identified 15 articles related to the implementation of the CNN architecture for lung imaging. Please note, segmentation and classification are two different things and have been explained in the Introduction Section. In this case, the research data will be broken down into 3 tables, namely for the application of segmentation, classification, and segmentation as well as classification.

Table 2. Implementation of CNN Architecture for Image Segmentation

Writer	Dataset Size	Year	CNN Architecture	Application
(Arvind et al., 2023)	944	2023	U-Net	Segmentation
(Aslan, 2022)	2905	2022	Alex-Net	Segmentation
(Ilhan et al., 2023)	100	2023	U-Net	Segmentation
(Chen et al., 2021)	240	2021	Seg-Net	Segmentation
(Xu et al., 2019)	201	2019	CNN	Segmentation
(Kusmareni et al., 2022)	566	2022	U-Net	Segmentation
(Astuti, 2021)	135	2021	Mask R-CNN	Segmentation

Table 3. Implementing the CNN Architecture for Classification

Writer	Dataset Size	Year	CNN Architecture	Application
(Khultsum et al., 2022)	720	2022	Mobile-Net	Klasifikasi
(Yopento et al., 2022)	2217	2022	CNN	Klasifikasi

Table 4. Implementation of CNN Architecture for Segmentation and Classification

Writer	Dataset Size	Year	CNN Architecture	Application
(Salama & Aly, 2022)	746	2022	AlexNet, GoogLeNet, ResNet, VGG16, VGG19, and U-Net	Segmentation and Classification
(Hastomo et al., 2021)	10300	2021	Res-Net 152	Segmentation and Classification
(Hira et al., 2021)	8830	2020	AlexNet, GoogleNet, ResNet-50, Se-ResNet-50, DenseNet121, Inception V4, Inception ResNetV2, ResNeXt-50, and Se-ResNeXt-50)	Segmentation and Classification
(Agustina et al., 2022)	4000	2022	VGG-16	Segmentation and Classification
(Hastomo et al., 2021)	4000	2021	ResNet-152, InceptionResNet-V2, MobileNet-V2 CNN	Segmentation and Classification
(Mohd Ashhar et al., 2021)	1646	2021	GoogleNet, SqueezeNet, DenseNet, ShuffleNet and	Segmentation and Classification

e-ISSN: 2614-8404
p-ISSN: 2776-3234

			MobileNetV2 CNN	
(Alshazly et al., 2021)	4173	2021	CovidResNet dan CovidDenseNet	Segmentation and Classification

The literature analysis was followed by exploring additional components, namely the function and accuracy of the implementation of the CNN architecture on lung imagery. Previous research has provided insights into how Convolutional Neural Network (CNN) architecture has been applied to the task of segmentation or classification of lung images. At this stage, it will be further explored by exploring how CNN specifically contributes to the segmentation or classification function, as well as the extent of the accuracy of its implementation. Understanding how CNNs perform in the context of lung imagery is essential for evaluating its potential and limitations in broader medical applications, as well as providing a foundation for research in developing more sophisticated methods.

Table 5. Application and Accuracy of CNN Architecture for Image Segmentation

Writer	Dataset Size	CNN Architecture	Application	Accuracy
(Arvind et al., 2023)	944	U-Net	Separating the lungs from the heart, ribs, diaphragm, sternum, and collarbone	The training accuracy is 92.71% and the generalization accuracy is outstanding at 93.87% Adam optimizer and underlying loss function is Dice coefficient.
(Aslan, 2022)	2905	Alex-Net	Diagnostic COVID-19	As a result, 3 class data consisting of the Normal, Viral Pneumonia, and COVID-19 classes were classified with 99.8% success
(Ilhan et al., 2023)	100	U-Net	Diagnostic COVID-19	The proposed system achieves an accuracy of 97.75%, 0.85, and 0.74, dice scores, and a Jaccard index
(Chen et al., 2021)	240	Seg-Net	Lung Cancer Diagnosis	The SegNet model has a sensitivity of 98.33%, specificity of 86.67%, accuracy of 92.50%, and a total segmentation time of 30.42 seconds
(Xu et al., 2019)	201	CNN	Segmentasi parenkim paru	The CNN model obtained an average F-score of 0.9917
(Kusmareni et al., 2022)	566	U-Net	Abnormalities of lung size	the average accuracy value is 0.9632, the sensitivity is 0.9586, and the specificity is 0.9675, the F1-Score is 0.9920, and the Jaccard coefficient is 0.9842
(Astuti, 2)	135	Mask R-CNN	Lung Cancer Malignancy	Rerata precision 0.852, sensitivity 0.958, specificity 0.82, dan Dice Similarity 0.894

Table 6. Application and Accuracy of CNN Architecture for Classification

Writer	Dataset Size	CNN Architecture	Application	Accuracy
(Khultsum et al., 2022)	720	Mobile-Net	Lung Cancer	Accuracy of 96.70% and Validation accuracy of 90.45%
(Yopento et al., 2022)	2217	CNN	Pneumonia	Precision is 91%, Recall is 92.8% and Accurasy is 91.54%. The accuracy level obtained based on the Epoch value is 50, the learning rate is 0.0001 and the batch value is 20.

Table 7. Implementation and Accuracy of CNN Architecture for Segmentation and Classification

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Writer	Dataset Size	CNN Architecture	Application	Accuracy
(Salama & Aly, 2022)	746	AlexNet, GoogLeNet, ResNet, VGG16, VGG19, and U-Net	Covid-19	The classification results showed that the use of pre-processed lung CT images as inputs for the U-Net hybrid with ResNet50 achieved the best performance. The proposed classification model achieved an accuracy (ACC) of 98.98%, area under the ROC curve (AUC) of 98.89%, sensitivity (Se) of 98.89%, precision (Pr) of 97.99%, F1 score of 97.88%, and a computational time of 1.8974 seconds.
(Hastomo et al., 2021)	10300	Res-Net 152	Covid-19, Lung Opacity, Pneumonia	The results of the study with 50 epoch trainings obtained excellent scores for training and validation accuracy of 95.5% and 91.8%. The test test with a total of 19,300 test data images obtained 99% testing accuracy, with the precision of each class being Covid (99%), Lung Opacity (99%), Normal (98%) and Viral Pneumonia (98%)
(Hira et al., 2021)	8830	AlexNet, GoogleNet, ResNet-50, Se-ResNet-50, DenseNet121, Inception V4, Inception ResNetV2, ResNeXt-50, and Se-ResNeXt-50)	Covid-19	The experimental results showed that the Se-ResNeXt-50 pre-training model achieved the highest classification accuracy of 99.32% for the binary class and 97.55% for the plural class among all pre-training models.
(Hastomo et al., 2021)	4000	ResNet-152, InceptionResNet-V2, MobileNet-V2 CNN	Covid-19, Lung Opacity, Pneumonia	The test accuracy of ResNet-152 is 99%, higher than InceptionResNet-V2 with a 98% result, and MobileNet-V2 with a 93% result. with the precision of each class isCovid (99%), Lung Opacity (97%), Normal (99%), Viral Pneumonia (99%)
(Mohd Ashhar et al., 2021)	1646	GoogleNet, SqueezeNet, DenseNet, ShuffleNet and MobileNetV2 CNN	Tumor Paro-Paro	Accuracy 94.53%, specificity 99.06%, sensitivity 65.67% and AUC 86.84%.
(Alshazly et al., 2021)	4173	CovidResNet dan CovidDenseNet	Covid-19	The CovidDenseNet model obtained the best performance with an accuracy of 81.77%, precision of 79.05%, sensitivity of 84.69%, specificity of 79.05%, F1 score of 81.77%, and an AUC score of 87.50%.

In conducting research, researchers often face various obstacles that can affect the smooth running of research. On the other hand, research also has the potential to present many opportunities in the future. Table 8 contains an explanation related to the barriers and future research opportunities of the researcher.

Table 8. Future Research Barriers and Opportunities

Research	Obstacles	Chance
(Arvind et al., 2023)	Difficulties in obtaining consent in data collection in the field of medical imaging	Optimization and equalization of the range of boundary boxes or organ edges
(Aslan, 2022)	Citra does not have real clinical data so it casts doubt on the results	Implementation of different hyper-parameter optimization techniques to give more optimal results

e-ISSN: 2614-8404
p-ISSN: 2776-3234

(Ilhan et al., 2023)	-	A more comprehensive system by considering pneumonia data in addition to the COVID-19 dataset.
(Chen et al., 2021)	-	-
(Xu et al., 2019)	The results of filling *holes* did not include the area of pleural effusion of the right lung and the pulmonary bular near the pulmonary field boundary	Propose a machine learning-based framework for finding and analyzing lung lesions
(Salama & Aly, 2022)	Data loses spatial information and is not reversible so that the fully connected layer is only implemented at the end of *the network.*	Future research can be carried out the process of classifying abnormalities in the lungs.
(Hastomo et al., 2021)	The system has not been able to detect and segment the area of malignant type cancer nodules .	Development of detection and segmentation techniques for areas with very low contrast
(Hira et al., 2021b)	-	-
(Hastomo et al., 2021)	The computational process takes up a lot of space so that the number of datasets used in the training process is affected	-
(Mohd Ashhar et al., 2021)	After the augmentation process, some important information in the CT image is lost	-
(Alshazly et al., 2021)	-	-
(Kusmareni et al., 2022)	-	Research with a larger dataset approach for medical problems of cancer, tumors, etc and other fields with the exploration of image data augmentation techniques to further improve accuracy while avoiding overfitting
(Astuti, 2021)	The accuracy of the train and the valid loss are still quite large (>40%) and need to be improved again so that the value becomes smaller	-
(Khultsum et al., 2022)	MobileNetV2 *misclassified* data into benign cancer type	Further studies on the GoogleNet network are needed to improve the accuracy of the classification of lung lesions in CT images.
(Yopento et al., 2022)	-	Collection of datasets from *larger* CT Scans

In the discussion stage, the findings from the literature analysis will be evaluated that discuss the function and accuracy of the implementation of Convolutional Neural Network (CNN) architecture on lung imagery. The results of the literature analysis show that the use of CNN architecture in lung image processing has resulted in significant advances in this field. The main function of CNNs in the task of segmentation or classification of lung images is its ability to automatically extract important features from the image, which in turn allows the identification and separation of relevant structures in the image. This is important in the diagnosis and monitoring of lung diseases such as pneumonia, COVID-19, and lung cancer.

In addition, most of the studies evaluated showed that the implementation of CNN architecture on lung imagery achieved a satisfactory level of accuracy. This high accuracy gives confidence that this technique can be used as an aid in medical diagnosis. However, some studies also underscore the challenges of dealing with variations in human lung imagery and uncertainty in the datasets used.

Furthermore, our discussion also discusses potential future developments in applying CNN architecture to lung imagery. This includes improvements in more sophisticated methods, the use of larger and more representative datasets, and ethical considerations in the implementation of these technologies in medical decision-making. Additionally, it is important to continuously improve the accuracy and generalization of CNN models to improve their role in the medical world.

IV. CONCLUSION

This literature review study examines the application of Convolutional Neural Network (CNN) architecture in segmentation and classification of pulmonary medical images. The results of the literature analysis show that the use of CNN in lung imaging is a positive step in the advancement of medical technology. CNN's ability to segment and classify, as well as varying degrees of accuracy, has strengthened its role in supporting the diagnosis of lung disease. Nonetheless, it is worth noting the challenges faced, and more research should be conducted to maximize the benefits of this technology in health monitoring and patient diagnosis.

1. Answer to Question RQ1: This study confirms that the CNN architecture can be effectively used in segmentation as well as classification of lung medical images.
2. Answer to Question RQ2: The results of the literature study show that the implementation of the CNN architecture on lung medical images for segmentation and classification generally achieves an adequate and satisfactory level of accuracy.
3. Answer to Question RQ3: The majority of studies face certain barriers and challenges in the implementation of CNN architecture on pulmonary medical imaging. However, future research opportunities are directed at the development of more appropriate methods and datasets to optimize research results in this field.

should only answer the objectives of the research. Tells how your work advances the field from the present state of knowledge. Without clear Conclusions, reviewers and

e-ISSN: 2614-8404
p-ISSN: 2776-3234

readers will find it difficult to judge the work, and whether or not it merits publication in the journal. Do not repeat the Abstract, or just list experimental results. Provide a clear scientific justification for your work, and indicate possible applications and extensions. This conclusion should be provided as a paragraph. You should also suggest future experiments and/or point out those that are underway.

REFERENCES

[1] I. Pitas, "Digital image processing algorithms and applications," *A Wiley-Interscience publication*. 2000.

[2] M. Xu *et al.*, "Segmentation of lung parenchyma in CT images using CNN trained with the clustering algorithm generated dataset," *Biomed. Eng. Online*, 2019, doi: 10.1186/s12938-018-0619-9.

[3] Y. Lu, X. Wu, P. Liu, H. Li, and W. Liu, "Rice disease identification method based on improved CNN-BiGRU," *Artif. Intell. Agric.*, 2023, doi: 10.1016/j.aiia.2023.08.005.

[4] Q. X. Zhang, G. H. Lin, Y. M. Zhang, G. Xu, and J. J. Wang, "Wildland Forest Fire Smoke Detection Based on Faster R-CNN using Synthetic Smoke Images," in *Procedia Engineering*, 2018. doi: 10.1016/j.proeng.2017.12.034.

[5] Y. Singh *et al.*, "The Role of Geometry in Convolutional Neural Networks for Medical Imaging," *Mayo Clin. Proc. Digit. Heal.*, 2023, doi: 10.1016/j.mcpdig.2023.08.006.

[6] R. Chauhan, K. K. Ghanshala, and R. C. Joshi, "Convolutional Neural Network (CNN) for Image Detection and Recognition," in *ICSCCC 2018 - 1st International Conference on Secure Cyber Computing and Communications*, 2018. doi: 10.1109/ICSCCC.2018.8703316.

[7] N. IBRAHIM *et al.*, "Klasifikasi Tingkat Kematangan Pucuk Daun Teh menggunakan Metode Convolutional Neural Network," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, 2022, doi: 10.26760/elkomika.v10i1.162.

[8] W. Setiawan, "PERBANDINGAN ARSITEKTUR CONVOLUTIONAL NEURAL NETWORK UNTUK KLASIFIKASI FUNDUS," *J. Simantec*, 2020, doi: 10.21107/simantec.v7i2.6551.

[9] S. Hira, A. Bai, and S. Hira, "An automatic approach based on CNN architecture to detect Covid-19 disease from chest X-ray images," *Appl. Intell.*, 2021, doi: 10.1007/s10489-020-02010-w.

[10] R. AGUSTINA, R. MAGDALENA, and N. K. C. PRATIWI, "Klasifikasi Kanker Kulit menggunakan Metode Convolutional Neural Network dengan Arsitektur VGG-16," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, 2022, doi: 10.26760/elkomika.v10i2.446.

[11] S. Arvind, J. V. Tembhurne, T. Diwan, and P. Sahare, "Improvised light weight deep CNN based U-Net for the semantic segmentation of lungs from chest X-rays," *Results Eng.*, 2023, doi: 10.1016/j.rineng.2023.100929.

[12] M. F. Aslan, "A robust semantic lung segmentation study for CNN-based COVID-19 diagnosis," *Chemom. Intell. Lab. Syst.*, 2022, doi: 10.1016/j.chemolab.2022.104695.

[13] X. Chen, Q. Duan, R. Wu, and Z. Yang, "Segmentation of lung computed tomography images based on SegNet in the diagnosis of lung cancer," *J. Radiat. Res. Appl. Sci.*, 2021, doi: 10.1080/16878507.2021.1981753.

[14] W. M. Salama and M. H. Aly, "Framework for COVID-19 Segmentation and Classification Based on Deep Learning of Computed Tomography Lung Images," *J. Electron. Sci. Technol.*, 2022, doi: 10.1016/j.jnlest.2022.100161.

[15] W. Hastomo, E. Hadiyanto, and D. Sutarno, "Klasifikasi Covid-19 Chest X-Ray Dengan Tiga Arsitektur Cnn (Resnet-152, Inceptionresnet-V2, Mobilenet-V2)," *Semin. Nas. Teknol. Inf. dan Komun. STI&K*, vol. 5, no. 1, pp. 2581–2327, 2021.

[16] S. M. Ashhar *et al.*, "Comparison of deep learning convolutional neural network (CNN) architectures for CT lung cancer classification," *Int. J. Adv. Technol. Eng. Explor.*, 2021, doi: 10.19101/IJATEE.2020.S1762126.

[17] H. Alshazly, C. Linse, M. Abdalla, E. Barth, and T. Martinetz, "COVID-Nets: deep CNN architectures for detecting COVID-19 using chest CT scans," *PeerJ Comput. Sci.*, 2021, doi: 10.7717/peerj-cs.655.

[18] A. A. Kusmareni, A. Desiani, S. Yahdin, M. Saviera, A. I. Putri, and D. A. Zayanti, "Segmentasi Paru-Paru Pada Citra Thorax Dada Dengan Menggunakan Metode Cnn U-Net," *JSI J. Sist. Inf.*, vol. 14, no. 2, pp. 2666–2676, 2022, doi: 10.18495/jsi.v14i2.16771.

[19] F. A. Hermawati and M. Imam Safii, "Sistem Deteksi Keganasan Kanker Paru-Paru pada CT Scan dengan Menggunakan Metode Mask Region-based Convolutional Neural Network (Mask R-CNN)," *Konf. Nas. Ilmu Komput.*, no. August, pp. 193–197, 2021.

[20] U. Khultsum, F. Sarasati, and G. Taufik, "Penerapan Metode Mobile-Net Untuk Klasifikasi Citra Penyakit Kanker Paru-Paru," *JURIKOM (Jurnal Ris. Komputer)*, 2022, doi: 10.30865/jurikom.v9i5.4918.

[21] J. Yopento, E. Ernawati, and F. F. Coastera, "Identifikasi Pneumonia Pada Citra X-Ray Paru-Paru Menggunakan Metode Convolutional Neural Network (CNN) Berdasarkan Ekstraksi Fitur Sobel," *Rekursif J. Inform.*, 2022, doi: 10.33369/rekursif.v10i1.17247.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Hybrid Feature Combination of TF-IDF and BERT for Enhanced Information Retrieval Accuracy

Pajri Aprilio[1], Michael[2], Putu Surya Nugraha[3], Hasanul Fahmi[4]
[1,2,3]Faculty of Computer Science, Informatics, President University, Cikarang, Indonesia
[4]UNITAR International University, School of Information Technology, Selangor, Malaysia
Email: [1]pajri.aprilio@student.president.ac.id, [2]michael2024@student.president.ac.id,
[3]putu.nugraha@student.president.ac.id, [4]fahmi.zuhri@unitar.my

Abstract – Text representation is a critical component in Natural Language Processing tasks such as information retrieval and text classification. Traditional approaches like Term Frequency-Inverse Document Frequency (TF-IDF) provide a simple and efficient way to represent term importance but lack the ability to capture semantic meaning. On the other hand, deep learning models such as Bidirectional Encoder Representations from Transformers (BERT) produce context-aware embeddings that enhance semantic understanding but may overlook exact term relevance. This study proposes a hybrid approach that combines TF-IDF and BERT through a weighted feature-level fusion strategy. The TF-IDF vectors are reduced in dimension using Truncated Singular Value Decomposition and aligned with BERT vectors. The combined representation is used to train a fully connected neural network for binary classification of document relevance. The model was evaluated using the CISI benchmark dataset and compared with standalone TF-IDF and BERT models. Experimental results show that the hybrid model achieved a training accuracy of 97.43 percent and the highest test accuracy of 80.02 percent, outperforming individual methods. These findings confirm that combining lexical and contextual features can enhance classification accuracy and generalization. This approach provides a more robust solution for improving real-world information retrieval systems where both term specificity and contextual relevance are important.

Keywords – TF-IDF, BERT, Text Classification, Information Retrieval, Hybrid Model, Semantic Embedding, Neural Network

I. INTRODUCTION

Natural Language Processing (NLP) has an important role in enabling machines to interpret and process human language for tasks such as information retrieval and text classification. Accurate text representation is fundamental to the success of these tasks. Traditional methods like Term Frequency-Inverse Document Frequency (TF-IDF) have long been used due to their simplicity and effectiveness in representing term importance [1]. However, these methods are limited in capturing the semantic and contextual meaning of language, leading to performance issues in complex NLP tasks. On the other hand, deep learning models such as Bidirectional Encoder Representations from Transformers (BERT) have demonstrated a better performance by understanding the contextual relationships between words in a sequence, thus enabling better text understanding.

TF-IDF has been widely adopted in IR systems due to its effectiveness in term-level statistical analysis [2]. Despite its popularity, its inability to understand context within a document limits its performance on complex linguistic tasks. To address this, models like BERT utilize deep bidirectional transformers to learn contextual representations of words and sentences, significantly enhancing performance across various NLP benchmarks including question answering and document ranking [3][4].

Recent developments in IR have leveraged dense representations from models like BERT for semantic search and document matching [5][6]. Studies such as [7] demonstrate that integrating contextual embeddings into ranking systems can significantly boost relevance modeling. Furthermore, Nogueira et al. show how BERT can improve re-ranking effectiveness in passage retrieval tasks [8]. Yang et al. present simple yet effective applications of BERT in ad hoc

e-ISSN: 2614-8404
p-ISSN: 2776-3234

retrieval, reinforcing its adaptability to diverse IR tasks [9].

However, while BERT excels at capturing the contextual meaning of words, it may underemphasize the importance of exact term matches which is a strength of traditional statistical approaches like TF-IDF. To bridge this gap, hybrid models combining statistical and contextual features are developed. Lin et al. highlight the potential of integrating pre-trained transformers with traditional signals to enhance ranking performance [10]. Moreover, the BEIR benchmark, developed by Thakur et al., supports evaluating hybrid models across heterogeneous datasets and demonstrates the effectiveness of combining retrieval paradigms [11].

Recent efforts in dense retrieval models have focused on pretraining and optimizing contextual embeddings for semantic matching. Gao and Callan [12][14] proposed corpus-aware language model pretraining, showing that language models tailored to the domain can significantly improve dense retrieval results without requiring extensive supervised data. Likewise, Zhan et al. [15] highlighted the importance of hard negatives in training dense models, enabling them to learn more effective decision boundaries for relevance. These advances validate the importance of fine-tuning semantic embeddings, but they still underutilize lexical signals like those found in TF-IDF.

Hybrid retrieval models remain relatively underexplored in comparison to dense-only methods, even though fusion strategies may offer improved robustness. For example, Qu et al. [16] introduced RocketQA, an optimized training framework for dense passage retrieval, but did not integrate traditional IR features like TF-IDF. Xiong et al. [17] proposed an efficient contrastive learning method, yet similarly focused solely on neural representations. In contrast, the model proposed in this study bridges statistical and semantic paradigms through a feature-level fusion strategy that balances term specificity with contextual understanding.

Furthermore, emerging techniques such as multiview and topic-aware training have demonstrated promise in improving generalization across domains. Ma et al. [18] introduced a multi-granularity view approach to dense retrieval, while Hofstätter et al. [19] presented a sampling strategy that enhances topic coverage during training. These approaches suggest that hybrid and diversified representation schemes can better address real-world IR scenarios. By combining TF-IDF and BERT features in a weighted manner, this study contributes to filling the gap in fusion-based IR models and aligns with current efforts to improve retrieval robustness.

Despite the promise of hybrid approaches, many existing works focus on dense representations alone or offer limited insights into effective fusion strategies between statistical and contextual features. Furthermore, evaluations are often conducted on limited datasets, which restrict the understanding of their generalization capabilities in real-world applications.

This study proposes a novel hybrid model that integrates TF-IDF statistical features with BERT semantic embeddings via a weighted feature-level fusion strategy. By reducing TF-IDF vector dimensions and aligning them with BERT embeddings, the proposed method creates a unified vector representation that captures both explicit keyword importance and deep contextual semantics. This dual-layer representation is then fed into a fully connected neural network for binary classification in an information retrieval context. The model is evaluated on the CISI benchmark dataset and demonstrates improved classification accuracy compared to standalone TF-IDF and BERT models.

The main objective of this study is to develop and evaluate a hybrid text representation model that combines TF-IDF and BERT for improved performance in information retrieval tasks. The goal is to leverage the complementary strengths of statistical and contextual representations to enhance relevance prediction accuracy.

II. RESEARCH METHODOLOGY

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig. 1 Research Flow Diagram for TF-IDF + BERT Combination Methodology.

Figure 1 shows the flow of this research. This research used the CISI dataset [20], which contains classic query-document pairs for information retrieval tasks, it is a collection of information science research articles and queries commonly used for evaluating information retrieval and document ranking systems (https://ir.dcs.gla.ac.uk/resources/test_collections/cisi/). The research involves several steps which includes Data preprocessing, question-answer pair generation, TF-IDF vectorization and dimension reduction, BERT embedding, combining BERT and TF-IDF, dataset splitting, model architecture development, model training, and model evaluation. The methodological steps are outlined as follows.

A. Dataset Description

The experiment in this study uses the CISI dataset, a well-known collection in the field of information retrieval. The dataset consists of scientific document abstracts and user queries. The dataset contains three main files: CISI.ALL, CISI,QRY, and CISI.REL. CISI.ALL contains 1460 document abstracts, each with a unique ID and content. Table 1 shows the sample of document content. CISI.QRY contains 112 user queries related to the documents. Table 2 shows a sample of the user query. CISI.REL contains 3114 relevance data that maps each query to its corresponding relevant documents. Table 3 shows the sample of relevance judgement documents.

Table 1. Sample content of CISI.ALL file

Document Id	Document
1	18 Editions of the Dewey Decimal Classifications Comaromi, J.P. The present study is a history of...
2	Use Made of Technical Libraries Slater, M. This report is an analysis of 6300 acts of use in 104...
3	Two Kinds of Power An Essay on Bibliographic Control Wilson, P. The relationships between the...
4	Systems Analysis of a University Library; final report and research project Buckland, M.K. The...
5	A Library Management Game: a report on a research project Brophy, P. Although the use of games in pr...

Table 1 presents a sample of the content from the CISI.ALL file, which is a component of the CISI test collection. The table includes severa entries, each comprising a unique Document ID and the corresponding text excerpt from the document. These excerpts illustrate the variety and structure of bibliographic content found in the dataset, which typically includes titles, author names, and partial abstracts. The dataset is valuable for evaluating information retrieval algorithms due to its structured and semantically rich textual data.

Table 2. Sample content of CISI.QRY file

Query Id	Query
1	What problems and concerns are there in making up descriptive titles? What difficulties are involved...
2	How can actually pertinent data, as opposed to references or entire articles themselves, be retrieve...
3	What is information science? Give definitions where possible. ...
4	Image recognition and any other methods of automatically transforming printed text into computer-rea...
5	What special training will ordinary researchers and businessmen need for proper information manageme...

Table 2 shows a sample of the CISI.QRY file, which contains user queries used for evaluating information retrieval systems. Each entry includes a Query ID and the corresponding question or search request. These queries reflect typical information needs in the field of library and information science, making the dataset useful for testing and benchmarking retrieval performance.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Table 3. Sample content of CISI.REL file

Relevance Judgement Id	Query Id	Relevant Docs Id
1	1	[1281, 650, 1162, 524, 269, 1164, 783, 894, 150, 28]
1	2	[669, 29, 670, 674, 429, 690, 692, 309, 695, 700]
1	3	[640, 131, 1027, 133, 901, 136, 138, 140, 909, 911]
1	4	[321, 420, 329, 332, 980, 310, 601, 315]
1	5	[642, 648, 137, 1035, 525, 400, 528, 32, 692, 56]

Table 3 displays a sample of the CISI.REL file, which provides relevance judgments used in evaluating information retrieval systems. Each row links a query (identified by a Query ID) to a list of relevant document IDs, based on expert judgment. This mapping is essential for assessing how well a retrieval system can return documents that match user needs.

B. Data Preprocessing

The text data was preprocessed by converting all characters to lowercase, removing punctuation, collapsing newlines and multiple spaces. Figure 2 shows the implementation of the data preprocessing. Lowercase conversion is done using lower() function from python. Next, multiple spaces are then converted to single space using regex re.sub(r'\s+', ' ', text). Finally, the newline character is then converted into spaces. Converting multiple spaces and newline characters into space is to reduce the dataset complexity. Further data preprocessing is not performed to pertain to the context of the sentences because BERT embedding will be used in this research.

```
# region FUNCTION DEFINITION
def preprocess_text(text):
    text = text.lower() # make lowercase
    text = re.sub(r'\s+', ' ', text) # convert multiple spaces into one space
    text = re.sub("\n", " ", text) # convert newlines to spaces
    return text
# endregion
```

Fig. 2 Data Preprocessing Implementation.

C. Relevance Pair Generation

Query-document pairs were created with binary relevance labels (relevant or not relevant) to serve as training samples for classification. Each pair was treated as an input unit for embedding and modeling stages.

Table 4 shows the sample of question-answer pairs. Relevance judgement is shown in column Relevant represented by 1 (relevant) and 0 (not relevant). In this study, there are a total 6228 pairs with 3114 pairs relevant and 3114 pairs not relevant.

Table 4. Sample content of CISI.REL file

No	Question - Answer Pair	Relevant
1	(What problems and concerns are there?, Relative Effectiveness of Document…)	1
2	(What problems and concerns are there?, Information Value of VINITI-published…)	0
3	(What problems and concerns are there?, Relative Effectiveness of Titles, Abstracts, and Subject …)	1
4	(What problems and concerns are there?, Principles of Selective Information Servicing…)	0
5	(What problems and concerns are there?, On basic features of information retrieval…)	1

D. Feature Extraction.

This step transforms each query-document pair into numerical feature vectors. The text is independently embedded using two methods: TF-IDF for statistical term weighting and BERT for semantic contextual representation. After vectorization, the extracted features are combined to be used for classification models. The following is the details of the feature extraction process.

- TF-IDF Vectorization: Each query and document was independently transformed into a 5,000-dimensional sparse vector using TfidfVectorizer. The max_feature parameter is set to 5000 to decrease the complexity of the dataset and increase model performance. This will limit the vocabulary size to 5,000 and enough to capture most frequent terms across the dataset. Other tests using higher max_feature shows that the performance is not better than max_feature 5000. The vectors of queries and documents were concatenated and formed a 10,000-dimensional feature vector. Figure 3 shows the implementation of TF-IDF vectorization.
- Dimensionality Reduction: To align with BERT's vector size and minimize computational load, Truncated SVD was applied, reducing the TF-IDF vector to 768 dimensions. Figure 4 shows the implementation of dimensionality reduction of the TF-IDF vector.
- BERT Embedding: Contextual embeddings for queries and documents were generated using the all-MiniLM-L6-v2 model from SentenceTransformers library. Each text was encoded into a 384-dimensional vector. Queries and

e-ISSN: 2614-8404
p-ISSN: 2776-3234

documents vectors are concatenated and create a 768-dimensional vector. Figure 5 shows the implementation of BERT embedding.

- Feature Combination: The reduced TF-IDF vectors and BERT embeddings were combined by using weighting. The following is a formula to combine TF-IDF and BERT vectors.

$$combined\_vector = bw\ x\ bv + tw\ x\ tv \quad (1)$$

where:
- *bw*: weight of BERT
- *bv*: BERT vector
- *tw*: weight of TF-IDF
- *tv*: TF-IDF vector.

In this research BERT weight is set to 0.9 and TF-IDF is set to 0.1. Based on experiment, this combination gives the best result. Figure 6 shows the implementation of feature combination.

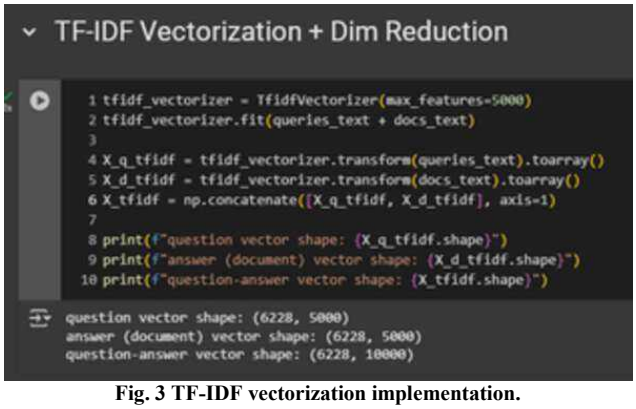


Fig. 3 TF-IDF vectorization implementation.

Fig. 4 TF-IDF dimensionality reduction using SVD

Fig. 5 BERT embedding implementation

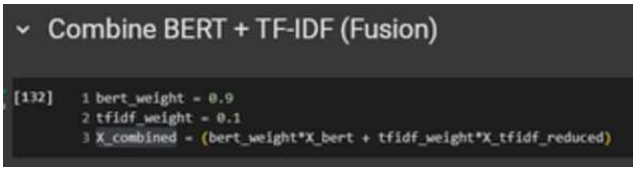


Fig. 6 Feature combination implementation

E. Dataset Split

This step split the dataset into test and training data. In this research the dataset is split into 80% training data and 20% testing data. The train_test_split function from sklearn is used to split the data. Stratify parameter is used to maintain the same proportion of labels in training and testing data. Figure 7 shows the implementation of dataset split.

Fig. 7 Dataset split implementation

F. Model Architecture Development

The model is developed using Fully Connected Neural Network (FCNN) that contains several layers. Figure 8 shows the implementation of the architecture. The architecture consists of the following layers:

1. **Input layer**: Accepts input of shape equal to the dimension of the feature vector. In the research, it accepts 1,536 features (768 from TF-IDF + 768 from BERT).
2. **First hidden layer**: A dense layer with 256 neurons.It uses the ReLU (Rectified Linear Unit) activation function to introduce non-linearity.
3. **Dropout layer**: A Dropout layer with a dropout rate of 30%. It helps to prevent overfitting by randomly disabling neurons during training.
4. **Second hidden layer**: A dense layer with 64 neurons, also using ReLU activation.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

5. **Output layer**: A dense layer with 1 neuron and sigmoid activation. Outputs a probability between 0 and 1, suitable for binary classification (relevant vs. not relevant).

```
[ ]  1 from keras.layers import Input, Dense, Dropout
     2 from keras.models import Sequential
     3
     4 model = Sequential([
     5     Input(shape=(X_combined_avg.shape[1],)),
     6     Dense(256, activation='relu'),
     7     Dropout(0.3),
     8     Dense(64, activation='relu'),
     9     Dense(1, activation='sigmoid')
    10 ])
    11
    12 model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
```

Fig. 8 Model architecture implementation

G. Model Training

The fully connected neural network was trained using the processed and labeled query-document pairs. The model was trained for 100 epochs with a batch size of 64. Throughout the training, the model achieved training accuracy of 97.43% in the final epoch. Figure 9 shows the model training implementation and Figure 10 shows the training result.

```
1 model.fit(X_train, y_train, epochs=100, batch_size=64)
78/78 [==============================] - 4s 51ms/step - loss: 0.0319 - accuracy: 0.9775
Epoch 73/100
78/78 [==============================] - 4s 49ms/step - loss: 0.0324 - accuracy: 0.9771
Epoch 74/100
78/78 [==============================] - 4s 51ms/step - loss: 0.0313 - accuracy: 0.9779
```

Fig. 9 Model training implementation

Fig. 10 Model training result

H. Model Evaluation

After training, the model's performance was evaluated using the test set, which consisted of 20% of the total data. The evaluation measured both the loss and the classification accuracy. The final evaluation achieve a test accuracy of 0.8002, indicating that the model correctly predicted the relevance of query-document pairs in approximately 80% of cases. This result demonstrates that the model generalized well to unseen data and did not suffer from overfitting. Figure 11 shows the implementation of model evaluation and its result.

```
Evaluate
1 loss, acc = model.evaluate(X_test, y_test)
2 print(f"Test Accuracy: {acc:.4f}")
39/39 [==============================] - 1s 6ms/step - loss: 1.1898 - accuracy: 0.8002
Test Accuracy: 0.8002
```

Figure. 11 Model training result

III. RESULTS AND DISCUSSION

This study evaluated the performance of three approaches in information retrieval tasks: TF-IDF, BERT, and a combination of TF-IDF and BERT. The evaluation was conducted based on accuracy performance metrics for both training and testing datasets. The experiment was conducted using different types of vectorization which are TF-IDF only, BERT only, and combination of TF-IDF and BERT.

Table 1. Accuracy Result

Method	Training	Testing
TF-IDF	0.9777	0.7376
BERT	0.9671	0.7777
TF-IDF + BERT	0.9743	0.8002

Table 1 shows the result of TF-IDF, BERT, and TF-IDF+BERT result. The TF-IDF method achieved a high training accuracy of 0.9777 but showed a lower testing accuracy of 0.7376, indicating potential overfitting and limitations in generalizing to unseen data. In contrast, the BERT model demonstrated more balanced performance with a training accuracy of 0.9671 and a higher testing accuracy of 0.7777, suggesting stronger generalization capabilities due to its contextual understanding of language.

The fusion approach, which combined the strengths of both TF-IDF and BERT, delivered the most optimal results with a training accuracy of 0.9743 and the highest testing accuracy of 0.8002. This indicates that integrating lexical-based statistical features from TF-IDF with semantic-rich embeddings from BERT can enhance model robustness and performance on diverse data.

These findings confirm the original objective of the study—to explore whether a hybrid approach could outperform individual models in information retrieval tasks. The results scientifically support the hypothesis that feature-level fusion enables the model to leverage both local and contextual textual representations, leading to improved accuracy.

Compared to methods which focus on either traditional TF-IDF-based models or deep learning models like BERT separately, our findings demonstrate that a synergistic combination can have good results. While BERT alone has been shown to outperform classical

e-ISSN: 2614-8404
p-ISSN: 2776-3234

methods in many NLP tasks, the addition of TF-IDF still provides valuable discriminative features, especially in domains with sparse or keyword-driven data.

In summary, the combination method between TF-IDF and BERT provides practical implications for improving retrieval performance in real-world applications.

IV. CONCLUSION

This research aimed to enhance information retrieval performance by combining traditional TF-IDF features with deep contextual representations from BERT. The proposed combination approach successfully outperformed individual models, demonstrating that integrating lexical and semantic information leads to improved generalization and classification accuracy. This work advances the current state of knowledge by offering a hybrid architecture that leverages the complementary strengths of statistical and deep learning methods, providing a more robust solution for text classification tasks. The findings highlight the potential of feature fusion in real-world information retrieval systems, particularly in applications where both keyword specificity and contextual understnding are crucial. Future work may explore integrating additional feature extraction methods or using attention mechanisms to dynamically weight the contribution of each representation, as well as validating the approach on larger and more diverse datasets to further assess scalability and adaptability.

REFERENCES

[1] Khattab, O., & Zaharia, M. (2020). ColBERT: Efficient and Effective Passage Search via Contextualized Late Interaction over BERT (*SIGIR '20.*). https://doi.org/10.1145/3397271.3401075

[2] Thakur, N., Reimers, N., Rücklé, A., Srivastava, A., & Gurevych, I. (2021). BEIR: a heterogenous benchmark for zero-shot evaluation of information retrieval models. arXiv (Cornell University). Retrieved from https://arxiv.org/pdf/2104.08663

[3] Devlin, J., Chang, M., Lee, K., & Toutanova, K. (2018). BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding. arXiv (Cornell University). https://doi.org/10.48550/arxiv.1810.04805

[4] Liu, Y., Ott, M., Goyal, N., Du, J., Joshi, M., Chen, D., . . . Stoyanov, V. (2019). ROBERTA: A robustly optimized BERT pretraining approach. arXiv (Cornell University). https://doi.org/10.48550/arxiv.1907.11692

[5] Karpukhin, V., Oğuz, B., Min, S., Lewis, P., Wu, L., Edunov, S., . . . Yih, W. (2020). Dense passage retrieval for Open-Domain question answering. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2004.04906

[6] Reimers, N., & Gurevych, I. (2019). Sentence-BERT: Sentence Embeddings using Siamese BERT-Networks. Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing (EMNLP-IJCNLP). https://doi.org/10.18653/v1/d19-1410

[7] MacAvaney, S., Yates, A., Cohan, A., & Goharian, N. (2019). CEDR: Contextualized Embeddings for Document Ranking. SIGIR'19: Proceedings of the 42nd International ACM SIGIR Conference on Research and Development in Information Retrieva. https://doi.org/10.1145/3331184.3331317

[8] Nogueira, R., & Cho, K. (2019). Passage Re-ranking with BERT. arXiv (Cornell University). https://doi.org/10.48550/arxiv.1901.04085

[9] Yang, W., Zhang, H., & Lin, J. (2019). Simple applications of BERT for ad hoc document retrieval. arXiv (Cornell University). https://doi.org/10.48550/arxiv.1903.10972

[10] Lin, J., Nogueira, R., & Yates, A. (2020). Pretrained transformers for text

e-ISSN: 2614-8404
p-ISSN: 2776-3234

ranking: BERT and beyond. arXiv (Cornell University). https://doi.org/10.48550/arxiv.2010.06467

[11] Thakur, N., Reimers, N., Rücklé, A., Srivastava, A., & Gurevych, I. (2021b). BEIR: a heterogenous benchmark for zero-shot evaluation of information retrieval models. arXiv (Cornell University). Retrieved from https://arxiv.org/pdf/2104.08663

[12] Gao, L., Callan, J. (2021). Unsupervised Corpus Aware Language Model Pretraining for Dense Retrieva. (*ACL Findings*). https://doi.org/10.18653/v1/2021.findings-acl.413

[13] Reimers, N., & Gurevych, I. (2020). Making Monolingual Sentence Embeddings Multilingual using Knowledge Distillation (EMNLP 2020). https://doi.org/10.18653/v1/2020.emnlp-main.733

[14] Gao, L., & Callan, J. (2021). Unsupervised Corpus Aware Language Model Pretraining for Dense Retrieval (*Proceedings of ACL 2021*). https://doi.org/10.18653/v1/2021.acl-long.455

[15] Zhan, J., Mao, Y., Liu, J., Callan, J., & Gao, W. (2021). Optimizing Dense Retrieval Model Training with Hard Negatives. *Proceedings of SIGIR '21*. https://doi.org/10.1145/3404835.3462893

[16] Qu, Y., Liu, L., Liu, J., Ren, P., Chen, Z., Ma, J., & de Rijke, M. (2021). RocketQA: An Optimized Training Approach to Dense Passage Retrieval (*Proceedings of NAACL 2021*). https://doi.org/10.18653/v1/2021.naacl-main.466

[17] Xiong, L., et al. (2021). Approximate Nearest Neighbor Negative Contrastive Learning for Dense Text Retrieval. (*ICLR 2021*). https://openreview.net/forum?id=ze8wPjDclz

[18] Ma, X., Yu, J., & Sun, M. (2022). Multiview Training for IR: Improving Dense Retrieval with Multi-granularity Views. *Proceedings of the Web Conference 2022 (WWW '22)*. https://doi.org/10.1145/3485447.3511970

[19] Hofstätter, S., Reimer, N., & Hanbury, A. (2021). Efficiently Teaching an Effective Dense Retriever with Balanced Topic Aware Sampling (*ECIR 2021*). https://doi.org/10.1007/978-3-030-72113-8_9

[20] Glasgow IDOM - CISI Collection. (n.d.). [Dataset]. Retrieved from https://ir.dcs.gla.ac.uk/resources/test_collections/cisi/

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Air Quality Classification Using Naive Bayes Algorithm With SMOTE Technique Based on ISPU Data

Alya Febriyanti Fadhilah[1*)], Ayu Ratna Juwita[2], Yusuf Eka Wicaksana[3], Tohirin Al Mudzakir[4]
[1234] Program Studi Teknik Informatika, Universitas Buana Perjuangan Karawang
Email: [1]if21.alyafadhilah@mhs.ubpkarawang.ac.id, [2]ayurj@ubpkarawang.ac.id, [3]yusuf.eka@ubpkarawang.ac.id, [4]tohirin@ubpkarawang.ac.id

Abstract *– Air pollution in DKI Jakarta is an important issue and has a negative impact on public health. This study applies the naive Bayes algorithm to classify air quality, Utilizing the SMOTE technique effectively addresses the issue of data imbalance. The data analyzed came from air pollution index data from 2022 to 2024, taken from five air monitoring stations in Jakarta. The analysis process was carried out following the CRISP-DM stages, starting from understanding the problem to evaluating the model. The results showed that SMOTE succeeded in increasing prediction accuracy in fewer classes. Without SMOTE, the model accuracy reached 90% but appeared biased towards fewer classes, with a recall value of only 0.75 and a precision of 0.62. While SMOTE, the model accuracy became 88%, with a precision value of 0.86, recall 0.87, and f1-score 0.87, which showed more balanced results across classes.*

Keywords – classification, naive bayes, SMOTE, ISPU, data mining

I. INTRODUCTION

Air pollution is a major issue that has a negative impact on human health, ecosystems, and infrastructure, especially in urban areas. Transportation, industrial, and other activities are the main causes of air pollution [1]. Air pollution is a global challenge that is concerning across various countries, one of which is Indonesia. Jakarta as the largest metropolitan city is known to have a fairly high level of air pollution. In early October 2024, air pollution in DKI Jakarta entered the "unhealthy" category, based on the Air Quality Index at 160 and a PM2.5 concentration of 68.7 µg/m³. This figure is 13.7 times higher than the WHO safe limit [2]. The standard recommended by the World Health Organization is 5 µg/m³ [3]. Greenpeace recorded around 7,390 premature deaths and 2,000 low birth weight babies due to exposure to air pollution. Children, the elderly, and people with comorbidities are the most vulnerable to the impacts [4].

The problem of air pollution in DKI Jakarta can be stated as the toughest and most complex challenge faced by the government [5]. The Indonesian government based on decree on Environmental Impact Management Agency (Bapedal) Number KEP-107/Kabapedal/11/1997 has prepared steps to overcome environmental impacts, namely deciding that the Air Pollution Standard Index is a tool for assessing air quality in an area and its effects on human health, animals, plants, as well as aesthetic value. The Air Pollution Standard Index is a value without a unit that indicates the state of ambient air quality at a certain location and time, in order to assess its effects on human health, aesthetics, and other living things [6].

Determining the ISPU level can be done by applying classification methods in data mining as an efficient solution [7]. Data mining is a method used to obtain new information from a group of data by identifying certain patterns and rules obtained from large data sets [8]. The application of data mining is one solution to analyze air quality in DKI Jakarta using a classification technique approach.

Based on research conducted by Lasulika [9]. About Comparison of Naive Bayes, Support Vector Machine and K-Nearest Neighbor to Find the Highest Level of Accuracy in Smoothness of Cable TV Payment. The results of the study stated that naive bayes produced the highest level of accuracy of 96% and AUC of 0.99, while K-NN obtained an accuracy of 92% at K=3 and SVM provided an accuracy of 66% and an AUC value of 0.786. Then by Arnap [10] conducted a study on Improving SQL Injection Attack Detection Using Naive Bayes and SMOTE Methods on Imbalanced Datasets. Producing an accuracy rate of 99.50%, f1-score of 99.50%, precision of 99.50% and recall of 99.50%, this shows that the SMOTE technique is effective in balancing classes in the dataset and improving SQL injection attack detection.

Another research by Nurhariza [11] namely the Implementation of the Niave Bayes Algorithm for Classification to Determine Student Achievement Based on Average Values, produced an accuracy of 98%, 100% precision and 98% recall. Next, Kurniadi [12]conducted a study on the Classification of Village Fund Direct Cash Assistance Recipients Using Naïve Bayes and SMOTE. His study conducted a comparison that produced an accuracy value of 97.07% for the naïve bayes model without SMOTE, while with SMOTE it increased to 97.80%, precision of 96.67%, and recall of 99.02%.

Based on the previous explanation, the purpose of this study is to analyze the performance of the naïve Bayes algorithm using the SMOTE technique in classifying air pollution in DKI Jakarta. It is expected that this study can produce a more accurate classification to support the decision-making process in managing and overcoming air pollution efficiently

e-ISSN: 2614-8404
p-ISSN: 2776-3234

II. METHODOLOGY

A. Reseacrch Stages

This study utilizes the research stages of a data mining series known as CRISP-DM. In research [13] according to Laroske, CRISP-DM is a standard data mining process used to solve general problems in research or business. CRISP-DM is an approach that uses a data development stage model that is often applied by experts in solving a problem [14]. The CRISP-DM method consists of six stages, namely Business Understanding, Data Understanding, Data Preparation, Modeling, Evaluation, and Deployment.

Fig 1. CRISP-DM methodology

1. Business Understanding

The first stage is to understand or analyze the problems that need to be solved in business. In this process, understanding is carried out on the monitoring of DKI Jakarta's air quality as a whole, so that accurate information is obtained.

2. Data Understanding

The second process includes data collection, data analysis and explanation, and identification of problems related to the data. The data collection process was obtained from the website http://satudata.jakarta.go.id about the DKI Jakarta Air Pollution Standard Index data in excel format. The data used covers the years 2022 to 2024 Each row of data describes the results of daily ISPU monitoring with the main attributes being the monitoring date, monitoring station, pollutant parameters such as PM10, PM2.5, CO, NO2, O3, SO2, and air quality category. Which were taken from collected five air quality measurement stations in DKI Jakarta, namely DKI1 Bundaran HI, DKI2 Kelapa Gading, DKI3 Jagakarsa, DKI4 Lubang Buaya, and DKI5 Kebon Jeruk. The reason for choosing these three years is because the time difference is not too far from the implementation of this research and can provide a more accurate picture of the current situation.

3. Data Preparation

In the third step, it includes the process of compiling the final dataset that will be used as input in data mining modeling. The data preparation process is carried out as follows:

1) Attribute Selection, namely the process of selecting the most relevant attributes such as CO, O3, SO2, NO2, PM10, PM2 and categories.
2) Transformation data, which is the process of changing the format or structure of data according to modeling such as recategorization and coding of categorical features.
3) Data Cleaning, which is the process of cleaning data that has the potential to interfere with modeling analysis, such as handling missing values and outliers.
4) Balancing Data is the process of equalizing the distribution of classes in a dataset so that the quantity of samples in every class becomes more balanced, such as the SMOTE technique which is applied to balance the distribution of datasets in minority classes by creating minority datasets so that the number is the same as the dataset in the majority class [15]. The SMOTE equation can be seen in equation (1).

$$Xnew = Xi + (Xi\hat{} - Xi) \times \delta \quad (1)$$

5) Data Division, which is the stage of separating the dataset into training data and test data with a certain ratio such as 80:20.

4. Modeling

In the modeling stage, the selected algorithm model is applied to the dataset. The data mining modeling process applied is naive bayes gaussian. The naive Bayes algorithm has superior performance in performing classification, especially in terms of the accuracy of the classification results produced [16]. The function of naive bayes gaussian is to calculate data attributes that have continuous properties directly [17]. The naive bayes gaussian equation can be seen in equation (2).

$$(Xi = xi|Y = yj) = \frac{1}{\sqrt{2\pi\sigma ij}} e \frac{(xi-\mu\ )^2}{2\sigma^2 ij} \quad (2)$$

One method to build a simple model is to assume that the data follows a Gaussian distribution with no covariance between dimensions. Thus, the model can be created simply by calculating the average and standard deviation of the data for each label.

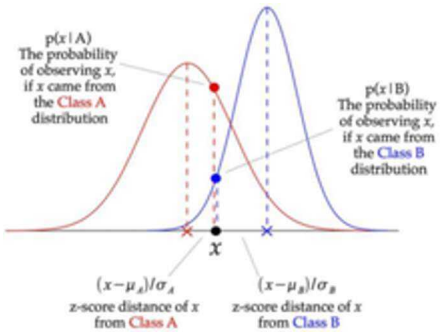


Fig 2. How the naive bayes gaussian classification works (www.researchgate.net)

Figure 2 illustrates how the naive bayes gaussian works, where each data point is calculated its z-score value against the class mean, which is the difference between the data

e-ISSN: 2614-8404
p-ISSN: 2776-3234

value and the class mean divided by the class standard deviation. Therefore, the naive bayes gaussian uses a slightly different approach and is quite effective in handling continuous data. Furthermore, the classification process is carried out for each attribute by referring to Bayes' Theorem, where new information is obtained through the calculation of the statistical probability of each attribute.

5. Evaluation

At the evaluation stage, an analysis is carried out on the accuracy of the results of the data processing process that has been applied. The evaluation process uses a confusion matrix that specifically describes the performance of the model. In this matrix, each row denotes the actual data class, while each column signifies the predicted data class [18].

Table 1. Confusion matrix

Actual Values	**Predicted Values**	
	Positive	***Negative***
Positive	*True Positive* (TP)	*False Negative* (FN)
Negative	*False Positive* (FP)	*True Negative* (TN)

1) Accuracy
The total count of frequencies accurately classified by the model. The mathematical equation for accuracy is given in formula 3.

$$\frac{TP+TN}{TP+FP+FN+TN} \quad (3)$$

2) Precision
When a model makes a positive prediction, the accuracy of that prediction indicates how often the result is correct. The mathematical equation for precision is given in formula 4.

$$\frac{TP}{TP+FP} \quad (4)$$

3) Recall
When the actual class has a positive value, this metric measures the extent to which the model correctly predicted positive. The mathematical equation for recall is in equation 5.

$$\frac{TP}{TP+} \quad (5)$$

4) F1-Score
This harmonic mean value is obtained by precision and recall. The mathematical equation of f1-score is found in equation 6.

$$\frac{2(Recall*Precision)}{(Recall+Pre\quad)} \quad (6)$$

B. Indeks Standar Pencemaran Udara

Indeks Standar Pencemaran Udara (ISPU) is a parameter applied to measure air quality by indicating the level of pollution due to the influence of chemical substances and particles in the atmosphere [19]. The calculation of ISPU is based on the upper and lower threshold values for ambient, as well as ambient concentrations obtained from measurement results using the following mathematical formula:

$$I = \frac{Ia-Ib}{xa-xb}(Xx - Xb) + Ib \quad (7)$$

The upper bound value of ISPU (Ia) is set at 100, while the lower bound value of ISPU (Ib) is set at 50. The ambient concentration for the upper limit (Xa) and lower limit (Xb) is obtained from the ISPU parameter concentration conversion table, with different Xa and Xb values depending on each parameter. Meanwhile, the actual ambient concentration value (Xx) is calculated based on the average ambient concentration during 24 hours of measurement.[20]. The air pollution index value has various categories which are used to measure the level of air pollution detected in Figure 3.

Fig 3. ISPU Category (www.climate4life.info)

Figure 3 illustrates the air quality classification system based on the ISPU standard issued by the Ministry of Environment and Forestry of the Republic of Indonesia. Air quality is classified into five levels based on the ISPU value: Good (1–50), Moderate (51–100), Unhealthy (101–200), Very Unhealthy (201–300), and Hazardous (≥301). Each category is marked with a certain color as a visual indicator, namely green for Good, blue for Moderate, yellow for Unhealthy, red for Very Unhealthy, and black for Hazardous.

III. RESULTS AND DISCUSSION

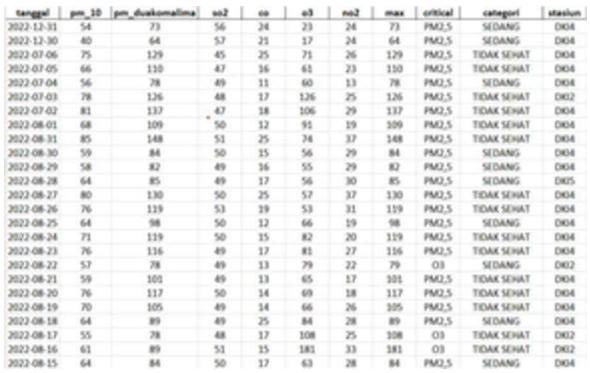
1. Business Understanding

DKI Jakarta air quality monitoring is carried out to obtain data that supports the air quality classification process. The data obtained provides accurate information on the level of air pollution based on the air pollution standard index and its impact on health due to exposure to pollution, so that it can help the community and government in making decisions based on current conditions.

2. Data Understanding

The total data successfully collected was 3,506 Air Pollution Standard Index data for 2022-2024, with details of 321 data in the good category, 269 data in the moderate category, 482 data in the unhealthy category and 4 data in the very unhealthy category.

e-ISSN: 2614-8404
p-ISSN: 2776-3234



tanggal	pm_10	pm_duakomalima	so2	co	o3	no2	max	critical	categori	stasiun
2022-12-31	54	73	56	24	23	24	73	PM2,5	SEDANG	DKI4
2022-12-30	40	64	57	21	17	24	64	PM2,5	SEDANG	DKI4
2022-07-06	75	129	45	25	71	26	129	PM2,5	TIDAK SEHAT	DKI4
2022-07-05	66	110	47	16	61	23	110	PM2,5	TIDAK SEHAT	DKI4
2022-07-04	56	78	49	11	60	13	78	PM2,5	SEDANG	DKI4
2022-07-03	78	126	48	17	126	25	126	PM2,5	TIDAK SEHAT	DKI2
2022-07-02	81	137	47	18	106	29	137	PM2,5	TIDAK SEHAT	DKI4
2022-08-01	68	109	50	12	91	19	109	PM2,5	TIDAK SEHAT	DKI4
2022-08-31	85	148	51	25	74	37	148	PM2,5	TIDAK SEHAT	DKI4
2022-08-30	59	84	50	15	56	29	84	PM2,5	SEDANG	DKI4
2022-08-29	58	82	49	16	55	29	82	PM2,5	SEDANG	DKI4
2022-08-28	64	85	49	17	56	30	85	PM2,5	SEDANG	DKI5
2022-08-27	80	130	50	25	57	37	130	PM2,5	TIDAK SEHAT	DKI4
2022-08-26	76	119	53	19	53	31	119	PM2,5	TIDAK SEHAT	DKI4
2022-08-25	64	98	50	12	66	19	98	PM2,5	SEDANG	DKI4
2022-08-24	71	119	50	15	82	20	119	PM2,5	TIDAK SEHAT	DKI4
2022-08-23	76	116	49	17	81	27	116	PM2,5	TIDAK SEHAT	DKI4
2022-08-22	57	78	49	13	79	22	79	O3	SEDANG	DKI2
2022-08-21	59	101	49	13	65	17	101	PM2,5	TIDAK SEHAT	DKI4
2022-08-20	76	117	50	14	69	18	117	PM2,5	TIDAK SEHAT	DKI4
2022-08-19	70	105	49	14	66	26	105	PM2,5	TIDAK SEHAT	DKI4
2022-08-18	64	89	49	25	84	28	89	PM2,5	SEDANG	DKI4
2022-08-17	55	78	48	17	108	25	108	O3	TIDAK SEHAT	DKI2
2022-08-16	61	89	51	15	181	33	181	O3	TIDAK SEHAT	DKI2
2022-08-15	64	84	50	17	63	28	84	PM2,5	SEDANG	DKI4

Fig 4. Air Quality Dataset

3. Data Preparation

Data Preprocessing includes attribute selection, Data Transformation, Data Cleaning, Data Balancing, and Data Splitting.

1) Attribute Selection

Based on the dataset from 2022 to 2024, there are 11 attributes shown in Figure 4. However, only 7 attributes are used in the classification, namely the categories PM10, PM2.5, SO2, CO, O3, NO2 and the category.

	pm_10	pm_duakomalima	so2	co	o3	no2	categori
0	54	73	56	24	23	24	SEDANG
1	40	64	57	21	17	24	SEDANG
2	75	129	45	25	71	26	TIDAK SEHAT
3	66	110	47	16	61	23	TIDAK SEHAT
4	56	78	49	11	60	13	SEDANG
...	...	...	...	...	...	...	...
3501	51	68	60	10	26	51	SEDANG
3502	65	87	59	11	35	22	SEDANG
3503	53	70	60	8	32	47	SEDANG
3504	51	74	61	8	33	44	SEDANG
3505	59	84	61	9	28	44	SEDANG

Fig 5. Dataset after attribute selection

2) Transformasi Data

Data transformation is carried out through two processes, namely recategorization, combining several categories into one, and categorical feature coding, converting categorical data into a numeric format.

a) Recategorization

Recategorization is done by combining the "very unhealthy" category into the "unhealthy" category because it only has 4 data that have little influence on the model. This recategorization is done to overcome data limitations, so that it can maintain model performance and increase the effectiveness of the SMOTE technique.

categori	
SEDANG	2699
TIDAK SEHAT	482
BAIK	321
SANGAT TIDAK SEHAT	4

Fig 6. Before re-categorization

categori	
SEDANG	2699
TIDAK SEHAT	486
BAIK	321

Fig 7. Re-categorization results

b) Encoding Categorical Feature

Categorical feature encoding is done by changing the category parameter numbers that were originally strings into numeric types. In this case, the categorical labels "good", "moderate", and "unhealthy" are changed to 2, 1, and 0.

pm_10	pm_duakomalima	so2	co	o3	no2	categori
54	73	56	24	23	24	1
40	64	57	21	17	24	1
75	129	45	25	71	26	0
66	110	47	16	61	23	0
56	78	49	11	60	13	1
...	...	...	...	...	...	...
51	68	60	10	26	51	1
65	87	59	11	35	22	1
53	70	60	8	32	47	1
51	74	61	8	33	44	1
59	84	61	9	28	44	1

Fig 8. Results of encoding categorical features

3) Data Cleaning

Data cleaning is carried out to clean data that has the potential to interfere with analysis and modeling. One of the main focuses in this process is handling data with "-" values and outliers so that the data is cleaner and ready for analysis.

	pm_10	pm_duakomalima	so2	co	o3	no2	categori
647	-	35	52	2	8	8	1
648	32	64	52	7	8	12	1
649	49	73	-	-	-	-	1
650	52	-	18	17	27	5	1
651	48	-	20	18	21	5	2

Fig 9. Dirty air quality data

In row 647, pm_10 column, there is data with the value "-", likewise in row 649 there is data with the value "-" in the so2, co, o3 and no2 columns. Data with the value "-" is converted to NaN to facilitate the calculation of missing data. The missing numbers are then overcome by filling in using the median of each parameter.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

	pm_10	pm_duakomalima	so2	co	o3	no2	categori
647	55	35	52	2	8	8	1
648	32	64	52	7	8	12	1
649	49	73	42	13	26	20	1
650	52	78	18	17	27	5	1
651	48	78	20	18	21	5	2

Fig 10. Missing Value filled with median

In Figure 10, there is no "-" data because it has been replaced using the median of each parameter. The median value used for each parameter is pm_10 has a median value of 55, pm_duakomalima has a median value of 78, so2 is 42, co is 13, o3 is 26 and no2 is 20.

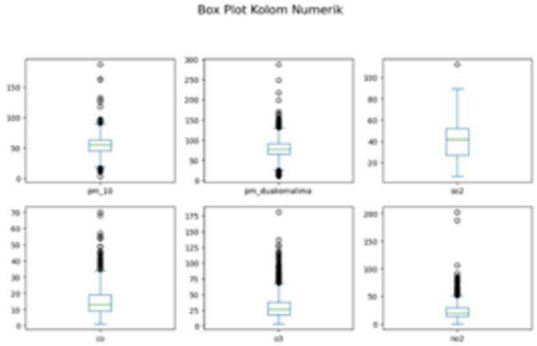


Fig 11. Outlier checking

In Figure 11, it can be seen that all parameters have outliers, parameters such as pm_10, pm_duakomalima, co, o3 and no2 have significant outliers, while the so2 parameter is not very significant. Parameters that have extreme outliers are handled with the Interquartile Range (IQR). Outliers will be replaced with lower or upper limits so as not to eliminate data.

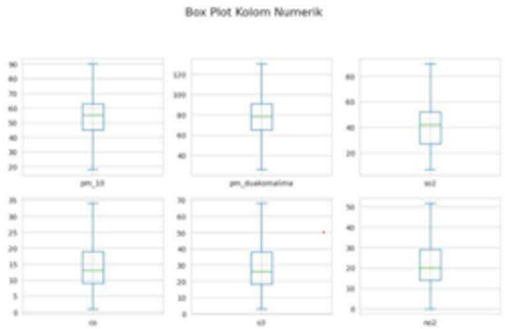


Fig 12. After performing the Interquartile Range

4) Balancing Data
Data balancing is done using SMOTE which is a technique in data imbalance.

Table 2. SMOTE Technique Results

Class	Original	SMOTE
0	486	2699
1	2699	2699
2	321	2699
Total	**3506**	**8097**

Category 0 is the minority class, while category 1 is the majority class, the SMOTE technique balances the data with the number of majority classes reaching 2699 data.

5) Data Sharing
The data obtained from the balancing process amounted to 2699 per category. As much as 80% was allocated as training data while 20% was test data. The results of the initial data division were 2804 for training data and 702 testing data. Meanwhile, the outcomes of the division in the SMOTE method were 6477 training data and 1620 test data.

4. Modeling

After the data preparation is complete, the next step is to perform the naive bayes gaussian algorithm modeling. In the modeling stage, two scenarios are created as in Figure 12.

Fig 13. Modeling scenario

This study scenario intends to compare results of the naïve bayes gaussian classification algorithm on datasets that go through the SMOTE sampling technique process with datasets that do not use the SMOTE technique. Figures 14 and 15 are the classification results.

Classification Report:

	precision	recall	f1-score	support
0	0.92	0.99	0.95	540
1	0.85	0.77	0.81	540
2	0.86	0.87	0.87	540
accuracy			0.88	1620
macro avg	0.88	0.88	0.88	1620
weighted avg	0.88	0.88	0.88	1620

Fig 14. Naïve Bayes Gaussian + SMOTE results

Figure 14 shows the train and test process the performance of the naïve Bayes model on the dataset that applies the SMOTE method. This stage produces an accuracy percentage of 0.88, with an f1-score of 0.88, precision of 0.88, and recall of 0.88. Although these results show a slight decrease in model accuracy, the distribution of precision, recall, and f1-score values between classes becomes more balanced. In minority class 2, there is a significant increase in performance, with a precision of 0.86, a recall of 0.87, and an f1-score of 0.87. With this, it can be shown that the application of SMOTE has succeeded in increasing the ability of the naïve Bayes model to

e-ISSN: 2614-8404
p-ISSN: 2776-3234

recognize data in the minority class without significantly reducing model performance.

Classification Report:

	precision	recall	f1-score	support
0	0.90	0.86	0.88	97
1	0.94	0.93	0.94	541
2	0.62	0.75	0.68	64
accuracy			0.90	702
macro avg	0.82	0.85	0.83	702
weighted avg	0.91	0.90	0.91	702

Fig 15. Naïve Bayes Gaussian results without SMOTE

Figure 15 shows the results of naïve bayes on a dataset that does not apply the SMOTE method. The model produces an accuracy percentage of 0.90, with a precision 0.90, recall 0.90, and f1-score 0.90. However, in minority class 2, the values obtained tend to be lower than the other classes, namely precision of 0.62, recall of 0.75, and f1-score of 0.68. This shows that the classification model is biased towards the majority class and is less than optimal in classifying the minority class.

Table 3. Performance Comparison

Metode	***Accuracy***	***Precision***	***Recall***	***F1 - Score***
Naïve bayes + SMOTE	88%	88%	88%	88%
Naïve bayes	90%	90%	90%	90%

5. Evaluation

The evaluation and comparison process is carried out to evaluate the performance of the classification model with naive bayes gaussian algorithm using a confusion matrix.

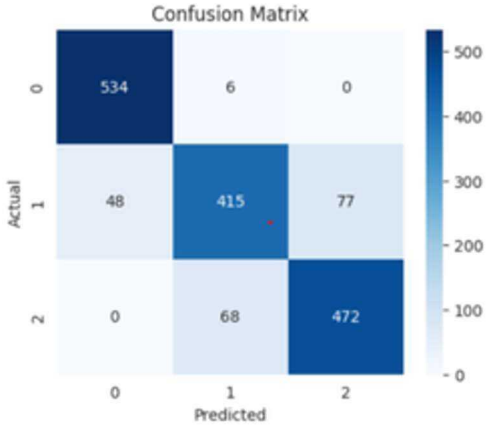


Fig16. Confusion Matrix Naive Bayes + SMOTE

Figure 16 shows the confusion matrix generated naive Bayes model test results that have applied the SMOTE method. The outcomes show that the model is able to predict classes 0 and 2 better and more balanced.

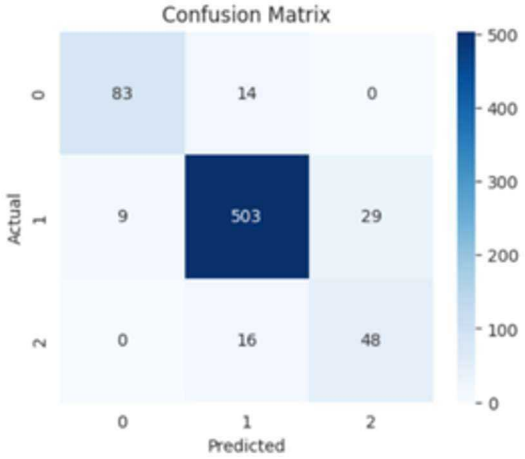


Fig 17. Naive Bayes Confusion Matrix

Figure 17 shows confusion matrix from the results of the naive Bayes test alone, which results in the model tending to be biased towards class 1, while the predictions for classes 0 and 2 are still low.

.

IV. CONCLUSION

Based on the results of the research that has been conducted, the following are the conclusions that can be obtained:

1. The application SMOTE successfully overcomes the imbalance of ISPU data by increasing the amount of data in the minority class. This makes the classification model, especially the naïve bayes gaussian algorithm, fairer in recognizing various classes. After SMOTE was applied, the prediction performance for the minority class increased, as indicated by the more balanced precision, recall, as well as f1-score values in every category compared to when not using SMOTE.
2. Based on the evaluation results, the naïve bayes model devoid of using SMOTE has an accuracy of 90%, but its performance is biased towards the majority class, which can be seen in the low recall value of 0.75 and precision of 0.62 for minority class. After the SMOTE technique was applied, the accuracy did decrease slightly, namely 88%, but at a recall value of 0.87, precision 0.86 and f1-score 0.87 in the minority class increased. This shows that the model is more balanced in classifying each air quality class.

REFERENCES

[1] A. Handayani, Silva, S. Soim, T. Agusdi, Enim, Rumsiasih, and A. Nurdin, "KLASIFIKASI KUALITAS UDARA DENGAN METODE SUPPORT VECTOR MACHINE," *JIRE (Jurnal Informatika & Rekayasa Elektronika)*, vol. 3, no. 2, pp. 187–199, 2020.

[2] Tempo, "Hari Pertama Oktober 2024, IQAir Catat Kualitas Udara Jakarta Memburuk," TEMPO. Accessed: Nov. 28, 2024. [Online]. Available:

e-ISSN: 2614-8404
p-ISSN: 2776-3234

https://www.tempo.co/lingkungan/hari-pertama-oktober-2024-iqair-catat-kualitas-udara-jakarta-memburuk--4050

[3] IQAir Staff Writers, "STANDAR WHO," IQAir. Accessed: Nov. 24, 2024. [Online]. Available: https://www.iqair.com/id/newsroom/new-epa-annual-pm25-air-quality-standards-expected-save-lives

[4] O. Health, "Polusi Jakarta Peringkat 1 di Dunia, Bagaimana Dampaknya pada Kesehatan?," ONE HEALTH CENTER OF EXCELLENCE UNIVERSITAS GADJAH MADA. [Online]. Available: https://ohce.wg.ugm.ac.id/polusi-jakarta-peringkat-1-di-dunia-bagaimana-dampaknya-pada-kesehatan/

[5] Bernadet, S. Listyarini, and L. Warlina, "Pengaruh Kebijakan Pencemaran Udara Sektor Transportasi Terhadap Nilai Indeks Kualitas Udara (Iku) Di Dki Jakarta," *Jurnal Ilmiah Pendidikan Lingkungan dan Pembangunan*, vol. 24, no. 01, pp. 1–13, 2023, doi: 10.21009/plpb.v24i01.30798.

[6] L. Qosim, Ahmad, "PERBANDINGAN METODE KLASIFIKASI SUPPORT VECTOR MACHINE (SVM) DAN NAIVE BAYES CLASSIFIER (NBC) UNTUK MENENTUKAN KUALITAS UDARA," p. 6, 2021.

[7] R. Firdaus *et al.*, "Implementasi Algoritma Random Forest Untuk Klasifikasi Pencemaran Udara di Wilayah Jakarta Berdasarkan Jakarta Open Data," vol. 14, no. 2, pp. 520–525, 2021.

[8] A. T. Ramadhan *et al.*, "Penerapan Algoritma Decision Tree Dalam Melakukan Analisis Klasifikasi Harga Handphone," *Jurnal Sistem Informasi dan Ilmu Komputer*, vol. 1, no. 4, pp. 195–206, 2023, [Online]. Available: https://doi.org/10.59581/jusiik-widyakarya.v1i4.1861

[9] M. E. Lasulika, "Komparasi Naïve Bayes, Support Vector Machine Dan K-Nearest Neighbor Untuk Mengetahui Akurasi Tertinggi Pada Prediksi Kelancaran Pembayaran Tv Kabel," *ILKOM Jurnal Ilmiah*, vol. 11, no. 1, pp. 11–16, 2019, doi: 10.33096/ilkom.v11i1.408.11-16.

[10] A. Arnap, "Enhancing SQL Injection Attack Detection Using Naïve Bayes and SMOTE Method on Imbalanced Datasets," vol. 4, no. 1, 2024.

[11] M. Nurhariza, A. Ratna Juwita, and D. Sulistya Kusumaningrum, "Implementasi Algoritma Naive Bayes Untuk Klasifikasi Menentukan Prestasi Siswa Berdasarkan Nilai Rata-Rata," vol. V, no. 1, pp. 65–77, 2024.

[12] D. Kurniadi, F. Nuraeni, and M. Firmansyah, "Klasifikasi Masyarakat Penerima Bantuan Langsung Tunai Dana Desa Menggunakan Naïve Bayes dan SMOTE," *Jurnal Teknologi Informasi dan Ilmu Komputer*, vol. 10, no. 2, pp. 309–320, 2023, doi: 10.25126/jtiik.20231026453.

[13] N. Ajijah and A. Kurniawan, "Klasifikasi Teks Mining Terhadap Analisa Isu Kegiatan Tenaga Lapangan Menggunakan Algoritma K-Nearest Neighbor (KNN)," *J-SAKTI (Jurnal Sains Komputer & Informatika)*, vol. 7, no. 1, pp. 254–262, 2023.

[14] K. Suhada, A. Elanda, and A. Aziz, "Klasifikasi Predikat Tingkat Kelulusan Mahasiswa Program Studi Teknik Informatika dengan Menggunakan Algoritma C4.5 (Studi Kasus: STMIK Rosma Karawang)," *Dirgamaya: Jurnal Manajemen dan Sistem Informasi*, vol. 1, no. 2, pp. 14–27, 2021, doi: 10.35969/dirgamaya.v1i2.182.

[15] G. Gumelar, Q. Ain, R. Marsuciati, S. Agustanti Bambang, A. Sunyoto, and M. Syukri Mustafa, "Kombinasi Algoritma Sampling dengan Algoritma Klasifikasi untuk Meningkatkan Performa Klasifikasi Dataset Imbalance," *SISFOTEK : Sistem Informasi dan Teknologi*, pp. 250–255, 2021.

[16] A. A. Mahran, R. K. Hapsari, and H. Nugroho, "Penerapan Naive Bayes Gaussian Pada Klasifikasi Jenis Jamur Berdasarkan Ciri Statistik Orde Pertama," *Network Engineering Research Operation*, vol. 5, no. 2, p. 91, 2020, doi: 10.21107/nero.v5i2.165.

[17] A. A. H. Kirono, I. Asror, and Y. F. A. Wibowo, "Klasifikasi Tingkat Kualitas Udara Dki Jakarta Menggunakan Algoritma Naïve Bayes," *e-Proceeding of Engineering*, vol. 9, no. 3, p. 1962, 2022.

[18] I. W. Saputro and B. W. Sari, "Uji Performa Algoritma Naïve Bayes untuk Prediksi Masa Studi Mahasiswa," *Creative Information Technology Journal*, vol. 6, no. 1, p. 1, 2020, doi: 10.24076/citec.2019v6i1.178.

[19] D. Perdana and A. Muklason, "Machine Learning untuk Peramalan Kualitas Indeks Standar Pencemar Udara DKI Jakarta dengan Metode Hibrid ARIMAX-LSTM," *ILKOMNIKA: Journal of Computer Science and Applied Informatics*, vol. 5, no. 3, pp. 209–222, 2023, doi: 10.28926/ilkomnika.v5i3.588.

[20] I. S. R. Dasrul Chaniago, Annisa Zahara, "Kementerian Lingkungan Hidup dan Kehutanan," 24-09. [Online]. Available: https://ditppu.menlhk.go.id/portal/read/indeks-standar-pencemar-udara-ispu-sebagai-informasi-mutu-udara-ambien-di-indonesia

e-ISSN: 2614-8404
p-ISSN: 2776-3234

The Implementation of VANET Routing Protocol for Vehicular Communication Using NS3 and SUMO

Iswar Sukarman[1], Ketut Bayu Yogha Bintoro[2*)]
[1]Program Studi Teknik Informatika, Fakultas Industri Kreatif dan Telematika, Universitas Trilogi
[2]Program Studi Sistem Informasi, Fakultas Industri Kreatif dan Telematika, Universitas Trilogi
Email: [1]iswarsukarman@gmail.com, [2]ketutbayu@trilogi.ac.id,

Abstract – Vehicular Ad-hoc Networks (VANETs) are dynamic wireless systems enabling vehicles to exchange data such as speed, location, and direction. A core component in VANETs is the routing protocol, with Ad-hoc On-Demand Distance Vector (AODV) being widely used. However, AODV struggles in highly dynamic environments, leading to reduced performance in throughput and end-to-end delay. This study proposes an improved AODV protocol using the Learning Automata approach (LA-AODV), which enhances relay node selection for better routing efficiency. The performance of LA-AODV is evaluated against standard AODV using NS-3 and SUMO simulations, focusing on key Quality of Service (QoS) metrics: throughput, packet delivery ratio, packet loss, and end-to-end delay. Simulation results show that LA-AODV significantly increases throughput (up to 90.84 Kbps) and reduces end-to-end delay by 20–35%, while lowering communication complexity (15–25% fewer Flow IDs). However, LA-AODV suffers from higher packet loss (up to 62%) and lower delivery ratios (37–92%) compared to AODV. This performance trade-off highlights LA-AODV's improved data efficiency at the cost of reliability. To mitigate delivery issues, solutions such as buffer tuning, adaptive queuing, or hybrid protocols are suggested. Future research should address these challenges and examine LA-AODV's scalability in larger VANET deployments.

Keywords – *V2V communication; AODV routing protocol; Connected Vehicle; LA-AODV; NS3 Simulation*

I. INTRODUCTION

The development of communication technology has changed the transportation industry, especially in terms of personal vehicles such as automobiles [1]. Today, smart cars have been equipped with advanced technology that allows vehicles to communicate with each other. Utilizing Wi-Fi technology known as Dedicated Short Range Communication (DSRC), DSRC is a special form of wireless communication that operates over short distances and is commonly used for data exchange between vehicles[2]. In addition, research is also growing in the field of Vehicle-to-vehicle (V2V) communication on the Vehicular Ad-Hoc Network (VANET) [3]. VANET allows vehicles to communicate directly with each other over a peer-to-peer network [4]-[5], [6]. Through V2V communication within the VANET network, vehicles can exchange information about position, speed, and direction of movement with other vehicles in the vicinity [5]. Measurement of distance between vehicles allows smart cars to detect precautions such as alerting the driver or even activating an automatic braking system to avoid collisions[6]. Thus, the driver can receive real-time information useful for running the vehicle safely and efficiently[7].

VANET technology has the potential to be a solution to overcome problems such as network traffic congestion[8], and identify more efficient network routes [9]-[10]. V2V communication in the VANET network has attracted significant attention from researchers, industry, and government due to its implementation which is important for improving vehicle safety in future generations[11]. The routing protocol is one of the key components in V2V communication in the VANET network to ensure effective and efficient data transmission between vehicles [12]. One of the commonly used routing protocols in Vehicle-to-vehicle communication on VANET networks is the Ad-hoc On-demand Distance Vector (AODV). AODV[13] is a protocol that can be applied to large-scale ad hoc networks, where routes to destination nodes are always updated[14]. This is possible because AODV uses sequence numbers as well as memory for routing table processing and reduces link redundancy[15].

The advantages of AODV as a simple routing protocol in V2V communication on the VANET network are indispensable because its implementation does not involve complicated algorithms[16],[17]. it exhibits significant limitations in dynamic vehicular environments. AODV is inherently reactive and lacks predictive mechanisms, which makes it ill-suited for rapidly changing network topologies caused by high vehicle mobility[18][19]. As vehicles frequently enter and leave communication ranges, AODV struggles to maintain stable routes, resulting in frequent link breakages and repeated route discoveries. These disruptions introduce high end-to-end delay, increase routing overhead, and degrade packet transmission reliability, especially under high-speed or high-density scenarios[20]. Furthermore, AODV does not consider vehicle speed, direction, or position when selecting relay nodes, leading to inefficient routing decisions and poor adaptation to network dynamics. These issues collectively limit its effectiveness in time-sensitive applications such as collision avoidance or cooperative driving [15]. To address this gap, this research proposes an enhanced AODV protocol, namely Learning Automata-based AODV (LA-AODV), which incorporates machine learning methods to improve routing performance in dynamic V2V environments. Unlike conventional AODV, LA-AODV dynamically adapts to network conditions by optimizing relay node selection, reducing delay, and improving packet delivery rates.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

This situation shows that the AODV routing protocol has not been optimally used in V2V communication on VANET networks involving fast and dynamic vehicle movements [21]. Therefore, further development and modification of this protocol is needed to create better and more effective solutions. One proposed modification of the AODV protocol is LA-AODV, which incorporates machine learning methods to improve the performance of the routing protocol. To measure routing protocol performance, metrics that reflect Quality of Service (QoS) are needed, such as Flow ID, Packet Loss Rate, Packet Delivery Ratio, Throughput, and End-to-End Delay[22].

Therefore, performance analysis of LA-AODV and AODV routing protocols is very important to determine which protocol is superior in V2V communication on VANET networks[23]. This analysis was run through NS3 and SUMO simulation software, to test routing protocol performance in various scenarios and V2V communication conditions on VANET networks [16]-[17]. The purpose of this research is expected to be one of the valuable suggestions in the application and development of V2V communication routing protocols on VANET in the future, to provide more efficient and optimal communication services between vehicles.

II. RESEARCH METHODOLOGY

In this study, AODV protocol modifications were carried out by considering the parameters of speed, acceleration, and direction of the nearest node (neighbor node) to predict the actual position of the vehicle. Then, measurements of the communication quality index with all nearby vehicles are made before the set of relay nodes is selected until the maximum estimated time is reached. The Learning Automata-AODV (LA-AODV) steps are described in Figure 1.

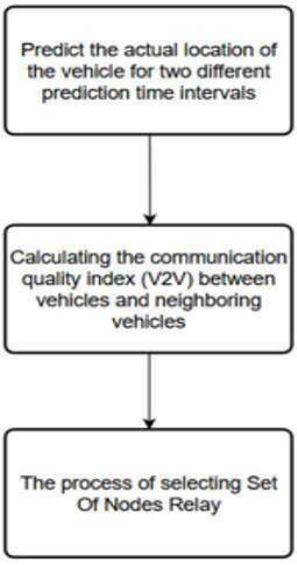


Fig 1. LA-AODV Methods[25]

Figure 1 show the steps of AODV learning automata (LA-AODV) in using AODV learning automata (LA-AODV) in an ad hoc vehicle network V2V communication. This figure assumes that the source node can detect the location of the neighbors and the destination node through the GPS service.

Each vehicle uses independent computing power to predict its future location and then broadcasts the prediction to all neighboring nodes. This allows each node to have periodic information about the actual location of the vehicles, which serves as a starting point for determining if the node can be selected as a relay. However, in the NS-3 simulation, there are limitations because NS-3 cannot use location services to determine the real-time location of each vehicle. Therefore, it is necessary to adjust by adding x and y coordinate fields to the HELLO package structure, as shown in Table 1. This change allows NS-3 to periodically update the vehicle's location within a defined prediction area.

Table 1. Modification of HELLO Packet Structure on adaptive LA-AODV

Dst IP Address	Dst Sequence Number	Hop Count	
Lifetime	Speed	Acceleration	
		X	y

Table 1 explains that the HELLO packet structure of the LA-AODV protocol has been modified by adding x and y coordinates as coordinates on the two-dimensional map of the grid. In addition, the HELLO packet contains information about the vehicle's direction, speed, and acceleration on the source and destination nodes[26]. Target node coordinates can be recognized when the target node is stationary or stationary, where they remain in the same place for a certain period. With this information, each node can estimate the location of the vehicle in the future period and use that information to determine whether a particular node can become a relay node or not.

2.1 Prediction of the Actual Location of the Vehicle

The main step of LA-AODV focuses on predicting the actual location of the vehicle at the moment and three seconds ahead based on changes in speed and relative position of the vehicle. The table mentioned then describes the input and output variables involved in predicting those locations in general. Thus, the purpose of the explanation is to provide a brief overview of the primary steps of the LA-AODV and the variables involved in predicting the location of the vehicle.

Table 2. Input Output of the Actual Prediction of the Proposed Vehicle

Input	Process	Output

e-ISSN: 2614-8404
p-ISSN: 2776-3234

x and y coordinates	Set the x and y coordinates on the grid map.	Predict the actual location of a vehicle
Vehicle speed	Set the speed of the vehicle at x and y coordinates at time t	Speed of each vehicle (v).
Prediction of the actual location of the vehicle at time t	Predicting the location of x and y at time t becomes input in calculating Prediction of the position of the x and y coordinates at time t + 3	Predicting the location of x and y coordinates at time t+3

Table 2 shows the input and output variables of the process to predict the actual location of the vehicle. The input variable contains the x and y coordinates of the vehicle and the speed of the vehicle at time t. While the output variable is the prediction of the actual location of the vehicle at time t + 1 and t + 3. Table 3 Show the pseudocode of LA-AODV

Table 3. LA-AODV Pseudocode

Algorithm 1. Learning Automata based-AODV

```
FOR each entry j in m_ipv4AddressEntry
    addr = j.first
    rte = j.second

    IF m_nb.IsNeighbor(addr) is true
        nt++
        dx = m_x - rte.GetX()
        dy = m_y - rte.GetY()
        dis = sqrt((dx*dx) + (dy*dy))
        modSpeed = fs * abs(m_speed1 - rte.GetSpeed1())
        modAccel = fa * abs(m_accel1 - rte.GetAccel1())
        modDistance = fd * dis
        TWR_total = modSpeed + modAccel + modDistance

        IF addr is equal to m_ipv4.GetAddress(1, 0).GetLocal()
            reward = 1
            node.setSelected(true)
        ELSE
            reward = 0.5
            node.setSelected(false)
        END IF

        delta_reward = reward - rte.getPrevReward()
        rte.setWeight(rte.getWeight() + alpha * delta_reward)
        rte.setPrevReward(reward)
        TWR_total = TWR_total + (alpha * reward)
    END IF
END FOR
```

The Learning Automata-based AODV algorithm show in Table 3 enhances the relay node selection process in VANETs by integrating adaptive learning techniques. It iterates through the IPv4 address table to analyze each neighbor node. For each node, the algorithm calculates the distance between vehicles, speed differences, and acceleration differences, applying weights to these metrics to compute a total weighted reward (TWR). If the node matches the local address, it is rewarded highly and marked as selected; otherwise, it receives a moderate reward. The reward difference is used to adjust the node's weight dynamically, ensuring that the algorithm prioritizes nodes with optimal mobility characteristics. This approach allows the protocol to adaptively optimize routing decisions based on real-time vehicular dynamics. The prediction process at time t is carried out using formulas in (1) and (2).

$$\boldsymbol{pred\_loc_x} = \sum_{i=1,t=1}^{i \le N, t \le M} (\boldsymbol{actual\_loc_x} + (\boldsymbol{v_t} . \boldsymbol{t}) + \left(\tfrac{1}{2}(\Delta \boldsymbol{v})\right) * \boldsymbol{2}) \quad (1)$$

$$\boldsymbol{pred\_loc_y} = \sum_{i=1,t=1}^{i \le N, t \le M} (\boldsymbol{actual\_loc_x} + (\boldsymbol{v_t} . \boldsymbol{t}) + \left(\tfrac{1}{2}(\Delta \boldsymbol{v})\right) * \boldsymbol{2}) \quad (2)$$

Eq (1) and (2) are used to predict the x and y -and coordinate location of a vehicle at time t. To calculate, the actual location of the vehicle on the x-axis will be added with the estimated average speed of the vehicle. The calculation is based on the position of the vehicle at time t $\text{pred\_lok}_x \Delta v_x \text{pred\_lok}_x$ multiplied by the difference in the speed of the vehicle while it is running at time t with the speed at the previous time, which is described in formulas (1) and (2).

This process is repeated iteratively until it reaches M and is carried out by several N vehicles.$v_t v_t - 1$. LA-AODV calculates the predicted location of the vehicle at time t+3 on both axes. The 3-second prediction time was chosen to take into account the rapid network topology changes in the VANET environment, requiring adjustments to the prediction time duration. Formulas (3) and 4 calculate the predicted location of the x and y coordinates of each vehicle at t + 3.

$$\boldsymbol{pred\_loc_{x+3}} = \boldsymbol{pred\_loc_x} + \sum_{\boldsymbol{t}\ \&\&\ \boldsymbol{t+3}}^{\boldsymbol{t<M}} \left(\left(\frac{\Delta \boldsymbol{v_t}}{\boldsymbol{t}}\right) + \left(\frac{\boldsymbol{1}}{\boldsymbol{2}}(\Delta \boldsymbol{v_t})\right) * \boldsymbol{t^2}\right) \quad (3)$$

$$\boldsymbol{pred\_loc_{y+3}} = \boldsymbol{pred\_loc_y} + \sum_{\boldsymbol{t}\ \&\&\ \boldsymbol{t+3}}^{\boldsymbol{t<M}} \left(\left(\frac{\Delta \boldsymbol{v_t}}{\boldsymbol{t}}\right) + \left(\frac{\boldsymbol{1}}{\boldsymbol{2}}(\Delta \boldsymbol{v_t})\right) * \boldsymbol{t^2}\right) \quad (4)$$

Eq (3) and (4) describe a way to predict the location of all vehicles at time t + 3 on the x and y axes. This prediction is based on the location of the vehicle at the previous time, i.e., as well as the acceleration and average speed of the vehicle at the previous time. $\text{pred\_lok}_x \text{pred\_lok}_y v_{t-3}$. Each vehicle multicasts, so that information can be obtained from other vehicles in the vicinity (neighbor vehicles) and vice versa. After that, all information obtained from neighbor vehicles is accumulated to obtain the minimum predicted location value of all neighbor vehicles. This information is important for updating the routing table in each vehicle and is used as input to determine the state of the vehicle with the minimum distance and speed using formula (5)

e-ISSN: 2614-8404
p-ISSN: 2776-3234

$$pred\_acc_{xy} = pred\_acc_{xy} MIN \left(\sum_{i=1,t=1}^{i \le N, t \le M} \sqrt{(|pred_{loc_{x+3}} - pred\_loc_x|)^2} \right) \quad (5)$$

Eq (5) is used to find a minimum value that represents the ratio of changes in vehicle movement on the x and y axes at two predicted time intervals. The smaller the movement of the vehicle, the better, and vice versa the greater the range of movement the less optimal.

2.2 Selection of a Set of Relay Nodes

Eq (6) calculates the Threshold Vehicle State (TVS) on each vehicle in a V2V communication network by combining factors that have a certain weight. These factors include the difference in speed, acceleration, direction between the next vehicle and the destination vehicle, and the communication quality index. The total weight given to these factors, referred to as TWR_total, is set as 1 as seen in formula (6).

$$TVS_i = \sum_{i=1}^{i} N \left((w_v * (|v_n - v_d|)) + (w_a * (|a_n - a_d|)) + (w_d * (|c_n - c_d|)) + (w_q * (comm_{quality_n})) \right) \quad (6)$$

Eq (6) describes how the selection of next-hop nodes is done by considering the average speed, acceleration, and direction of node I compared to the number of nodes present. Calculated and used as a threshold to determine whether vehicle I is in optimal or suboptimal state. The vehicle is said to be optimal if it has the lowest value compared to the TVS of its neighboring nodes. Conversely, the vehicle is said to be less than optimal if it is above the minimum value of other nodes.$TVS_i$$TVS_i$ TVS_i

2.3 Learning Automata on AODV

Eq (7) is the process of updating (Δ_d) to the value of R in a V2V communication network at time t + 3. If a node is ignored, the R-value remains unchanged. However, if a node is selected, the R penalty will be added by 1 at this point. Conversely, if a node is selected and receives a reward, the updated R-value is calculated.

$$\Delta_d(t+3) = \begin{Bmatrix} R(t), if d_{ignore} = 0, penalty \\ R(t) + 1, if d_{seleted} = 1, reward \end{Bmatrix} \quad (7)$$

The next update is at time T+3 and related rewards. If a node has a value that is better than the TVS_update threshold, it is considered optimal performance and receives a reward. However, if the value is below or equal to the threshold, then the node is considered suboptimal and penalized. This process lasts until time t reaches threshold M. In Eq (8) calculate the TVS_update, which determines the optimality of nodes based on consideration factors. variable R represents the actual value that describes the performance of the node. This value changes over time as the node receives a reward or penalty based on decisions made in the renewal process.

$$\overline{TVS}_{update} = \frac{1}{N} \sum_{i=1}^{i} pred\_loc_x \quad (8)$$

By combining rewards and penalties into R values, the system adaptively adjusts node performance based on the response and outcome of actions performed. This allows dynamic customization to optimize node performance in V2V communication networks.

III. RESULTS AND DISCUSSION

The simulation analysis metrics will give you an idea of the extent to which LA-AODV has an advantage over AODV in terms of network performance. The resulting analytical data provides important information that helps us understand how effective the network or simulation being evaluated is.

3.1. Flow ID

One of the first things that can be noticed is the total number of nodes in the network which gives an idea of how large and complex the network under study is. The results of Flow ID can be seen in Figure 2.

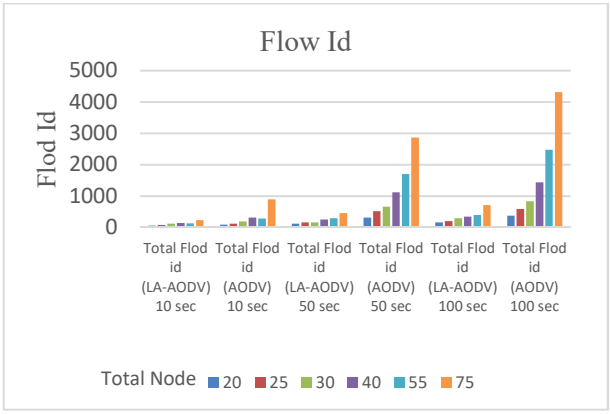


Fig 2. Comparison of Flow ID routing protocols LA-AODV and AODV

Based on Figure 2, the communication complexity of the LA-AODV protocol tends to be lower than AODV when the number of nodes in the network is increasing and the simulation period is getting longer. on a total of 20 nodes, (LA-AODV) has a relatively lower Flow ID compared to (AODV) at each observation time. There is an increase in communication complexity from 10 seconds to 100 seconds.

In general, (LA-AODV) has a lower flow ID value compared to (AODV) on a total of 20 nodes. Low Flow ID (LA-AODV) indicates less complexity of network traffic, potentially reducing conflicts or higher overhead. Differences in Flow ID values between (LA-AODV) and (AODV) can impact network resources. The lower the Flow ID value, the better the network performance in terms of resources. This analysis implies that routing protocols (LA-AODV) tend to have lower Flow ID rates compared to (AODV). This may indicate that protocol modification (LA-AODV) with Learning performs well in reducing communication complexity on the network.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

3.2. Packet Loss Ratio

This Packet Loss Ratio indicates how large a proportion of packets are lost in the delivery process. The results of the comparison of AODV and LA-AODV Packet Loss Ratio are shown in Figure 3.

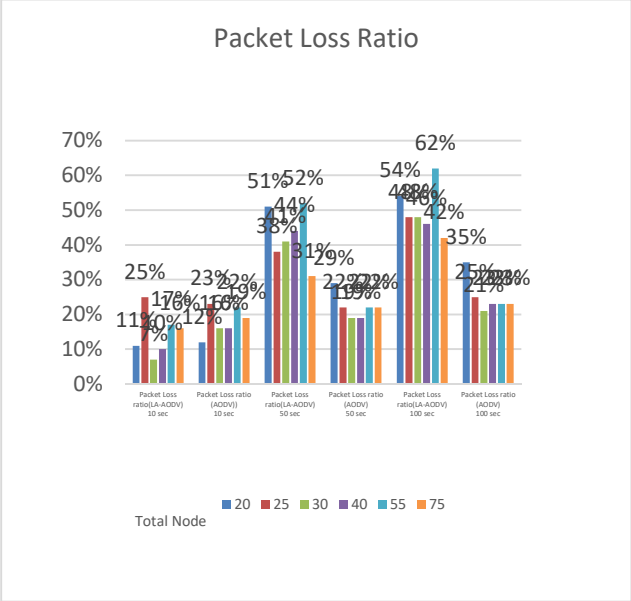


Fig 3. Comparison of LA-AODV and AODV Packet Loss Ratio

Comparative Analysis can be seen in Figure 3 that the Packet Loss Ratio tends to vary depending on the routing protocol used, simulation time, and number of nodes in the network. In general, the Packet Loss Ratio (LA-AODV) results tend to be higher than (AODV). (LA-AODV) has significant variation between time scenarios and the number of nodes in the network. In the longer time scenarios of 50 sec and 100 sec, the Packet Loss Ratio (LA-AODV) tends to increase, indicating an increase in packet loss with the highest value at 52% on node 55 time 50 seconds and 62% on node 55 time 100 seconds.

The number of nodes in the network also affects the Packet Loss Ratio (LA-AODV), with increases in the number of nodes and simulation time likely to increase packet loss. The Packet Loss Ratio (AODV) also shows variations depending on time scenarios and the number of nodes in the network. In some cases, the Packet Loss Ratio (AODV) is lower than (LA-AODV) with the lowest value at 19% at node 30, 40 times 50 seconds, and 21% at node 30 time 100 seconds, the results indicate better performance in packet loss. Increased simulation time and the number of nodes in the network tend to increase the Packet Loss Ratio (AODV), although not as large as that of the protocol (LA-AODV).

This analysis implies that the routing protocol (LA-AODV) tends to have a higher packet loss rate compared to (AODV). This may indicate that protocol modification (LA-AODV) with Learning has poor performance in terms of packet loss.

3.3. Packet Delivery Ratio

The LA-AODV packet delivery ratio has a significant variation between time scenarios and the number of nodes in the network. The Packet Delivery Ratio (AODV) also shows variations depending on time scenarios and the number of nodes in the network. In some cases, the Packet Delivery Ratio (AODV) is higher compared to the Packet Delivery Ratio (LA-AODV), indicating better performance in package delivery. The results of the PDR comparison can be seen in Figure 4.

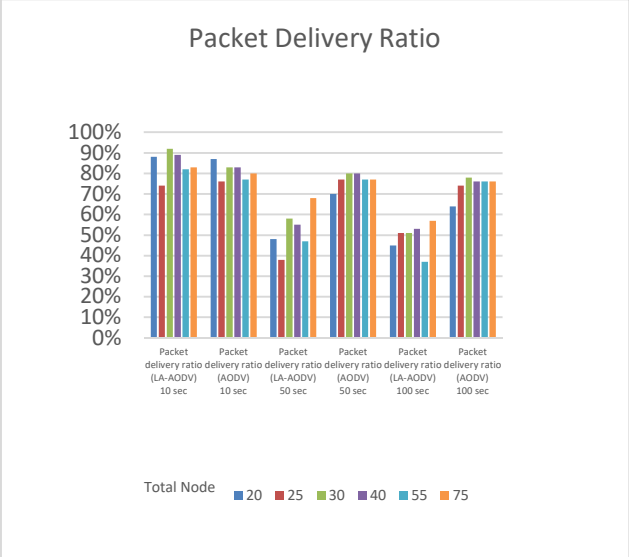


Fig 4. Comparison of PDR LA-AODV and AODV

Based on the comparison of PDR LA-AODV and AODV in Figure 4, the results of Packet Delivery Ratio analysis for routing protocols (LA-AODV) and (AODV) on various time scenarios and the number of nodes in the network. The Packet Delivery Ratio (LA-AODV) shows significant variation depending on the time scenario and the number of nodes in the network. In general, the Packet Delivery Ratio (LA-AODV) tends to be lower than the Packet Delivery Ratio (AODV). In the 10-second time scenario, the Packet Delivery Ratio (LA-AODV) ranges from 74% to 92% with an increase in the number of nodes. In the 50-second time scenario, the Packet Delivery Ratio (LA-AODV) ranges from 38% to 58% with an increase in the number of nodes. In the 100-second time scenario, the Packet Delivery Ratio (LA-AODV) ranges from 37% to 57% with an increase in the number of nodes.

The Packet Delivery Ratio (AODV) also shows variations depending on time scenarios and the number of nodes in the network. In general, the Packet Delivery Ratio (AODV) tends to be higher than the Packet Delivery Ratio (LA-AODV). In the 10-second time scenario, the Packet Delivery Ratio (AODV) ranges from 76% to 87% with an increase in the number of nodes. In the 50-second time scenario, the Packet Delivery Ratio (AODV) ranges from 70% to 80% with an increase in the number of nodes. In the 100-second time scenario, the Packet Delivery Ratio (AODV) ranges from 64% to 78% with an increase in the number of nodes. This analysis implies that the AODV routing protocol tends to have a higher packet delivery rate

e-ISSN: 2614-8404
p-ISSN: 2776-3234

compared to LA-AODV. This shows that modification of routing protocols using Learning Automata on AODV has not been able to achieve the efficiency and reliability of packet delivery.

3.4. Average Throughput

High average throughput in V2V communication on VANET networks means there is sufficient capacity to transfer data at high speeds between vehicles. With high Average Throughput, the risk of data packet loss or delay can be minimized, ensuring important information can be sent and received quickly and accurately. The results of the comparison of the Average throughput of LA-AODV and AODV are in Figure 5.

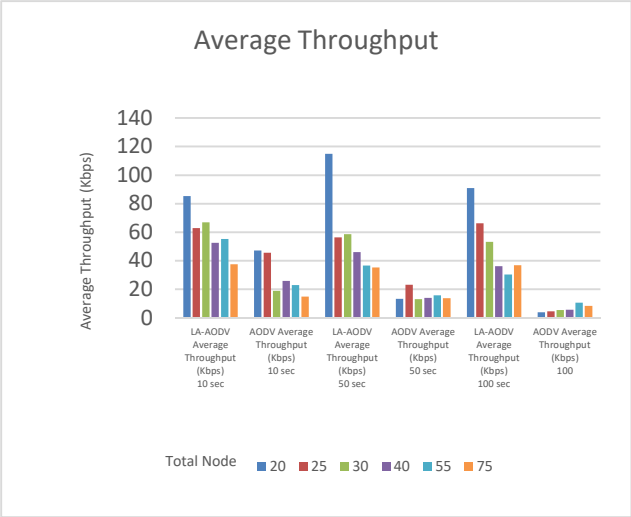


Fig 5. Comparison of Average throughput of LA-AODV and AODV

A comparative analysis of Average throughput in Figure 5, shows that in the 10-second time scenario, the average throughput of LA-AODV ranges from 37.5406 Kbps to 85.3425 Kbps, with the highest average at total node 20 and the lowest average at total node 75. In the 50-second time scenario, the average throughput of LA-AODV ranges from 35.3186 Kbps to 114.821 Kbps, with the highest average at total node 20 and the lowest average at total node 75. In the 100-second time scenario, the average throughput of LA-AODV ranges from 30.2889 Kbps to 90.8452 Kbps, with the highest average at total node 20 and the lowest average at total node 75. In the 10-second time scenario, the average AODV throughput ranges from 4.0365 Kbps to 47.2603 Kbps, with the highest average on total node 20 and the lowest average on total node 100.

In the 50-second time scenario, the average AODV throughput ranges from 4.65076 Kbps to 23.3256 Kbps, with the highest average at 25 total nodes and the lowest average at 100 total nodes. In the 100-second time scenario, the average AODV throughput ranges from 5.81214 Kbps to 14.1218 Kbps, with the highest average at 40 total nodes and the lowest average at 100 total nodes. The impact of the data is that the LA-AODV routing protocol tends to have a higher average throughput compared to AODV in various scenarios. This shows that modifying routing protocols using Learning Automata on AODV can improve data transmission efficiency. In longer-time scenarios, the difference in throughput between the two protocols becomes more significant. This analysis implies that the LA-AODV routing protocol has a higher average throughput rate compared to AODV. This suggests that modification of routing protocols using Learning Automata on AODV is capable of increasing enough capacity to transfer data at high speeds between vehicles.

3.5. End-to-End Delay

In a fast and dynamic highway situation, information sent between vehicles must arrive in a very short time to support informed decision-making in real-time. For example, when a vehicle detects a hazard or emergency, such as sudden braking or an obstacle in the road, the information must immediately reach other vehicles in the vicinity for them to react quickly. The results of the End to end-to-end delay comparison can be seen in Figure 6.

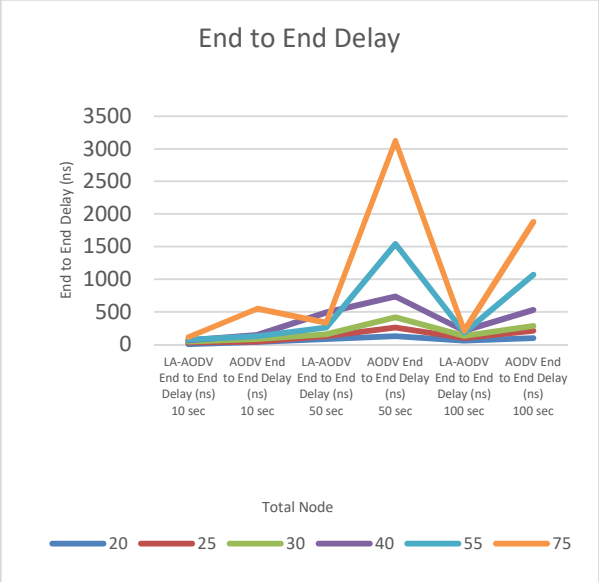


Fig 6. Comparison of End-to-End Delay LA-AODV and AODV

Figure 6 shows a comparison of End to End Delay (LA-AODV) and (AODV), at a total of 20 nodes, (LA-AODV) has a relatively lower End-to-End Delay compared to (AODV) at each observation time. There was an increase in End-to-End Delay packet delivery time from 10 seconds to 50 seconds but later decreased by 100 seconds for both protocols. In general, (LA-AODV) has a lower End-to-End Delay value compared to (AODV) on a total of 20 nodes. Low End-to-End Delay (LA-AODV) indicates an increase in packet delivery efficiency, potentially resulting in faster communication within the network. The difference in End-to-End Delay values between (LA-AODV) and (AODV) can have an impact on network service quality.

The lower the End-to-End Delay value, the better the network performance in terms of packet delivery time. In real network implementations, this difference in End-to-End Delay values can affect real-time applications that require fast response times, such as video streaming or voice communication. Thus, the implications of the data analysis results show that the use of the LA-AODV routing

e-ISSN: 2614-8404
p-ISSN: 2776-3234

protocol has a lower End-to-End Delay compared to the AODV protocol. This shows that modification of routing protocols using Learning Automata on AODV can improve the efficiency of sending packets between vehicles

IV. CONCLUSION

The comparative analysis of LA-AODV and AODV highlights a critical performance trade-off. LA-AODV, enhanced with Learning Automata, significantly improves Flow ID efficiency, average throughput, and end-to-end delay, making it suitable for dynamic vehicular environments. These gains result from its ability to adaptively select optimal relay nodes based on real-time mobility metrics. However, these improvements come at the cost of increased packet loss and reduced delivery ratios, primarily due to the delay in convergence during the learning process. On the other hand, AODV, with its simpler and more immediate routing mechanism, maintains better reliability in terms of packet loss and delivery but lacks performance in terms of throughput and delay under dynamic conditions. To make LA-AODV more reliable and practical for large-scale deployment, future research should focus on: Accelerating the convergence of the Learning Automata algorithm by introducing adaptive learning rates or reinforcement adjustment mechanisms. Integrating hybrid routing strategies that combine reactive and proactive approaches to mitigate packet loss during route discovery and learning phases. Enhancing buffer management and queuing policies to temporarily store packets during route learning delays. Leveraging cross-layer design, where information from lower layers (MAC, physical) assists in more accurate relay selection and route maintenance. Testing scalability and stability of LA-AODV in denser and more heterogeneous VANET environments to evaluate real-world feasibility.

REFERENCES

[1] A. Kinerja *et al.*, "Dengan Menggunakan Standar IEEE 802 . 11 Dan 802 . 11p Pada Jaringan," vol. 5, no. 5, pp. 1898–1906, 2021.[1]A. Kinerja *et al.*, "Dengan Menggunakan Standar IEEE 802 . 11 Dan 802 . 11p Pada Jaringan," vol. 5, no. 5, pp. 1898–1906, 2021.

[2] K. B. Y. Bintoro, "A Study of V2V Communication on VANET: Characteristic, Challenges and Research Trends," *JISA(Jurnal Inform. dan Sains)*, vol. 4, no. 1, pp. 46–58, 2021, doi: 10.31326/jisa.v4i1.895.

[3] A. Patil, M. Deeksha, N. Shekar, V. Shet, and M. Kulkarni, "Transmit Data Rate Control Based Decentralized Congestion Control Mechanism for VANETs," *2019 Int. Conf. Data Sci. Commun. IconDSC 2019*, no. Cl, pp. 1–5, 2019, doi: 10.1109/IconDSC.2019.8816902.

[4] D. C. Rumantyo, P. H. Trisnawan, and R. A. Siregar, "Implementasi Protokol Anchor-Based Street and Traffic Aware Routing (A- Star) menggunakan Intersection Node pada Vehicular Ad - Hoc Network (VANET)," *... Teknol. Inf. dan ...*, vol. 3, no. 11, pp. 10538–10546, 2019.

[5] A. T. Agustin, D. R. Akbar, and D. Risqiwati, "Analisis kinerja jaringan VANET dengan model propagasi free space dan two ray ground pada routing AODV," *J. Repos.*, vol. 1, no. 2, p. 69, 2019, doi: 10.22219/repositor.v1i2.10.

[6] N. Rosele, K. Mohd Zaini, N. Ahmad Mustaffa, A. Abrar, S. I. Fadilah, and M. Madi, "Digital transformation in wireless networks: A comprehensive analysis of mobile data offloading techniques, challenges, and future prospects," *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 36, no. 5, p. 102071, 2024, doi: 10.1016/j.jksuci.2024.102071.

[7] P. S. Bharathi and G. Harish, "Optimizing V2V communication in ITS: The benefits of silver-coated DSRC," *Meas. Sensors*, vol. 31, no. November 2023, p. 101011, 2024, doi: 10.1016/j.measen.2023.101011.

[8] A. S. M. Thabit, C. A. Kerrache, and C. T. Calafate, "A survey on monitoring and management techniques for road traffic congestion in vehicular networks," *ICT Express*, no. September, 2024, doi: 10.1016/j.icte.2024.10.007.

[9] R. N. Aziza, P. C. Siswipraptini, and R. Cahyaningtyas, "Protokol Routing Pada Vanet: Taksonomi Dan Analisis Perbandingan Antara Dsr, Aodv, Dan Tora," *J. Ilm. FIFO*, vol. 9, no. 2, p. 98, 2017, doi: 10.22441/fifo.2017.v9i2.002.

[10] R. N. Hidayah, I. Indrabayu, and I. S. Areni, "Analisis Performansi Protokol Routing Proaktif pada Jaringan Mobile Adhoc," *J. Penelit. Enj.*, vol. 22, no. 2, pp. 120–128, 2018, doi: 10.25042/jpe.112018.04.

[11] J. Li, Y. Zhang, M. Shi, Q. Liu, and Y. Chen, "Collision avoidance strategy supported by LTE-V-based vehicle automation and communication systems for car following," *Tsinghua Sci. Technol.*, vol. 25, no. 1, pp. 127–139, 2020, doi: 10.26599/TST.2018.9010143.

[12] R. Anisia, R. Munadi, and R. M. Negara, "Analisis Performansi Routing Protocol OLSR Dan AOMDV Pada Vehicular Ad Hoc Network (VANET)," *J. Nas. Tek. Elektro*, vol. 5, no. 1, p. 87, 2016, doi: 10.25077/jnte.v5n1.204.2016.

[13] K. Bayu, Y. Bintoro, A. Syahputra, A. H. Rismanto, and M. Marchenko, "THE PERFORMANCE ANALYSIS OF REACTIVE AND PROACTIVE ROUTING PROTOCOLS FOR V2V COMMUNICATION IN DYNAMIC TRAFFIC SIMULATION," *J. Tek. Inform.*, vol. 5, no. 4, pp. 1277–1285, 2024, [Online]. Available: http://jutif.if.unsoed.ac.id/index.php/jurnal/article/view/2237

[14] N. Basil, S. H. Ahammad, and E. E. Elsayed, "Enhancing wireless subscriber performance through AODV routing protocol in simulated mobile Ad-hoc networks," vol. 3, no. 1, pp. 16–26, 2024.

[15] H. A. Suharyadi, "ANALISIS KINERJA PROTOKOL AODV DAN DSDV PADA JARINGAN VANET (Performance Analysis of the AODV and DSDV Protocols on the VANET Network)," 2018.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

[16] D. A. Ardiansyah, R. Primananda, and A. Bhawiyuga, "Analisis Kinerja Protokol Routing Ad Hoc On Demand Distance Vector (AODV) Pada Jaringan Vehicular Ad Hoc Network (VANET) Berdasarkan Variasi Model Jalan," *J. Pengemb. Teknol. Inf. dan Ilmu Komput.*, vol. 3, no. 2, pp. 201–209, 2019.

[17] P. Kaushal, M. Khurana, and K. R. Ramkumar, "Comparative analysis of reactive routing protocols for vehicular adhoc network communications," *Bull. Electr. Eng. Informatics*, vol. 13, no. 3, pp. 1621–1630, 2024, doi: 10.11591/eei.v13i3.5322.

[18] B. Amina and E. Mohamed, "Performance Evaluation of VANETs Routing Protocols Using SUMO and NS3," *Colloq. Inf. Sci. Technol. Cist*, vol. 2018-Octob, pp. 525–530, 2018, doi: 10.1109/CIST.2018.8596531.

[19] S. Maiti, S. Winter, L. Kulik, and S. Sarkar, "The Impact of Flexible Platoon Formation Operations," *IEEE Trans. Intell. Veh.*, vol. 5, no. 2, pp. 229–239, 2020, doi: 10.1109/TIV.2019.2955898.

[20] A. Al-Ahwal and R. A. Mahmoud, "Performance Evaluation and Discrimination of AODV and AOMDV VANET Routing Protocols Based on RRSE Technique," *Wirel. Pers. Commun.*, vol. 128, no. 1, pp. 321–344, 2023, doi: 10.1007/s11277-022-09957-8.

[21] P. D. Pradana, R. M. Negara, and F. Dewanta, "Protokol Routing Dsr Dan Aodv pada Simulasi Jaringan Vehicular Ad-hoc Network (VANET) untuk Keselamatan Transportasi dengan Studi Kasus Mobil," *eProceedings Eng.*, vol. 4, no. 2, pp. 1996–2004, 2017.

[22] M. Oche, A. B. Tambuwal, C. Chemebe, R. M. Noor, and S. Distefano, *VANETs QoS-based routing protocols based on multi-constrained ability to support ITS infotainment services*, vol. 26, no. 3. Springer US, 2020. doi: 10.1007/s11276-018-1860-7.

[23] A. M. Bamhdi, "Efficient dynamic-power AODV routing protocol based on node density," *Comput. Stand. Interfaces*, vol. 70, no. November 2019, p. 103406, 2020, doi: 10.1016/j.csi.2019.103406.

[24] Y. D. Gloriawati, R. Primananda, and M. H. H. Ichsan, "Studi Perbandingan Kinerja Routing Protokol DSDV dan OSLR dengan Skenario Pemutusan Link menggunakan NS3," *... Teknol. Inf. dan Ilmu ...*, vol. 5, no. 11, pp. 4878–4884, 2021.

[25] K. B. Y. Bintoro and T. K. Priyambodo, "Learning Automata-Based AODV to Improve V2V Communication in A Dynamic Traffic Simulation," *Int. J. Intell. Eng. Syst.*, vol. 17, no. 1, pp. 666–678, 2024, doi: 10.22266/ijies2024.0229.56.

[26] K. Bayu, Y. Bintoro, M. Marchenko, R. C. Saputra, A. Syahputra, and D. National, "Performance Analysis of AODV and DSDV Routing Protocols for UDP Communication in," *Sinkron*, vol. 8, no. 4, pp. 2287–2297, 2024.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Overview of Vehicle-to-Everything Communication: Technological Advancements, Applications, and Future Prospects in Intelligent Transportation Systems

Ketut Bayu Yogha Bintoro[1*)]
[1]Program Studi Teknik Informatika, Fakultas Industri Kreatif dan Telematika, Universitas Trilogi
Email: [1]ketutbayu@trilogi.ac.id

Abstract – Vehicle-to-Everything (V2X) communication is a cornerstone technology in modern Intelligent Transportation Systems (ITS), enabling real-time data exchange between vehicles, infrastructure, pedestrians, and networks. V2X enhances road safety, traffic management, and driving experience, contributing to the global vision of connected and autonomous transportation. This paper presents a comprehensive overview of V2X communication, detailing its key components, types, and technological standards, including Dedicated Short-Range Communication (DSRC), LTE-V2X, and 5G. We explore current applications of V2X, such as safety enhancements, traffic optimization, infotainment, and environmental sustainability, and discuss significant challenges in deployment, including technical limitations, security and privacy concerns, and infrastructure requirements. Furthermore, this study examines future directions in V2X, emphasizing the role of 5G, edge computing, AI integration, and the implications for electric and autonomous vehicles. Realizing V2X's full potential requires robust policy support, international standardization, and infrastructure investments, particularly in countries with varying levels of technological maturity. This paper provides insights into the evolution of V2X and outlines critical considerations for advancing toward a safer, more efficient, and sustainable global transportation ecosystem

Keywords – *V2X Communication, Intelligent Transportation Systems (ITS), Autonomous Vehicles, Traffic Management*

I. INTRODUCTION

In recent years, communication technologies have transformed various industries, with a significant impact on the transportation sector. One of the most notable advancements in this field is Vehicle-to-Everything (V2X) communication[1], which allows vehicles to communicate with each other and with infrastructure, pedestrians, and broader network systems. V2X communication is a critical element within ITS[2] aimed at improving safety, efficiency, and sustainability in modern transportation[3].

V2X communication enables real-time data exchange among connected vehicles, allowing them to share information on speed, location, road conditions, and potential hazards. The capability supports the development of autonomous vehicles and connected vehicle networks, which rely on such data to make informed decisions in complex traffic environments[4]. By fostering an interconnected transportation ecosystem, V2X helps to reduce accidents, optimize traffic flow, and minimize environmental impacts by reducing congestion and idling times[5]. Countries have started implementing V2X technologies to enhance road safety and traffic management. For instance, Japan has widely deployed Dedicated Short-Range Communications (DSRC) technology, enabling Vehicle-to-Infrastructure (V2I) interactions that assist drivers in detecting traffic signals and pedestrians, especially in challenging weather conditions[6]. In Europe, Germany has introduced Cooperative Intelligent Transport Systems (C-ITS) based on cellular V2X (C-V2X) technology, which supports real-time traffic data exchange among vehicles, providing route adjustments and early warnings of potential collisions[7]. Meanwhile, the United States has integrated V2X solutions in specific urban centers, such as Ann Arbor, Michigan, where connected intersections improve signal timing based on traffic density[8].

The motivations for implementing V2X communication extend beyond convenience; the technology has critical implications for safety, efficiency, and environmental sustainability in urban and rural transportation networks. Road safety is a significant concern globally, with the World Health Organization estimating that approximately 1.3 million people die in traffic accidents each year. V2X communication can help reduce these fatalities by enabling vehicles to receive timely warnings about potential dangers, such as sudden braking, lane changes, or obstacles on the road[9]. The growing problem of traffic congestion has economic and environmental costs. According to the Texas A&M Transportation Institute, in 2021, Americans spent an estimated 3.4 billion hours stuck in traffic, leading to increased fuel consumption and carbon emissions[10]. V2X solutions, which allow vehicles to communicate with traffic lights and other infrastructure, can help mitigate this problem by coordinating vehicle movement, thereby reducing congestion, travel times, and overall emissions[11]. For instance, adaptive signal control systems in cities like Los Angeles have shown measurable travel time and emissions reductions through V2X-based traffic optimization[12].

Despite its advantages, implementing V2X has challenges, including technological, infrastructural, and regulatory barriers[13]. For example, Japan's DSRC implementation provides reliable short-range communication but lacks the coverage required for long-distance connectivity, limiting its scalability. On the other

e-ISSN: 2614-8404
p-ISSN: 2776-3234

hand, Europe's C-V2X system, though capable of supporting high data rates and extensive coverage, requires a robust 5G infrastructure, which involves significant costs and regional cooperation. The effectiveness of V2X systems also hinges on interoperability across manufacturers and countries, posing an additional challenge for global standardization[14].

The study aims to provide a comprehensive yet concise overview of V2X communication. It explores the technology's evolution, from early systems like DSRC to more advanced LTE-V2X and 5G-enabled C-V2X. Additionally, the paper delves into the types of V2X communication, such as V2V, V2I[15], Vehicle-to-Pedestrian (V2P), and Vehicle-to-Network (V2N). Each type plays a distinct role in creating a cohesive and intelligent transportation system[16]. The discussion will also cover technological standards and protocols in V2X, including DSRC and C-V2X, analyzing their respective advantages and limitations. The paper will then explore various applications of V2X, from safety enhancements like collision avoidance to traffic management solutions, as well as the system's impact on infotainment and environmental sustainability. Finally, the challenges hindering widespread adoption will be discussed, such as latency, cybersecurity, infrastructure requirements, and regulatory constraints. The objective is to highlight the current state of V2X communication and identify potential research directions that can address existing limitations and pave the way for fully autonomous, connected transportation networks..

II. OVERVIEW OF V2X COMMUNICATION

V2X communication represents an integrated suite of technologies that allow vehicles to communicate with various entities in their environment, including other vehicles (V2V), infrastructure such as traffic lights and road signs (V2I), pedestrians and cyclists (V2P), and broader network infrastructures (V2N). This multi-dimensional communication capability enhances situational awareness and supports decision-making for both human drivers and autonomous driving systems[17]. By transmitting real-time information about a vehicle's speed, location, and direction, V2X allows for proactive responses to potential risks and facilitates smoother interactions on the road. This interconnected ecosystem is central to the development of safer and more efficient traffic systems and the broader vision of autonomous vehicles that can operate with minimal human intervention[18].

2.1 Importance in ITS

Within the ITS framework, V2X is pivotal for creating a dynamic and adaptive transportation network. ITS aims to harness advanced communication, control, and information technologies to improve road safety, reduce traffic congestion, and enhance overall transportation efficiency[19]. V2X communication, as a core component of ITS, enables vehicles to share real-time data on road conditions, potential hazards, and congestion patterns. For instance, vehicles equipped with V2V communication can receive alerts about sudden braking, lane changes, or obstacles on the road ahead, enabling drivers to respond more quickly to potential dangers. Similarly, V2I communication allows traffic lights to adapt in real time to changing traffic conditions, reducing congestion and waiting times at intersections. In cities with high traffic density, such as Singapore and Tokyo, adaptive signal control systems based on V2X communication have already shown positive results, reduced travel time and decreasing fuel consumption[20].

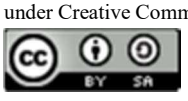
The significance of V2X in ITS also extends to emergency response. By enabling rapid and precise communication between vehicles and infrastructure, emergency vehicles can receive priority at traffic signals, allowing them to navigate more efficiently through congested areas. Additionally, V2X can provide real-time location data to emergency services during an accident, facilitating faster response times and potentially saving lives[21].

2.2 Evolution of V2X Technologies

The evolution of V2X technology has been marked by significant advancements in communication protocols and network capabilities, evolving from basic short-range communication systems to high-speed, high-capacity cellular networks.

- Dedicated Short-Range Communications (DSRC)[22]: DSRC was one of the first technologies developed for V2X applications. Operating in the 5.9 GHz band, DSRC offers low-latency communication and is effective over short distances (typically up to 300 meters). DSRC has been widely adopted in Japan, where it is used in applications such as electronic toll collection, traffic signal prioritization, and safety warnings for pedestrians and vehicles. DSRC's strengths lie in its dedicated spectrum and reliable performance for safety-critical applications. However, its limited range and inability to scale beyond a certain number of users make it less suitable for dense urban environments and applications requiring long-range communication.
- Cellular V2X (C-V2X) with LTE and 5G[23]: With the emergence of LTE-V2X and the recent development of 5G-V2X, cellular technologies have become increasingly popular for V2X applications. Unlike DSRC, which is limited to short-range, line-of-sight communication, cellular V2X allows for extended coverage, making it suitable for urban and rural areas. LTE-V2X is designed to operate alongside traditional cellular networks, enabling a wide range of V2X applications without requiring additional infrastructure. For example, China has implemented LTE-V2X in several smart cities, providing vehicles access to real-time traffic data, navigation, and safety alerts.

With the rollout of 5G, C-V2X has gained even more capabilities, including ultra-low latency, high data



e-ISSN: 2614-8404
p-ISSN: 2776-3234

rates, and improved reliability. These features are essential for advanced V2X applications such as cooperative adaptive cruise control, platooning, and automated lane merging, where rapid communication and synchronization are critical. For example, in Germany, 5G-V2X technology has been deployed along specific highway corridors, allowing for high-speed data exchange between vehicles and infrastructure, supporting platooning and other automated driving functions. The primary advantage of 5G-V2X is its ability to handle high data volumes and dense traffic scenarios. However, the high cost of 5G infrastructure and the need for widespread deployment remain significant challenges.

- Comparison of DSRC and C-V2X[24]: Each technology has its strengths and limitations. DSRC is well-suited for short-range, low-latency applications and has the advantage of using a dedicated spectrum, making it highly reliable for safety applications. However, DSRC's limited range and inability to scale effectively in urban environments with high vehicle density restrict its broader use. On the other hand, LTE and 5G-enabled C-V2X provide broader coverage and higher data rates, making them suitable for both safety-critical applications and infotainment. The limitations of C-V2X include dependency on cellular network infrastructure and associated costs, particularly for the high-speed and low-latency requirements of 5G.

2.3. Key Examples of V2X Implementation

Several countries have adopted V2X technology to enhance their transportation systems, leveraging different technologies and applications according to local infrastructure and regulatory environments.

- Japan (DSRC): Japan is one of the pioneers in deploying DSRC-based V2X systems. Its V2X infrastructure supports applications such as electronic toll collection and traffic signal prioritization, improving traffic flow and safety in urban areas. A notable example is Japan's ITS Spot Service, which provides in-vehicle information on traffic signals, toll stations, and weather conditions. While DSRC has proven effective in Japan's controlled traffic environment, its limited scalability and range are constraints for future long-distance communication applications[13].
- China (LTE-V2X)[25]: China has implemented LTE-V2X as part of its nationwide intelligent city initiatives. LTE-V2X technology allows vehicles to access real-time information on traffic conditions, weather, and navigation, enhancing driver awareness and road safety. The broad deployment of LTE-V2X in China is facilitated by the country's extensive 4G infrastructure, enabling large-scale implementation without additional costs. However, as the country transitions to 5G, challenges in interoperability and upgrading existing infrastructure remain.
- Germany (5G-V2X)[26]: Germany has focused on deploying 5G-V2X technology along its major highways, supporting advanced applications such as vehicle platooning, which allows vehicles to travel closely together in coordinated groups, reducing fuel consumption and increasing road capacity. In this setup, 5G's ultra-low latency enables rapid data exchange and synchronized vehicle movements. While Germany's 5G-V2X deployments highlight the potential of 5G for V2X, high infrastructure costs and the complexity of 5G deployment continue to pose barriers.

2.4. Advantages and Disadvantages of V2X Technologies

Each V2X technology offers distinct advantages and disadvantages, making them more suitable for different use cases. **DSRC** (Dedicated Short-Range Communication) is known for its reliable low-latency communication, dedicated spectrum, and maturity as a technology. However, it faces limitations such as a relatively short communication range and scalability challenges. It is less effective in high-density urban areas where the demand for communication can exceed its capacity. On the other hand, **LTE-V2X** provides broader coverage and benefits from existing infrastructure, making it suitable for both urban and rural environments. Despite these advantages, LTE-V2X is constrained by the capabilities of LTE networks, including higher latency and limited data rates, as well as its reliance on cellular networks for communication. In contrast, **5G-V2X** offers ultra-low latency and high data rates and is particularly well-suited for high-speed and advanced applications, such as autonomous driving. However, it also comes with drawbacks, including high infrastructure costs, complex deployment, and limited availability, particularly in regions where 5G infrastructure still needs development.

The progression of V2X technologies from DSRC to LTE-V2X and 5G-V2X illustrates an ongoing evolution to meet the needs of connected and autonomous transportation systems. Each generation has built upon the strengths and addressed the limitations of previous technologies, advancing towards a future where fully autonomous and coordinated vehicles can operate safely and efficiently in real-world environments. Despite current challenges, V2X technology remains essential for realizing the vision of intelligent and adaptive transportation networks that can respond to and mitigate real-time challenges on the road

III. TECHNOLOGICAL STANDARDS IN V2X

DSRC (Dedicated Short-Range Communications) is the earliest technology specifically developed for V2X communication, designed for short-range (approximately 300 meters) and low-latency interactions between vehicles.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

While reliable for safety applications, its limitations in scalability and data throughput have led to the development of alternatives such as LTE-V2X and its successor, 5G-CV2X. These cellular-based technologies enable higher data rates and lower latency, with 5G significantly enhancing capacity, connection density, and response times for advanced V2X applications and autonomous driving. Additionally, IEEE 802.11p, a wireless standard foundational to DSRC, and Cellular V2X (C-V2X), which leverages cellular networks for improved range, coverage, and reliability, are key advancements suitable for both urban and rural environments.

IV. APPLICATIONS OF V2X COMMUNICATION

4.1. Safety Applications

V2X communication has a transformative impact on road safety by enabling vehicles to receive early warnings and share critical information with other road users and infrastructure. Safety applications of V2X are focused on preventing accidents and protecting all road users, including pedestrians, cyclists, and drivers. Critical safety applications include:

- Collision Avoidance[27]: V2X communication allows vehicles to detect potential collision scenarios by exchanging data with nearby vehicles and infrastructure. For instance, if a vehicle brakes suddenly, nearby vehicles receive instant alerts, allowing drivers or automated systems to react accordingly. This type of alert is beneficial at intersections and in heavy traffic, where sudden stops can lead to chain-reaction collisions.
- Blind-Spot Detection[28]: By sharing real-time location and speed data, V2X enhances the effectiveness of blind-spot detection systems, mainly when a vehicle may be in the driver's blind spot. Blind-spot detection enabled by V2X communication is highly effective for lane changes on highways and helps to reduce the risk of side collisions.
- Lane-Change Assistance[29]: Lane-change assistance powered by V2X communication guides safe lane changes by monitoring the positions of nearby vehicles. This is particularly useful in multi-lane highways and congested traffic, where lane changes can be risky. The system alerts drivers or autonomous systems to avoid a lane change if an obstacle or another vehicle is approaching.

Countries like the United States and Japan have implemented pilot programs using V2X-enabled collision avoidance and blind-spot detection systems to improve highway safety. For example, Japan's Smartway system integrates V2X-based lane-change assistance and collision avoidance, resulting in fewer accidents on major highways. However, the effectiveness of V2X safety applications depends on the number of equipped vehicles on the road, as a lack of V2X-capable vehicles can limit the full potential of collision prevention systems.

4.2. Traffic Management

V2X communication significantly improves traffic management by providing a more responsive and efficient approach to controlling traffic flow. Through data exchange between vehicles and infrastructure, V2X enables adaptive traffic management, which can adjust to real-time traffic conditions and support the coordination of various traffic control systems:

- Dynamic Traffic Light Control[30]: V2X-enabled traffic lights can adjust signal timing based on real-time data from approaching vehicles, optimizing traffic flow at intersections. This is particularly useful during peak hours or in high-traffic areas. In Singapore, adaptive signal control systems use V2X communication to detect the number of vehicles waiting at intersections, adjusting green light times to minimize congestion.
- Ramp Metering[31]: V2X communication can improve ramp metering by allowing highway entry ramps to monitor approaching traffic and manage the rate of vehicle entry onto highways. In Los Angeles, ramp metering systems equipped with V2X capabilities regulate the flow of vehicles entering highways, resulting in smoother traffic flow and reduced congestion during rush hours.
- Incident Response[32]: V2X enhances incident response by providing real-time data about accidents or road obstructions to traffic management centers. When an accident occurs, V2X-equipped vehicles and infrastructure can relay information about the location and severity of the incident to other drivers, enabling them to take alternative routes. Emergency response vehicles can also receive priority at traffic signals, reducing response times and enhancing overall safety.

While V2X-based traffic management systems have shown significant promise, such as in the innovative city projects in China, challenges remain. For instance, traffic control systems require considerable investment in V2X infrastructure, and interoperability across different traffic management systems can be complex.

4.3. Infotainment

V2X communication also enhances the infotainment experience for drivers and passengers by providing seamless access to media, navigation services, and internet-based applications. As vehicles become increasingly connected, infotainment services supported by V2X communication offer a more personalized and engaging experience:

- Media Streaming and Internet Access[33]: V2X-enabled infotainment allows passengers to stream media, browse the internet, and stay connected during their journey. For instance, V2X-equipped vehicles in Germany provide in-car streaming services for passengers on long journeys,

e-ISSN: 2614-8404
p-ISSN: 2776-3234

enhancing the travel experience by offering entertainment options beyond traditional radio and music players.

- Real-Time Navigation and Route Assistance[34]: V2X communication supports real-time navigation by updating drivers on road conditions, traffic jams, and available parking spots. This service is precious in urban areas, where high traffic density can make it challenging to find efficient routes. For example, cities like Seoul and Tokyo use V2X technology to provide real-time navigation updates to drivers, helping them avoid congested areas and save time.
- Enhanced Passenger Experience: By integrating V2X technology with advanced infotainment systems, manufacturers enhance the overall passenger experience. Features like hands-free voice controls, smart assistant integration, and multi-screen setups allow passengers to enjoy a seamless in-car experience.

While V2X-enabled infotainment provides convenience and entertainment, it also presents challenges. Streaming services and high-speed data access require stable and high-capacity networks, which may only be available in some regions. Additionally, concerns regarding driver distraction and data privacy are important considerations.

4.4. Environmental Impact

V2X communication contributes to environmental sustainability by promoting eco-friendly driving practices and reducing the carbon footprint of vehicles. By optimizing traffic flow and minimizing idling times, V2X communication helps reduce emissions and fuel consumption, which is essential in the fight against climate change. Critical environmental applications include:

- Eco-Driving Applications[35]: V2X-enabled eco-driving applications provide drivers with recommendations on optimal speed, acceleration, and braking patterns to reduce fuel consumption. These applications analyze data from surrounding vehicles and infrastructure to suggest the most efficient driving practices. For example, V2X-based eco-driving systems in the Netherlands encourage fuel-efficient driving, resulting in lower emissions and reduced fuel costs.
- Smart Traffic Signals and Idling Reduction[36]: V2X-enabled intelligent traffic lights can reduce idling times by adjusting real-time signal timings to match traffic flow. This approach helps prevent unnecessary stops and starts, lowering fuel consumption and emissions. In several European cities, intelligent traffic signal systems have been implemented to reduce idling, particularly in high-traffic areas.
- Eco-Routing[37]: V2X-based eco-routing applications provide drivers with route options that minimize fuel consumption, taking into account traffic conditions, elevation changes, and speed limits. These applications are beneficial for reducing emissions in urban areas and encouraging sustainable driving habits.

While V2X has a positive environmental impact, challenges exist in implementation. Eco-driving and eco-routing applications rely on the widespread adoption of V2X technology, which can be costly for both consumers and municipalities. Additionally, the environmental benefits are maximized when many vehicles on the road are V2X-enabled.

V. CHALLENGES IN V2X COMMUNICATION

V2X communication systems encounter multiple technical challenges that impact their reliability, scalability, and effectiveness. Among these, latency, signal interference, network reliability, and interoperability between different communication standards are particularly significant:

- **Latency Issues**[16]: V2X applications often require real-time or near-real-time data transmission to ensure timely responses to road conditions and potential hazards. However, maintaining low latency in V2X networks can be difficult, especially in high-density environments or areas with significant network congestion. For instance, collision avoidance systems need minimal latency to alert drivers or autonomous systems of immediate dangers. Latency issues, if unresolved, can compromise the effectiveness of safety applications, increasing accident risks. While technologies like 5G-V2X promise lower latency, their deployment still needs to be improved, restricting the full realization of V2X capabilities.
- **Signal Interference**[38]: V2X communications operate over shared radio frequencies, leading to potential interference from other vehicles, devices, and environmental factors. Urban areas with dense traffic, multiple wireless signals, and tall buildings can worsen interference, affecting communication quality and reliability. For example, Dedicated Short-Range Communication (DSRC) has shown vulnerability to interference in metropolitan settings, impacting its performance.
- **Network Reliability**[9]: Ensuring uninterrupted V2X communication is essential, particularly for safety applications. However, network reliability can fluctuate due to tunnel signal loss, poor connectivity in rural areas, and network congestion in densely populated areas. V2X reliability could be more consistent across geographical locations, creating challenges for standardization.
- **Interoperability**[39]: V2X technologies include DSRC, LTE-V2X, and emerging 5G-C-V2X standards, each with unique characteristics and

e-ISSN: 2614-8404
p-ISSN: 2776-3234

compatibility issues. Vehicles and infrastructure may use different V2X technologies, making communication difficult. For example, if a DSRC-equipped vehicle interacts with 5G infrastructure, it may not communicate seamlessly. A lack of interoperability limits V2X adoption and challenges regulatory agencies in defining universal standards.

V2X communication introduces significant security and privacy challenges, as the system relies on continuously exchanging sensitive data between vehicles, infrastructure, and networks. Cybersecurity risks and privacy concerns are paramount in V2X design and deployment:

- **Cybersecurity Risks**[2][40]: V2X networks are vulnerable to various cyber threats, including spoofing, data interception, and hacking, which could allow malicious actors to control or disrupt vehicle communications. For instance, spoofing attacks can create fake traffic alerts, causing unnecessary slowdowns or potential accidents. Unauthorized access to V2X systems could also allow hackers to interfere with vehicle functions, posing direct threats to driver and passenger safety. The large attack surface and high-stakes nature of V2X communication make cybersecurity an essential consideration.
- **Data Privacy**[41]: V2X communication often requires transmitting personal and vehicle data, such as location, speed, and driving behavior. Without robust data privacy measures, there is a risk that personal information could be misused or exploited. Location tracking and data sharing concerns could deter individuals from using V2X-enabled vehicles. Additionally, privacy regulations, such as the General Data Protection Regulation (GDPR) in Europe, mandate stringent data protection protocols, adding complexity to V2X implementation.
- **Policy and Regulatory Challenges**[42]: Addressing cybersecurity and privacy in V2X networks involves creating comprehensive policies and standards. Governments must collaborate with industry stakeholders to establish regulations that ensure the security and privacy of V2X data without stifling innovation. However, finding a balance between privacy protections and the need for real-time data sharing remains challenging.

The deployment of V2X infrastructure requires substantial investment, planning, and logistical coordination. Implementing and maintaining V2X infrastructure can be incredibly challenging in urban areas with dense populations, complex traffic networks, and legacy systems that may not be compatible with modern V2X technologies:

- **High Costs of Infrastructure**[43]: Building V2X infrastructure involves significant costs, from installing roadside units (RSUs) to upgrading existing traffic systems to support V2X. High-density cities which would benefit most from V2X deployment, often face budget constraints and competing infrastructure demands, making it challenging to prioritize V2X. Additionally, in rural or less populated areas, where there is less demand for advanced traffic management, the financial justification for V2X infrastructure investment is limited.
- **Deployment Complexity in Urban Environments**[44]: Dense urban areas present unique challenges, as the integration of V2X infrastructure must coexist with pre-existing traffic systems and infrastructure. Installing RSUs at intersections, highways, and other high-traffic zones requires precise planning to avoid disrupting existing systems. Furthermore, urban landscapes with tall buildings can impact V2X signal quality, necessitating additional infrastructure investments to ensure seamless communication.
- **Legacy Systems and Compatibility**: Many cities still rely on older traffic management systems incompatible with V2X technology. Integrating V2X with legacy infrastructure requires significant upgrades and, in some cases, complete replacements. Compatibility issues can slow down V2X adoption, as infrastructure owners must weigh the costs and benefits of upgrading.
- **Policy and Standardization Gaps**: Governments and regulatory bodies must develop standardized V2X policies to achieve widespread adoption. However, there has yet to be a global consensus on V2X technology standards, making it challenging for automotive manufacturers and infrastructure developers to commit to a single solution. Standardization is especially relevant as countries adopt different V2X standards, such as DSRC or C-V2X. With regulatory alignment, V2X deployment may remain cohesive.

Beyond technical, security, and infrastructure challenges, V2X communication faces policy-related challenges that can impact its deployment and effectiveness. These include regulatory alignment, data governance, and public-private partnerships:

- **Regulatory Alignment**[45]: Developing universal V2X standards and regulations is essential for interoperability across regions and countries. However, governments vary in their approach to V2X policies, which can create complications for global automotive companies and infrastructure developers. Harmonizing standards on a regional or international level would enable smoother V2X adoption but requires extensive collaboration.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

- **Data Governance and Usage**[46]: The success of V2X systems depends on the ability to share data effectively between vehicles and infrastructure. Developing clear policies on data usage, ownership, and sharing is essential to foster stakeholder collaboration while protecting user privacy and security. Data governance frameworks that support V2X must address who controls the data, how it is used, and how it can be shared across organizations.
- **Public-Private Partnerships (PPPs)**[47]: Implementing V2X on a large scale often requires cooperation between government agencies and private companies. Effective PPPs can provide the resources, expertise, and funding necessary for V2X deployment. However, forming these partnerships requires careful negotiation to balance public interests with commercial goals, which can delay projects if not managed effectively.

.

VI. FUTURE DIRECTIONS IN V2X COMMUNICATION

The evolution of V2X communication will be shaped by advancements in connectivity technologies, data processing capabilities, and artificial intelligence (AI)[48]. These developments promise to expand V2X capabilities, bringing it closer to supporting fully autonomous vehicles and enhancing its potential for transforming global transportation systems. However, realizing these future directions requires addressing policy, regulatory, and infrastructure-related factors, especially in countries with varying technological and infrastructural maturity levels.

6.1. Enabling Ultra-Reliable and Low-Latency Communication

The rollout of 5G technology marks a significant advancement for V2X communication, as it introduces Ultra-Reliable Low-Latency Communication (URLLC) and Massive Machine-Type Communication (MTC), both critical for real-time, high-density data exchanges in V2X systems.

- **5G's Impact**: 5G technology enables data transfer rates 10 to 100 times faster than 4G LTE, reducing latency to milliseconds. This low latency is essential for applications that require immediate feedback, such as collision avoidance and autonomous driving. For example, in scenarios involving rapid vehicle movements and complex maneuvers, 5G can facilitate immediate communication between vehicles and infrastructure, minimizing response times and enhancing safety. Countries with robust 5G infrastructure, like South Korea and Japan, are already piloting V2X applications in urban settings, demonstrating its feasibility for high-traffic environments.
- **Looking Ahead to 6G**: The potential of 6G, expected to be available by the 2030s, is even more promising. With higher frequency bands, increased bandwidth, and enhanced AI integration, 6G will support real-time, data-intensive applications required for fully autonomous vehicles. Additionally, 6G will likely improve coverage and connectivity in remote areas, expanding V2X applicability beyond urban centers. In countries with advanced infrastructure, 6G may allow for the deployment of autonomous fleets on a broad scale. In contrast, in countries with developing infrastructure, 6G can contribute to improving connectivity, thus aiding in the development of V2X foundations.

6.2 Edge Computing and Artificial Intelligence in V2X

The convergence of edge computing and AI within V2X communication is poised to enable faster data processing at the network edge, significantly reducing latency and improving real-time decision-making.

- **Edge Computing in V2X**: With edge computing, data processing, and analytics can occur closer to the data source, such as on-road sensors or in-vehicle devices, rather than relying solely on distant cloud servers. This is critical in V2X applications, where milliseconds can make a difference. Edge computing will reduce network congestion, ensure data privacy, and improve response times. In high-density urban environments, edge-based V2X systems can support traffic management systems that dynamically adjust to real-time traffic flow and road conditions. For instance, vehicles can access immediate hazard alerts and adapt routes in response to traffic patterns.
- **AI Integration for Predictive Capabilities**: AI-driven V2X systems can offer predictive capabilities, such as forecasting traffic congestion, detecting hazardous conditions, and enabling dynamic route adjustments. Additionally, AI can facilitate predictive maintenance, analyzing vehicle performance, and predicting potential mechanical issues before they occur. Integrating AI could lead to intelligent cities in countries with advanced infrastructure where transportation systems proactively adjust to optimize traffic flow, reduce emissions, and increase public safety. AI integration might initially focus on enhancing essential V2X functions for countries with limited infrastructure, such as traffic incident alerts and emergency vehicle prioritization.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

6.3. Towards Fully Autonomous Vehicles

The integration of V2X communication is a cornerstone for the future of autonomous vehicles, enabling coordinated decision-making and safer navigation in complex traffic scenarios.

- **V2X as the Foundation for Autonomy**: Autonomous vehicles require constant data about their surroundings to make safe driving decisions. V2X communication provides this data, extending the range and reliability of information available to autonomous systems. For example, an autonomous vehicle with V2X can receive signals about traffic light changes, pedestrian movements, and other vehicles' positions, enabling more accurate navigation through intersections or congested areas. Autonomous fleets equipped with V2X can optimize routes, adjust speeds, and synchronize movements, reducing traffic congestion and improving road safety.
- **Integration with Electric Vehicles (EVs)**: As the world moves toward sustainable transportation, integrating V2X with electric vehicles (EVs) presents a significant opportunity. V2X can help optimize charging station usage by directing EVs to available charging points, especially during peak hours. Moreover, V2X can facilitate energy-efficient route planning for EVs, reducing range anxiety by ensuring access to charging infrastructure when needed. Countries with well-developed charging networks, such as Norway and the Netherlands, could see even more significant benefits, while those with emerging EV markets could leverage V2X to enhance charging accessibility.

6.4. Policy and Infrastructure Considerations

The success of these future directions depends heavily on policy alignment, regulatory frameworks, and infrastructure investment. Countries with advanced infrastructure may adopt these V2X advancements more readily, while those with limited infrastructure face additional hurdles that require targeted policy and investment.

- **Investment in Infrastructure**: In countries with developed infrastructure, investment can focus on expanding 5G/6G networks, establishing edge data centers, and integrating AI-driven solutions. This is likely to accelerate the deployment of V2X systems, particularly in urban areas. Conversely, initial investments in countries with underdeveloped infrastructure should target establishing foundational V2X systems and connectivity networks to build a foundation for future advancements.
- **Standardization and Regulatory Frameworks**: Establishing universal standards for V2X communication is essential to ensure compatibility across borders and facilitate global adoption. Countries with advanced V2X policies, such as the European Union, have made significant strides in defining regulatory guidelines for V2X and autonomous vehicles, setting an example for other regions. For nations lacking regulatory frameworks, there is an urgent need for government and industry collaboration to establish foundational standards that support interoperability and data privacy.
- **Data Privacy and Cybersecurity Policies**: Protecting user data and preventing cyberattacks are critical in V2X systems that process large volumes of sensitive information. Countries leading in V2X deployment must set stringent cybersecurity protocols to prevent unauthorized access and maintain data privacy. Policymakers in all countries must establish clear guidelines around data ownership, usage, and sharing to build public trust and ensure safe adoption.

The future of V2X communication is prosperous with potential, from enhanced safety applications to the integration of fully autonomous and electric vehicles. While countries with advanced infrastructure are poised to benefit more quickly, those with limited infrastructure can strategically build foundational V2X systems and create supportive policies that prepare for the gradual adoption of these advancements. Ultimately, realizing V2X's full potential will depend on coordinated efforts in technology development, regulatory support, infrastructure investment, and international collaboration to create a safer, more efficient, and sustainable transportation ecosystem.

VII. CONCLUSION

V2X communication has emerged as a transformative technology within ITS, potentially enhancing road safety, improving traffic management, and supporting the shift toward autonomous and connected vehicles. By facilitating real-time data exchange among vehicles, infrastructure, and other road users, V2X communication can significantly contribute to safer and more efficient transportation systems. Through safety, traffic management, infotainment, and environmental applications, V2X holds promise for addressing contemporary transportation challenges, including congestion, emissions, and accident rates. However, the deployment of V2X technology faces various challenges, such as technical limitations, security and privacy concerns, and the need for substantial infrastructure investments. Addressing these challenges will require technological advancements—such as 5G and 6G networks, edge computing, and AI integration—and robust policy frameworks prioritizing cybersecurity, interoperability, and data privacy. Countries with developed infrastructure may lead the way in adopting these technologies, while nations with less advanced infrastructure face unique obstacles that call for gradual development and strategic investment.

Looking forward, the future of V2X communication lies in embracing emerging technologies like 5G, 6G, edge

e-ISSN: 2614-8404
p-ISSN: 2776-3234

computing, and AI, which will enhance V2X capabilities and support fully autonomous driving. Integrating V2X with electric vehicle ecosystems further reinforces its role in sustainable transportation by optimizing resource use and supporting eco-friendly driving practices. For successful global implementation, coordinated policy, investment, and standardization efforts are essential. Ultimately, V2X communication represents a pivotal step toward realizing a safe, efficient, and sustainable transportation future, benefiting both urban and rural environments and developed and emerging economies

REFERENCES

[1] B. Fu, J. Ren, and G. Wang, "Dynamic Optimal Radio Resource Management Scheme for V2V," *Proc. - 2019 Int. Conf. Artif. Intell. Adv. Manuf. AIAM 2019*, pp. 238–242, 2019, doi: 10.1109/AIAM48774.2019.00055.

[2] M. D. Furtado, R. D. Mushrall, and H. Liu, "Threat Analysis of the Security Credential Management System for Vehicular Communications," *2018 IEEE Int. Symp. Technol. Homel. Secur. HST 2018*, 2018, doi: 10.1109/THS.2018.8574206.

[3] Ketut Bayu Yogha Bintoro, S. D. H. Permana, and A. Syahputra, "V2V Communication in Smart Traffic Systems : Current Status , Challenges and Future Perspectives," vol. 19, no. 1, pp. 21–31, 2024.

[4] M. Rapelli, C. Casetti, and M. Sgarbi, "A Distributed V2V-Based Virtual Traffic Light System," *2020 International Conference on COMmunication Systems & NETworkS (COMSNETS)*. IEEE, 2020. doi: 10.1109/comsnets48256.2020.9027339.

[5] A. Ioana, A. Korodi, and I. Silea, "Automotive IoT Ethernet-Based Communication Technologies Applied in a V2X Context via a Multi-Protocol Gateway," *Sensors*, vol. 22, no. 17, 2022, doi: 10.3390/s22176382.

[6] L. Wang, "Performance analysis of EDCA for IEEE 802.11p/DSRC based V2V communication in discrete event system," *IEEE Vehicular Technology Conference*, vol. 2017. pp. 1–5, 2018. doi: 10.1109/VTCFall.2017.8288272.

[7] W. Albattah, S. Habib, M. F. Alsharekh, M. Islam, S. Albahli, and D. A. Dewi, "An Overview of the Current Challenges, Trends, and Protocols in the Field of Vehicular Communication," *Electron.*, vol. 11, no. 21, 2022, doi: 10.3390/electronics11213581.

[8] E. Uhlemann, "The US and Europe Advances V2V Deployment [Connected Vehicles]," *IEEE Veh. Technol. Mag.*, vol. 12, no. 2, pp. 18–22, 2017, doi: 10.1109/MVT.2017.2680660.

[9] A. T. Sasongko, G. Jati, B. Hardian, and W. Jatmiko, "The reliability of routing protocols as an important factor for road safety applications in VANET-based autonomous cars," *J. Comput. Sci.*, vol. 16, no. 6, pp. 768–783, 2020, doi: 10.3844/JCSSP.2020.768.783.

[10] A. B. Nkoro and Y. A. Vershinin, "Current and future trends in applications of Intelligent Transport Systems on cars and infrastructure," *2014 17th IEEE Int. Conf. Intell. Transp. Syst. ITSC 2014*, pp. 514–519, 2014, doi: 10.1109/ITSC.2014.6957741.

[11] X. Liu, "Congestion control in V2V safety communication: Problem, analysis, approaches," *Electron.*, vol. 8, no. 5, 2019, doi: 10.3390/electronics8050540.

[12] F. Goudarzi, H. Asgari, and H. S. Al-Raweshidy, "Traffic-aware VANET routing for city environments-a protocol based on ant colony optimization," *IEEE Syst. J.*, vol. 13, no. 1, pp. 571–581, 2019, doi: 10.1109/JSYST.2018.2806996.

[13] P. K. Singh, S. K. Nandi, and S. Nandi, "A tutorial survey on vehicular communication state of the art, and future research directions," *Veh. Commun.*, vol. 18, p. 100164, 2019, doi: 10.1016/j.vehcom.2019.100164.

[14] A. Molina-Galan, B. Coll-Perales, and J. Gozalvez, "C-V2X Assisted mmWave V2V Scheduling," *2019 IEEE 2nd Connected and Automated Vehicles Symposium (CAVS)*. IEEE, 2019. doi: 10.1109/cavs.2019.8887840.

[15] M. Gupta, J. Benson, F. Patwa, and R. Sandhu, "Secure V2V and V2I Communication in Intelligent Transportation using Cloudlets," *IEEE Trans. Serv. Comput.*, vol. 1374, no. c, pp. 1–1, 2020, doi: 10.1109/tsc.2020.3025993.

[16] S. A. Ahmad and M. Shcherbakov, "A survey on routing protocols in vehicular ad hoc networks," *2018 9th Int. Conf. Information, Intell. Syst. Appl. IISA 2018*, 2019, doi: 10.1109/IISA.2018.8633700.

[17] M. Muhammad and G. A. Safdar, "5G-based V2V broadcast communications: A security perspective," *Array*, vol. 11, p. 100084, 2021, doi: 10.1016/j.array.2021.100084.

[18] Y. Li and C. He, "Connected Autonomous Vehicle Platoon Control Considering Vehicle Dynamic Information," *Chinese Control Conf. CCC*, vol. 2018-July, pp. 7834–7839, 2018, doi: 10.23919/ChiCC.2018.8483514.

[19] A. Daniel, A. Paul, A. Ahmad, and S. Rho, "Cooperative Intelligence of Vehicles for Intelligent Transportation Systems (ITS)," *Wirel. Pers. Commun.*, vol. 87, no. 2, pp. 461–484, 2016, doi: 10.1007/s11277-015-3078-7.

[20] M. M. Hamdi, L. Audah, S. A. Rashid, A. H. Mohammed, S. Alani, and A. S. Mustafa, "A Review of Applications, Characteristics and Challenges in Vehicular Ad Hoc Networks (VANETs)," *HORA 2020 - 2nd Int. Congr. Human-Computer Interact. Optim. Robot. Appl. Proc.*, 2020, doi: 10.1109/HORA49412.2020.9152928.

[21] M. Benza *et al.*, "Intelligent Transport Systems (ITS) applications on dangerous good transport on road in Italy," *Proc. - 2012 7th Int. Conf. Syst. Syst. Eng. SoSE 2012*, pp. 223–228, 2012, doi: 10.1109/SYSoSE.2012.6384180.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

[22] D. Tian, H. Luo, J. Zhou, Y. Wang, G. Yu, and H. Xia, "A self-adaptive V2V communication system with DSRC," *Proc. - 2013 IEEE Int. Conf. Green Comput. Commun. IEEE Internet Things IEEE Cyber, Phys. Soc. Comput. GreenCom-iThings-CPSCom 2013*, pp. 1528–1532, 2013, doi: 10.1109/GreenCom-iThings-CPSCom.2013.271.

[23] M. N. Tahir and M. Katz, "Performance evaluation of IEEE 802.11p, LTE and 5G in connected vehicles for cooperative awareness," *Eng. Reports*, vol. 4, no. 4, pp. 1–14, 2022, doi: 10.1002/eng2.12467.

[24] S. Ali, "Vehicle to Vehicle communication," 2019, doi: 10.13140/RG.2.2.24951.88487.

[25] D. Li, M. Liu, F. Zhao, and Y. Liu, "Challenges and countermeasures of interaction in autonomous vehicles," *Sci. China Inf. Sci.*, vol. 62, no. 5, pp. 3–5, 2019, doi: 10.1007/s11432-018-9766-3.

[26] K. Fukuda, "Science, technology and innovation ecosystem transformation toward society 5.0," *Int. J. Prod. Econ.*, vol. 220, no. August 2017, p. 107460, 2020, doi: 10.1016/j.ijpe.2019.07.033.

[27] J. Li, Y. Zhang, M. Shi, Q. Liu, and Y. Chen, "Collision avoidance strategy supported by LTE-V-based vehicle automation and communication systems for car following," *Tsinghua Sci. Technol.*, vol. 25, no. 1, pp. 127–139, 2020, doi: 10.26599/TST.2018.9010143.

[28] N. G. Ghatwai, V. K. Harpale, and M. Kale, "Vehicle To vehicle communication for crash avoidance system," *Proc. - 2nd Int. Conf. Comput. Commun. Control Autom. ICCUBEA 2016*, pp. 1–3, 2017, doi: 10.1109/ICCUBEA.2016.7860118.

[29] H. Xu, Y. Zhang, C. G. Cassandras, L. Li, and S. Feng, "A bi-level cooperative driving strategy allowing lane changes," *Transp. Res. Part C Emerg. Technol.*, vol. 120, no. December 2019, 2020, doi: 10.1016/j.trc.2020.102773.

[30] S. islam Bouderba and N. Moussa, "Impact of green wave traffic light system on V2V communications," *2018 6th International Conference on Wireless Networks and Mobile Communications (WINCOM)*. IEEE, 2018. doi: 10.1109/wincom.2018.8629638.

[31] Z. Sun, T. Huang, and P. Zhang, "Cooperative decision-making for mixed traffic: A ramp merging example," *Transp. Res. Part C Emerg. Technol.*, vol. 120, no. January, p. 102764, 2020, doi: 10.1016/j.trc.2020.102764.

[32] R. I. Meneguette, G. P. R. Filho, D. L. Guidoni, G. Pessin, L. A. Villas, and J. Ueyama, "Increasing intelligence in inter-vehicle communications to reduce traffic congestions: Experiments in Urban and highway environments," *PLoS One*, vol. 11, no. 8, pp. 1–26, 2016, doi: 10.1371/journal.pone.0159110.

[33] C. Cho and S. Ahn, "Efficient Maintenance of AODV Routes in the Vehicular Communication Environment with Sparsely Placed Road Side Units," *Mob. Inf. Syst.*, vol. 2018, 2018, doi: 10.1155/2018/6252907.

[34] S. Zhao and K. Zhang, "A distributionally robust stochastic optimization-based model predictive control with distributionally robust chance constraints for cooperative adaptive cruise control under uncertain traffic conditions," *Transp. Res. Part B Methodol.*, vol. 138, pp. 144–178, 2020, doi: 10.1016/j.trb.2020.05.001.

[35] Q. Xin, R. Fu, W. Yuan, Q. Liu, and S. Yu, "Predictive intelligent driver model for eco-driving using upcoming traffic signal information," *Phys. A Stat. Mech. its Appl.*, vol. 508, pp. 806–823, 2018, doi: 10.1016/j.physa.2018.05.138.

[36] L. F. Abanto-Leon, A. Koppelaar, and S. Heemstra De Groot, "Network-assisted resource allocation with quality and conflict constraints for V2V communications," *IEEE Veh. Technol. Conf.*, vol. 2018-June, pp. 1–5, 2018, doi: 10.1109/VTCSpring.2018.8417745.

[37] J. Guanetti, Y. Kim, and F. Borrelli, "Control of connected and automated vehicles: State of the art and future challenges," *Annu. Rev. Control*, vol. 45, no. March, pp. 18–40, 2018, doi: 10.1016/j.arcontrol.2018.04.011.

[38] F. Benedetto, A. Calvi, F. D'Amico, and G. Giunta, "Applying telecommunications methodology to road safety for rear-end collision avoidance," *Transp. Res. Part C Emerg. Technol.*, vol. 50, pp. 150–159, 2015, doi: 10.1016/j.trc.2014.07.008.

[39] ETSI EN 302 890-1, "Intelligent Transport Systems (ITS); Facilities layer function; Part 1: Services Announcement (SA) specification," *Etsi*, vol. 1, pp. 1–19, 2019.

[40] E. Talavera, A. Diaz Alvarez, and J. E. Naranjo, "A Review of Security Aspects in Vehicular Ad-Hoc Networks," *IEEE Access*, vol. 7, pp. 41981–41988, 2019, doi: 10.1109/ACCESS.2019.2907861.

[41] M. Garai and N. Boudriga, "A secure QoS aware VANET," *2016 Int. Conf. Adv. Commun. Syst. Inf. Secur. ACOSIS 2016 - Proc.*, 2017, doi: 10.1109/ACOSIS.2016.7843919.

[42] M. Oche, A. B. Tambuwal, C. Chemebe, R. M. Noor, and S. Distefano, *VANETs QoS-based routing protocols based on multi-constrained ability to support ITS infotainment services*, vol. 26, no. 3. Springer US, 2020. doi: 10.1007/s11276-018-1860-7.

[43] J. Zhao, Y. Chen, and Y. Gong, "Study of connectivity probability of vehicle-to-vehicle and vehicle-to-infrastructure communication systems," *IEEE Veh. Technol. Conf.*, vol. 2016-July, pp. 1–4, 2016, doi: 10.1109/VTCSpring.2016.7504493.

[44] A. Khalifa, O. Kermorgant, S. Dominguez, and P. Martinet, "Vehicles platooning in urban environments: Integrated consensus-based longitudinal control with gap closure maneuvering and collision avoidance capabilities," *2019 18th Eur. Control Conf. ECC 2019*, pp. 1695–1701, 2019, doi: 10.23919/ECC.2019.8795940.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

[45] T. Zhu and Z. Liu, "Intelligent Transport Systems in China: Past, Present and Future," *Proc. - 2015 7th Int. Conf. Meas. Technol. Mechatronics Autom. ICMTMA 2015*, pp. 581–584, 2015, doi: 10.1109/ICMTMA.2015.146.

[46] I. Wahid, A. A. Ikram, M. Ahmad, S. Ali, and A. Ali, "State of the Art Routing Protocols in VANETs: A Review," *Procedia Comput. Sci.*, vol. 130, pp. 689–694, 2018, doi: 10.1016/j.procs.2018.04.121.

[47] I. C. Chang, Y. F. Wang, and C. F. Chou, "Efficient VANET unicast routing using historical and real-time traffic information," *Proc. Int. Conf. Parallel Distrib. Syst. - ICPADS*, pp. 458–464, 2011, doi: 10.1109/ICPADS.2011.57.

[48] I. Malygin, V. Komashinsky, and V. V. Tsyganov, "International experience and multimodal intelligent transportation system of Russia," *Proc. 2017 10th Int. Conf. Manag. Large-Scale Syst. Dev. MLSD 2017*, pp. 1–5, 2017, doi: 10.1109/MLSD.2017.8109658.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

The Effect of Online Adminduk Service Applications on the Number of Population Administration Applications

Faidlul Ilahi[1], Saikin[2*)], Maulana Ashari[3], Sofiansyah Fadli[4]
[1,2,3]Department of Information Systems, STMIK Lombok, Lombok, Indonesia
[4]Department of Informatics engineering, STMIK Lombok, Lombok, Indonesia
Email: [1]faidlulilahi@gmail.com, [2]eken.apache@gmail.com, [3]aarydarkmaul@gmail.com, [4]sofiansyah182@gmail.com

Abstract – This study aims to investigate the effect of using the population and civil registration office Online Service Application (SEMAIK) on the number of population administration (Adminduk) applications at the Population and Civil Registration Office (Disdukcapil) of Central Lombok Regency. The direct impact of the implementation of this application on the number of civil registration applications has not been widely studied empirically. Therefore, this research is important to determine the extent to which the use of the SEMAIK application has an effect on increasing applications for population administration services. The SEMAIK application, as an innovation of the Central Lombok Disdukcapil, is designed to make it easier for citizens to apply for civil registration documents online without the need to visit the Disdukcapil office directly. This research method uses the System Usability Scale (SUS) to assess the level of acceptance and satisfaction of application users. The study involved 48 respondents, resulting in an average SUS score of 73.9, which indicates that the application is in the "Acceptable" satisfaction category with a grade of C and a qualitative assessment between 'Good' to "Excellent"."Data analysis shows that there is an increase in the number of Adminduk applications through the SEMAIK application during the 2021-2023 period, which is correlative with an increase in user satisfaction scores. This result confirms that the level of application acceptance is at a relatively good level. User satisfaction with the SEMAIK application has contributed to an increase in the number of Adminduk document submissions in Central Lombok Regency. This research provides important insights into the importance of usability in public service applications and its implications for the efficiency of population administration services.

Keywords – *Population Administration Service Application, User Satisfaction, System Usability Scale (SUS), Public Service Innovation, Public Service Efficiency.*

I. INTRODUCTION

Developments in the realm of information technology have a significant influence on our lives. The use of information technology can increase understanding and simplify all aspects of life [1]. The use of information technology in the context of government encourages the development of e-government, which is expected to provide benefits by increasing community empowerment through increased access to information, improving the quality of government services to the community, and increasing efficiency and transparency in government management [2]. In improving the quality of services in accordance with presidential instructions, the Central Lombok Population and Civil Registration Office seeks to make changes by utilizing information technology. In 2021, the Central Lombok Population and Civil Registration Office made changes to the Adminduk submission or application system. The use of digital technology is not only focused on the needs of the community but can also be optimized by government agencies [3].

Disdukcapil Central Lombok innovates by developing a service system that can be done online in the form of an application. Using the advances in information technology available today is the right action to support the implementation of the obligations and responsibilities of government parties [4]. The utilization of information technology in Disdukcapil Central Lombok is by creating a Service Information System in the form of a website and then developing it into an application for Android and ios devices called SEMAIK. This application is intended for the people of Central Lombok who want to take care of population administration without the need to queue at the Disdukcapil office. Utilization of the population administration information system can provide convenience in compiling population reports by referring to data that has been entered into the system [5]. SEMAIK continues to undergo improvements every year, from the appearance of the interface to the procedures for making applications. However, since the SEMAIK application was implemented to replace the old system, researchers have found few research journals that discuss the quality of public acceptance of the application using usability testing. Evaluation and testing of the level of community satisfaction with the application is mostly only carried out by the Central Lombok Population and Civil Registration Office. In measuring the level of satisfaction and acceptance of the community, especially the Central Lombok community and SEMAIK application service users, researchers will use usability testing analysis with the System Usability Scale (SUS) method.

Usability is a qualitative evaluation that measures the extent to which users can easily use the interface of an application [6]. Usability is a parameter to assess the extent to which users are able to access the functionality of a system effectively, efficiently, and satisfactorily when achieving certain goals [7]. Usability testing is a form of non-functional software testing that considers evaluation from the aspect of human interaction [8]. This research

e-ISSN: 2614-8404
p-ISSN: 2776-3234

chose the SUS method in testing because SUS is in the form of a questionnaire with ten statements, considered very simple and easy for respondents to understand. The result of this questionnaire is a single score scored using a 0-100 scale, making it easier for researchers to evaluate the quality and acceptance of the application. The testing approach with the SUS method focuses on the user's pperspective o that the results are in accordance with the experience experienced by the end user [9].

Usability evaluation on mobile device applications with the heuristic evaluation and UsabilityTestingMethod with 20 respondents was obtained in the satisfaction aspect, resulting in an SUS value of 45.62 with not acceptable acceptance [10]. Then, research with the title Analysis of Online Learning Systems Using the SUS Method resulted in an average SUS value of 65.67 with a marginal high acceptance level [11]. The next research is entitled Analysis of the Code Farmer Website Using SUS (System Usability Scale). From 20 red, the average SUS value is 72.25, with an acceptable level [12]. Research on the Riau Education website with the title Usability Evaluation of the Riau Provincial Education Office Website Using the System Usability Scale Method, totaling 96 respondents, the average SUS value is 7, with a marginal low acceptance level [13]. Research on the Shopee website with the title Shopee Website Usability Evaluation Using SUS obtained an SUS score of 67.08 with a marginally high acceptance level [14]. Finally, testing on the Sipinter e-learning website at SMK Nurul Islam Cianjur received an SUS score of 66.61 at an acceptable level [15].

The purpose of this study was to determine the effect of the new system implemented, namely the SEMAIK application at the Central Lombok Regency Population and Civil Registration Office, on the number of applications or submissions for population administration (Adminduk). By measuring the level of satisfaction and acceptance of the SEMAIK application using the SUS (System Usability Scale) method, researchers can determine the level of public acceptance of the SEMAIK application service. From the level of community acceptance, researchers will also compare it with Adminduk application data so that researchers can determine the effect and relationship of the SEMAIK application implementation on the number of Adminduk applications or submissions in the Central Lombok Regency area. The hope of this research is that the SEMAIK application can develop so that it continues to serve the people of Central Lombok to provide convenience in making submissions or applications in managing population administration. Disdukcapil Central Lombok continues to strive to listen to opinions and suggestions from the community in developing the SEMAIK application so that it can be accepted and useful for the community. With this research, hopefully it can be a reference and assessment material in developing the SEMAIK application so that the number of submissions and applications using this service can continue to increase.

II. RESEARCH METHODOLOGY

This study was designed to determine the effect of using the online population administration service application (SEMAIK) on the number of applications for population administration at the Population and Civil Registration Office of Central Lombok Regency. To achieve these objectives, a systematic methodological approach was used to obtain valid and reliable data and information.

A. Research Stages

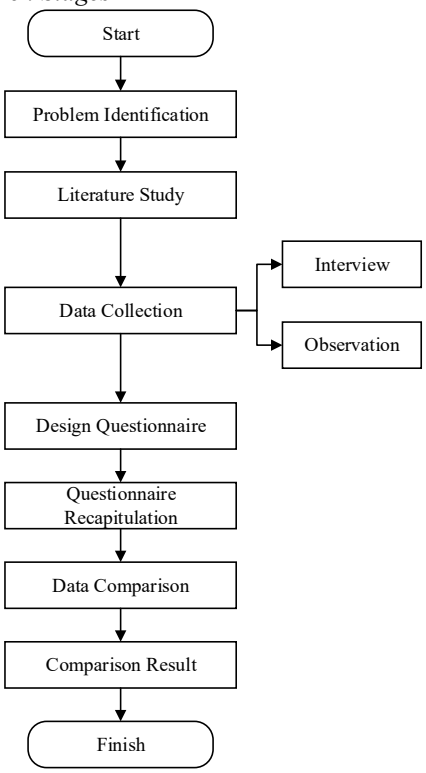


Fig 1. Research Stages

1. Problem Identification
   The purpose of this study is to assess the level of community acceptance of the SEMAIK application and identify the impact that the SEMAIK application has on the services provided by Disdukcapil Central Lombok. In particular, this study will evaluate how much the SEMAIK application contributes to the number of population administration applications.
2. Literature Study/Data Collection
   The literature study activity involved finding related research sources to support the ongoing research. The sources used in this research include scientific journals, books, and theses. To gain a deeper understanding of the research being carried out, researchers also conducted interviews and direct observations at the Central Lombok Disdukcapil office.
   a. An interview is an activity to collect data directly by asking or discussing with the resource person. The sources interviewed by the researcher included SEMAIK employees (admin) of the Central Lombok Disdukcapil, vendor owners of the SEMAIK application, and people who made submissions at the service and information counters.
   b. Observation is an action that is carried out directly, involving direct observation, study, and testing using the SEMAIK application using the admin computer at the Central Lombok Disdukcapil office. In addition, researchers also monitored the activities of people who submitted applications through the SEMAIK application at the service counter. From this stage, researchers obtained data on Adminduk

e-ISSN: 2614-8404
p-ISSN: 2776-3234

applications through the SEMAIK application for the 2021-2023 period. This data comes from the database managed by the vendor handling the SEMAIK application. The following data is in tabular form.

Table 1. SEMAIK Application Submission Data for the 2021-2023 Period (Data Source: Disdukcapil)

Type of Service	2021	2022	2023
Birth Certificate	437	588	472
Death Certificate	84	137	236
Identity card revision	742	647	518
Lost/damaged identity card	338	387	441
Child Identity Card	410	437	548
New family card for baby	533	477	624
New family card for marriage	360	283	436
New family card to add member	72	121	213
Family card lost/damaged and revision	176	297	348
SKP WNI	249	178	226
Total	**3401**	**3552**	**4062**

3. Developing a Questionnaire
A questionnaire is the first form of a survey. In the questionnaire, each respondent is given a series of questions or statements that must be answered, and then the respondent's answers will be further analyzed [16]. The use of the SUS questionnaire is an effective way to collect statistically valid data while providing an assessment with a clear and accurate score [8]. The System Usability Scale (SUS) questionnaire consists of ten statements that are rated by respondents using a Likert scale of 1-5 as an indicator of the level of agreement with each statement. The SUS questionnaire, which has been translated into Indonesian by [17], has gone through a reliability measurement process. The evaluation resulted in an Alpha Cronbach coefficient of 0.841 [8]. The SUS questionnaire is then converted into a Google Form, which will be distributed to each respondent via a link from Google Form. Participants in SUS are individual end users of a software product to be evaluated or tested [18]. Respondents from this study totaled 48 people who were users of the SEMAIK application. The following will be presented SUS Questionnaire Instrument in Table 2 and the Likert Scale in Table 3.

Table 2. SUS Questionnaire Instrument

No	SUS Statement	Score
1	I think I will use this SEMAIK app again.	1-5
2	I feel this SEMAIK application is complicated to use.	1-5
3	I feel this SEMAIK application is easy to use.	1-5
4	I need help from other people or technicians in using this SEMAIK application.	1-5
5	I feel that the features of this SEMAIK application run properly.	1-5
6	I feel that there are many things that are inconsistent (mismatched) in this SEMAIK application.	1-5
7	I feel others will understand how to use this SEMAIK app quickly.	1-5
8	I feel this SEMAIK app is confusing.	1-5
9	I feel there are no obstacles in using the SEMAIK app.	1-5
10	I need to familiarize myself first before using this SEMAIK application.	1-5

Table 2 contains 10 statements from the SUS questionnaire instrument that have a choice of scores 1-5 to be selected by respondents. Respondents must choose one of 1-5.

Table 3. Likert Scale

Scale	Score
Strongly Disagree	1
Disagree	2
Neutral	3
Agree	4
Strongly Agree	5

Table 3 is a Likert scale that is commonly used in SUS questionnaires. It can be seen from each score that it shows the level of agreement with the statements in the SUS questionnaire. Respondents will choose one of these score options [8].

4. Questionnaire Recapitulation
The results of the questionnaire will then be calculated using the following equation:

$$SUS = 2{,}5x\left[\sum_{n=1}^{5}(U_{2n-1}-1)^2+(5-U_{2n})\right] \quad (1)$$

From the amount obtained, it will then be totaled as a whole, and then the average value of the SUS score will be sought. The score range on the System Usability Scale (SUS) questionnaire is from 0 to 100, with an average value of 68 for websites. If the score exceeds 68, it indicates that the user is satisfied [8]. From the interval score obtained, the level of satisfaction will then be measured using Acceptabii, Gradgrade scale , d adjective rating.

Fig 2. SUS Satisfaction Assessment Instrument published by A. Bangor, P.T. Kortum, and J.T. Miller, 2009

5. Data Comparison
The results of the SUS assessment of the SEMAIK application will then be linked to data on the number of Adminduk applications to determine the relationship between the effect of the implementation of the SEMAIK application through the SUS method and the number of Adminduk applications at the Central Lombok Civil Registration Office.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

6. Comparison Results
   Comparison results are the final stage of research in the form of conclusions.

III. RESULTS AND DISCUSSION

The SEMAIK application is a breakthrough in the provision of online public services by the Central Lombok Disdukcapil, in the form of a website-based application with the link https://semaik.lomboktengahkab.go.id/ and Android applications that can be downloaded on the Play Store by searching for "SEMAIK Disdukcapil Central Lombok." Launched in 2021, SEMAIK is the result of innovation by the Central Lombok Disdukcapil, which aims to facilitate population administration services for the people of Central Lombok without having to attend the physical Disdukcapil office. The process of applying for population administration through SEMAIK requires supporting documents in accordance with the specified requirements. The application provides 12 online services;, these include making birth and death certificates, printing new Electronic Identity Cards (KTP EL), applying for lost or damaged KTP EL, printing KTP recording certificates, printing new Family Cards (KK) for newborn babies, printing new KKs for new events such as marriage (Pecah KK), printing new KKs for additional family members, printing KKs for lost, damaged, or revised cases, printing Child Identity Cards (KIA), applying for Indonesian Citizen Recording Certificates (SKPWNI), and complaint or assistance services.

Fig 3. SEMAIK Home Screen

A. SUS Questionnaire Recapitulation

Based on the SUS questionnaire assessment conducted on the SEMAIK application involving 48 respondents who are end users or end users, the following results are obtained:

Table 4. SUS Questionnaire Results (Data Source: Results of research data processing)

Respondent	XI	X2	X3	X4	X5	X6
R1	3	4	4	2	3	2
R2	4	4	4	2	4	2
R3	3	4	4	4	4	2
R4	5	4	4	2	4	3
R5	3	3	2	3	2	3
R6	2	4	2	4	3	3
R7	4	2	4	1	4	3
R8	4	4	2	3	2	3
R9	5	1	4	1	4	3
R10	4	2	3	1	4	4
R11	3	1	5	3	4	3
R12	5	3	5	2	4	2
R13	3	4	1	3	3	3
R14	4	4	3	4	2	3
R15	4	1	4	2	4	2
R16	4	2	4	3	4	2
R17	3	2	4	4	4	2
R18	3	1	5	5	5	2
R19	5	3	3	4	3	2
R20	4	2	4	4	2	2
R21	5	2	3	5	5	3
R22	5	3	3	4	5	1
R23	4	2	3	2	4	2
R24	4	1	4	4	5	2
R25	3	1	5	1	4	1
R26	4	3	5	4	4	3
R27	4	3	5	3	3	3
R28	4	2	5	5	5	3
R29	5	3	3	4	3	2
R30	4	2	4	4	2	2
R31	3	2	3	5	5	3
R32	5	3	3	4	5	1
R33	4	2	3	2	4	2
R34	4	1	4	4	5	2
R35	3	3	2	3	2	3
R36	2	4	2	4	3	3
R37	4	2	4	1	4	3
R38	4	4	2	3	2	3
R39	5	1	4	1	4	3
R40	4	2	3	1	4	3
R41	4	1	5	3	4	3
R42	3	4	1	3	3	3
R43	5	4	3	4	2	3
R44	5	1	4	2	4	2
R45	4	2	4	3	3	2
R46	3	2	4	4	4	2
R47	5	1	4	1	4	3
R48	4	2	3	1	4	3

Table 5. SUS Questionnaire Results continued

Respondent	X7	X8	X9	X10	Jumlah	Jumlah dikali 2,5
R1	3	2	2	2	27	67.5
R2	4	2	3	2	31	77.5
R3	5	2	4	3	35	87.5
R4	3	3	4	2	34	85
R5	3	3	4	4	30	75
R6	2	4	3	4	31	77.5
R7	3	2	4	2	29	72.5
R8	3	4	2	4	31	77.5
R9	5	1	3	1	28	70
R10	4	2	4	2	30	75
R11	4	1	4	1	29	72.5
R12	3	2	4	2	32	80
R13	1	4	4	3	29	72.5
R14	3	3	4	2	32	80
R15	4	2	2	1	26	65
R16	4	1	3	4	31	77.5
R17	3	2	5	5	34	85
R18	2	3	4	4	34	85

e-ISSN: 2614-8404
p-ISSN: 2776-3234

R19	3	2	4	5	34	85
R20	2	3	3	3	29	72.5
R21	3	2	3	3	34	85
R22	3	2	4	5	35	87.5
R23	1	2	4	4	28	70
R24	4	2	4	3	33	82.5
R25	4	1	5	2	27	67.5
R26	3	2	3	4	35	87.5
R27	3	2	3	4	33	82.5
R28	3	2	4	4	37	92.5
R29	3	2	4	5	34	85
R30	2	3	3	3	29	72.5
R31	3	2	3	3	32	80
R32	3	2	4	5	35	87.5
R33	1	2	4	4	28	70
R34	4	2	4	3	33	82.5
R35	3	3	4	4	30	75
R36	2	4	3	5	32	80
R37	3	2	4	2	29	72.5
R38	3	4	2	4	31	77.5
R39	3	1	5	1	28	70
R40	4	2	3	2	28	70
R41	3	1	4	1	29	72.5
R42	1	4	3	3	28	70
R43	3	3	4	2	33	82.5
R44	4	2	2	1	27	67.5
R45	4	1	4	3	30	75
R46	3	2	3	3	30	75
R47	3	1	3	1	26	65
R48	4	2	3	2	28	70
					Jumlah	3695
					Rata rata	73.9

Based on table 4 and table 5, the average SUS value is 73.9, which means that the SEMAIK application is quite good in terms of satisfaction and acceptance. By using the SUS satisfaction assessment instrument as in Figure 1, four acceptability ranges are at Marginal High, having Grade C, and radjective ratings in the Good to Excellent category range can be seen in Figure 4.

Fig 4. Assessment of SUS results of SEMAIK application on SUS Satisfaction Assessment Instrument

IV. CONCLUSION

In this study using the SUS method, the SEMAIK application received an average SUS score of 73.9, with acceptability ranges being at Marginal High, having Grade C, and for adjective ratings in the Good to Excellent category range, the level of user satisfaction and acceptance is good. This research is very limited, given the small number of respondents. The hope of the researcher is that in future studies the number of respondents involved in similar research can be increased in order to get much better SUS score results.

REFERENCES

[1] M. D. Wicayani, "Evaluasi Kualitas Sistem Informasi Pelayanan Dinas Kependudukan dan Pencatatan Sipil Kabupaten Jember Menggunakan Metode Webqual 4.0 dan Importance Performance Analysis (IPA)," 2019.

[2] N. A. Prastiwi, S. Kholil, and S. T. Sumanti, "Pengelolaan Website Dinas Komunikasi Dan Informatika Kabupaten Asahan Sebagai Akses Informasi Publik," *SIBATIK JOURNAL: Jurnal Ilmiah Bidang Sosial, Ekonomi, Budaya, Teknologi, Dan Pendidikan,* vol. 1, no. 11, pp. 2605-2614, 2022.

[3] S. M. Gucci, "Evaluasi User Experience dan Rekomendasi Perbaikan pada Sistem Informasi Pelayanan Dispendukcapil Jember dengan Menggunakan Metode User Experience Questionnaire," Fakultas Ilmu Komputer, 2022.

[4] A. C. D. Susilo, "Analisis Model Penerimaan Teknologi (Technology Acceptance Model) Aplikasi Sistem Informasi Pelayanan (SIP) DISPENDUK Jember," 2019.

[5] D. Kristianto and Y. Findawati, "Perancangan dan Analisis Sistem Informasi Pelayanan Administrasi Kependudukan Sebagai Pengembangan E-government Di Kecamatan Krembung," *JATISI (Jurnal Teknik Informatika dan Sistem Informasi),* vol. 9, no. 2, pp. 1693-1704, 2022.

[6] M. Prabowo, *Metodologi pengembangan sistem informasi*. LP2M Press IAIN Salatiga, 2020.

[7] R. A. Putri, "Monograf Evaluasi Usability Microsoft Teams Menggunakan System Usability Scale," 2021.

[8] T. Wahyuningrum, *Buku Referensi Mengukur Usability Perangkat Lunak*. Deepublish, 2021.

[9] V. Y. P. Ardhana, "Analisis Usability Testing pada SITIDES Menggunakan System Usability Scale dan PIECES Framework," *Bulletin of Informatics and Data Science,* vol. 1, no. 2, pp. 89-97, 2022.

[10] A. R. Millah, S. H. Wijoyo, and R. I. Rokhmawati, "Evaluasi Usability pada Aplikasi Perangkat Bergerak SIP Dispendukcapil Jember dengan Metode Heuristic Evaluation dan Usability Testing," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer,* vol. 4, no. 4, pp. 1213-1220, 2020.

[11] Z. Miftah and I. P. Sari, "Analisis Sistem Pembelajaran Daring Menggunakan Metode Sus," *Research and Development Journal of Education,* vol. 1, no. 1, pp. 40-48, 2020.

[12] M. A. Kusumadya, F. Hidayat, and D. Chandra, "Analisis Website Petani Kode Menggunakan SUS (System Usabilty Scale)," *Jurnal Informatika Polinema,* vol. 8, no. 4, pp. 41-46, 2022.

[13] S. Aisyah, E. Saputra, N. E. Rozanda, and T. K. Ahsyar, "Evaluasi Usability Website Dinas Pendidikan Provinsi Riau Menggunakan Metode System Usability Scale," *Jurnal Ilmiah Rekayasa dan Manajemen Sistem Informasi,* vol. 7, no. 2, pp. 125-132, 2021.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

[14] F. G. Sembodo, G. F. Fitriana, and N. A. Prasetyo, "Evaluasi Usability Website Shopee Menggunakan System Usability Scale (SUS)," *Journal of Applied Informatics and Computing,* vol. 5, no. 2, pp. 146-150, 2021.

[15] S. Budi, A. Fatkharrofiqi, M. Abduillah, and E. S. Laela, "Pengujian Kegunaan Website E-learning Pada SMK Nurul Islam Cianjur Dengan Menggunakan Skala Sistem Usabilitas," *SITEKIN: Jurnal Sains, Teknologi dan Industri,* vol. 19, no. 1, pp. 35-39, 2021.

[16] A. Mulyana *et al.*, *Metode penelitian kuantitatif*. Tohar Media, 2024.

[17] R. Nurlistiani and N. Purwati, "Interpretasi Pengujian Usabilitas E-Learning di Masa Pandemi COVID-19 Menggunakan System Usability Scale," in *Prosiding Seminar Nasional Darmajaya*, 2021, vol. 1, pp. 164-171.

[18] U. Ependi, T. B. Kurniawan, and F. Panjaitan, "System usability scale vs heuristic evaluation: a review," *Simetris: Jurnal Teknik Mesin, Elektro dan Ilmu Komputer,* vol. 10, no. 1, pp. 65-74, 2019.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Implementation of a Website-Based Proposal Seminar Registration System Using the Waterfall Method at Sheikh Abdul Halim Hasan Binjai Institute

Rizka[1], Fitra Hidayat Lubis[2], Asro Hayati Berutu[3], Saprina Putri Utama Ritonga[4], M. Khalil Gibran[5]
[1,2,3,4,5]Program Studi Ilmu Komputer, Fakultas Sains dan Teknologi, Universitas Islam Negeri Sumetera Utara
Email: [1]riskavivo171@gmail.com, [2]hidayatfitra80@gmail.com, [3]asrohayatiberutu@gmail.com,
[4]saprinaputriutamaritonga@gmail.com, [5]m.khalil1100000202@uinsu.ac.id

Registration of proposal seminars at the Sheikh Abdul Halim Hasan Binjai Institute is still done manually, which causes problems such as late information, errors in data recording, and lack of efficiency in administrative management. The institute currently has approximately 1,200 active students, with an average of 150–200 students submitting seminar proposals each semester. This increasing number of participants makes the manual system even more burdensome and prone to errors. To overcome these problems, a website-based proposal seminar registration system was implemented. This system is designed to make it easier for students to register, as well as help the administration in managing the data of seminar participants in a more effective and structured manner. The system development uses the PHP programming language with a MySQL database and the waterfall development method as a systematic approach in the implementation process. The results of the implementation show that the system is able to improve the efficiency of the registration process, minimize data errors, and provide real-time information for students and supervisors. With this system, it is expected that the proposal seminar administration process will become more organized and transparent.

Keywords: Information System, Proposal Seminar, Online Registration, Website, Implementation.

I. INTRODUCTION

The development of information technology has had a significant impact in various fields of life, including the higher education sector. Efficiency in academic administration management is one of the important challenges, especially in the process of registering student proposal seminars. Institut Sheikh Abdul Halim Hasan Binjai is currently still implementing a manual system in the registration process, which causes various obstacles such as delays in data processing, risk of losing documents, and inefficiency in validation and scheduling.

Moreover, the number of students has been increasing steadily—by approximately 15% each year—from around 1,000 in 2020 to about 1,150 in 2024. As a result, the manual system is no longer considered adequate to support the smooth running of the academic process. Therefore, the implementation of a website-based proposal seminar registration system is a strategic solution that not only addresses administrative inefficiencies but also supports the overall digital transformation of the campus. This system allows students to upload documents online, monitor their registration status in real-time, and reduce dependence on physical files [1].

In addition to providing convenience for students, the system also helps the administration in verifying data, preparing seminar schedules, and managing information in a structured and efficient manner. This transformation is in line with the concept of digital transformation in higher education, which emphasizes the importance of adopting digital technology to improve service quality and institutional governance (Vial, 2019).

II. RESEARCH METHODOLOGY

2.1 Research Location

Research and implementation of this system was carried out at the Institute of Sheikh Abdul Halim Hasan Binjai, which is located at Jl. Ir. H. Juandao. 5, Timbang Langkat, Kec. East Binjai, Binjai City, North Sumatra 20735. This location was chosen because it is an institution where practical work is carried out and has a real need for digitizing the administrative process of registering seminar proposals [2].

2.2 Research Time

Research and system development activities were carried out during the implementation of practical work which took place from August 5, 2024 to September 5, 2024. During this period, the author made observations, analyzed the old system, designed a new system, and tested the functionality of the website-based system [3].

2.3 Research Methods

The research method used in this project is the software engineering approach with the Waterfall model. This model was chosen because it offers a systematic and sequential development process that is suitable for projects with well-defined requirements from the outset.

Fig 1. Waterfall Development Model

The Waterfall model consists of the following stages:

1. Requirements Analysis
   Identifying the problems of the existing manual system and formulating the functional and non-functional requirements of the new system.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

2. System Design
   Designing the system structure, which includes flowcharts, use case diagrams, activity diagrams, and database design to provide a blueprint for system development.
3. Implementation
   Developing the system based on the design using web technologies such as PHP and MySQL.
4. Testing
   Conducting tests using the black-box testing method to verify whether each function of the system works according to the requirements.
5. Maintenance
   Performing corrections or improvements after the system is implemented, including fixing bugs or adding new features as needed [4].

2.4 Technology Used

In developing this proposal seminar registration system, the technologies used include:

XAMPP: As a local server to run Apache and MySQL.

1. PHP: Server-side programming language for building application logic.
2. HTML & CSS: To build the structure and appearance of the system interface.
3. MySQL: As a database management system to store registration data.
4. phpMyAdmin: As a visual aid in database management.
5. Visual Studio Code: A text editor used to write, manage, and debug program code [5].

2.5 System Design

This system is designed to digitize the proposal seminar registration process with two types of users, namely students and admins. The main features of the system include:

1. Login page: To differentiate student and admin access.
2. Registration Form: Filled in by students with digital documents such as KTM, KHS, and proof of payment.
3. Admin Dashboard: Admin can verify data, approve/reject registration, and filter by faculty.
4. Status Notification: Students can see the status of their application whether it is approved, rejected, or pending.

System design includes:

The system design is carried out using the Unified Modeling Language (UML) approach, which includes several diagrams to facilitate understanding and implementation of the system, namely:

1. Use Case Diagram: To illustrate the interaction between the user and the system.
2. Flowchart: To visualize the workflow process of the system.
3. Activity Diagram: To describe the activity steps of the system.
4. Database Design: Using three main tables: student, admin, and registration.

This section presents the design process of a web-based seminar proposal registration system through several diagrams and modeling stages, as follows:

A. Use Case Diagram

The Use Case Diagram is a visual modeling tool that is part of the Unified Modeling Language (UML), commonly used in software engineering to describe the functional behavior of a system from the user's perspective. It outlines the interactions between external entities, known as actors, and the system itself through defined use cases, which represent specific functionalities or services provided by the system [6].

Use case diagrams typically consist of actors, use cases, and the relationships between them. Actors may be human users or external systems that interact with the application. The diagram helps stakeholders understand the system's scope and the boundaries of what it will do. It is especially useful during the early stages of system analysis and requirement gathering because it presents a high-level overview without delving into internal logic or implementation.

In addition to identifying interactions, use case diagrams provide clarity on user roles, system functionality, and expectations from different user types. This makes them a critical part of system documentation and a reference point throughout the development lifecycle.

In this system, there are two primary actors: students and the website admin.

Fig 2. Use Case Diagram of the Seminar Proposal Registration System

The admin has access to several key functions in the system, including logging into the platform, reviewing student registration data, approving or rejecting submissions, and deleting entries when necessary. After completing these tasks, the admin can log out of the system. On the other hand, students are able to log in to the system, fill out the seminar proposal registration form by uploading the required documents, check the status of their registration (whether accepted or rejected), and then log out after completing the process `[2].

B. Flowchart

e-ISSN: 2614-8404
p-ISSN: 2776-3234

A flowchart is a graphical representation used to systematically illustrate workflows or processes. In a flowchart, process steps are displayed using standardized symbols, such as rectangles to represent process activities, diamonds for decision points, and arrows to indicate the logical sequence or flow of actions. These symbols help in understanding the order of operations and the decision-making paths within a process.

Flowcharts are highly beneficial in various contexts, including system design, business analysis, and software development. In system design specifically, flowcharts are used to visualize workflow, document procedures, and design systems in a more structured and comprehensible manner for different stakeholders. By using flowcharts, complex processes become simpler and easier to interpret.

The creation of a flowchart involves several steps, including identifying key actions, selecting appropriate symbols, and determining the logical flow between steps. Flowcharts enhance efficiency and effectiveness in understanding processes, facilitate communication across teams, and support more informed decision-making.

The flowchart is used to describe the system's workflow systematically using standard graphic symbols such as arrows, process boxes, and decision diamonds

Fig 3. Flowchart of the Seminar Proposal Registration System

The registration process begins when a student accesses the login page and enters their email and password. The system then validates the credentials provided. If the login information is valid, the student is redirected to the main page; otherwise, they are returned to the login page to re-enter their data. Once successfully logged in, the student fills out the seminar proposal registration form with the required information and uploads supporting documents. The system processes and stores the submitted data, after which the student can view the result of their registration, whether it is approved or rejected.

C. Activity Diagram

An activity diagram is a type of diagram used to visualize the workflow or sequence of activities within a system. It focuses on the processes, system components, and the interactions between these components to ensure integrated and efficient functionality. In an activity diagram, the main activities are depicted using symbols such as circles for actions, arrows for flows, and structured boxes for process steps [7].

One practical example of an activity diagram is its application in a web-based seminar proposal registration system. The activity diagram illustrates the process flow from user login, registration form submission, to the validation and data management performed by the admin. It also shows how the collected information is processed and how the registration outcomes are presented to students. With the help of an activity diagram, the workflow of the system becomes more structured and easier to understand for all stakeholders involved.

The use of activity diagrams is essential in system design as it helps visualize how the system interacts with users and how data flows between components. This greatly supports the planning, development, and evaluation of the system to ensure operational efficiency and effectiveness [8].

The Activity Diagram describes the flow of activities from login to form submission, verification, and final result. It provides a visual model of the dynamic behavior of the system.

Fig 4. Activity Diagram of the Seminar Proposal Registration System

e-ISSN: 2614-8404
p-ISSN: 2776-3234

This diagram helps in understanding the workflow in a structured and efficient manner.

D. Database Design

A database is a core component of any application, functioning as a repository for structured and integrated data. It allows the application to manage, store, and retrieve information efficiently and in an organized manner. The primary purpose of a database is to provide a structure that facilitates easy access and manipulation of data, enabling information to be processed quickly and accurately[9].

In the context of an application, the database serves as the "backbone" that connects all components of the system such as features, menus, and services so that they can interact seamlessly. Without a proper database, data generated by the application cannot be managed effectively. For example, in a web-based seminar proposal registration system, the database stores student records, registration forms, and related information, allowing the data management process to be conducted in a structured and integrated way [10].

Moreover, the database plays a crucial role in ensuring data integrity and supporting informed decision-making. With a well-designed database, applications can run more efficiently and help users access the necessary information without concerns about data loss or inconsistencies [6].

The database is named db_sidang_seminar and consists of three main tables: students, admin, and registration [11].

Table 1. Structure of Students Table

Field Name	Data Type	Size	Description
nim	varchar	15	-
name	varchar	100	-
email	varchar	100	-
password	varchar	255	-

Table 2. Structure of Admin Table

Field Name	Data Type	Size	Description
id_admin	Int	11	Primary Key
name	varchar	100	-
email	varchar	100	-
password	varchar	255	-

Table 3. Structure of Registration Table

Field Name	Data Type	Size	Description
id_registration	int	11	Primary Key
name	varchar	200	-
nim	int	15	-
faculty	varchar	200	-
program	varchar	200	-
advisor_one	varchar	200	PDF
advisor_two	varchar	200	PDF
student_id_card	varchar	200	PDF
tuition_payment_proof	varchar	200	PDF
seminar_payment_proof	varchar	200	PDF
proposal_cover_copy	varchar	200	PDF
approval_form_one	varchar	200	PDF
approval_form_two	varchar	200	PDF
seminar_application_letter	varchar	200	PDF
transcript_semesters_1_to_7	varchar	200	PDF
seminar_attendance_card	varchar	200	PDF
status	enum	3	'Pending', 'Approved', 'Rejected'
registration_date	date	-	-

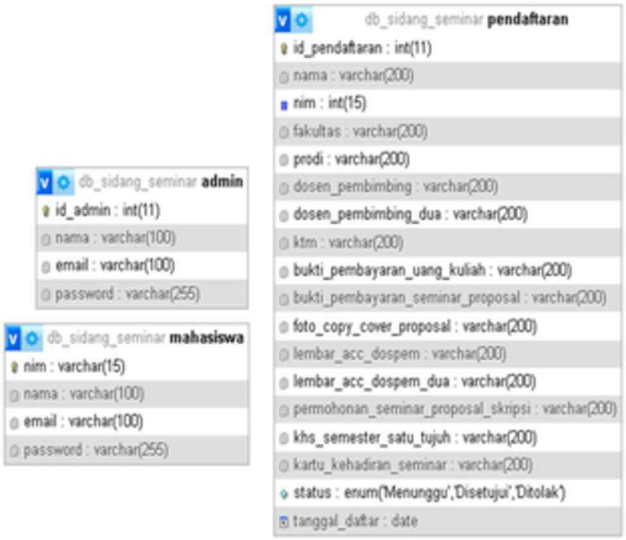


Fig 5. Database Relationship Design of the Seminar Proposal Registration System

III. RESULTS AND DISCUSSION

The seminar proposal registration system consists of two user levels: website admin and student. Upon accessing the system, users are directed to the login page [12].

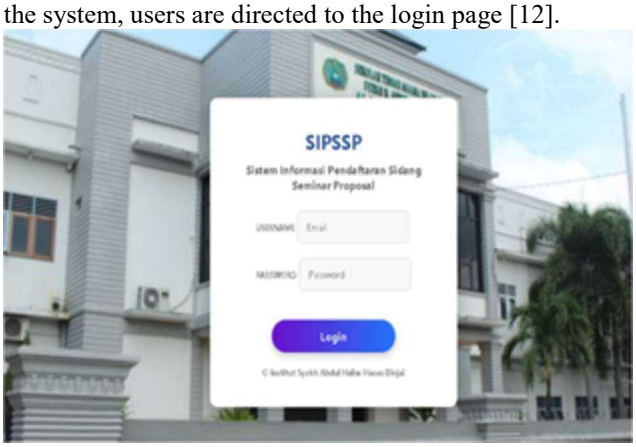


Fig 6. Login Page of the Seminar Proposal Registration System

Each user role has specific functions and access rights, which are explained as follows:

e-ISSN: 2614-8404
p-ISSN: 2776-3234

1. Admin Login

When logging in as an admin, the user is directed to the admin dashboard [13].

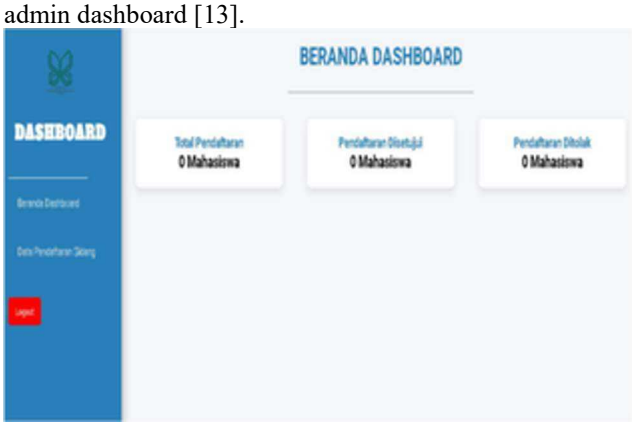


Fig 7. Admin Dashboard Page

Fig 8. Admin Registration Data Page (Empty State)

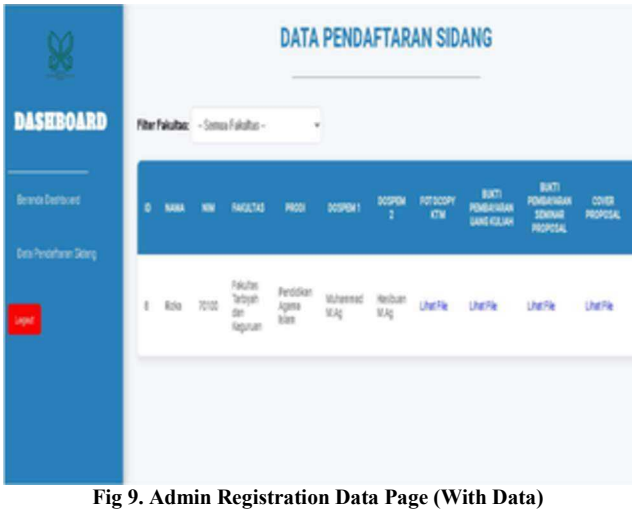


Fig 9. Admin Registration Data Page (With Data)

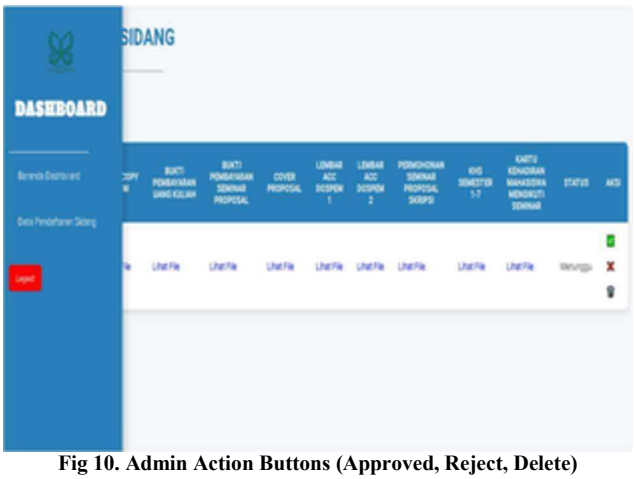


Fig 10. Admin Action Buttons (Approved, Reject, Delete)

The dashboard consists of two main menus: Home and Registration Data. The Home page displays an overview of registered data, while the Registration Data menu allows the admin to view detailed registration entries, filter data by faculty, and perform actions such as approving, rejecting, or deleting submissions [14].

2. Student Login

The interface for student users slightly differs from the admin view.

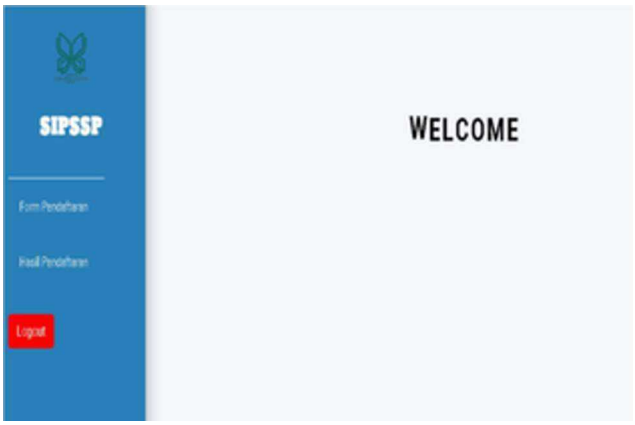


Fig 11. Student Dasboard Page

Fig 12. Seminar Proposal Registration Form (Student)

e-ISSN: 2614-8404
p-ISSN: 2776-3234

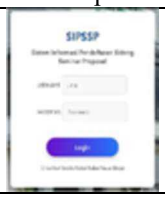
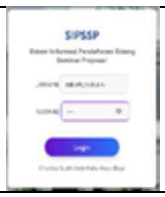
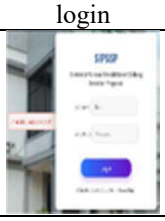
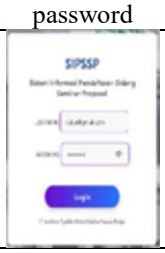
Fig 13. Registration Result Page (Student)

Student users are provided with two main menus: the Registration Form and the Registration Results. Students can input the required data through the form, and afterward, view the results of their submission—whether it is approved, rejected, or deleted by the admin [15].

Testing is an essential phase in the software development lifecycle to ensure the system operates as expected and meets user requirements. In this project, black box testing was conducted to validate the functional aspects of the seminar proposal registration system without examining its internal code structure. The black box testing focuses on the input-output behavior of the system, verifying that the system processes inputs correctly and generates the expected outputs. The following table summarizes the black box test cases, including test inputs, expected outcomes, and actual results:

1. Testing on the Login Form

Table 4. Black Box Testing Table on Login Form

Field	Description
No	1
Test Scenario	Did not input data
Test Case	
Expected Result	The system will notify that the data is empty
Test Result	
Note	Successful
No	2
Test Scenario	Input data but one is incorrect
Test Case	
Expected Result	The system will reject the login
Test Result	
Note	Successful
No	3
Test Scenario	Input correct email and password
Test Case	
Expected Result	The system will grant login access and redirect to the main page
Test Result	
Note	Successful

2. Testing on the Registration Form

Table 5. Black Box Testing Table on Registration Form

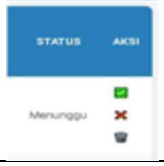
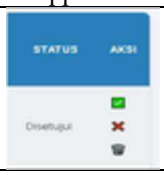
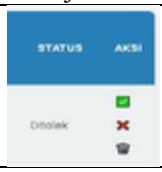
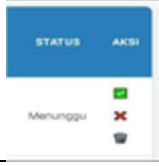
Field	Description
No	1
Test Scenario	Did not input data into the registration form
Test Case	
Expected Result	The system will notify that the data is empty
Test Result	
Note	Successful
No	2

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Test Scenario	Input data but not completely
Test Case	
Expected Result	The system will notify which data fields are still empty
Test Result	
Note	Successful
No	3
Test Scenario	Input complete and correct data
Test Case	
Expected Result	The system will accept the data
Test Result	
Note	Successful

3. Testing on the Admin Dashboard Form

Table 6. Black Box Testing Table on Admin Dashboard Form

Field	Description
No	1
Test Scenario	Click the checkmark button
Test Case	
Expected Result	The system will change the data status to "Approved"
Test Result	
Note	Successful
No	2
Test Scenario	Click the cross button
Test Case	
Expected Result	The system will change the data status to "Rejected"
Test Result	
Note	Successful
No	3
Test Scenario	Click the trash bin button
Test Case	
Expected Result	The system will delete the data
Test Result	
Note	Successful

4. Testing the Data Filtering by Each Faculty

Table 7. Black Box Testing Table on Data Filter by Each Faculty

Field	Description
No	1
Test Scenario	Filter data by Faculty of Sharia and Law
Test Case	
Expected Result	The system will display registration data from the Faculty of Sharia and Law
Test Result	
Note	Successful
No	2
Test Scenario	Filter data by Faculty of Education and Teaching

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Test Case	
Expected Result	The system will display registration data from the Faculty of Education and Teaching
Test Result	
Note	Successful
No	3
Test Scenario	Filter data by Faculty of Economics and Islamic Business
Test Case	
Expected Result	The system will display registration data from the Faculty of Economics and Islamic Business
Test Result	
Note	Successful

IV. Conclusion

This study concludes that the design and implementation of a web-based seminar proposal registration system can significantly streamline and improve the administrative process at Institut Syekh Abdul Halim Hasan Binjai. The system enables students to register online, submit required documents digitally, and monitor the status of their submissions, thereby minimizing manual interaction and reducing processing time.

To ensure the system's functionality and reliability, black box testing was conducted across several main features, including login, registration, admin dashboard operations, and data filtering by faculty. The results showed that all functionalities performed as expected. For instance, the login form correctly responded to both valid and invalid inputs, the registration form validated incomplete data accurately, and the admin dashboard successfully updated or deleted records. Furthermore, the data filtering feature appropriately displayed data based on selected faculties.

The system provides an efficient, accessible, and user-friendly platform that benefits both students and administrative staff. It improves data accuracy, simplifies validation procedures, and supports better transparency in registration handling. The use of a web-based system also aligns with the institution's goal of digital transformation in academic services.

Future development of this system may include the integration of notification features, mobile responsiveness, or synchronization with the campus academic system to further enhance usability and operational efficiency.

References

[1] K. Natanael, T. Tugiman, and A. Basri, "Analisis dan Perancangan Sistem Informasi Pendaftaran Online Seminar & Workshop Berbasis Website," *Algor*, vol. 2, no. 2, pp. 23–30, 2021, doi: 10.31253/algor.v2i2.546.

[2] S. Sukriadi, I. Irma, and H. Ansar, "Sistem Informasi Pendaftaran Peserta Didik Baru Berbasis Web di SMP Satap Negeri Tengapadange Menggunakan Pemodelan Waterfall," *J. Ilm. Sist. Inf. dan Tek. Inform.*, vol. 6, no. 1, pp. 68–76, 2023, doi: 10.57093/jisti.v6i1.150.

[3] J. M. Polgan *et al.*, "Perancangan Sistem Informasi Pendataan Perjalanan Dinas Berbasis Web Di BKAD Provsu," *J. Minfo Polgan*, vol. 13, pp. 1938–1943, 2024.

[4] A. Saleh, F. Azmi, A. Ridwan, and M. K. Gibran, "Pengembangan dan Pemanfaatan Aplikasi Literasi Digital Berbasis Android untuk Meningkatkan Kompetensi Mengajar Guru," *Indones. J. Comput. Sci.*, vol. 12, no. 2, pp. 284–301, 2023.

[5] F. H. Zulfallah and S. Hidayatuloh, "Analisis dan Perancangan Sistem Informasi Pendaftaran Magang pada Inspektorat Jendral Kementerian Pendidikan dan Kebudayaan," *J. Esensi Infokom J. Esensi Sist. Inf. dan Sist. Komput.*, vol. 5, no. 1, pp. 26–34, 2022, doi: 10.55886/infokom.v5i1.294.

[6] S. Samsudin, N. Nurhalizah, and U. Fadilah, "Sistem Informasi Pendaftaran Magang Dinas Pemuda Dan Olahraga Provinsi Sumatera Utara," *J. Teknol. Dan Sist. Inf. Bisnis*, vol. 4, no. 2, pp. 324–332, 2022, doi: 10.47233/jteksis.v4i2.489.

[7] N. Ichsan, S. Alfarizi, D. Gunawan, A. R. Mulyawan, and H. Basri, "Sistem Informasi Pendaftaran Santri Baru Berbasis WEB dengan Pemanfaatan UML Pada PONPES Daarun Nizham," *Profitabilitas*, vol. 1, no. 1, pp. 1–11, 2021, doi: 10.31294/profitabilitas.v1i1.318.

[8] A. Nurhadi and E. Indrayuni, "Sistem Informasi Pendaftaran Vaksinasi Covid-19," *J. Inf. Syst. Informatics Comput.*, vol. 5, no. 4, pp. 453–466, 2021, doi: 10.52362/jisicom.v5i2.491.

[9] N. N. K. Sari, "Sistem Informasi Pendaftaran Tes Toefl Pada Upt Bahasa Universitas Palangka Raya

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Berbasis Website," *J. Teknol. Inf. J. Keilmuan dan Apl. Bid. Tek. Inform.*, vol. 15, no. 1, pp. 53–59, 2021, doi: 10.47111/jti.v15i1.1958.

[10] E. S. Susanto, H. Aprianti, and M. Sejahtera, "Sistem Informasi Pendaftaran Siswa Baru Pada Smkn 2 Sumbawa Besar Berbasis Web," *J. Inform. Teknol. dan Sains*, vol. 2, no. 2, pp. 129–135, 2020, doi: 10.51401/jinteks.v2i2.594.

[11] H. R. Zubair and I. Ernawati, "Perancangan Sistem Informasi Pendaftaran Murid Baru Pada Paud Kangguru Kecil Berbasis Web," *J. Ilm. Matrik*, vol. 24, no. 2, pp. 165–174, 2022, doi: 10.33557/jurnalmatrik.v24i2.1835.

[12] M. Badrul, R. Ardy, S. Nusa Mandiri Jl Jatiwaringin Raya No, and K. Cipinang Melayu Jakarta Timur, "Penerapan Metode Waterfall pada Perancangan Sistem Informasi Pendaftaran Siswa Baru," *J. Sains Komput. Inform. (J-SAKTI*, vol. 5, no. 1, pp. 52–61, 2021.

[13] Dewi Fatmarani Surianto, Shasa Inayah Vega, Nafil Rizqullah Rajab, A. Arianugerah Ilham, and Della Fadhilatunisa, "Perancangan Sistem Informasi Pendaftaran Siswa Baru Pada SMA Makassar Berbasis Website," *J. Mediat.*, vol. 6, no. 3, pp. 54–61, 2024, doi: 10.59562/mediatik.v6i3.1459.

[14] R. D. Asworowati, D. Mustomi, P. R. Adawia, A. D. Suhendra, A. Natong, and M. Cahya Ningrum, "Perancangan Sistem Informasi Pendaftaran Pasien Rawat Jalan Pada Rumah Sakit Ibu dan Anak Gizar Berbasis Mobile," *J. Teknol. Dan Sist. Inf. Bisnis*, vol. 5, no. 4, pp. 542–549, 2023, doi: 10.47233/jteksis.v5i4.1059.

[15] A. Yudahana, I. Riadi, and A. Elvina, "Perancangan Sistem Informasi Pendaftaran Peserta Didik Baru (Ppdb) Berbasis Web Menggunakan Metode Rapid Apllication Development (Rad)," *Rabit J. Teknol. dan Sist. Inf. Univrab*, vol. 8, no. 1, pp. 47–58, 2023, doi: 10.36341/rabit.v8i1.2977.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Information System For Calculating Daily Sugar Limit In Packaged Beverages With Prototype Method

Galuh Panca Wirasa[1*)], Nur Chalik Azhar[2]
[1]Teknik Informatika, Fakultas Teknologi Industri dan Informatika, Universitas Muhammadiyah Prof. Dr. Hamka
[2] Fakultas Teknologi Industri dan Informatika, Universitas Muhammadiyah Prof. Dr. Hamka
Email: [1]2103015175@uhamka.ac.id, [2]nurchalik_azhar@uhamka.ac.id

Abstract – Excess sugar consumption is a global concern as it plays an active role in increasing the risk of non-communicable diseases (NCDs) such as obesity, type 2 diabetes and heart disease. In Indonesia, intense consumption of sugary packaged drinks is influenced by lifestyle changes and low public awareness of its impact. This study develops a web-based system to help users determine the safe limit of consumption of packaged sugary drinks, based on daily calorie needs calculated using the Mifflin-St Jeor formula. the application was designed using the prototype method to ensure interactive and user-oriented development. Assessment conducted through the System Usability Scale (SUS) method indicated that the prototype achieved an average score of 76.6, placing it in the 'Good' classification with a Grade B rating. This finding proves that the system has a good level of usability and is acceptable to users. This system has the potential to become an educational media that supports increasing public awareness of the dangers of excessive sugar consumption, through providing information that is easily accessible and easy to understand, and is expected to contribute to efforts to prevent non-communicable diseases (NCDs) in Indonesia.

Keywords – Sugar, Packaged Beverages, Non-Communicable Diseases, Prototype

I. INTRODUCTION

Excessive sugar consumption has become a global concern in recent years. Sugar, which is commonly used as an added sweetener in a wide variety of beverages and food products, can have adverse health effects if consumed in excess. World Health Organization (WHO) has warned that sugar consumption beyond safe limits can lead to an increased risk of obesity, type 2 diabetes and coronary heart disease. [1]. This warning is all more serious because people's diets tend to change, with the consumption of foods and beverages containing high sugar content becoming more prevalent. [2].

This phenomenon is of concern in Indonesia. Non-communicable diseases (NCDs) such as obesity and diabetes mellitus, which were once more common in developed countries, are now rising sharply in developing countries such as Indonesia. [3]. According to data from Global Burden of Disease 2019 and Injuries Collaborators 2020, NCD are the cause of 80% of death cases in Indonesia in just five years [4], One of factors for high number of NCD is pattern of public consumption, particularly the high consumption sugar-sweetened packaged beverages (SSB). Based on research, Indonesia ranks third in Southeast Asia with consumption of packaged sweetened drinks of 20.23 liters per person [5].

This problem is driven by the increasing consumption of sugar-rich packaged beverages, which have become an easily accessible option for people of all ages and socioeconomic backgrounds. [6], which makes it one of the main causes of the high rate of diabetes in society, this can worsen the health situation, resulting in a variety of diseases associated with excess sugar consumption.

Several previous studies have developed various applications to help calculate daily calorie needs and healthy diet planning. OnTrack [7] using CNN and UCD methods with food recognition features, gamification, and meal plan recommendations for teenagers aged 17-21 years, with excellent usability test results (score 79.5).[8] designed an R&D-based android application that provides clear calorie information and received a positive user response. [9] uses fuzzy logic to provide menu suggestions based on an individual's nutritional status based on anthropometric and daily activity inputs. [10] developed the prototype-based Go Healthy Life, with features of calorie calculation, BMI, and online nutrition consultation, which proved to be effective and accurate with a 92% success rate. Meanwhile, the Bowll application [11] It is built using the waterfall method, provides calorie estimation as well as BMI calculation, and the application can show a positive response to user needs.

From various previous studies have developed applications to support a healthy lifestyle, but no one has specifically discussed related to the daily sugar intake limit in consuming packaged beverages based on user characteristics, using calorie calculations. Previous studies have tended to focus on food in general or calorie counting without highlighting the specific impact of sugar consumption in sugary drinks, which is a contributor to health risks such as obesity and diabetes.

This research aims to develop a web-based application designed to help people calculate the safe limit of consuming packaged sugary drinks based on user characteristics. In addition, this research also focuses on evaluating the effectiveness of the application, as well as increasing public awareness about the dangers of excessive sugar consumption and helping to manage daily sugar intake more wisely. This application is equipped with education to provide a deeper understanding of the health impacts of excessive sugar consumption.

Web application was developed using the prototype method, which allows developers and users to interact continuously during the development process, resulting in a more organized application [12]. Through this strategy, application development can be more flexible and responsive to user feedback at every stage. For calorie calculations using the Mifflin-St Jeor formula, which considers aspects such as age, gender, weight, height, and level of physical activity [13]. In addition, to assess the level of user usability of the developed application, the

e-ISSN: 2614-8404
p-ISSN: 2776-3234

System Usability Scale (SUS) evaluation method was used. This method was chosen because it has been proven as a reliable and simple measuring tool in evaluating user perceptions of the ease of use of the system, as well as providing a quantitative description of the usability quality of the resulting prototype [14].

II. RESEARCH METHODOLOGY

in development of web applications, using prototype method. In this process, a design flow is needed to explain each component and process involved to provide a clear picture of how the system is designed and implemented.

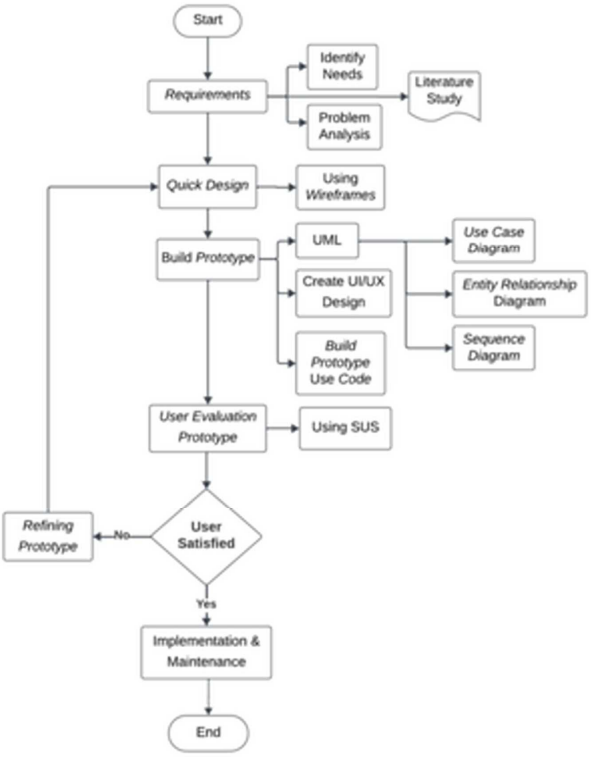


Fig 1. Research flow

A. Requirement

Identification of needs is carried out to determine and ensure that all components, both hardware and software, are available and according to the specifications needed so that the research process can run smoothly.

In this research, using literature study as a collection of needs, this is done by searching various sources such as journals, where the collected literature material is evaluated to ensure its suitability for the ideas and hypotheses developed [15].

Next, a problem analysis is conducted as a way to understand and identify the problem. purpose of the analysis is to find the root of the problem, assess its impact, and formulate an effective solution. This process is according to the results of literature study, which is then processed to identify knowledge gaps or certain aspects that have not been implemented in previous research [16].

B. Quick Design

At the design stage, wireframes are used to design user interface. Wireframes provide the basic structure and main elements of application page without paying attention to visual details such as color or typography [17]. use of wireframes helps in visualizing the page layout and information structure, thus facilitating the design validation process before entering UI/UX design stage.

C. Build Prototype

In making prototype, using Unified Modeling Language (UML) to visualize the system created. author uses three types of UML diagrams, namely:

- Use Case Diagram, is utilized to illustrate how actors interact with the primary functions offered by the system.
- Entity Relationship Diagram (ERD), serves to model data structure and relationships among the entities within the system.
- Sequence Diagram, this diagram is used to show interactions between objects in the system according to time sequence. This diagram will help model interactions between the user, web interface, and database.

The process of creating UI/UX to provide a clearer picture of the final appearance of the web application. UI/UX implementation will focus on principles such as, design consistency, accessibility, and simplicity.

in making this prototype, the author uses coding to design system, which has been made previously. in its implementation, the author utilizes Tailwind CSS as a CSS framework to speed up the interface design process. also, author also uses Next.js as a JavaScript framework that helps develop web applications with high performance.

D. User Evaluation prototype

Prototype evaluation is carried out to assess the quality of prototype based on level of usability. This evaluation is to identify strengths and weaknesses of prototype based on user feedback.

In usability assessment using the System Usability Scale (SUS), this method consists of ten statements that are assessed after user uses the system using a Likert scale from 1 which means strongly disagree to 5 which indicates strongly agree [18], With questions like these.

Table 1. SUS question

No	Questions	Reference Source
1	I would be happy to use this system again.	[19]
2	I feel the system is complicated to use.	[19]
3	I find this system easy to use.	[19]
4	I need help from other people or technicians in using this system.	[19]
5	I feel that the features of this system are working properly.	[19]
6	I feel that there are many inconsistencies (mismatches in this system).	[19]
7	I feel others will understand how to use this system quickly.	[19]
8	I find this system confusing.	[19]
9	I feel no obstacles in using this system.	[19]
10	I need to familiarize myself first before using this system.	[19]

e-ISSN: 2614-8404
p-ISSN: 2776-3234

as illustrated by the questions listed above. Subsequent section outlines the SUS score adjustment process:

- For odd numbered questions (positive questions), score is reduced by 1.
- For even numbered questions (negative questions), score minus 5.
- Total scores are then summed, converted to a 0-100 scale, and result is multiplied by 2.5.

Then to determine the category of system, a sus assessment is used as shown in the following figure.

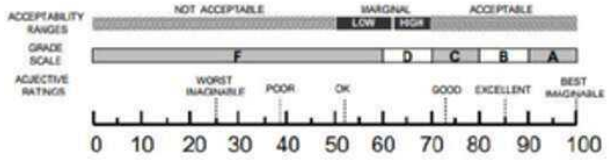


Fig 2. SUS score

For prototype assessment, we will select age group under 17 years old. based on Yayasan Lembaga Konsumen Indonesia (YLKI) in June 2023 in 10 cities in Indonesia, it was found that 25.9% of children under 17 years old consume sugar-sweetened packaged beverages (SSB) every day. In addition, 31.6% of children in this age group consume SSB 2 to 6 times a week. This shows that age group under 17 years old is a suitable segment to be targeted in the prototype assessment.

E. Refining Prototype

After SUS evaluation is conducted, the results will determine whether prototype gets a C or D grade, which states that prototype needs improvement. These improvements include feature enhancements, or interface design, and then will be re-evaluated so that the results show improvement [20]. if prototype meets specified usability standards such as getting grade A or B which indicates prototype is feasible to use, then the next step can be done.

F. Implementation & Maintenance

After prototype has passed the evaluation, prototype is considered ready to be implemented into the full development stage. for this stage, author will host the results of this prototype to the website publicly so that it can be used directly by users. hosting is done to ensure the application can be accessed by users.

III. RESULTS AND DISCUSSION

Research findings obtained based on the methods previously described in making, Information System for Calculating Daily Sugar Limit in Packaged Beverages with Prototype Method.

A. Requirement

Based on the results of literature study, previously developed applications focus on calculating total calories of food and beverages, without paying special attention to the impact of sugar consumption in packaged sweet drinks. in addition, in terms of education, there are not many applications that present information about the dangers of sugar consumption, either in the form of articles or videos.

Therefore, author proposes several solutions, by developing a web-based application that can calculate safe limit of daily sugar consumption, providing educational content in the form of online articles and videos, focusing information on sugar content in various types of packaged sweet drinks, and providing recommendations for drinks that are suitable and safe for consumption based on the needs of each individual.

B. Quick Design

Design drawings of the proposed system. following is a complete description of the system design based on wireframe images that have been made.

Fig.3 Wireframe

Input page is designed to be simple, consisting of columns such as gender with radio button options for “Male” or “Female”, age, height, weight, and physical activity level selected through a dropdown menu, the system will display the calculation results of the amount of daily sugar consumption and daily calories based on these data.

After user obtains calculation result, user selects the beverage product. system will display results of calculation amount sugar consumption product, complete with visual illustrations in the form the number of bottles or cups that illustrate maximum consumption limit. It is also equipped with educational information related to sugar, such as fun facts, online articles, and videos.

In addition, users can also add beverage product data through input form, and on the right side, there is a search panel, helping users to view and search list of beverage products that already exist in database system.

about page, contains application developer information as well as project objectives. on the left, there is a photo of creator, name, student number, and identity information. on the right, there is a project description, which explains background and purpose of creating a web.

C. Build Prototype

in this prototyping stage, using 3 stages, namely making UML, making UI/UX design and implementation using code, here are the results.

1. UML (Unified Modelling Language)

e-ISSN: 2614-8404
p-ISSN: 2776-3234

a. Use Case Diagram

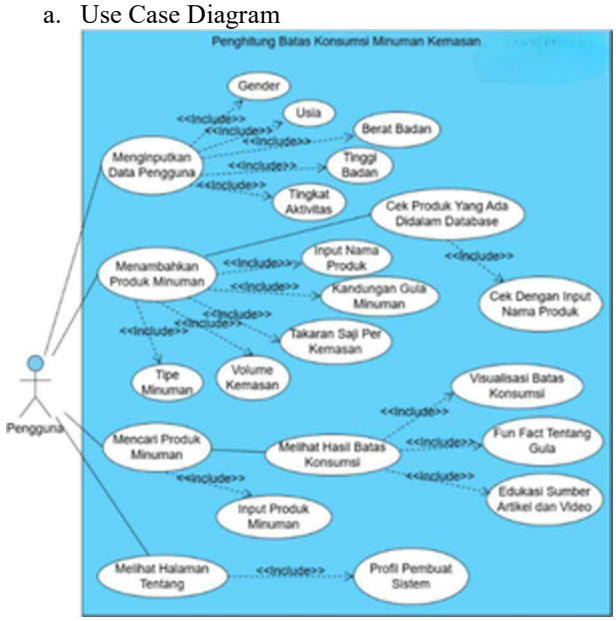


Fig. 4 use case diagram

on this diagram, users can perform various activities, such as entering personal data (gender, age, weight, height, and activity level) to calculate daily calorie and sugar requirements. In addition, users can search and add beverage products. system also offers features such as checking available products in database, visualization of consumption limits, presentation of interesting facts about sugar, and education through articles and videos. there is also an about page, to view profile of system creator.

b. Entity Relationship Diagram (ERD)

Fig. 5 entity relationship diagram

This ERD illustrates relationship between main entities in the system, namely Users, Product List, Beverage Products, and Education. each entity has a certain role in helping overall usability of the system.

User entity is the main actor who interacts with system, which has attribute to calculate calorie requirement and daily sugar limit for certain beverage products through calculation relationship process.

Product List entity contains information related to beverage products, such as product name, sugar content, serving size per package, package volume, and beverage type, which are related to Beverage Products through the process of adding, where the product list becomes data source in product recording.

Beverage Product is related to Education through the display process, which indicates that after beverage product is calculated, system will provide educational information related to sugar consumption, either through articles, videos, or fun facts, complete with source references.

c. Sequence Diagram

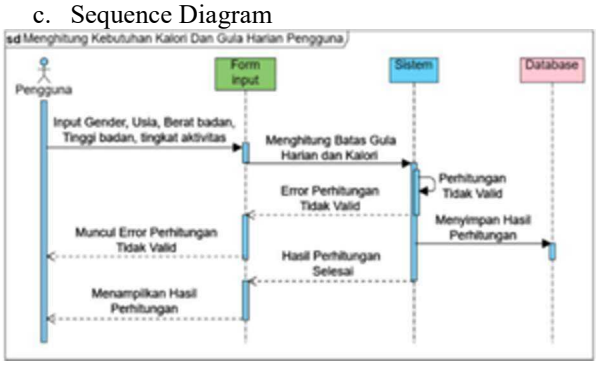


Fig. 6 calculate user daily calorie and sugar

Page calculates the user's daily calorie and sugar needs, this sequence diagram shows flow of interactions between user, input form, system, and database in process of calculating daily sugar and calorie consumption limits. data entered by user is processed by system, then results are stored in database and displayed. if data is invalid, system will display an error message for correction.

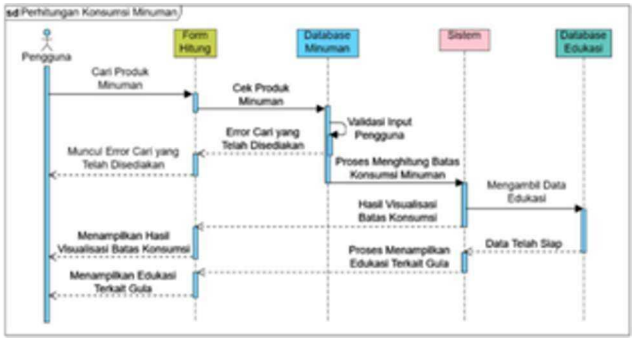


Fig. 7 determining bottled consumption and education

Calculation page to determine the consumption of bottled and educational drinks, this Sequence diagram is interaction between user, calculation form, system, and database. user searches for beverage products, then system verifies through database. if the product is not found, an error message appears. if available, system processes data and calculates consumption limit based on user input. calculation results are displayed in form of a visualization of a bottle or cups, accompanied by educational information related to sugar.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

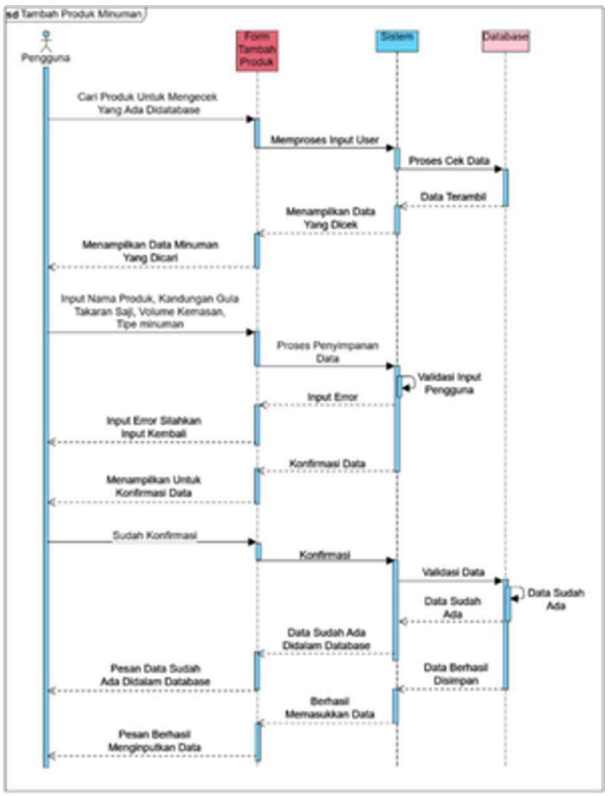


Fig. 8 add beverage products

Add beverage product page, illustrates flow of adding beverage products. user can check availability of product in database. system validates input, displays an error message if an error occurs, and requests a correction. Once valid, system displays a confirmation and again checks for data duplication. if data does not exist, system saves information and provides a success message. This process ensures data validity, prevents duplication, and provides feedback to user.

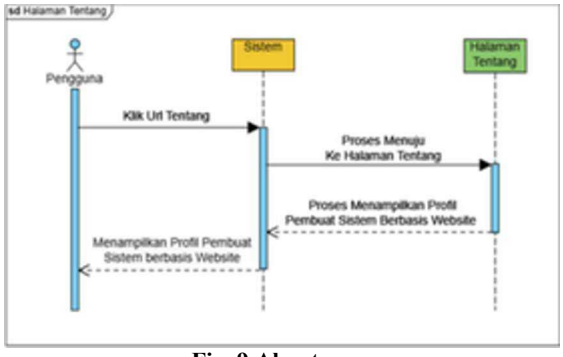


Fig. 9 About page

About Page, this sequence diagram shows interaction when a user accesses profile page. It starts when user clicks URL to about page, system processes request, then displays profile information in user interface.

2. Create UI/UX Design

UI/UX design is focused on aspects of visual consistency, accessibility, and interface simplicity to support improved user experience. Following are the results of UI/UX design that has been made.

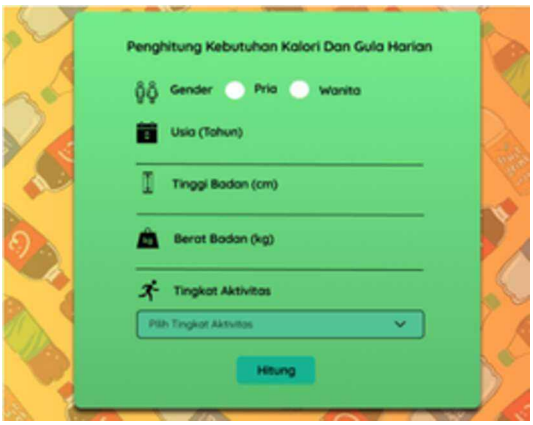


Fig. 10 calculate user daily calorie and sugar

Interface of this daily calorie and sugar requirement is designed simply, with the use of green gradation colors, supported by icons that clarify each input such as age, height, and weight, with elements arranged vertically. selection of elements such as radio buttons and dropdowns to facilitate interaction.

Fig. 11 calculation result

Calculation result display, presents information with the use of green color. Important numbers such as sugar consumption and calories are displayed to stand out with different colors. messages are displayed in an easy-to-understand manner, with buttons to continue interaction.

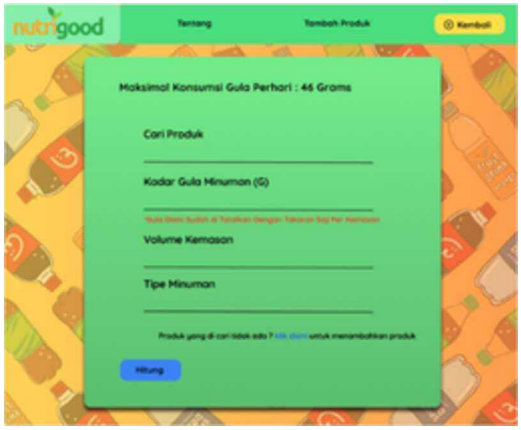


Fig. 12 Find Beverage Products

A form for calculating beverage consumption, a beverage search feature with a sequential layout, for users

e-ISSN: 2614-8404
p-ISSN: 2776-3234

to fill in information such as sugar content, package volume, and beverage type. a consistent green color maintains visual continuity, with red text emphasis to warn users of serving sizes. daily sugar consumption limit information is displayed at the top, and there is also an option to add products.

Fig .13 Ready to Drink Type Calculation Result

This view presents beverage consumption results with a two-column structure. The left side contains input data, while right side displays visual results of number of bottles that can be consumed, complete with illustrations that facilitate understanding. use of the right color and text size helps to highlight important information. It is also equipped with fun facts, education through articles and videos about sugar.

Fig. 14 Type Calculation Result Must be Dissolved

This display is same for presenting the results of beverage consumption, difference being type of beverage that "must be dissolved" or powdered beverages. displays the visual results of the number of cups that can be consumed.

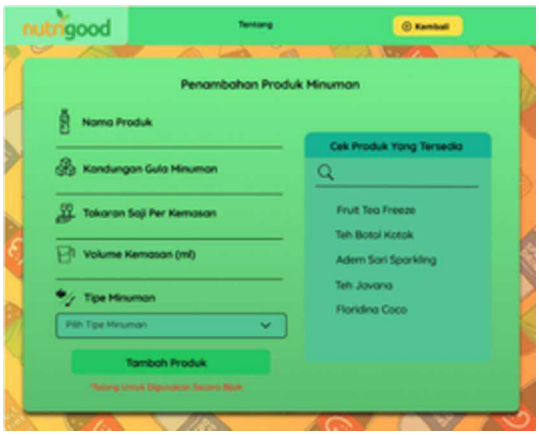


Fig.15 Add beverage products

This view was created to add beverage product data. Icons on each field help clarify the input function. the right side displays a list of available products with a search feature. this design supports data completeness and ease of user navigation.

Fig.16 Confirm add beverage product

Displays a confirmation modal box before the product data is saved. with a warning icon that signals importance. Product information is displayed, making it easy for users to double-check. This can provide control and clarity, preventing input errors before data is submitted.

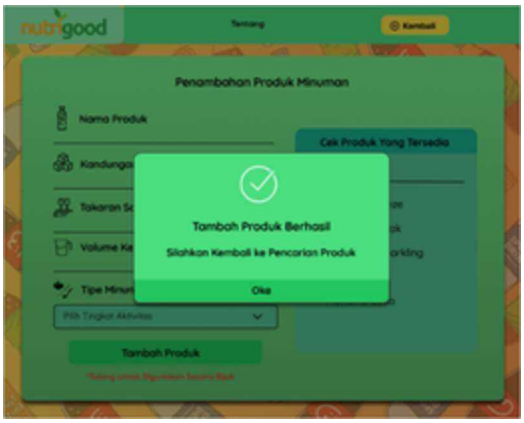


Fig.17 Add product successfully

Shows a success notification after the product has been successfully added. with an icon that confirms success message. instruction text directs user to the next step. this provides clear feedback and no confusion.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig.18 About Page

This view contains personal information and project description with a balanced two-column layout. left side displays the author's profile with name, NIM, and institution, accompanied by author's photo. right side contains a brief explanation of purpose and benefits, making it easier for users to understand context of application. this serves as an introduction to purpose of using the system.

3. Build Prototype use Code

Prototype is developed using coding according to previously design. Core of this system use mifflin-st jeor formula to calculate daily calorie needs. this aims to determine amount of daily sugar limit. following are the calculation stages in the application.

1. System requests inputs from user, such as, Age, Gender, Weight (in kg), Height (in cm), and Physical activity level.
2. Based on data provided by user, system uses Mifflin-St Jeor formula to calculate BMR by adjusting formula for men or women, example, if a man is 30 years old with a body weight of 70 kg and a height of 175 cm. then BMR = (10 × 70) + (6.25 × 175) - (5 × 30) + 5 = 1648.75 kcal/day.

```
// jika radio button laki-laki terpilih
if (male.current?.checked) {
  // jika isi radio button berupa "male"
  if (male.current?.value === "male") {
    // maka rumusnya ini
    BMR = 10 * weight + 6.25 * height - 5 * age + 5;
  }
}
// jika radio button perempuan terpilih
if (female.current?.checked) {
  // jika isi radio button berupa "female"
  if (female.current?.value === "female") {
    // maka rumusnya ini
    BMR = 10 * weight + 6.25 * height - 5 * age - 161;
  }
}
```

Fig. 19 BMR calculation code based on gender

3. Adjustment to Activity Level (TDEE), calculated BMR value is then multiplied by activity factor based on user's activity level to obtain daily calorie requirement. For example, if user chooses an activity level of "ModeratelyActive", then TDEE = 1648.75 × 1.55 = 2555 kcal/day.

```
// variabel kosong untuk menampung nilai
let activityFactor;
// cek nilai dari tingkat aktifitas
// jika tingkat aktifitas "sedentary"
if(activityLevel.current?.value === "sedentary"){
  // maka "activityFactor = 1.2" akan mengisi nilai
  activityFactor = 1.2
} else if (activityLevel.current?.value === "lightlyActive"){
  activityFactor = 1.375;
}else if (activityLevel.current?.value === "moderatelyActive"){
  activityFactor = 1.55;
}else if (activityLevel.current?.value === "veryActive"){
  activityFactor = 1.725;
}else if (activityLevel.current?.value === "extraActive"){
  activityFactor = 1.9;
}
// lalu variabel TDEE menyimpan jumlah kalori perhari
const TDEE = BMR! * activityFactor;
```

Fig.20 Calculating TDEE based on activity level

4. Based on TDEE value, app calculates daily sugar consumption limit according to WHO guidelines, which is 10% of total daily calories. For example, if TDEE is 2555 kcal, then calorie limit is 2555 × 0.1 = 255.5 kcal. since 1 gram of sugar is equivalent to 4 kcal, daily sugar consumption limit is 255.5 ÷ 4 = 63 grams of sugar per day. These results are then saved into the browser's local storage using localStorage.

```
// untuk menghitung jumlah gula perhari
  const kalori = TDEE * 0.1 // berdasarkan pedoman WHO 10%
  // hasil kalori dibagi 4 karena 1 g gula = 4 kalori
  const maxGulaPerhari = kalori / 4;
  // untuk menyimpan ke penyimpanan lokal browser
  localStorage.setItem("maxGula", String(maxGulaPerhari));
```

Fig. 21 Calculate daily sugar limit from TDEE

5. After obtaining daily sugar consumption limit, user selects a beverage product. for example, user selects Product A, which contains 22 grams of sugar in 300 ml, then sugar content per 1 ml is calculated by dividing total sugar content and total contents of drink, which is 22 / 300.

```
// untuk mengambil data gula harian pengguna
useEffect(() => {
  const maxSugars = localStorage.getItem("maxGula");
  if (maxSugars) {
    setMaksimalGulaHarianPengguna(Number(maxSugars));
  }
}, []);
//ubah total gula menjadi per 1 ml
const gulaPerSatuML = kandunganGulaDidalamProduk / totalIsiMinuman;
```

Fig.22 Take sugar data & calculate per ml

6. Calculate number of bottles that can be consumed by dividing user's daily sugar consumption limit by sugar content per 1 ml, then dividing result by total contents of drink, and rounding the result.

```
// menghitung jumlah botol yang dapat dikonsumsi
const maxKonsumsiPerMl = maksimalGulaHarianPengguna / gulaPerSatuML;
// hasilnya dibulatkan kebawah
const jumlahBotol = Math.floor(maxKonsumsiPerMl / totalIsiMinuman);
```

Fig. 23 Number bottles can consume

7. Calculate the remaining consumption in ml using modulus (%) to obtain amount of drink that is not enough to fill a full bottle. remainder is then converted into a percentage of total contents of one bottle or cup, which is then used for CSS masking styling purposes. If there is a remainder, then that percentage will be added as the last element in the array, representing an additional bottle with the remaining available consumption.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

```
// menghitung sisa konsumsi
const remaining = maxKonsumsiPerMl % totalIsiMinuman;
// sisa tersebut dikonversi ke dalam persen
const percentageFillForRemaining = Math.round(
  (remaining / totalIsiMinuman) * 100
);
// jumlah botol diubah menjadi array
// yang diisi 100 disetiap botol yang ada
const isiArray: number[] = Array(jumlahBotol).fill(100);
// jika terdapat sisa maka array "jumlahBotol"
// diisi oleh variabel ini "berapaPersenYangTersedia"
if (berapaPersenYangTersedia > 0) {
  isiArray.push(berapaPersenYangTersedia);
}
```

Fig. 24 Remaining consumption in percent

With this code, app can calculate the user's daily sugar consumption limit based on calorie needs, convert it into units of beverage bottles, and display remaining consumption visually, providing clear instructions.

D. User Evaluation prototype

Evaluation was conducted using the System Usability Scale (SUS). The data collection process was carried out online through distributing questionnaires using Google Form to respondents with a total of 38 respondents, the majority of whom were aged 17 years and under. This questionnaire produces a total SUS score from each respondent, which is then processed to get an average score, for more details the evaluation results are as follows.

Table 2. Result answer of SUS question

Q	Answer to the Question				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Q1	0	0	1	21	16
Q2	3	30	5	0	0
Q3	0	0	3	28	7
Q4	5	26	4	3	0
Q5	0	0	1	15	22
Q6	17	14	5	2	0
Q7	0	3	8	20	7
Q8	8	23	5	2	0
Q9	0	0	2	18	18
Q10	1	20	9	7	1

After all the data is collected, the value of each odd question is subtracted by 1, and the value of even questions is subtracted by 5. Next, the results of all questions are summed up, then multiplied by 2.5. Finally, the values are averaged to obtain a final score that represents the overall usability level of the system.

Table 3. Sus score result

Q	Answer to the Question					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
Q1	0	0	2	63	64	129
Q2	12	90	10	0	0	112
Q3	0	0	6	84	28	118
Q4	20	78	8	3	0	109
Q5	0	0	2	45	88	135
Q6	68	42	10	2	0	122
Q7	0	3	16	60	28	107
Q8	32	69	10	2	0	113
Q9	0	0	4	54	72	130
Q10	4	60	18	7	0	89
Total Score						1164
Multiplied by 2.5						2910
Final Result Total Overall SUS Score (average)						76.6

The evaluation results show that system obtained an average score of 76.6 based on SUS interpretation classified as a “Good” category, with grade B and included in Acceptable range. this shows system is considered very easy to use and well received by users.

E. Refining Prototype

Based on the results of user evaluation by utilizing the System Usability Scale (SUS) method, prototype achieved an average score of 76.6. The score is included in “Good” category and is at grade B, which indicates that system has a good level of usability and is acceptable to users. Thus, no major revisions are needed to prototype design, because it has met the expected usability standards.

F. Implementation & Maintenance

Results of the fully finished prototype will be publicly hosted so that it can be used directly by users. hosting process is carried out by utilizing various free and paid hosting service provider platforms by being hosted online, the application can be accessed by anyone via internet network, without need for additional installations on the user's device.

This step aims to test the performance of application in real conditions to ensure that all application features work well on various devices and networks. hosting also makes it easier for the development team to further develop and improve the system.

With availability of prototypes available online, users can easily access and try application anytime and anywhere, so that the reach of users becomes wider and more flexible.

IV. CONCLUSION

After designing and evaluating a prototype web-based application to help people calculate the safe limit of consuming packaged sweetened drinks. by emphasizing usability aspect as the main parameter, with evaluation results using SUS obtained an average score of 76.6, which is categorized as “Good” and included in Grade B. These findings indicate that the interface design and interaction flow implemented have met the standards of user comfort and efficiency.

Scientifically, this work contributes to the field of software engineering and health with a primary focus on user evaluation. Practically, it also plays a role in increasing public awareness of the dangers of excessive sugar consumption and providing tools to manage daily sugar intake more wisely.

This research has limitations, especially regarding the number of respondents in the evaluation process. In addition, evaluation used is still limited to quantitative methods, so it does not fully describe the personal experience of users in depth.

In the future, it is recommended to expand scope of testing by involving more participants from diverse backgrounds so that the findings can be applied more widely. implementing qualitative evaluation methods such as interviews or direct observation, should be realized to

e-ISSN: 2614-8404
p-ISSN: 2776-3234

gain a more thorough understanding of user needs and perceptions.

REFERENCES

[1] WHO, *Guideline: sugars intake for adults and children*. 2015.

[2] M. T. Veronica, I. M. B. Ilmi, and Y. C. Octaria, "Kandungan Gula Sangat Tinggi dalam Minuman Teh Susu dengan Topping Boba.," *Amerta Nutrition*, vol. 6, 2022, [Online]. Available: https://doi.org/10.20473/amnt.v6i1SP.2022.171-176

[3] A. Asyfah, U. Usraleli, M. Magdalena, S. Sakhnan, and M. Melly, "Hubungan Obesitas dengan Kejadian Hipertensi di Wilayah Kerja Puskesmas Sidomulyo Rawat Inap," *Jurnal Ilmiah Universitas Batanghari Jambi*, vol. 20, no. 2, pp. 338–343, 2020, [Online]. Available: http://dx.doi.org/10.33087/jiubj.v20i2.926

[4] M. E. dr. Siti Nadia Tarmizi, "Cegah Meningkatnya Diabetes, Jangan Berlebihan Konsumsi Gula, Garam, Lemak ," https://kemkes.go.id.

[5] F. Ferretti and M. Mariani, "Sugar-sweetened beverage affordability and the prevalence of overweight and obesity in a cross section of countries," *Global Health*, vol. 15, no. 1, Apr. 2019, doi: 10.1186/s12992-019-0474-x.

[6] W. Widiastuti, A. Zulkarnaini, and G. Mahatma, "REVIEW ARTIKEL: PENGARUH POLA ASUPAN MAKANAN TERHADAP RESIKO PENYAKIT DIABETES," *Journal of Public Health Science*, vol. 1, no. 2, pp. 108–125, 2024, [Online]. Available: https://doi.org/10.59407/jophs.v1i2.1066

[7] R. Darianty, A. H. Qiu, and O. Barus, "Penerapan UCD dalam Aplikasi Tracking Kalori: OnTrack Solusi Kalori Seimbang," *Buletin Pagelaran Mahasiswa Nasional Bidang Teknologi Informasi dan Komunikasi*, vol. 1, no. 1, pp. 6–10, 2023, [Online]. Available: https://buletingemastik.id/index.php/bg/article/view/3

[8] U. M. Afif and S. Purnama, "Aplikasi Perhitungan Nilai Kalori Bahan Makanan Berbasis Anroid," *Journal of SPORT (Sport, Physical Education, Organization, Recreation, and Training)*, vol. 5, no. 2, 2021, [Online]. Available: https://doi.org/10.37058/sport.v5i2.2751

[9] Y. W. A. Rustam and H. Gunawan, "Perancangan Aplikasi Perhitungan Kebutuhan Kalori Tubuh Harian Berdasarkan Asupan Konsumsi Makanan Menggunakan Logika Fuzzy," *INFORMASI (Jurnal Informatika dan Sistem Informasi)*, vol. 14, no. 2, pp. 94–109, 2022, [Online]. Available: https://doi.org/10.37424/informasi.v14i2.174

[10] A. Dwi Suryani and Q. Jafar Ardian, "RANCANG BANGUN IDENTIFIKASI KEBUTUHAN KALORI DENGAN APLIKASI GO HEALTHY LIFE," 2020. [Online]. Available: https://dx.doi.org/10.33365/jtsi.v1i1.51

[11] A. F. Fahanani, I. Y. Habibie, and L. Kamajaya, "PENGEMBANGAN APLIKASI BOWLL UNTUK PERHITUNGAN KEBUTUHAN KALORI DENGAN METODE WATERFALL," *Jurnal Informatika Polinema*, vol. 9, no. 1, pp. 103–110, 2022, [Online]. Available: https://doi.org/10.33795/jip.v9i1.1141

[12] D. Wahyu Setiadi, I. Rizqillah Rajabi, and I. Adlil Dzil Ikram, "Rancang Aplikasi Penjualan Dengan Metode Prototype Berbasis Web," vol. 2, no. 11, pp. 742–747, 2024, doi: 10.5281/zenodo.14482683.

[13] M. D. Muffin, S. TSt Jeor, L. A. Hill, B. J. Scott, and S. A. Daugherty, "A new predictive equation for resting energy expenditure in healthy individuals 3," 1990. [Online]. Available: https://doi.org/10.1093/ajcn/51.2.241

[14] D. M. D. U. Putra, A. S. Kusuma, A. G. Willdahlia, and N. K. N. N. Pande, "Evaluasi Usability E-Modul Basis Data Menggunakan Metode System Usability Scale (SUS)," *Jurnal Ilmiah Global Education*, vol. 5, no. 2, pp. 1800–1809, Jun. 2024, doi: 10.55681/jige.v5i2.2764.

[15] M. N. Adlini, A. H. Dinda, S. Yulinda, O. Chotimah, and S. J. Merliyana, "Metode penelitian kualitatif studi pustaka," *Jurnal Edumaspul*, vol. 6, no. 1, pp. 974–980, 2022, [Online]. Available: https://digilib.uinsgd.ac.id/32855/1/Metode%20Penelitian%20Kualitatif.pdf

[16] B. Arianto, *Penyusunan State of The Art Penelitian*. 2024.

[17] P. Harumsari, H. Fikri, and H. Hannie, "RANCANG INTERFACE UI/UX E - LEARNING BERBASIS WEB MENGGUNAKAN METODE USER CENTERED DESIGN UNTUK MENINGKATKAN EFISIENSI KEGIATAN BELAJAR MENGAJAR: STUDI KASUS SDN PASIR KAMUNING II," *JATI (Jurnal Mahasiswa Teknik Informatika)*, vol. 8, pp. 10597–10607, Sep. 2024, doi: 10.36040/jati.v8i5.10960.

[18] J. Brooke, "SUS: A quick and dirty usability scale," *Usability Eval. Ind.*, vol. 189, Nov. 1995.

[19] Z. Sharfina and H. B. Santoso, "An Indonesian adaptation of the System Usability Scale (SUS)," in *2016 International Conference on Advanced Computer Science and Information Systems (ICACSIS)*, 2016, pp. 145–148. doi: 10.1109/ICACSIS.2016.7872776.

[20] M. Firdaus and A. Pramono, "EVALUASI DAN PENGEMBANGAN DESAIN ANTARMUKA APLIKASI CATATMAK PENCATATAN KEUANGAN PRIBADI MENGGUNAKAN METODE USER CENTERED DESIGN," *JATI (Jurnal Mahasiswa Teknik Informatika)*, vol. 9, pp. 2173–2180, Mar. 2025, doi: 10.36040/jati.v9i2.12935.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

The DeLone and McLean Model for Measuring Success Hospital Management Information System Case Study: Praya Regional Hospital

Ajeng Mastuti Kartini[1], Sofiansyah Fadli[2*], Hairul Fahmi[3], Saikin[4]
[1]Department of Information Systems, STMIK Lombok, Praya, Indonesia
[2,3]Department of Informatics Engineering, STMIK Lombok, Praya, Indonesia
Email: [1]ajengkartini1010@gmail.com, [2*]sofiansyah182@gmail.com, [3]iroel.ami@gmail.com, [4]eken.apache@gmail.com

Abstract – The advancement of information technology in the health sector encourages hospitals to implement Hospital Management Information Systems (SIMRS) to improve efficiency, effectiveness, and service quality. This study aims to measure the success rate of SIMRS implementation at Praya Regional Hospital using the DeLone and McLean model, which includes six variables: system quality, information quality, service quality, usage, user satisfaction, and net benefits. Data was collected through distributing questionnaires to 101 respondents in all service units of RSUD Praya. The analysis was conducted using the Structural Equation Modeling-Partial Least Square (SEM-PLS) method. The results showed that only three of the nine hypotheses proposed proved significant, namely the effect of user satisfaction on net benefits, service quality on usage, and usage on net benefits. These findings indicate that technical aspects and system services need to be improved to achieve optimal SIMRS implementation. This research contributes to the evaluation of hospital information systems and can serve as a reference in making future system development decisions.

Keywords – DeLone and McLean Model; SIMRS; SEM-PLS; Information System Evaluation

I. INTRODUCTION

In the era of globalization, advances in information technology have had a major influence in various fields, including the health sector. As a health care facility, hospitals are required to provide fast, accurate, and quality services [1]. To support its operations, the execution of a Healing center Administration Data Framework (SIMRS) may be a must, as stipulated in Permenkes RI Number 82 of 2013. SIMRS points to move forward effectiveness, viability, execution, and polished skill in healing center management while expanding access and improving service quality [2]. SIMRS implementation requires readiness from various parties, including medical personnel, doctors, and patients, so that the system can run optimally [3].

RSUD Praya Lombok Tengah, as a type B hospital, has implemented the Hospital Management Information System (SIMRS) in almost all installation units. However, in its implementation there are still some obstacles, such as frequent network disruptions; the input feature of lab support results in the inpatient installation; the patient service history data feature, as well as some annoying pop-ups; long data storage; the cursor does not auto-focus on the input form; and management support that is not yet optimal. These problems result in service delays and inaccuracies in data filling, which in turn can affect the quality of services provided [4].

The successful usage of the Healing Center Administration Data Framework (SIMRS) can be measured using the DeLone & McLean model, which consists of six main variables: system quality, information quality, service quality, usage, user satisfaction, and net benefits [5]. This model is used to evaluate the effectiveness of the system and its positive and negative impacts [6]. Previous research shows the data quality, framework quality, and benefit quality have a critical impact on client utilization and fulfillment [3]. However, some studies reveal inconsistencies in the relationship between system quality and net benefits obtained [1].

Human, organizational, and technological factors play a crucial role in the successful implementation of Hospital Management Information System (SIMRS) [7]. One of the main challenges is the low level of user participation in the system development process. Initial interviews showed that some users experienced difficulties in operating SIMRS, especially when network or server disruptions occurred. Therefore, technical support as well as training for hospital staff is needed to improve the effectiveness of system use.

This study aims to identify the supporting and inhibiting factors in the implementation of SIMRS at Praya Regional Hospital. In addition, this study also evaluates the relationship between information quality, system quality, and service quality to the level of use, user satisfaction, and net benefits generated by the system. The results of this study are expected to provide a clearer insight into the level of success of SIMRS implementation and become a reference for the hospital in improving the performance of information systems and the quality of patient services.

II. RESEARCH METHODOLOGY

A. DeLone and McLean Information System Success Measures

The DeLone and McLean model began to be developed in 1949 by Shannon and Weaver and Mason in 1949, as well as other information systems research [8].

e-ISSN: 2614-8404
p-ISSN: 2776-3234

The DeLone and McLean Information System success model is linked to system quality in measuring technological success, which is defined as the accuracy and efficiency of a system as an information producer, while information quality calculates semantic success, which is defined as the success of a piece of information in providing the desired meaning, user variables, and user satisfaction separately affect the two elements [2]. The positive and negative effects of the user component measures can be seen in the results of measuring user satisfaction. Afterwards, users and user satisfaction have an impact on individuals and organizations [3]. The DeLone and McLean success model from 1992 can be seen in Figure 1.

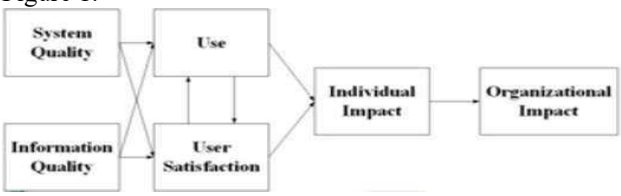


Fig 1. Information System success model [4]

DeLone and McLean improved the best form of information systems released in 2003 [5]. The latest DeLone and McLean success model can be seen in figure 2.

Fig 2. Information System success model [5]

B. Hypothesis

According to [9], the hypothesis is the initial perspective of the problem item under study, translated into a question item display. Hypotheses can also be described as theoretical responses to the formulation of research questions rather than as empirical answers.

Hypotheses have 3 forms that can be used in taking research answers, including the following:

1) Descriptive Hypothesis is the answer to the problem regarding the formulation of research problems.
2) Comparative Hypothesis is a problem perspective based on comparative problems.
3) Associative Hypothesis is the initial answer to the relationship problem.

C. Population and Sample

According to Sugiyono [9], The term "population" refers to the category of things or individuals that researchers use to examine and make conclusions because they have a certain number and characteristics, while the sample represents only a small part of the size and makeup of the population. If the size of the population causes the researcher to be unable to review the entire population due to restrictions, the researcher to use a sample from the population. Based on several population factors collected and analyzed, the results aim to describe the characteristics of all population factors.

Quantitative analysis of sample data produces statistics that are used to estimate population parameters. Statistics are numerical measurements calculated from sample measurements, and parameters are numerical descriptive measurements where the calculations are derived from population measures. Sample statistics are used to draw conclusions about population measurements [10].

D. Sampling Technique

Sampling technique is a method for selecting or obtaining samples from a population to be used as research material. Researchers can make generalizations about the characteristics of population members by analyzing samples or understanding the quality of sample subjects [11]. This research takes a non-probability sampling model with a saturated sample technique [12]. Non-probability sampling is a procedure for obtaining a sample where each element or group of the population is not given the same opportunity to be sampled, while a saturated sample is a method of sampling from the entire population [13].

E. Measurement Technique

The estimation demonstration is assessed by checking the legitimacy and unwavering quality of the pointers that make up the idle factors. In measuring the external show, there are three arrangements, to be specific: focalized legitimacy, discriminant legitimacy, or utilizing normal fluctuation extricated and developing unwavering quality in measuring utilizing composite unwavering quality and Cronbach's alpha [14].

F. Structural Equation Modeling (SEM)

SEM is a multivariate statistical model that allows analysts to predict the influence and attachment between many variables [15]. SEM crucially offers reliability in conducting path analysis [16]. Path analysis is the relationship between intervening and dependent variables. Researchers clearly define what one variable contributes to another, usually displayed in the form of a diagram [17].

G. Partial Least Square (PLS)

PLS is similar to variance-based SEM formation, which allows testing the simultaneous formation of measured and structural. The structural model is used for testing causality, while the measurement model is used as a measure of validity and reliability (testing hypotheses with predictive formation) [18]. Latent variables can be described by PLS accompanied by measurements using their indicators [19]. The use of PLS is because the data does not depend on assumptions, normal distribution is also not required, and it is not a requirement to have a large sample size. PLS is used to process data and answer existing hypotheses [18].

H. Research Stage

This thesis has five research stages, starting from the planning stage to the documentation stage, as shown in Figure 3.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

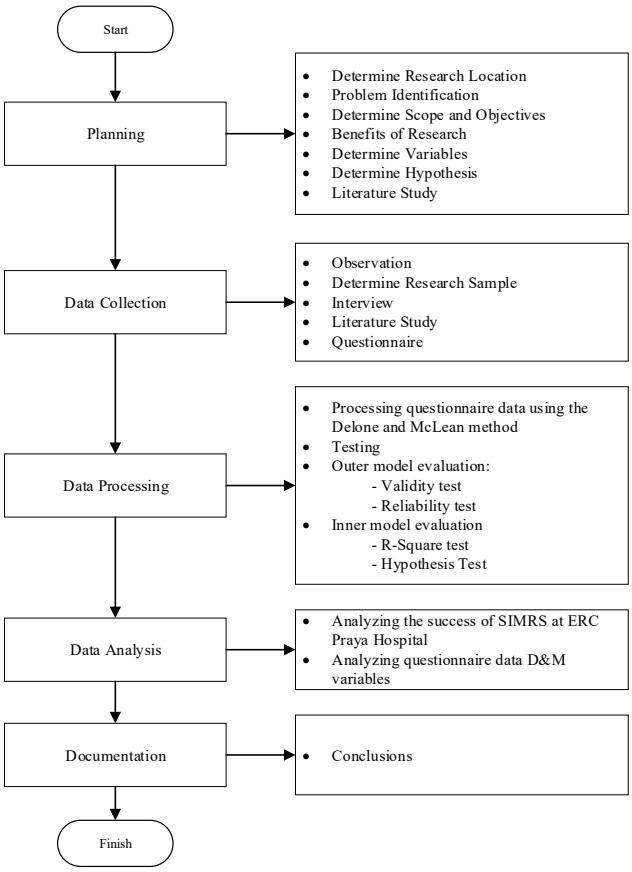


Fig 3. Flowchart of Research Methodology

I. Planning Stage

Ensuring the problems contained in the research regarding the successful implementation of SIMSR at Praya Hospital, determining the place of research, identifying problems, determining the scope and objectives, and benefits of research. This research will determine whether SIMRS users are satisfied and find out the problems they face when using the system.

1) Determining the Place of Research
   The first stage carried out is to determine the research location as a case study that will be researched later. This research takes a case study at Praya Central Lombok Hospital, and then the researcher makes observations first to see the conditions that exist at Praya Hospital. Researchers entered a research permit to the general department of the hospital.
2) Problem Identification
   Problem identification is carried out after the stage of determining the place of research is completed. Problem identification is carried out by looking at the situation of the case study under study, namely by looking at SIMRS, so that it can be identified how to analyze the success of the hospital management information system in the RSUD Praya, especially in all service units that are directly involved in using SIMRS.
3) Determining Scope and Objectives
   The scope is taken based on the interconnected and related parts of the hospital installation, namely the Medical Record Service Unit at Praya Regional Hospital. The goal is for researchers to focus more on research results that are more effective and efficient.
4) Benefits of Research
   The benefits of research at Praya Hospital were carried out to find out and improve user perceptions in the Medical Record Service Unit about user success on SIMRS.
5) Determining Variables
   The variable formation in this study applies the DeLone and McLean method, which has three main variables, namely, variable X consisting of system quality, information quality, and service quality. Variable Y consists of usage, user satisfaction, and net benefits, which are determining variables.
6) Determining the Hypothesis
   The hypothesis designed will be tested to prove whether the hypothesis is correct or not. The conceptual DeLone and McLean method is shown in Figure 4.

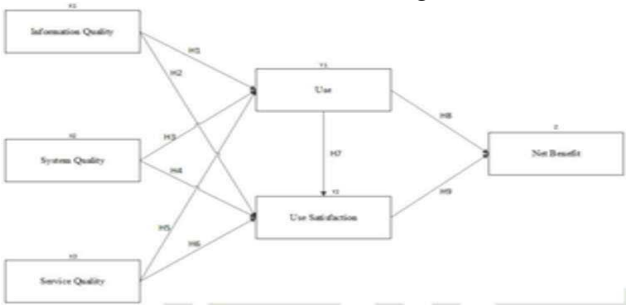


Fig 4. Hypothesis

The conceptual description of the hypothesis taken from the previously described research [20] is shown in Table 2.

Table 2. Hypothesis Description [21]

Hypothesis	Description
1	Information quality has a positive influence on usage.
2	Information quality has a positive influence on user satisfaction.
3	System quality has a positive influence on usage.
4	System quality has a positive influence on user satisfaction.
5	Service quality has a positive influence on usage.
6	Service quality has a positive influence on user satisfaction.
7	Usage has a positive influence on user satisfaction.
8	Usage has a positive influence on net benefits.
9	Usage satisfaction has a positive influence on net benefits.

7) Literature Study
   The procurement of literature studies has the aim of producing information or explanations of theories that will be referred to in research and that will support problem solving. There are two data in the literature study, namely:
   1) Primary
      Primary data is a way of retrieving information directly from the original source within the scope of the research site. Data obtained through sources who know directly the condition of the object of research, namely the Medical Record Service Unit. Through the data obtained, they will be used as respondents in the study.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

2) Secondary
Secondary data is a method whose origin is outside the research target; the data is obtained based on books and journals, both national and international, related to the DeLone and McLean success method.

J. Data Collection Stage

The step is obtained from the continuation of the first flow. The purpose of this stage is to make it easier for researchers to find out information and facilitate research. The activities carried out include:

1) Observation
Observing at Praya Central Lombok Hospital, the purpose of observation is to ask questions about the object under study, namely the Medical Record Service Unit.
2) Determining the Research Sample
SIMRS users in the Medical Record Service Unit totaled 101 employees, all of whom were used as samples in this study, namely the Medical Record Service Unit. Tests were taken utilizing non-probability testing procedures with soaked tests. In the inquiry [10], about the soaked test procedure, the assurance of the test is that all individuals of the populace are utilized as tests
3) Interview
At this stage the researcher meets directly to ask questions about the object under study, namely the Medical Record Service Unit. The intended targets are the SIMRS admin and employees assigned to the Medical Record Service Unit. Preparation for observations and interviews is to make a timeline of observations and interviews, then present observation sheets. The observation and interview timeline can be seen in Table 3.

Table 3. Observation Timeline

Stage	Activities	Result
1	Visiting the research site, introducing yourself and adapting to the environment, and interviewing one of the employees aimed at finding profile information, organizational structure, and how SIMRS management works in the Medical Records Service Unit.	The results obtained are a. Getting to know the staff in the SIMRS Medical Record Service Unit. (Appendix F). b. Interview List (Appendix A) c. Organizational Structure Data and Company Profile d. How the Medical Record Service Unit is managed.
2	The activities carried out are a. Observation on SIMRS Medical Record Service Unit. b. Observing the Medical Record Service Unit.	Obtaining a SIMRS printscreen at the Medical Record Service Unit. (Appendix B).

4) Questionnaire
Observation is done by distributing questionnaires as a way of collecting data. The questionnaire in this study was built to determine the success of the Medical Record Service Unit that has been used at Praya Central Lombok Hospital (Appendix C). After the questionnaire was distributed, the next requirement test was carried out by testing the validity and reliability of the data. Validity testing is used to know whether all research items or indicators proposed to measure research variables are valid. Variables are determined based on the DeLone and McLean method in making questionnaires. Based on research conducted [22], the variables and questionnaire statements obtained from a summary of sources on the DeLone and McLean model variables in this final project can be seen in Table 4.

Table 4. Variables and Questionnaire Statements

No	Indicator	Source	Statement
1	**Information Quality**		
	Completeness	[23]	SIMRS produces complete information according to the user's work needs.
	Accuracy		SIMRS provides information according to actual data.
	Reliability		Users can rely on the data to fulfill their information needs for work.
	Data Update		SIMRS provides information that is current and always updated.
2	**System Quality**		
	System Flexibility	[23]	SIMRS can be used easily and change the available data according to work needs.
	System Integration		SIMRS interaction with users and agencies can be done very well.
	Response Time		SIMRS has good access speed so that it can help users in completing work.
	Language		The language referred to by SIMRS is very easy to understand.
	Convenience of Access		SIMRS is very comfortable and easy to use.
	Error Fixing		SIMRS provides repair facilities if it fails.
3	**Service Quality**		
	Empathy	[21]	SIMRS provides some feedback that may be useful for the user's work.
	System Response		SIMRS responds according to what the user does.
4	**Use**		
	Total Access	[21]	Users routinely use SIMRS.
	Daily Used Time		Users have used SIMRS for a long time.
5	**Use Satisfaction**		
	Information Satisfaction.	[21]	Users are satisfied with the features and functions in the system.
	Overall Satisfaction.		Users are satisfied with the information available because it suits their needs.
6	**Net Benefits**		
	Speed of Task Completion.	[24]	SIMRS helps users in completing work quickly.
	Job Performance.		SIMRS impacts user performance for the better.
	Effectiveness.		SIMRS makes users more effective at work
	Ease of Work.		SIMRS makes it easier for users to do work.
	Usability.		SIMRS is very useful in completing the work of Hospital activities

III. RESULTS AND DISCUSSION

A. Demographic Characteristics of Respondents

Based on the results of distributing questionnaires A questionnaire distributed via Google Forms to SIMRS users obtained data on 101 respondents with the following characteristics:

e-ISSN: 2614-8404
p-ISSN: 2776-3234

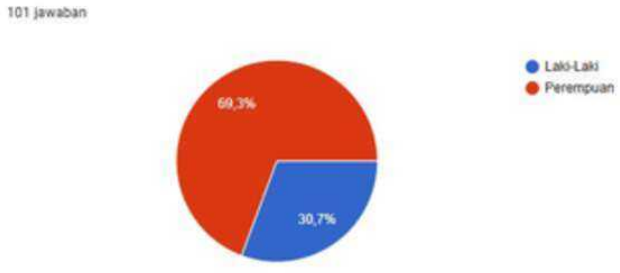


Fig 5: Percentage of Respondent Gender

Figure 5 displays the percentage of respondent gender. It can be seen that of the 101 respondents, 69.3% were female and 30.7% were male. So that the research is dominated by female respondents.

B. Respondents' Education Level

Based on Figure 6, of 101 respondents, the majority (54.5%) have an undergraduate education (S1), followed by 34.7% with a Diploma Three (D3), and 10.9% answered other. This research is dominated by respondents with a bachelor's degree.

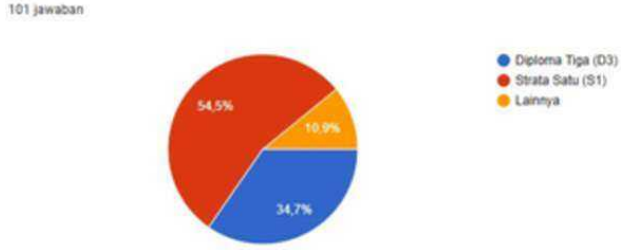


Fig 6. Percentage of Respondents' Education Level

C. Training on the use of SIMRS

Based on Figure 7, the majority of respondents (96%) have participated in training activities using SIMRS, and 4% have not participated in training activities. This study was dominated by respondents who had participated in training activities on the use of SIMRS.

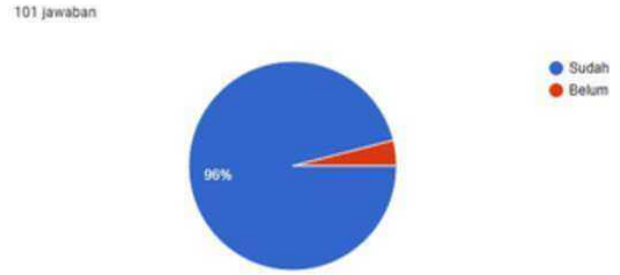


Fig 7. Percentage of respondents who have participated in SIMRS training activities.

D. Period of SIMRS Use

Based on Figure 8, most of the respondents' SIMRS user period is more than 5 years (45.5%), followed by 27.7% of respondents who have used SIMRS for more than 2 yearsd 26.7% of respondents who have used SIMRS for less than 2 years. So that the research is dominated by respondents who have used SIMRS for more than 5 years.

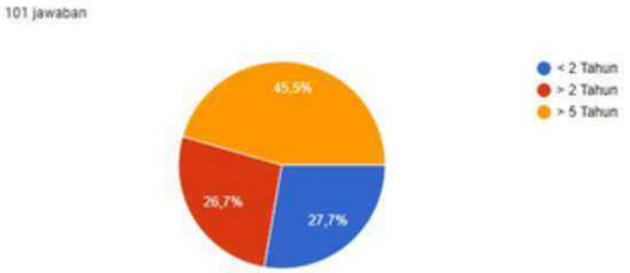


Fig 8. Percentage of SIMRS usage period

E. *Outer Model*

Testing the measurement model or outer model is carried out to determine the validity and reliability seen from the attachment between variables and each indicator.

1. Convergent Validity

The outputs of this test are convergent validity and reliability [25].

Table 5. Outer Loadings Value

	(IQ)	(NB)	(PP)	(SQ)	(U)	(US)
IQ1	0.829					
IQ2	0.713					
IQ3	0.844					
IQ4	0.794					
KP1			0.913			
KP2			0.892			
NB1		0.834				
NB2		0.890				
NB3		0.868				
NB4		0.872				
NB5		0.765				
SQ1				0.661		
SQ2				0.673		
SQ3				0.654		
SQ4				0.703		
SQ5				0.901		
SQ6				0.901		
U1					0.959	
U2					0.909	
US1						0.905
US2						0.917

Table 5 shows that the outer loadings value on the variable indicators of system quality, information quality, service quality, user satisfaction, use, and benefits has met the minimum limit of 0.6. All variable indicators have met the minimum outer loadings value limit so that they have met the convergent validity standard.

2. Discriminant Validity

Discriminant validity can be seen in the Average Variance Extracted value, as in Table 6.

Table 6. Average Variance Extracted (AVE) Value

Variable	Average Variance Extracted (AVE)
Information Quality (IQ)	0.634
Net Benefits (NB)	0.717
Service Quality (PP)	0.815
System Quality (SQ)	0.573
Use (U)	0.873
User Satisfaction (US)	0.830

In table 6, all variables have met the Average Variance Extracted (AVE) value, which is 0.5, so that they have met convergent validity. For the next testing stage, namely reliability, by looking at the Cronbach's alpha value and the composite reliability value.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

3. Reliability Test

Table 7. Cronbach's Alpha and Composite Reliability Values

	Cronbach's alpha	Composite reliability (rho_c)
Information Quality (IQ)	0.809	0.874
Net Benefits (NB)	0.902	0.927
Service Quality (PP)	0.773	0.898
System Quality (SQ)	0.851	0.887
Use (U)	0.860	0.932
User Satisfaction (US)	0.796	0.907

The Cronbach's alpha and composite reliability values of all variables are more than 0.70, so all variables are reliable.

F. Inner Model

The structural model (inner model) defines the relationship between latent constructs by looking at the results of the parameter coefficient estimate and its significance level. The structural model is generated as follows:

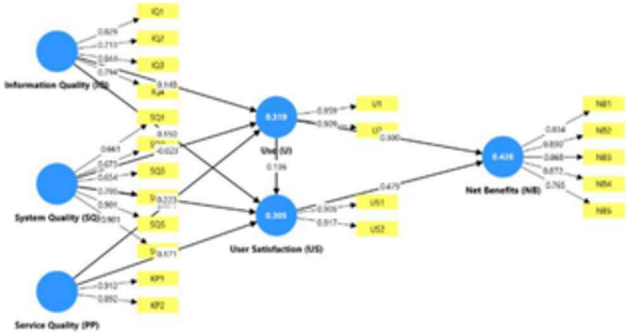


Fig 9. User Page Display

Structural model testing is seen from several indicators, namely R-squares, f-squares, and goodness of fit models.

1. R-Square

There are three categories in gathering R-square values. In case the R-square estimate is 0.75, it is within the solid category; for an R-square estimate of 0.50, it is within the direct category, and 0.25 is within the powerless category [26]. The R-square estimate of the subordinate variable gotten in this investigation can be seen in table 8.

Table 8. R-Square Value

Variable	*R-square*	Prediction Model
User Satisfaction (US)	0.305	Weakness
Use (U)	0.319	Weakness
Net Benefits (NB)	0.428	Weakness

After calculating through SmartPLS 4 in accordance with the table above, it explains that the user satisfaction variable has an r-square value of 0.305. This means that the effect of information quality, system quality, service quality, and usage on user satisfaction is 30.5%. The r-square value on the usage variable is 0.319; this means that the effect of information quality, system quality, and service quality on usage is 31.9%. The r-square value on the net benefit variable is 0.428. This means that the effect of SIMRS users and user satisfaction on net benefits is 42.8%.

2. F-Square

F-square is a measure used to assess the relative impact of an influencing variable (exogenous) on the influenced variable (endogenous). The amount of substantive influence is classified into 3, namely 0.02 (small/bad), 0.15 (medium/sufficient), and 0.35 (large/good) (Setiaman, 2023).

Table 9. F-Square Value

Variable Relationship	F-Square	Substantive Effect
Use Satisfaction (US) -> Net Benefits (NB)	0.345	Small
Information Quality (IQ) -> Use Satisfaction (US)	0.015	Small
Information Quality (IQ) -> Use (U)	0.014	Small
Service Quality (KP) -> Use Satisfaction (US)	0.020	Medium
Service Quality (KP) -> Use (U)	0.163	Small
System Quality (SQ) -> Use Satisfaction (US)	0.041	Small
System Quality (SQ) -> Use (U)	0.000	Small
Use (U) -> Use Satisfaction (US)	0.017	small
Use (U) -> Net Benefit (NB)	0.135	Small

G. Goodness of Fit

This menu is designed to ensure the system runs smoothly and securely. In addition, system and database updates can be managed through this menu to maintain optimal website performance.

Table 10. Model Goodness of Fit Test Results

No	Structural Model	*Cut-Off Value*	Estimated	Description
1	SRMR	< 0,10	0.160	Bad Fit
2	d_ULS	> 0,05	5.877	Fit
3	d_G	> 0,05	1.250	Fit
4	Chi-Square	< 0,05	590.334	Fit
5	NFI	Approaching 1	0.614	Fit

Based on the results of the PLS goodness-of-fit model test in table 10, it shows that the SRMR value of the PLS model is 0.160, which is higher than 0.10, indicating that the model is not good. For the d_ULS output result, namely 5.877, the result is higher than 0.05, which means it shows a good model. For the d_G output result, namely 1.250, the result is higher than 0.05, indicating a good model. The chi-square result is 590.334, which is higher than 0.05 and means the model is good. The NFI output results show a result of 0.614, meaning that the model is well accepted.

H. Hypothesis Testing

The accepted and rejected path coefficient results can be seen in table 11 below:

Table 11. Path Coefficient on Model Testing

No	Variable	t-count	p-value	Description
1	Use Satisfaction (US) → Net Benefits (NB)	5.749	0.000	Accepted
2	Information Quality (IQ) → Use Satisfaction (US)	0.907	0.364	Rejected
3	Information Quality (IQ) → Use (U)	1.147	0.252	Rejected
4	Service Quality (KP) → Use Satisfaction (US)	0.986	0.324	Rejected
5	Service Quality (KP) → Use (U)	3.965	0.000	Accepted

e-ISSN: 2614-8404
p-ISSN: 2776-3234

6	System Quality (SQ) → Use Satisfaction (US)	1.689	0.091	Rejected
7	System Quality (SQ) → Use (U)	0.054	0.957	Rejected
8	Use (U) → Use Satisfaction (US)	1.427	0.154	Rejected
9	Use (U) → Net Benefits (NB)	2.551	0.011	Accepted

Based on the table above, the results of testing each hypothesis based on the results of t-statistics and sig values on path coefficients are explained as follows:

1. H1: Use Satisfaction (US) has a significant effect on Net Benefits (NB) The t-count value = 5,749 and p-value = 0.000, so the hypothesis is accepted.
2. H2: Information Quality (IQ) has no significant effect on Use Satisfaction (US) The t-count value = 0.907 and p-value = 0.364, so the hypothesis is rejected.
3. H3: Information Quality (IQ) has no significant effect on Use (U) The t-count value = 1.147 and p-value = 0.252, so the hypothesis is rejected.
4. H4: Service Quality (KP) has no significant effect on Use Satisfaction (US) The t-count value = 0.986 and p-value = 0.324, so the hypothesis is rejected.
5. H5: Service Quality (KP) has a significant effect on Use (U) The t-count value = 3.965 and the p-value = 0.0, so the hypothesis is accepted.
6. H6: System Quality (SQ) has no significant effect on User Satisfaction (US) The t-count value = 1.689 and p-value = 0.091, so the hypothesis is rejected.
7. H7: System Quality (SQ) has no significant effect on Use (U). The t-count value = 0.054 and the p-value = 0.957, so the hypothesis is rejected.
8. H8: Use (U) has no significant effect on Use Satisfaction (US) The t-count value = 1.427 and p-value = 0.154, so the hypothesis is rejected.

IV. CONCLUSION

Based on the results of research on the implementation of the Hospital Management Information System (SIMRS) at Praya Regional Hospital using the DeLone and McLean model, it can be concluded that of the nine hypotheses proposed, only three hypotheses were accepted, namely that user satisfaction has a significant effect on net benefits, service quality has a significant effect on usage, and usage has a significant effect on net benefits. The other six hypotheses were rejected because they did not meet the required significance and t_values, indicating that information quality, system quality, and most aspects of use have not been able to have a significant effect on user satisfaction or on the use of SIMRS directly. In general, the outer model test results show that all indicators in this study meet the validity and reliability criteria. However, the R-square values for the user satisfaction, usage, and net benefit variables are in the weak category, which means that the independent variables only explain a small part of the variation that occurs in the dependent variable. In addition, the goodness-of-fit test results show that there are some weaknesses in the fit of the model, especially in the SRMR value, which still exceeds the ideal threshold. In addition, to obtain more in-depth results, further research is recommended to be carried out by involving other service units and considering external variables outside the DeLone and McLean model that may also affect the successful implementation of hospital information systems.

REFERENCES

[1] S. A. Azni, "Analisis Parameter Keberhasilan Sistem Informasi Manajemen Rumah Sakit (SIMRS) dengan Metode DeLone dan McLean (Studi Kasus Pada Rumah Sakit Swasta di Kota Padang)," Universitas Andalas, 2023.

[2] B. Alferi, T. D. Wulan, and F. A. Susanto, "EVALUASI KESUKSESAN SISTEM PENDAFTARAN ONLINE DI RSI SURABAYA DENGAN MENGGUNAKAN METODE (DELONE & MCLEAN)," in *PROSIDING NATIONAL CONFERENCE FOR UMMAH*, 2020, vol. 1, no. 1.

[3] A. Annur, "Implementasi Sistem Informasi Manajemen Rumah Sakit (SIMRS) RSUD Natuna dengan Pendekatan DeLone Dan McLean," Universitas Islam Sultan Agung Semarang, 2024.

[4] W. H. DeLone and E. R. McLean, "Information systems success measurement," *Foundations and Trends® in Information Systems,* vol. 2, no. 1, pp. 1-116, 2016.

[5] P. H. Saputro, A. D. Budiyanto, and A. Santoso, "Model DeLone and McLean untuk mengukur kesuksesan e-government Kota Pekalongan," *Scientific Journal of Informatics,* vol. 2, no. 1, pp. 1-8, 2015.

[6] N. Agustina and E. Sutinah, "Model Delone dan McLean Untuk Menguji Kesuksesan Aplikasi Mobile Penerimaan Mahasiswa Baru," *InfoTekJar (Jurnal Nas. Inform. dan Teknol. Jaringan),* vol. 3, no. 2, pp. 76-82, 2019.

[7] R. P. S. Ringo and H. Hendri, "Model Delone Dan Mclean Untuk Mengukur Kesuksesan Pada Aplikasi PeduliLindungi Dimasa Pandemi Covid-19," *Jurnal Informatika Dan Rekayasa Komputer (JAKAKOM),* vol. 2, no. 2, pp. 207-215, 2022.

[8] A. Anfal, "Pengaruh Kualitas Pelayanan Dan Citra Rumah Sakit Terhadap Tingkat Kepuasan Pasien Rawat Inap Rumah Sakit Umum Sundari Medan Tahun 2018," *Excellent Midwifery Journal,* vol. 3, no. 2, pp. 1-19, 2020.

[9] D. Sugiyono, "Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D," 2013.

[10] A. Syamil *et al.*, *Akuntansi manajemen: Konsep-konsep dasar akuntansi manajemen era digital*. PT. Sonpedia Publishing Indonesia, 2023.

[11] M. Ernawati, E. H. Hermaliani, and D. N. Sulistyowati, "Penerapan DeLone and McLean Model untuk Mengukur Kesuksesan Aplikasi Akademik Mahasiswa Berbasis Mobile," *IKRA-ITH Informatika: Jurnal Komputer dan Informatika,* vol. 5, no. 1, pp. 58-67, 2021.

[12] A. Chusen, A. Wulansari, and E. M. Safitri, "Evaluasi Kesuksesan Sistem Informasi Rumah Sakit Dengan Pendekatan Model DeLone dan

e-ISSN: 2614-8404
p-ISSN: 2776-3234

McLean," *Jurnal Ilmiah Komputasi,* vol. 23, no. 4, pp. 485-494, 2024.

[13] Y. R. Permana, M. Halid, U. Hasanah, R. P. A. Putra, and I. Ikhwan, "Faktor Kesuksesan SIM-RS Berdasarkan Teori DeLone and McLean di Rumah Sakit Umum Daerah Kota Mataram," *J-REMI: Jurnal Rekam Medik dan Informasi Kesehatan,* vol. 4, no. 2, pp. 83-88, 2023.

[14] R. Jumardi, E. Nugroho, and I. Hidayah, "Analisis Kesuksesan Implementasi Sistem Informasi Skripsi pada Program Studi Teknik Informatika Universitas Pembangunan Nasional "Veteran" Yogyakarta," in *Seminar Nasional Aplikasi Teknologi Informasi (SNATi)*, 2015.

[15] F. S. Rahayu, R. Apriliyanto, and Y. S. P. W. Putro, "Analisis Kesuksesan Sistem Informasi Kemahasiswaan (SIKMA) dengan Pendekatan Model DeLone dan McLean," *Indonesian Journal of Information Systems,* vol. 1, no. 1, pp. 34-46, 2018.

[16] I. Ghozali and H. Latan, "Partial least squares konsep, teknik dan aplikasi menggunakan program smartpls 3.0 untuk penelitian empiris," *Semarang: Badan Penerbit UNDIP,* vol. 4, no. 1, pp. 35-46, 2015.

[17] A. Wicaksono, *Metodologi Penelitian Pendidikan: Pengantar Ringkas*. Garudhawaca, 2022.

[18] R. Ramadhani and N. S. Bina, *Statistika Penelitian Pendidikan: Analisis Perhitungan Matematis dan Aplikasi SPSS*. Prenada Media, 2021.

[19] Z. S. Syafhil and L. Kartika, "Analisis Kesuksesan Karir Alumni Program Mahasiswa Berprestasi Di Perguruan Tinggi," *Perspekt. Ilmu Pendidik,* vol. 35, no. 1, pp. 9-24, 2021.

[20] M. T. Taufik and S. Hajar, "Analisis kualitas pelayanan penerbitan e-ktp melalui aplikasi lakse pada dinas kependudukan dan pencatatan sipil kota batam," *Jurnal Kolaboratif Sains,* vol. 6, no. 5, pp. 453-468, 2023.

[21] W. H. DeLone and E. R. McLean, "The DeLone and McLean model of information systems success: a ten-year update," *Journal of management information systems,* vol. 19, no. 4, pp. 9-30, 2003.

[22] I. K. Widyawati, R. R. R. Wasita, and I. G. N. M. Nugraha, "Analisis Penerapan Sistem Manajemen Rumah Sakit dengan Menggunakan Metode DeLone & McLean di Rumah Sakit Wira Bhakti Mataram," *Jurnal Informasi Kesehatan Indonesia,* vol. 10, no. 1, pp. 35-49, 2024.

[23] J. Iivari, "An empirical test of the DeLone-McLean model of information system success," *ACM SIGMIS Database: the DATABASE for Advances in Information Systems,* vol. 36, no. 2, pp. 8-27, 2005.

[24] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS quarterly,* pp. 319-340, 1989.

[25] R. P. Putra, A. Wibowo, Y. Farlina, and D. Susilawati, "Penerapan Model Delone And Mclean Website Sistem Informasi Akademik STIKES Sukabumi," *Swabumi,* vol. 10, no. 1, pp. 44-54, 2022.

[26] A. E. Johan, "Pengaruh User Experience dan Kepercayaan Terhadap Kepuasan Pengguna Mobile Application E-Wallet DANA Menggunakan Metode DeLone & McLean," Fakultas Sains dan Teknologi UIN Syarif Hidayatullah Jakarta, 2023.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Development of Smart Plant Watering System Application Based on Internet of Things

Adnan Nuur Bachtiar[1*)], Mochammad Faisal[2], Muhammad Darwis[3]
[1]Informatics Engineering Study Program, Faculty of Engineering Sciences, Paramadina University
[2] Informatics Engineering Study Program, Faculty of Engineering Sciences, Paramadina University
[3] Informatics Engineering Study Program, Faculty of Engineering Sciences, Paramadina University
Email: [1]adnan.bachtiar@students.paramadina.ac.id, [2]mochammad.faisal@students.paramadina.ac.id , [3]muhammad.darwis@paramadina.ac.id

Abstract – In 2024, air pollution levels in Jakarta were recorded as the highest in Southeast Asia, based on various air quality monitoring reports. This condition has become an increasingly alarming environmental issue, with pollution levels frequently exceeding the safe threshold set by the World Health Organization (WHO). One of the efforts by the Jakarta Provincial Government to address this problem is a free plant distribution program for the public. Plants play a crucial role in absorbing carbon dioxide, producing oxygen, and reducing airborne pollutant particles. However, plant maintenance—especially watering—poses its own challenges. Inefficient watering can cause plants to experience stress, wilt, or even die. With the advancement of technology, an automatic plant watering system based on the Internet of Things (IoT) presents a potential solution to improve the efficiency and sustainability of plant care. This study aims to develop a smart plant watering system application based on IoT that can automatically control watering based on real-time soil moisture levels. The system was applied to spider plants (Chlorophytum comosum) grown in pots with a diameter of 15 cm. By using an ESP32 microcontroller, a soil moisture sensor (Capacitive Soil Moisture Sensor v1.2), an air temperature and humidity sensor (DHT11), and a water pump, the system automatically activates watering when the soil moisture is below 55% and stops when it exceeds 65%. Sensor data is stored in a database and displayed through a web-based application for remote monitoring.

Keywords – Plant, Air Pollution, Internet of Things, Microcontroller, Soil Moisture

I. INTRODUCTION

Air pollution in Jakarta is an increasingly worrying environmental problem. Based on data from various sources, pollution levels in Jakarta often exceed the threshold set by the World Health Organization (WHO), mainly due to motor vehicle emissions and industrial activities [1], [2]. Poor air quality can have negative impacts on public health, such as increasing the risk of respiratory and cardiovascular diseases [3]. To address this problem, the DKI Jakarta Provincial Government (Pemprov) is planning a program to distribute free plants to the public to reduce air pollution in Jakarta [4].

Characteristics of plants that can reduce air pollution are green plants that can reduce CO2 in the air through photosynthesis. And to anticipate or adapt to global warming, among other things, it can be minimized through planting new plants [5]. Planting plants has many benefits, both for the environment and for humans themselves. Plants produce oxygen, absorb carbon dioxide, and help regulate air temperature. In addition, plants are also a source of food, medicine, and fuel. Historically, humans have depended on plants for their survival [6].

Some plants that can reduce air pollution such as Mother-in-law's Tongue (Sansevieria) which has a unique shape and can absorb carbon monoxide and carbon dioxide [7]. The Mother-in-law's Tongue (Sansevieria) plant can reduce carbon monoxide gas levels by 22.21 ppm [8], then there are the spider plant and the golden pothos (Scindapsus Aureus) which have been proven to have leaf surface characteristics that can collect PM2.5 indoors, microorganisms in the phyllosphere can detoxify PM2.5 [9].

Regular watering of plants is essential to ensure optimal plant growth. Water plays a role in the process of photosynthesis, helps transport nutrients, and maintains soil moisture so that plant roots remain healthy [10]. Plants that lack water can experience stress, wilt, and even die if left for a long period of time [11]. In addition, irregular or excessive watering can also cause other problems, such as plants being susceptible to disease due to being given too much water [12]. Therefore, an efficient watering method is needed that is in accordance with the needs of each type of plant to maintain ecosystem balance and environmental sustainability.

To ensure optimal plant watering, we can utilize technology to support the desired plant growth. One of them is by implementing an automatic plant watering system based on the Internet of Things (IoT) [13]. The Internet of Things (IoT) is one technology that can help to water plants intelligently. The Internet of Things (IoT) itself is a technology that connects many devices that are connected to each other using the internet to be able to communicate, connect, control, and exchange information with other devices [14].

Previous research has been conducted to build a smart farming system using the Internet of Things in the form of automatic plant watering, especially for chili plants (Capsicum annum L)[15] . Researchers use NodeMCU as the main processing unit, Driver Relay to control the water pump, and LCD (Liquid Crystal Display) to display soil conditions and pump status. Researchers get test results that the system works well. This study uses NodeMCU as the

e-ISSN: 2614-8404
p-ISSN: 2776-3234

main unit for the main processing to read sensors, display data to the LCD screen, and drive the water pump.

The next research is an automatic watering system based on the Internet of Things (IoT) which aims to facilitate the care of ornamental plants, especially the golden pothos plant [16]. This study also uses NodeMCU as a link between hardware and systems. The sensors used are soil moisture sensors and air temperature sensors (DHT11), then integrating the system with Telegram to provide notifications to users regarding plant conditions and watering status. Furthermore, research conducted by Amsar Yunan (2022) entitled "Plant Watering Techniques Using Microcontrollers Based on the Internet of Things" also integrates the system with Telegram to inform users about the results of soil moisture sensor readings regarding dry or wet soil moisture conditions. Users set the soil moisture reading if the soil moisture is <65% then the soil will be declared dry, and the pump will turn on to water the plants. Then the pump will turn off when the soil moisture sensor reading gets a humidity result of >66% [17].

Previous research entitled "Implementation of Smart Monitoring and Control System for Eggplant Plants Based on Internet of Things with Drip Irrigation Method", the author used NodeMCU V3 microcontroller as an actuator and water pump controller, then used FC-28 Soil Moisture sensor to measure soil moisture, and DHT11 sensor to measure temperature and air humidity [18]. The author set the water pump on and off with reference if the soil moisture is below 50% then the pump will turn on, then if the soil moisture is at 60% then the pump will turn off. The system is integrated with an android-based application called Blynk then the data will be stored in the Thingspeak database. Similar research was also conducted by M. Iqbal Hasani (2023) where the author carried out automatic watering using a microcontroller and water level sensor to measure soil moisture [19]. then the system is integrated into an android-based application called Blynk so that users can monitor from anywhere. In addition, the author applies the Naive Bayes method for data analysis and decision making in plant watering where the accuracy level of the data analysis is 94.3%. "Implementation of the Internet of Things (IoT) in a Mobile-Based Plant Watering Automation System"

Based on the explanations above, a study entitled "Development of Smart Plant Watering System Application Based on Internet of Things" was conducted. This study aims to apply Internet of Things (IoT) technology to improve the efficiency of plant watering. IoT enables automation of plant watering by considering soil moisture levels in real-time, thus optimizing water usage.

This study also has advantages over previous studies, especially in terms of data presentation and system flexibility. The application developed uses a PHP-based web platform, so the interface can be adjusted to user needs without relying on third-party platforms such as Blynk or Telegram. In addition, this system records sensor data in real-time into a database, allowing users to review the complete history of sensor readings. This approach provides added value in terms of data control and a more flexible user experience.

II. RESEARCH METHODOLOGY

The development of the smart plant watering system application was developed based on the IoT Design Methodology proposed by Arshdeep Bahga and Vijay Madisetti in their book entitled "Internet of Things A Hands-On Approach" [20], [21], the stages in the Methodology are as in Figure 1.

Fig 1. IoT Design Methodology

A. Purpose and Requirement

The purpose of this system is to automatically water plants using soil moisture reading data, as well as provide monitoring of temperature and humidity around the plants.

B. Process Model Specification

The interaction between the system and the user is modeled and described using Use Cases.

C. Domain Model Specification

In this stage, identify the entities and actors used in system development.

D. Information model Specification

In this stage, the data structure used by the system is explained. This structure includes attributes of data such as temperature, soil moisture, air humidity, pump status, and recording time. All are stored in the database and processed to be displayed in visual form.

E. Service Specification

System services are described based on Input and output. Services in this system are sensor data reading, automatic decision making in watering, sending data to the server, and automatic pump control.

F. IoT Level Specification

This system adopts a Hybrid/IoT Level 3 approach, where decision making and sensor reading are done locally on the ESP32, but data is sent to the Cloud Server.

G. Function View Specification

Grouping/organizing system functions into several modules, starting from the sensor module which contains soil moisture sensors and temperature and air humidity sensors, the control module which contains rules for controlling the pump on and off, the communication module, and the display module.

H. Operational View Specification

This stage explains the implementation of services and

e-ISSN: 2614-8404
p-ISSN: 2776-3234

system management, where the system is set to read sensors in real-time and activate the pump when the activation requirements are met.

I. Device and Component Integration

Fig 2. Schema Component

This stage combines hardware components, including sensors, microcontrollers, and actuators into an IoT system that is interconnected and runs automatically and in real-time.

J. Application Development

In this stage, application development and coding are carried out. In this stage, there are 2 codings, namely coding for the microcontroller and coding for the interface. Microcontroller coding is done using the C++ programming language on the Arduino IDE platform, where the ESP32 is programmed to be able to read the results of soil moisture sensors and DHT11 sensors, and make decisions in watering plants and send sensor readings and decisions to the server using the HTTP protocol. Then the interface coding uses the PHP programming language to display data on the server in real time to the user.

III. RESULTS AND DISCUSSION

A. Purpose and Requirement

The purpose of this research is to develop a smart plant watering system. Here are some things that underlie the research "Development of a Smart Plant Watering System Based on the Internet of Things"

a. Purpose
   To develop an IoT-based watering automation system that uses soil moisture and temperature sensors to automatically control plant watering to ensure efficient water usage.
b. Behavior
   This system measures soil moisture and temperature to determine irrigation needs, so water is only delivered when needed.
c. System Management Requirement
   The system must be able to provide remote monitoring and control of irrigation through an easily accessible management interface. In addition, the system must be able to read the air temperature and humidity around the plants to provide additional information to the user.
d. Data Analysis Requirement
   The system must be able to analyze soil moisture data to provide efficient irrigation recommendations. All are set in such a way as to provide minimum and maximum soil moisture thresholds.
e. Application Deployment Requirement
   This application is implemented with a cloud server and can be accessed from any device connected to the internet where it can be accessed at any time. Then the system sends sensor data in real time.
f. Security
   The application must have a user login feature to perform authentication and data protection to maintain data privacy and security.

B. Process Model Specification

Fig3. Flowchart

In Figure 3. The system uses an automatic processing flow that utilizes a soil moisture sensor to automatically activate the water pump when soil moisture is below a certain threshold, then utilizes the DHT11 sensor to help monitor the air temperature and humidity around the plants.

C. Domain Model Specification

Fig 4. Domain Model Specification

e-ISSN: 2614-8404
p-ISSN: 2776-3234

In Figure 4. It is a Domain Model to describe the relationship between entities. In this stage, the important components of the system are determined and classified based on the five elements of the IoT domain model: Physical entities, virtual entities, devices, resources, and services.

a. Physical Entity
   - Land (Dependent variable)
     The main entity whose humidity is monitored and controlled by the system is using a soil moisture sensor.
   - Water
     The main entity used to water the soil if the sensor detects that the soil moisture is below the required safe threshold.
   - Air
     The entity used to find out the temperature and humidity of the air around the plant. This entity will be monitored by DHT11.

b. Virtual Entity
   - Monitoring
     Refers to the process of monitoring soil moisture levels and temperature through sensors.
   - Controlling
     Refers to the system's ability to turn the water pump on and off as needed based on soil moisture sensor data.
   - Alerting
     Refers to the system's ability to notify the user about the soil moisture level.

c. Device
   - Soil Moisture Sensor
     Sensors used to detect soil moisture levels in real-time.
   - DHT11 Sensor
     Sensors that measure air temperature and measure air humidity around the land to provide additional data in system needs analysis.
   - ESP32 Microcontroller
     The control unit that receives data from sensors, performs initial processing, and sends the data to the database.
   - Water pump
     A unit for pumping water so that it can be sprinkled onto areas of land that require watering.

d. Resource
   - ESP32
     Running Firmware that manages sensor readings and decision making locally.
   - Network
     The system uses a cloud database to store sensor data periodically and provides access to monitoring and visualization services, these services are supported by a PHP-based website interface hosted on a server that allows user interaction with the system.

e. Service
   - Controlling Service
     Monitor sensor data and regulate irrigation system conditions according to specified rules. A service that manages water pump activity based on data received from sensors.
   - Sensor Service
     Read humidity and temperature values, send data to cloud database, and perform real-time data analysis for monitoring via web.

D. Information Model Specification

Fig 5. Information Model Specification

In Figure 5. there are 3 main virtual entities that represent the physical entities involved, namely Land, Air, and Water. The Land entity has a level-humidity attribute of type Level. Which level is obtained from the results of the Moisture Sensor reading then the reading results are sent to device 1. Then the Air Entity has a value-air attribute that contains information on temperature and humidity. Data is obtained from the DHT11 sensor which is sent to device 1. Finally, there is a Water entity of type state-air. This entity represents the status of the water pump controlled by device 2 with a value of ON or OFF. Where device 2 gets commands from device 1 from the results of reading the soil moisture sensor.

E. Service Specification

Fig 6. Service Specification

In Figure 6 is the Service Specification of the system, this system uses the HTTP protocol to send data from the device to the server. Where sensor reading data and pump status are sent via URL with parameters such as in the endpoint with the service name save_data.php. This allows data to be sent in real-time to the server automatically.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

F. IoT Level Specification

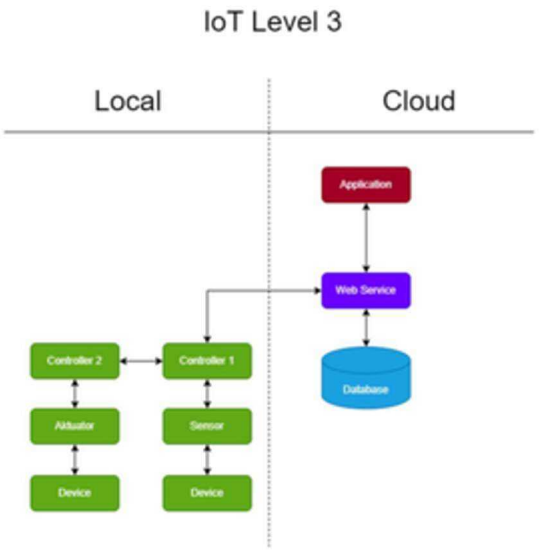


Fig 7. IoT Level Specification

In Figure 7, the author uses 2 controllers with the same tasks. Controller 1 reads the soil moisture sensor and DHT11 sensor, sends a command to controller 2 to turn on/off the pump depending on the soil moisture reading, then sends the data into the database. Controller 2 is tasked with receiving commands from controller 1 to turn on the Actuator and then sending a response back to controller 1. And the data is displayed in the web-based application that has been created.

G. Functional View Specification

Fig 8. Function View Specification

In Figure 8, the division of roles and functions of each component. Where the device layer is a physical device such as sensors, actuators, and ESP32 with communication using REST/HTTP allows communication between the controller and the web service. Using a web-based application with the PHP programming language and MySQL database.

H. Operational View Specification

Table 1. Operational View Specification

Application	Database Service : MySQL Application Server : Website, PHP
Management	MySQL, Website, PHP
Security	Authentication : Databases Authorization : Database
Service	Web Service
Communication	REST, HTTP
Devices	Controller : ESP32 Sensor : Soil Moisture Sensor, DHT11 Aktuator : Water Pump

The following table 1 shows various operational options related to the deployment and operation of the IoT system. This stage is important to ensure that all system components can work in an integrated manner. MySQL is chosen as the database server because it is the most famous database service. The application runs on a web base with the PHP programming language.

I. Device and Component Integration

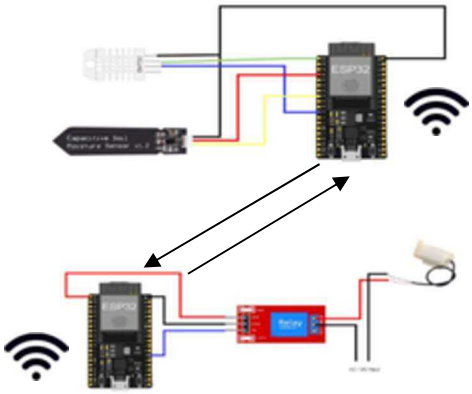


Fig 9. Device & Component Integration

Figure 9 shows a series of images in the development of this system. The author uses 2 controllers that communicate with each other. The first controller is tasked with reading the results of the soil moisture sensor and the temperature and air humidity sensor, where the safe soil humidity for the spider plant is between 30 - 50%. In the first controller determines whether the soil humidity is at a safe threshold or not, then the controller sends a command to the second controller to turn the water pump on or off. In sending the results of the sensor reading and pump execution, the first controller performs the task. The first controller sends data using REST HTTP into the cloud database that has been provided.

J. Application Development

At the application implementation stage, the author took several steps to implement the application starting from creating a web-based application using PHP and a database using MySQL, installing and configuring controllers and sensors, installing sensors and devices, and visualizing and analyzing data.

1. Application Development

In developing the application, the author developed a web-based application using the PHP programming language and Bootstrap 5 as the UI.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig 10. website appearance

Figure 10 shows the display results of the application, where users can control the reading results from the installed sensors, then can find out the statistics of plant soil moisture in real time.

2. Hardware assembly and integration

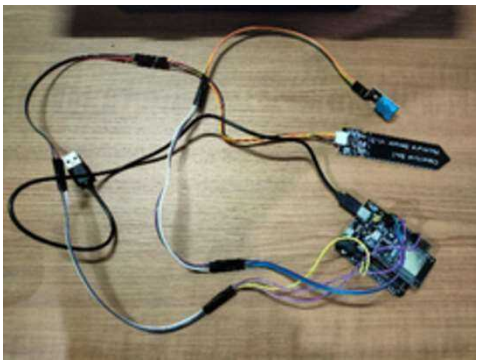


Fig 11. controller assembly 1

In figure 11 the hardware is assembled, controller 1 is connected to the soil moisture sensor and the DHT11 sensor.

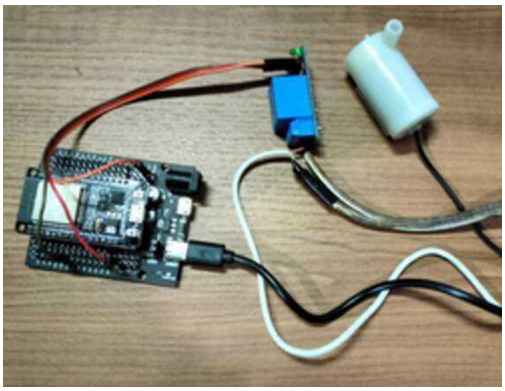


Fig 12. controller assembly 2

Then in Figure 12, controller 2 is connected to a relay, which will conduct electricity to turn on the water pump.

3. ESP32 Programming

ESP32 is programmed using the C++ programming language on the Arduino IDE platform, where Controller 1 is programmed to read the soil moisture sensor and DHT11 sensor then sends a command to controller 2 to turn the water pump on or off and after that controller 1 sends data to the database using HTTP. Controller 2 is programmed to receive commands from controller 1 to turn on the pump. Figure 13 is a script to send commands to turn the pump on and off by controller 1.

```
// Rute untuk menerima perintah dari ESP-A
server.on("/pump", HTTP_GET, [](){
    if (server.hasArg("status")) {
        String pumpStatus = server.arg("status");

        if (pumpStatus == "ON") {
            digitalWrite(RELAYPIN, HIGH);
            Serial.println("Pompa HIDUP!");
            delay(5000);  // Pompa hidup 5 detik
            digitalWrite(RELAYPIN, LOW);
            Serial.println("Pompa MATI!");
            server.send(200, "text/plain", "Pompa ON (5 detik)");
        } else if (pumpStatus == "OFF") {
            digitalWrite(RELAYPIN, LOW);
            Serial.println("Pompa MATI!");
            server.send(200, "text/plain", "Pompa OFF");
        } else {
            server.send(400, "text/plain", "Perintah tidak valid");
        }
    } else {
        server.send(400, "text/plain", "Parameter status tidak ditemukan");
    }
});

server.begin();
```

Fig 13. Script ESP32

K. Application Testing

This stage is carried out after the application has been successfully developed, system testing using blackbox testing to determine the success of the application function as desired. Some of the tests carried out are explained in table 2.

Table 2. Blackbox Testing

No	Description	Expected results	Results
1	Controller 1 sends sensor and pump reading data into the database.	Controller 1 can send data into the database, and the database can receive reading results from the controller.	Succeed
2	Controller 2 turns on the water pump	Controller 2 receives a command from controller 1 to turn on the water, and the controller turns on the water pump.	Succeed
3	Pump runs for 5 seconds	When controller 2 gets the on command, the pump will turn on for 5 seconds, then turn off again automatically.	Succeed
4	Data is displayed on the website	The website can display data that has been received by the database.	Succeed

e-ISSN: 2614-8404
p-ISSN: 2776-3234

IV. CONCLUSION

The use of the Internet of Things (IoT) system in automatic plant watering can be used by users to control the irrigation of their plants so that plants get water on time and according to plant needs by utilizing a microcontroller to read sensors and turn on and off the water pump in real-time then send data into a MySQL database to be displayed via a PHP-based website application. This system can be further developed by adding notification features, and adding sensors for plant maintenance..

REFERENCES

[1] "NAFAS Indonesia." Accessed: Mar. 08, 2025. [Online]. Available: https://nafas.co.id/article/Bagaimana-dengan-kualitas-udara-Jakarta

[2] "Kualitas Udara Jakarta Terburuk Nomor 2 Dunia, Warga Disarankan Pakai Masker - Nasional Katadata.co.id." Accessed: Mar. 08, 2025. [Online]. Available: https://katadata.co.id/berita/nasional/66e795e7b56ff/kualitas-udara-jakarta-terburuk-nomor-2-dunia-warga-disarankan-pakai-masker

[3] R. Umah and E. Gusmira, "Dampak Pencemaran Udara Terhadap Kesehatan Masyarakat di Perkotaan," *Profit: Jurnal Manajemen, Bisnis dan Akuntansi*, vol. 3, no. 3, pp. 103–112, 2024.

[4] "Di Balik Keputusan Pemprov DKI Pakai Lidah Mertua sebagai Solusi Polusi – Jakarta Berketahanan." Accessed: Mar. 10, 2025. [Online]. Available: https://lingkunganhidup.jakarta.go.id/jakartaberketahanan/?p=16225

[5] M. D. Udin, I. Istiadi, and F. Rofii, "Aquascape Dengan Kontrol Fotosintesis Buatan Pada Tanaman Air Menggunakan Metode Kendali Logika Fuzzy," *Transmisi: Jurnal Ilmiah Teknik Elektro*, vol. 23, no. 3, pp. 103–111, 2021.

[6] G. Viroli, A. Kalmpourtzidou, and H. Cena, "Exploring benefits and barriers of plant-based diets: Health, environmental impact, food accessibility and acceptability," *Nutrients*, vol. 15, no. 22, p. 4723, 2023.

[7] B. Putra, K. Exaudi, R. Passarella, and P. Sari, "Pemantauan Penyerapan Gas Beracun Menggunakan Tanaman Sansevieria Pada Ruangan Tertutup," *Komputika : Jurnal Sistem Komputer*, vol. 11, pp. 95–102, Feb. 2022, doi: 10.34010/komputika.v11i1.4751.

[8] K. P. Cahyanti and D. A. A. Posmaningsih, "Tingkat kemampuan penyerapan tanaman sansevieria dalam menurunkan polutan karbon monoksida," *Jurnal Kesehatan Lingkungan (JKL)*, vol. 10, no. 1, 2020.

[9] A. D. Haq, A. R. Rahim, and L. A. D. Rahayu, "Potensi sirih gading (Epipremnum aureum) dan lili paris (Chlorophytum comosum) sebagai sarana fitoremediasi PM2. 5 di dalam ruangan," *Jurnal Kedokteran*, vol. 10, no. 1, pp. 347–354, 2021.

[10] A. Sumarianti, K. D. Jayanti, and Y. Tanari, "Pengaruh frekuensi penyiraman terhadap pertumbuhan dan hasil bawang merah (Allium cepa L.)," *Agrovigor: Jurnal Agroekoteknologi*, vol. 15, no. 1, pp. 39–43, 2022.

[11] C. A. Nugroho and A. W. Setiawan, "Pengaruh frekuensi penyiraman dan volume air terhadap pertumbuhan tanaman sawi pakcoy pada media tanam campuran arang sekam dan pupuk kandang," *AGRIUM: Jurnal Ilmu Pertanian*, vol. 25, no. 1, pp. 12–23, 2022.

[12] D. E. Nadindra and J. C. Chandra, "Sistem IoT penyiram tanaman otomatis berbasis Arduino dengan kontrol Telegram," *SKANIKA: Sistem Komputer dan Teknik Informatika*, vol. 5, no. 1, pp. 104–114, 2022.

[13] R. Alamsyah, E. Ryansyah, A. Y. Permana, and R. Mufidah, "Sistem Penyiraman Tanaman Otomatis Menggunakan Logika Fuzzy dengan Teknologi Internet of Things Berbasis ESP8266 dan Aplikasi Blynk," *Jurnal Informatika dan Teknik Elektro Terapan*, vol. 12, no. 2, 2024.

[14] A. Selay *et al.*, "Internet Of Things," *Karimah Tauhid*, vol. 1, no. 6, pp. 860–868, 2022.

[15] I. W. B. Darmawan, I. N. S. Kumara, and D. C. Khrisne, "Smart garden sebagai implementasi sistem kontrol dan monitoring tanaman berbasis teknologi cerdas," *Jurnal SPEKTRUM Vol*, vol. 8, no. 4, pp. 161–170, 2021.

[16] P. A. Wulandari, P. Rahima, and S. Hadi, "Rancang Bangun Sistem Penyiraman Otomatis Berbasis Internet of Things Pada Tanaman Hias Sirih Gading," *Jurnal Bumigora Information Technology (BITe)*, vol. 2, no. 2, pp. 77–85, 2020.

[17] A. Yunan, S. Safriati, and H. Hermalinda, "Teknik Penyiraman Tanaman Menggunakan Mikrokontroler Berbasis Internet of Things," *Journal of Information System Research (JOSH)*, vol. 3, no. 3, pp. 331–337, 2022.

[18] E. Anugrah, M. Hasbi, and M. P. Lukman, "Penerapan Sistem Monitoring Dan Kendali Pintar Untuk Tanaman Terung Berbasis Internet of Things Dengan Metode Penyiraman Irigasi Tetes," *Jurnal RESISTOR (Rekayasa Sistem Komputer)*, vol. 4, no. 2, pp. 204–212, 2021.

[19] M. I. Hasani and S. Wulandari, "Implementasi Internet of Things (IoT) Pada Sistem Otomatisasi Penyiraman Tanaman Berbasis Mobile," *ILKOMNIKA*, vol. 5, no. 3, pp. 149–161, 2023.

[20] M. Darwis, H. A. Al Banna, S. R. Aji, D. Khoirunnisa, and N. Natassa, "IoT Based Early Flood Detection System with Arduino and Ultrasonic Sensors in Flood-Prone Areas," *JURNAL TEKNIK INFORMATIKA*, vol. 16, no. 2, pp. 133–140, 2023.

[21] "Metodologi Desain IoT - Tutorial IoT untuk Pemula - Startertutorials." Accessed: May 07, 2025. [Online]. Available: https://www.startertutorials.com/blog/iot-design-methodology.html

e-ISSN: 2614-8404
p-ISSN: 2776-3234

IoT Implementation for Hydroponic Water Monitoring Using Web-Based *pH* and *TDS* Sensors with Node-Red

Mochammad Faisal[1*)], Adnan Nuur Bachtiar[2], Muhammad Darwis[3]
[1] Informatics Engineering Study Program, Faculty of Engineering Sciences, Paramadina University
[2] Informatics Engineering Study Program, Faculty of Engineering Sciences, Paramadina University
[3] Informatics Engineering Study Program, Faculty of Engineering Sciences, Paramadina University
Email: [1]mochammad.faisal@students.paramadina.ac.id, [2] adnan.bachtiar@students.paramadina.ac.id, [3]muhammad.darwis@paramadina.ac.id

Abstract – Due to land scarcity, rapid urbanization, and shrinking agricultural space, urban environments such as Jakarta face increasing agricultural challenges. By enabling efficient, soil-free cultivation in limited areas, hydroponics has emerged as a promising solution to address these issues. However, ensuring the consistency of the quality of hydroponic water systems, especially in terms of *pH* and total dissolved solids (*TDS*), is often done manually, which is ineffective and prone to human error. Several *IoT*-based solutions have been proposed; however, many rely on cloud services or mobile platforms, which limit accessibility in offline environments. This study introduces a scalable, internet-independent hydroponic water quality monitoring system that uses *pH* and *TDS* sensors connected to an *ESP32* microcontroller. A *Node-RED* dashboard, accessible by a browser on a local network, is used by the system to display data in real time, using the *MQTT* protocol. The system, developed using the *IoT* Platform Design Methodology, underwent *black-box testing* to ensure that its data acquisition, transmission, and visualization were accurate. The results showed reliable performance without any functional errors. Classified as a Level 2 *IoT* system, it allows real-time monitoring without automation and the possibility of future expansion such as data storage and actuator control. The proposed system provides a practical and scalable solution for urban hydroponic farmers working in areas with limited internet connectivity.

Keywords – IoT, Sensor, TDS, pH, Node-RED, IoT Platform Design Methodology, ESP32

I. INTRODUCTION

Natural population growth in recent decades has led to an increase in food demand in many places, including big cities like Jakarta. Jakarta faces major problems in terms of food distribution and availability because it is a capital city with a high level of urbanization. The city is vulnerable to food crises due to dependence on supplies from outside the region, limited agricultural land due to land conversion into organizational and commercial areas, and rapid population growth [1]. To overcome these problems, one alternative solution that is starting to be developed is hydroponic farming, a plant cultivation technique that uses nutrient-enriched air media without soil. Because it can be used in narrow areas, hydroponics supports the concept of urban farming and is efficient and environmentally friendly, making it very suitable for application in urban environments. In addition, it has been proven that this technique can increase plant productivity while reducing our dependence on excessive pesticides and chemical fertilizers [2][3].

Hydroponics is an alternative for people to grow plants that use little land. Hydroponics uses water as a substitute for soil [4]. This is one of the efforts to implement an urban farming system [2]. Hydroponic farming requires more care compared to conventional farming methods that use soil as a medium. As a result, more attention is needed to the plants [5]. Currently, the parameters of the widely used hydroponic system are still manually regulated by humans, with parameters such as nutrient concentration, *pH*, and water level being monitored [6]. The process of water evaporation is a separate problem in hydroponics, because low water levels in the nutrient solution can affect plant growth. Therefore, the control system must provide water automatically when the amount of water in the nutrient solution tank increases [7].

In recent years, research has shown that Internet of Things (*IoT*) technology is very useful for agricultural environmental monitoring systems, such as air quality measurement. *IoT*-based systems enable real-time monitoring of environmental parameters for the needs of conventional and hydroponic farming systems. Collaborating with microcontrollers such as *ESP32*, ESP8266 and ATmega328 can improve the accuracy and efficiency of air quality monitoring [8][9][10]. Such systems can read sensor values periodically and send them to a data processing platform via lightweight communication protocols such as *MQTT* [11][12].

Monitoring water parameters is very important in hydroponic farming. According to many studies, manually operated hydroponic systems face a number of problems, including inaccuracy in maintaining *pH* and *TDS* levels, which can inhibit plant growth. As a result, to improve the efficiency and stability of nutrients in hydroponic solutions, sensor-based and Internet of Things-based automated systems have been widely used [9][13]. Some studies even combine simple regression models and fuzzy logic-based control techniques to control nutrient pumps and stabilize *TDS* levels [14][15].

For data visualization and management, platforms such as *Node-RED* are widely used as monitoring dashboards because they are flexible and open-source, supporting various protocols such as *MQTT* and HTTP. *Node-RED* has been proven to have the ability to display sensor data in real-time in the form of labels, system indicators, or graphs that can be accessed via a local network [12][16][17]. With this implementation, users, especially farmers or managers of home-scale hydroponic systems, can monitor and

e-ISSN: 2614-8404
p-ISSN: 2776-3234

understand the condition of the solution easily without having to do manual measurements every time.

Overall, the systems developed in various studies show a tendency to combine *pH* and *TDS* sensors with lightweight data processing systems and wireless microcontrollers. Real-time water quality monitoring, data-driven parameter control, and easily accessible information dissemination for users are the main focuses of these studies. However, only a few systems can optimize web-based visualization without cloud, and most current systems still use monitoring without sophisticated automatic control. Considering these differences, this study develops a web-based hydroponic water quality monitoring system that uses *pH* and *TDS* sensors with *Node-RED*. It is expected that this system will provide an effective and efficient solution that can be accessed locally by hydroponic users.

In this study, an Internet of Things-based hydroponic water quality monitoring system using *pH* and *TDS* sensors was built and integrated into a web-based platform called *Node-RED*. *Node-RED* is a web-based tool that allows real-time data processing and displays data from Internet of Things devices in a format that is easier for users to understand [18]. Users can monitor water quality remotely and get information about plant conditions instantly with this system [19].

This study uses the *IoT Platform Design Methodology* approach. To design and ensure that the hydroponic water quality monitoring system works well. A literature study was conducted to learn how the Internet of Things, *pH* and *TDS* sensors work, and how to build a web-based monitoring system using *Node-RED*. Meanwhile, the experiment was designed to test the accuracy of the sensor in reading water parameters and evaluate the system's ability to display data in real-time. This method is expected to enable the system to provide more accurate results and be more accessible to users.

The purpose of implementing the Internet of Things (*IoT*) is to ensure that water quality can be monitored in real-time and improve the quality of the harvest. The use of the Internet of Things (*IoT*) as a solution to overcome this challenge, which allows monitoring of water quality using *pH* sensors and *TDS* sensors in real-time, can be monitored through a web-based application using *Node-RED*.

II. RESEARCH METHODOLOGY

This study uses the *IoT Platform Design Methodology* approach, a method designed to build an Internet of Things (*IoT*) system systematically, from the needs stage to implementation and evaluation [20]. This methodology was chosen because it is in accordance with the research objectives, namely to develop an *IoT*-based hydroponic water quality monitoring system using *pH* and *TDS* sensors that can be accessed via the web via *Node-RED*. This study was conducted by following the *IoT Platform Design Methodology* which consists of ten stages, which can be seen in *Figure 1*.

Fig 1 IoT Platform Design Methodology

A. *Purpose & Requirements Specification*

The purpose of this stage is to identify the main objectives of the system and the specifications of the needs that must be met. This system is intended to integrate air quality in hydroponic cultivation based on two main parameters: *pH* and *TDS*. This system needs to collect data from sensors in real-time, transmit data via wireless communication, and present data in graphical form via a web platform. In addition, the system also requires scalability, local network security, and simple data processing capabilities.

B. *Process* Model Specification

At this stage, the system process flow is designed to show the relationship between components. The system starts with an *ESP32* microcontroller that tracks the *pH* and *TDS* sensors. The *MQTT* protocol is used to send the collected information to the local broker. Next, the data is processed and displayed by *Node-RED* on the web dashboard. This process takes place cyclically and in real-time.

C. *Domain* Model Specification

In this stage, the main system components are explained. The physical entity consists of a hydroponic nutrient solution measured by *pH* and *TDS* sensors, while the virtual entity sends *pH* and *TDS* data to the *Node-RED* platform. Devices in this system include *ESP32 pH* and *TDS* sensors, and other resources

e-ISSN: 2614-8404
p-ISSN: 2776-3234

include Wi-Fi connectivity, *MQTT* protocol, and firmware. Using the dashboard, the monitoring service sends and displays data in real-time to the user.

D. *Information* Model Specification

At this stage, defining the data structure, such as *pH* value and *TDS* value are two type of numeric data. Information is structured based on sensor attributes and displayed in dynamic visualizations on the web dashboard. This model helps map the relationship between sensors, devices, and data delivery to users.

E. Service Specifications

Real-time water quality monitoring is the system's core service. The *MQTT* protocol is used to send sensor data to a specific subject on a local broker. The program works with *Node-RED*, which processes and displays the data in the form of graphs and status indicators. Since it does not use public or cloud access, the service endpoint is secure and located locally.

F. *IoT* Level Specification

At this stage, determine the *IoT* level category. This system falls into the Internet of Things Level 2 category according to the Internet of Things taxonomy, which means that they have the ability to monitor in real-time conditions without using automatic control. Although data is sent and displayed directly, it does not perform automatic actions or decisions about the environment (such as turning on a pump). By adding control components, the system can still be developed to a higher level.

G. *Functional* View Specification

At this stage, the main functions of the system are explained, including reading *pH* and *TDS* sensor data; sending data via *MQTT*; receiving data in *Node-RED*; and viewing data on the dashboard. Each function is performed with a specific software and software role: *ESP32* to process data, Mosquitto *MQTT* broker to send data, and *Node-RED* as a visualization manager.

H. *Operational* View Specification

At this stage, it explains the preparation of the operational model of the system used, such as the device used by the user can use their browser to view *pH* and *TDS* data directly on the web dashboard during operation. The system runs locally on a single Wi-Fi network. *ESP32* needs to be connected to the *MQTT* broker consistently, and *Node-RED* must run on a local computer or server connected to the same network. The system does not consume much power and can operate 24 hours a day.

I. Device & Component Integration

At this stage, hardware assembly such as *ESP32*, *pH* sensor, and *TDS* sensor and component connectivity settings using breadboard and jumper cables are carried out followed by microcontroller programming using Arduino IDE, Wi-Fi connection testing, and communication with *MQTT* brokers. Integration is carried out to ensure that all components function properly and can communicate synchronously.

J. *Application* Development

At this stage, application development is carried out using *Node-RED*, and has a dashboard element that displays graphs of *pH* and *TDS* values and water status indicators. *Node-RED* logic flow includes processing JSON payloads, subscribing to *MQTT* topics, and presenting values in UI elements. The application can be accessed via a browser without the need to connect to the internet.

III. RESULTS AND DISCUSSION

A. Purpose & Requirements Specification

a. Purpose

This system aims to monitor water quality in a hydroponic system using *pH* and *TDS* sensors. With this monitoring, the system can ensure that water parameters are always in optimal conditions for plant growth, helping to increase the efficiency of hydroponic farming and minimizing potential plant damage due to changes in water quality.

b. Behavior

The system operates automatically and continuously in real-time. The *pH* and *TDS* sensors will read data at certain intervals. Then, the data is sent to the *IoT* platform via the *MQTT* protocol and displayed in graphical form on the *Node-RED* dashboard and stored for historical analysis. Although the system does not require manual intervention during the data collection process, users can track and monitor the condition of the sensors.

c. Requirements

a. System Management Requirements

The system must provide a management interface to monitor the sensor status and perform calibration and maintenance if necessary. The presence of this feature is essential to ensure the reliability of measurements in the long term. In addition, the system must provide a regular data backup function. This function is intended to protect important data from loss in the event of technical disruptions or device failures.

b. Data Analysis Requirements

The system must have the ability to perform basic analysis on the data collected from the sensors. Calculation of daily average values of *pH* and *TDS* and finding patterns or trends in the changes in these values are part of this analysis. This analysis will greatly help users understand water quality fluctuations

e-ISSN: 2614-8404
p-ISSN: 2776-3234

and make decisions about improvements or adjustments more proactively.

c. Application Deployment Requirement

The system should be able to run locally on a device such as a Raspberry Pi or other minicomputer. This is done to prevent users from having to rely entirely on their internet connection. However, the system should also be designed in a way that allows for further development to support integration to cloud platforms if needed. At this stage, the main focus is on ease of installation, maintenance, and scalability of the system.

d. Security

The system must have authorization and authentication mechanisms to ensure that only authorized users can change configurations or view sensitive data. In addition, encrypting communications between devices (such as *ESP32* and *MQTT* brokers) ensures data security. This is done to prevent unauthorized persons from viewing or changing data.

e. Scalability Requirements

The system must be designed to be modular and flexible so that it can accommodate the addition of new sensors or devices without significantly changing the architecture. In addition, the system must be able to handle increasing numbers of devices and data volumes while maintaining stable and responsive performance. Thus, the system must allow for future development and expansion without compromising the quality of monitoring services.

f. Real-Time Data Processing

To ensure that the information provided is always up-to-date and allows users to make quick decisions, the system must be able to manage continuous streaming data with low latency. Data received from sensors must be processed immediately and displayed on the user dashboard without significant delay.

g. Maintenance and Calibration Requirements

To keep the system operating properly, the system must also provide routine maintenance procedures such as checking the status of the device and notification of failure or performance degradation warnings. In addition, the system must provide a mechanism that makes it easy for users to perform sensor calibration periodically, including guidance or calibration automation features if possible.

B. Process Model Specification

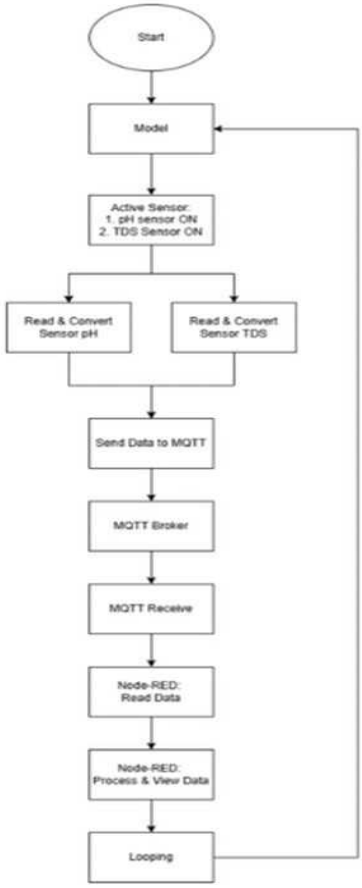


Fig 2 Process Model Specification

In Figure 2. The process starts from reading data by *pH* and *TDS* sensors, processed by *ESP32*, sent to the broker via the *MQTT protocol* (*Mosquitto*), and then sent to *Node-RED* to be displayed on the web dashboard. This process is cyclic and occurs periodically at set intervals.

C. Domain Model Specification

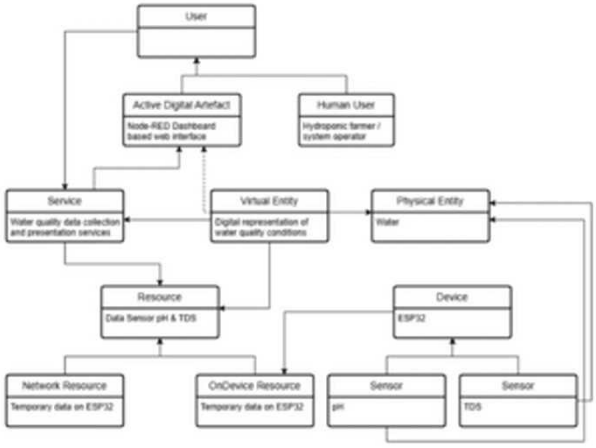


Fig 3 Domain Model Specification

In figure 3 shows the Domain Model, which shows the relationships between system entities. At this point,

e-ISSN: 2614-8404
p-ISSN: 2776-3234

the important elements of the system are identified and classified based on the five main components of the Internet of Things (*IoT*) domain model: physical entities, virtual entities, devices, resources, and services. In the *Node-RED* dashboard, *pH* and *TDS* values are displayed as virtual entities. In contrast, *pH* and *TDS* sensors are depicted as input devices that measure water conditions (physical entities). *ESP32* processes the sensor data resources and sends them via the *MQTT* communication service. Furthermore, the data is visualized via *Node-RED* for end users to access. The structured flow of information from the physical environment to the digital display that can be monitored in real-time by the user is connected by the relationships between these entities.

1 Physical Entity
- Water

In hydroponic systems, water quality is the main physical entity monitored. To determine the acidity level and the amount of dissolved substances in the Water, *pH* and *TDS* sensors detect water conditions. An important factor for hydroponic plant growth is water quality.

2 Virtual Entity
- Digital Representation of Water Quality Conditions

The *pH* and *TDS* values of the sensors are processed by the *ESP32* and sent as digital representations. To make it easier for users to monitor water conditions in real-time, the data is visualized in the *Node-RED* dashboard. It is possible to monitor or analyze the actual water conditions through the digital representation of these virtual entities.

3 Device
- *ESP32*

Acting as a data processing and sending center, *ESP32* manages input from *pH* and *TDS* sensors and sends data to the *MQTT* broker to be forwarded to *Node-RED*. In addition, *ESP32* stores temporary data that can be accessed by the system.
- *pH* Sensor and *TDS* Sensor

pH & *TDS* Sensor Are input devices used to capture water quality conditions. The *pH* sensor detects the acidity level of water, and the *TDS* sensor measures the amount of total dissolved substances.

4 Resource
- Data *pH* and *TDS* Sensor

This is the main resource of the system to generate monitoring information. For analysis and display, the data is collected and sent via *ESP32*.
- On Device Resource

Before the data is sent to the visualization platform, temporary data stored on the *ESP32* is used.
- Network Resource

Shows how the local network is used to send data from the *ESP32* to the *MQTT* broker and then to *Node-RED*.

5 Service
- Water Quality Data Collection and Presentation Services

The service includes collecting data from *pH* and *TDS* sensors, sending data via *MQTT*, and presenting information on the *Node-RED* dashboard. The service allows users to monitor water conditions visually and in real-time via a browser.

6 Active Digital Artefact
- *Node-RED* Dashboard based web interface

a web-based digital interface that displays monitoring data. To make it easy for users to understand, *Node-RED* presents *pH* and *TDS* information in the form of graphs and color indicators.

7 Human User
- Hydroponic Farmers / System Operators

To monitor water quality, people using the system can interact with the dashboard, view data in real-time, and then take action based on the information the system provides.

8 User
- User

A generic entity that interacts with an Active Digital Artifact. In the context of this system, a user can access information through a browser and rely on the system to make decisions about hydroponic water management.

D. Information Model Specification

Fig 4 Information Model Specification

In Figure 4 shows an information model that describes the data structure and main attributes of a hydroponic water quality monitoring system. This model shows how data is generated, classified, and displayed as virtual entities in an *IoT*-based system.

The Device entity is an *ESP32* microcontroller unit, which functions as a data processing and sending center. *ESP32* receives data from *pH* and *TDS* sensors connected to it, and then forms a digital representation in the form of a Virtual Entity.

Water Quality is a virtual entity with ID = WQ1, EntityType is Water, and functions as a digital representation of the actual water conditions monitored in the hydroponic system.

This virtual entity has two main characteristics:

1. *pH* Level
   - AttributeName: pHValue
   - AttributeType: Float

   The acidity value of the water determined by the *pH* meter usually represents this attribute, which

e-ISSN: 2614-8404
p-ISSN: 2776-3234

usually ranges between 0 and 14. The ideal hydroponic value is around 5.5 to 6.5.

2. *TDS* Level
   - AttributeName: TDSValue
   - AttributeType: Integer

   This attribute indicates the amount of total dissolved solids (*TDS*) in the water in ppm, or parts per million. The value indicated by the *TDS* sensor is the level of nutrient density in the hydroponic solution.

The *ESP32* sends the values of these two attributes periodically to a visualization platform, such as *Node-RED*. Thus, users can see the values in real-time and make adjustments if the values are outside the optimal limits.

E. Service Specification

Fig 5 Service Specification

Figure 5 shows the System Service Specification that illustrates how the system uses the *MQTT* protocol to help sensors communicate with a central monitoring controller. In this configuration, *MQTT* endpoints labeled *pH* and *TDS* send *pH* and *TDS* sensor readings to the endpoint, which sends real-time data to a service called the Water Quality Monitoring Controller via a lightweight protocol.

As a central *MQTT* subscriber, this service collects and monitors all incoming data from the two sensor channels. This data is then processed and translated into system outputs such as the Current Mode status, which indicates whether the system is operating in manual or automatic mode. This structure allows for efficient, real-time communication with low bandwidth, allowing users or automated modules to make timely decisions about the water quality status.

F. *IoT* Level Specification

Fig 6 IoT Level Specification

Figure 6 shows that the system consists of a single local monitoring node consisting of various integrated components. The microcontroller device (*ESP32*), which acts as the main controller, is where the process begins. This device directly indicates the water quality by reading the *pH* and *TDS* sensor values in the hydroponic system.

The internal control uses *ESP32* to handle the data after the sensor values are read. It validates and converts the data into a digital format that can be sent. Next, the data is sent to the service section via the *MQTT* communication protocol. The service section delivers the data to the application interface, which is a web-based *Node-RED* dashboard.

The entire process is done locally without cloud involvement, so the dashboard can display the *pH* and *TDS* values in real-time in the form of graphs and label status. In addition, the system can show the current system mode (Auto/Manual) as additional information displayed to the user. This allows the system to collect and process data entirely within the local network, making it suitable for use in places where there is no cloud.

G. Functional View Specification

Application	
Web Application Node-RED Dashboard	**Application Server** Node-RED Engine
Management Application Management Device Management	**Service** Web Service **Communication** MQTT (MQTT Broker, Node-RED Logic)
Device Sensor (pH Sensor, TDS Sensor), Microcontroller (ESP32)	

Fig 7 Functional View Specification

Figure 7 shows the structure of an Internet of Things (IoT)-based system divided into three main layers: applications, services, and devices. Each layer shows the role and function of each system component in a modular

e-ISSN: 2614-8404
p-ISSN: 2776-3234

and hierarchical manner. The physical components in the device layer, or device layer, include pH and TDS sensors. They are used to measure the quality of the nutrient solution in a hydroponic system. The ESP32 microcontroller is connected to both sensors, which functions as the main controller to read sensor data, perform initial processing, and transmit data wirelessly using the MQTT protocol, which is very lightweight and supports real-time communication. The service layer includes management components and interaction systems. In the Management sector, there are Application Management and Device Management functions that are operated through the logic flow on Node-RED. Meanwhile, in the Service section, the system implements a Web Service based on Node-RED Logic and the MQTT protocol managed by the MQTT Broker as a liaison to transfer data from the device to the application. This architecture allows the system to provide a real-time and cloud-independent hydroponic water quality monitoring solution, making it particularly suitable for deployment in urban environments that have limited internet access but still require a reliable monitoring system.

H. Operational View Specification

Table 1 Operational View Specification

Application	Application Server: *Node-RED* Engine
Service	*Web Service*
Communication	*MQTT (MQTT Broker, Node-RED Logic)*
Devices	Controller: *ESP32* Sensor: *pH Sensor*, *TDS Sensor*

Table 1 shows various operational options that can be used to implement and operate an Internet of Things system that combines hydroponic water quality. To ensure that all hardware and software components can work in an integrated and mutually supportive manner, this stage is very important.

ESP32 serves as the main controller in this system, connecting *pH* and *TDS* sensors to measure water quality parameters. The data obtained is then sent in real-time via the *MQTT* communication protocol, which is lightweight and ideal for Internet of Things-based applications.

This system uses *Node-RED* Engine and *MQTT* Broker (Mosquitto) as an application server. *Node-RED* not only receives and processes data from the broker but also provides an interactive web dashboard interface that directly displays *pH*, *TDS*, and system status. This system is ideal for use in areas with limited internet because it operates locally without relying on the cloud.

I. Device and Component Integration

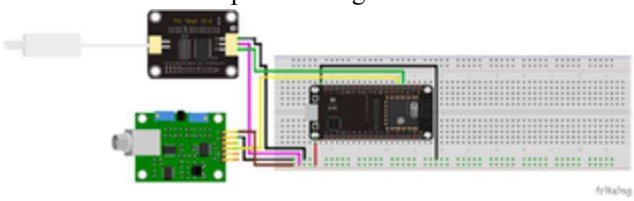


Fig 8 Device and Component Integration

The process of integrating all software and hardware in the system into one functional unit is depicted in Figure 8 Device and Component Integration. In order for the system to monitor hydroponic water quality in real-time, the integration of these components is very important.

The two main components of the system are the physical components (hardware) and the logical components (software). The *ESP32* microcontroller is directly connected to the hardware with two sensors: a *pH* sensor and a *TDS* sensor. The *pH* sensor measures the acidity or alkalinity of the nutrient solution, and the *TDS* sensor measures the amount of dissolved substances present in the water concerning nutrient levels.

The *ESP32* acts as a control center that calculates the values of both sensors. After the reading is complete, the data is formatted and packed in JSON format using firmware developed in the Arduino IDE. Next, the data is sent to a locally running broker, *Mosquitto*, via the *MQTT* protocol.

On the software side, *Node-RED* is a workflow-based visual platform used to process and display sensor data. *Node-RED* subscribes to topics sent by the *ESP32* and displays *pH* and *TDS* values on a web-based dashboard in real-time.

Using a browser that is on the same network as the *Node-RED* server, you can access this dashboard without being connected to the internet. Through the use of value indicators and graphs, users can track changes in water quality and use this data to make decisions.

Ensuring that sensor data can be read, sent, received, and visualized efficiently, this process runs automatically and synchronously. In order for this monitoring system to run well, good hardware and software integration is essential.

J. Application Development

In the application implementation stage, the author carried out several stages to realize an *IoT*-based hydroponic water quality monitoring system. The first stage uses the *Node-RED* platform to produce real-time graphic visualization of *pH* and *TDS* sensor data. Next, the author sets up data communication using the *MQTT* protocol, which functions as an information exchange path between the application platform and the microcontroller. To ensure that data reading runs smoothly, the next stage is to configure the controller (*ESP32*) and connect it to the *pH* and *TDS* sensors. After the configuration is complete, the author installs the sensors and hardware on the hydroponic system. This includes testing the stability of the readings and network connections. Data visualization and analysis are the final steps in this implementation. In the *Node-RED* web dashboard, data sent by the *ESP32* via *MQTT* is displayed. This allows users to see changes in *pH* and *TDS* values in real-time and make decisions based on the information they see.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

1. Application Development

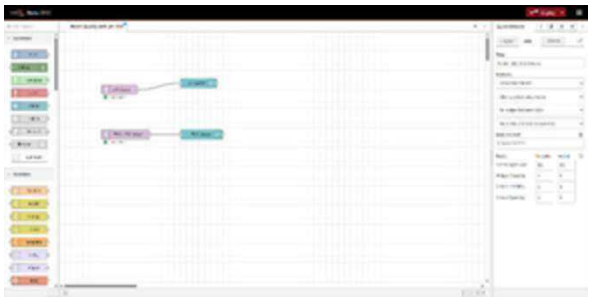


Fig 9 Node-RED Flow

Figure 9 shows the *Node-RED* flow configuration to receive *pH* sensor and *TDS* sensor data from the *MQTT* Broker and then display it in the form of a bar graph.

Fig 10 Node-RED Dashboard Output

Figure 10 is a *Node-RED* dashboard displaying the *pH* sensor and *TDS* sensor data previously received from the *MQTT* Broker.

2. Hardware assembly and integration

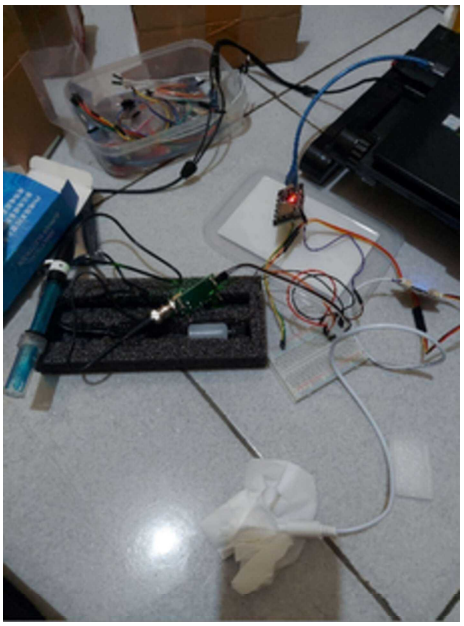


Fig 11 Controller Assembly

In Figure 11 the hardware is assembled, the *ESP32* microcontroller is connected to the *pH* sensor and *TDS* sensor.

3. *ESP32* Programming

The *ESP32* is programmed using the C++ programming language through the Arduino IDE platform. This microcontroller is configured to read data from the *pH* sensor and *TDS* sensor, then process it before sending it via the *MQTT* protocol. Figure 12, Figure 13, and Figure 14 show the complete scripts used to read sensor data and send it to the *MQTT* broker periodically.

```
#include <WiFi.h>
#include <PubSubClient.h>

const char* WIFI_SSID = "SSID";
const char* WIFI_PASSWORD = "Pass";

const char* MQTT_SERVER = "broker.emqx.io";
const int MQTT_PORT = 1883;
const char* TDS_TOPIC = "salz/sensor/tds";
const char* PH_TOPIC = "salz/sensor/ph";
WiFiClient espClient;
PubSubClient mqttClient(espClient);

const int TDS_PIN = 34;
const int PH_PIN = 35;

const float reffVoltage = 3.3;
const int ADC_RES = 4096;
const float TDS_FACTOR = 0.5;

const float PH_SLOPE = 0.18;
const int SAMPLE_AVERAGE = 10;
unsigned long BAUD_RATE = 115200;


float tdsValue;
float tdsVoltage;
float phValue;
float phVoltage;

void connectWiFi() {
  delay(10);
  Serial.println("Menghubungkan ke WiFi...");
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);

  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.print(".");
  }

  Serial.println("\nWiFi terhubung.");
  Serial.print("IP Address: ");
  Serial.println(WiFi.localIP());
}

void mqttCallback(char* topic, byte* payload, unsigned int length) {
  Serial.print("Pesan diterima di topic: ");
```

Fig 12 Script ESP32 (a)

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig 13 Script ESP32 (b)

Fig 14 Script ESP32 (c)

K. Application Testing

This stage is carried out after the application has been successfully developed; System testing is carried out using *black-box testing* to ensure that the application functions properly as expected. Table 2 shows some of the tests carried out.

Table 2 Black-box Testing

No	Description	Expected Results	Results
1	The *pH* sensor reads the value of the hydroponic solution	The *pH* value is displayed on the dashboard according to the actual value.	Success
2	*TDS* sensor reads dissolved substance levels	*TDS* values are displayed on the dashboard according to actual values.	Success
3	*ESP32* sends sensor data to *MQTT* broker	Data successfully sent to *MQTT* topic and received by *Node-RED*	Success
4	*Node-RED* receives and displays sensor data	Data appears on the dashboard in real-time	Success
5	Users access the dashboard from a browser	The dashboard opens and displays the *pH* and *TDS* graphs.	Success
6	The system continues to run while the sensor is given repeated input.	No crashes, values stay updated in real-time	Success

The black-box testing results showed that the system operated as expected in all scenarios. Both the *pH* and *TDS* sensors were able to accurately detect and transmit the actual hydroponic solution values, which were then displayed correctly on the *Node-RED* dashboard. The *ESP32* microcontroller consistently sent data from the sensors to the *MQTT* broker, and the *Node-RED* interface received and visualized this data in real-time. Furthermore, the dashboard remained accessible through the browser interface, and the displayed graphs were continuously updated in response to new data input. The system remained active and responsive without any delays or crashes even when multiple sensors interacted. These results demonstrate that the system can reliably and

e-ISSN: 2614-8404
p-ISSN: 2776-3234

continuously monitor hydroponic water quality. These results make the system feasible for use in real-world situations.

IV. CONCLUSION

This research has created and implemented a hydroponic water quality monitoring system based on the Internet of Things (*IoT*) that uses *pH* and *TDS* sensors connected to the *ESP32* microcontroller. By using the *MQTT* communication protocol, this system can read water quality data periodically and send it in real-time to the *Node-RED* platform. This data is then presented in a web dashboard that can be accessed through the *Node-RED* platform.

Acidity levels (*pH*) and dissolved solids levels (*TDS*) are two main hydroponic parameters that can be monitored stably by the system. The implementation stage includes hardware and software integration. The results of the *black-box* method test show that all system features, including sensor readings, data transmission, and information visualization, have run according to expectations and planned specifications.

This system is included in the *IoT* Level 2 category, which means that they can perform real-time monitoring but do not have automatic control functions. However, this system is built modularly and allows for further development, including storing historical data into a database and automatic actuator control.

It is hoped that this system will be a simple yet successful solution to help hydroponic farmers maintain nutrient stability and increase crop yields by monitoring water quality more efficiently, practically, and accurately.

REFERENCES

[1] D. Descartes, H. Harianto, and F. Falatehan, "Penyuluhan Pertanian dan Pengaruhnya terhadap Pendapatan Usahatani di Gapoktan Rorotan Jaya, Rorotan, Cilincing, Provinsi Dki Jakarta," *Jurnal Ekonomi Pertanian dan Agribisnis*, vol. 5, no. 2, pp. 390–403, Apr. 2021, doi: 10.21776/ub.jepa.2021.005.02.10.

[2] T. S. Yulia, "Strategi Pemanfaatan Media Air (Hidroponik) Pada Budidaya Tanaman Kangkung, Pakcoy, Dan Sawi Sebagai Alternatif Urban Farming," *Journal on Education*, vol. 06, no. 01, pp. 5835–5848, Dec. 2023.

[3] L. Pamungkas, P. Rahardjo, and I. G. A. P. Raka Agung, "RANCANG BANGUN SISTEM MONITORING PADA HIDROPONIK NFT (NURTIENT FILM TEHCNIQUE) BERBASIS IOT," *Jurnal SPEKTRUM*, vol. 8, no. 2, p. 9, 2021, doi: 10.24843/spektrum.2021.v08.i02.p2.

[4] F. Nurrizky, H. Budiyono, and Ismarani, "ANALISIS PENGEMBANGAN USAHA HIDROPONIK PADA DHIEFFI FARM HIDROPONIK KOTA BEKASI," *CEFARS : JURNAL AGRIBISNIS DAN PENGEMBANGAN WILAYAH*, vol. 8, no. 1, pp. 74–85, Apr. 2025, doi: 10.33558/cefars.v8i1.10895.

[5] M. P. Manek, M. S. Pareira, and M. A. Tuas, "Optimalisasi Pemberian Pupuk Organik Cair untuk Pertumbuhan Tanaman Kangkung (Ipomea sp.) dengan Sistem Hidroponik," *Hidroponik : Jurnal Ilmu Pertanian Dan Teknologi Dalam Ilmu Tanaman*, vol. 2, no. 1, pp. 213–227, Feb. 2025, doi: 10.62951/hidroponik.v2i1.269.

[6] A. Hermanto, T. Ahmad, H. Al Mubarok, and A. Kridoyono, "PEMBUATAN SISTEM PEMANTAUAN PH DAN PPM AIR PADA HIDROPONIK BERBASIS *IoT*," *Jurnal Sistem Informasi dan Informatika (Simika) P-ISSN*, vol. 8, no. 1, pp. 2622–6901, 2025.

[7] N. Heriyani and S. Ernawati, "PEMANFAATAN TEKNOLOGI IOT BERBASIS MOBILE DALAM UPAYA MONITORING KUALITAS AIR PADA TANAMAN HIDROPONIK," Jun. 2024.

[8] S. Tansa, N. Latekeng, R. Yunginger, and I. Z. Nasibu, "Monitoring Kualitas Air Sungai (Kekeruhan, Suhu, *TDS*,*pH*) Menggunakan Mikrokontroler Atmega328," *Jambura Journal of Electrical and Electronics Engineering*, vol. 6, no. 1, pp. 70–75, 2024, doi: 10.37905/jjeee.v6i1.23315.

[9] N. L. Luqyana, F. Arinie, and A. Muzzakhim, "Telemonitoring Padatan Terlarut pada Filtrasi Air Limbah Laundry Menggunakan Sensor *TDS* dan Sensor *pH* untuk Media Budidaya Tanaman Hidroponik Berbasis Mikrokontroler," *Jurnal Jartel: Jurnal Jaringan Telekomunikasi*, vol. 11, no. 2, pp. 67–73, 2021, doi: 10.33795/jartel.v11i2.55.

[10] I. Z. J. M. Fahd, M. F. Hasan, A. F. Andoko, and A. Sumarahinsih, "Rancang Bangun Alat Ukur Kualitas Air pada Penampungan Air Hujan dengan Sensor *TDS* Berbasis Mikrokontroller ESP8266," *JASIEK (Jurnal Aplikasi Sains, Informasi, Elektronika dan Komputer)*, vol. 5, no. 1, pp. 1–8, 2023, doi: 10.26905/jasiek.v5i1.10015.

[11] U. Umar, "RANCANG BANGUN SISTEM KONTROL DAN MONITORING PH, SUHU AIR DAN *TDS* PADA SISTEM AKUAPONIK BERBASIS INTERNET OF THINGS (IOT)," *JTT (Jurnal Teknologi Terapan)*, vol. 10, no. 1, p. 19, Mar. 2024, doi: 10.31884/jtt.v10i1.557.

[12] D. Wijayanto, E. P. Silmina, and A. A. Aditiya, "PROTOTYPE IOT UNTUK PEMANTAUAN NUTRISI DAN PH PADA HIDROPONIK MENGGUNAKAN *ESP32* DI KEBUN HIDROPINIK VEFAR YOGYAKARTA," *HOAQ (High Education of Organization Archive Quality): Jurnal Teknologi Informasi*, vol. 15, no. 2, pp. 100–106, 2024.

[13] F. Hakim, I. W. Supardi, and N. N. Ratini, "Perancangan dan Pembuatan Sistem Kontrol Penyiraman Tanaman Hidroponik Otomatis Menggunakan Sensor *TDS* Berbasis Mikrokontroler ATMEGA328," *BULETIN FISIKA*, vol. 25, no. 1, p. 1, 2024, doi: 10.24843/bf.2024.v25.i01.p01.

[14] A. N. Sholihah, T. Tohir, and A. R. Al Tahtawi, "Kendali *TDS* nutrisi hidroponik deep flow technique berbasis *IoT* menggunakan fuzzy logic," *JITEL (Jurnal Ilmiah Telekomunikasi, Elektronika,*

e-ISSN: 2614-8404
p-ISSN: 2776-3234

dan Listrik Tenaga), vol. 1, no. 2, pp. 89–98, 2021, doi: 10.35313/jitel.v1.i2..89-98.

[15] M. W. Hamdani, A. Stefanie, and Saragih Yuliarman, "Perancangan dan Implementasi Metode Kontrol Fuzzy Logic Mamdani pada Sistem Kontrol *TDS* dan *pH* Hidroponik," *JTT (Jurnal Teknologi Terpadu)*, vol. 10, no. 2, pp. 171–183, 2022, doi: 10.32487/jtt.v10i2.1555.

[16] Rouhillah, R. Faulianur, and F. Fazila, "Alat Monitoring Kualitas Air Minum Menggunakan Sensor *TDS* Berbasis Internet of Things," *J-Innovation*, vol. 12, no. 2, pp. 43–47, Dec. 2024, doi: 10.55600/jipa.v12i2.212.

[17] M. C. A. Prabowo, A. A. Janitra, and N. M. Wibowo, "Sistem Monitoring Hidroponik Berbasis *IoT* dengan Sensor Suhu, *pH*, dan Ketinggian Air Menggunakan ESP8266," *JURNAL TECNOSCIENZA*, vol. 7, no. 2, pp. 312–323, 2023, doi: 10.51158/tecnoscienza.v7i2.894.

[18] G. N. De Side, G. M. D. Putra, and D. A. Setiawati, "*IoT* (internet of things) microclimate monitoring system using node-red platform at plant factory," *IOP Conf Ser Earth Environ Sci*, vol. 1441, no. 1, p. 012012, Jan. 2025, doi: 10.1088/1755-1315/1441/1/012012.

[19] A. Rifa'i, "SISTEM PEMANTAUAN DAN KONTROL OTOMATIS KUALITAS AIR BERBASIS INTERNET OF THINGS (IOT) MENGGUNAKAN PLATFORM NODE-RED UNTUK BUDIDAYA UDANG," *JTT (Jurnal Teknologi Terapan)*, vol. 7, no. 1, p. 19, 2021, doi: 10.31884/jtt.v7i1.317.

[20] A. Bahga and Madisetti Vijay, *Internet of Things: A Hands-On Approach*. 2014. Accessed: May 15, 2025. [Online]. Available: https://books.google.co.id/books?id=JPKGBAAAQBAJ&printsec=frontcover#v=onepage&q&f=false

e-ISSN: 2614-8404
p-ISSN: 2776-3234

UI/UX Using Design Thinking Method in Clarient Hotel Application Design

Dimas Setiawan[1)], Muhammad Ragil Shafa Abdur Rafi Dalhats[2)]
[1,2]Program Studi Teknik Informatika, Universitas Trilogi

Email: [1]23032003ds@gmail.com, [2]dalhats@gmail.com

Abstract – Clairent Hotel is an online hotel room booking application specifically targeting the Bali area. A crucial aspect of developing an effective application is designing the user interface (UI) and user experience (UX) to meet the needs of users. This is particularly important for delivering an optimal experience during both leisure and business trips in Bali. To achieve this, the development of the Clairent Hotel application utilizes the Design Thinking methodology, which encompasses five key stages: empathize, define, ideate, prototype, and test. This approach is crucial as it prioritizes understanding the user's perspective and needs, fostering innovative solutions that enhance usability and satisfaction. By engaging in empathy-driven research, the design team can uncover insights into user behaviors and preferences, which informs the definition of the core problems to be addressed. Ideation allows for brainstorming creative solutions, while prototyping enables the visualization of these ideas in a tangible format. Finally, testing ensures that the application meets user expectations and functions effectively. The result of this research is a Clairent Hotel application that operates seamlessly, featuring an intuitive user interface that facilitates easy navigation. By employing the Design Thinking process, the application not only addresses user needs but also enhances the overall user experience, ultimately contributing to greater customer satisfaction and loyalty.

Keywords – UI/UX, Design Thinking, Method.

I. INTRODUCTION

Various aspects of life are affected by the advancement of information technology, and design is one of them. A plan or design made before an item, system, component, or structure is made is called design. The goal is to make the object to be made useful, beautiful, and functional for humans. Ensuring the right balance between UI and UX is essential for successful UI/UX design, which means a pleasant interaction between the application and the user without neglecting the importance of an attractive appearance. It is very important for businesses to ensure that the application or website is easy for users to use[1][2].

Clairent Hotel is an innovative online hotel room booking application tailored specifically for the vibrant and diverse tourism market of the Bali region. As the demand for seamless travel experiences continues to rise, the importance of crafting an effective application cannot be overstated. A critical component of this process is the meticulous design of the user interface (UI) and user experience (UX), which must be thoughtfully aligned with the varied needs and preferences of users. This emphasis on user-centric design is vital for delivering an exceptional experience to both leisure travelers seeking relaxation and exploration, as well as business travelers requiring efficiency and convenience during their stay.

Clairent Hotel serves as a comprehensive platform for hotel rental services, offering a wide range of accommodations that cater to different budgets and preferences. Given the competitive nature of the hospitality industry in Bali, it is imperative that the application is not only user-friendly but also highly accessible across various devices and operating systems. A well-designed UI ensures that users can easily navigate through the application, find relevant information, and complete bookings with minimal effort. Meanwhile, a positive UX enhances user satisfaction by creating an engaging and enjoyable interaction with the application, fostering trust and encouraging repeat usage.

Moreover, the application must incorporate features that address the specific needs of its users, such as personalized recommendations, easy comparison of hotel options, and streamlined payment processes. By focusing on these aspects, Clairent Hotel aims to position itself as a leader in the online hotel booking market in Bali, ultimately enhancing the overall travel experience for its users. In a region known for its rich culture and stunning landscapes, providing a reliable and efficient booking platform is essential for helping travelers create memorable experiences during their stay.

User interface (UI) and *user experience* are two important components that cannot be separated in the product design process. *User interface* or the interface is what is visible in the operation of a program, while *user experience* is what the user feels when operating the program. User experience is determined by how easy or difficult it is to interact with the interface elements that have been created by the designer. Use of the method *Design Thinking* [3], [4]will affect the design of the user interface and user experience of a product. Methods *Design Thinking* has a series of processes including *Empathize*, *Define*, *Ideate*, *Prototype*, *Test*. Each process in the method *Design Thinking* used to find out user needs and problems, which will then be resolved into a solution that is translated into the form of interface and interaction design [5],[6], The UI/UX Design with Design Thinking Method for The University Complaint Website[7].

II. RESEARCH METHODOLOGY

Design Thinking Method

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Design thinking is a cross-disciplinary creative solution-based approach that combines analytical thinking, practical skills, and creativity in thinking [8],[9][10] . The method that will be used is the Design Thinking method. This method is to create solutions that begin with the Empathize process for a particular need that is centered on humans (human centered). Not only that, there are 3 processes, namely inspiration is used to find solutions to a problem or find a new discovery. Ideation is a series that produces new thoughts[11],[12], where these thoughts are developed more widely and tested, and the last stage is implementation, which is implementing the final result to prospective users. In the development process, the three stages are developed into five stages, basically there are not many differences, but some parts have been highlighted, so that the procedure is more detailed[13].

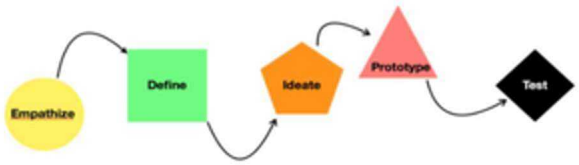


Fig 1. Design Thinking Framework

The Design Thinking method has 5 stages, namely, Empathize aims to understand users in the context of the product designed through observation and distributing questionnaires with the first given scenario. The second stage is Define, which aims to determine the formulation of the problem as the main objective of the research[14]. The third stage is Ideate [15], which aims to produce ideas or concepts as a basis for making prototyping [16]. Fourth, Prototype is the initial design of the product to be made in order to find errors early and obtain new possibilities. The last is Trial. Trials are carried out to collect data from various user responses or to see whether the application is suitable for use or not.

III. RESULTS AND DISCUSSION

Discussion Results

The primary outcome of this discussion is the development of the Clairent Hotel application, which demonstrates that creating UI/UX through the design thinking method can be achieved by following the appropriate steps. The application is designed to simplify the hotel reservation process for users, featuring a clean and organized UI/UX design.

Splash Screen

When opening the application, the screen will display a Splash Screen, here the User can see a glimpse of the Clairent Hotel logo when opening the Clairent Hotel application.

Fig 2. Splash Screen Wireframe

Login Page

After going through the splash screen, you will then enter the login page. On this login page, users can enter their email address and password if they are already registered in the Clairent Hotel application. Then just click the login button and the user will enter the next page.

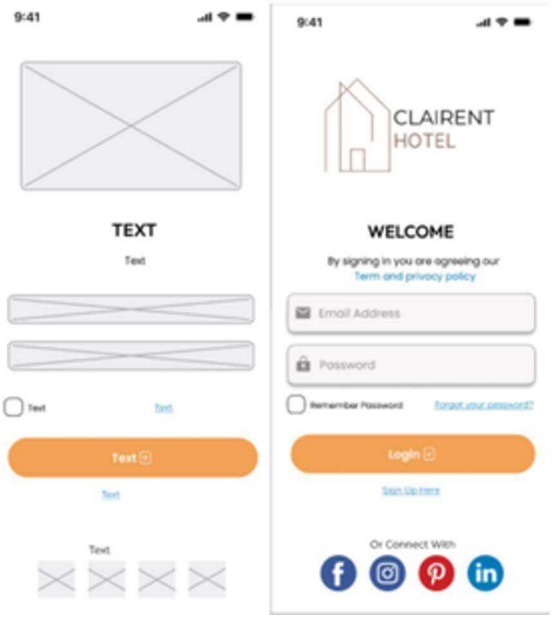


Fig 3. Login Page Wireframe

Sign Up Page

Then there is a sign up page. When the user has not created an account, the user can create an account on this page, simply enter the data in the column, then the account has been created, the user can proceed to the login page, then log in with the data that has been created.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

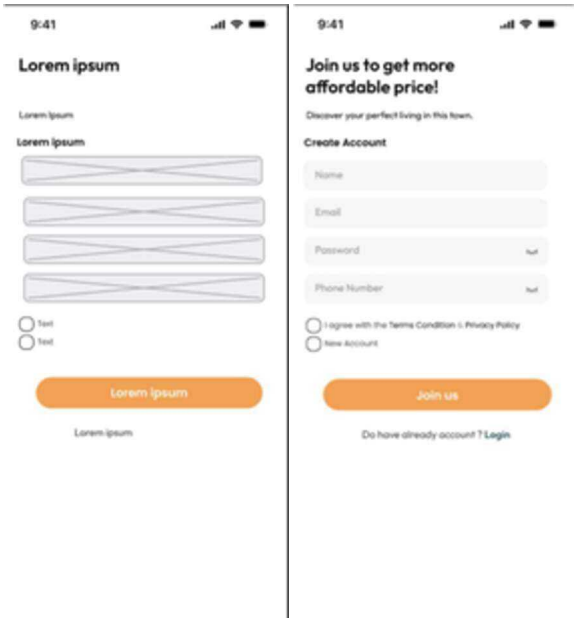


Fig 4. Wireframe Sign Up Page

Home Page

Next, if the user is logged in, the user will enter the home page, where all the information and accessibility of the application are, starting from the location of the accommodation, how many people will stay, and how many rooms are rented. On this page there is also a search and a glimpse of the Clairent Hotel hotel rental offers. Then there is a menu that can be seen, such as Book Now for hotel reservations, Our Restaurant to see information about restaurants at the Clairent Hotel, then there is Location, which is where the hotel is located, then there is Rate Us to display hotel reviews, then there is FAQ, which is questions and answers about Clairent Hotel information, and finally there is Contact Us to communicate with the hotel's Customer Service. Under the menu there is Bottom Navigation used to see the home, and profile, users can also click on the middle part of the "+" sign to make a hotel reservation.

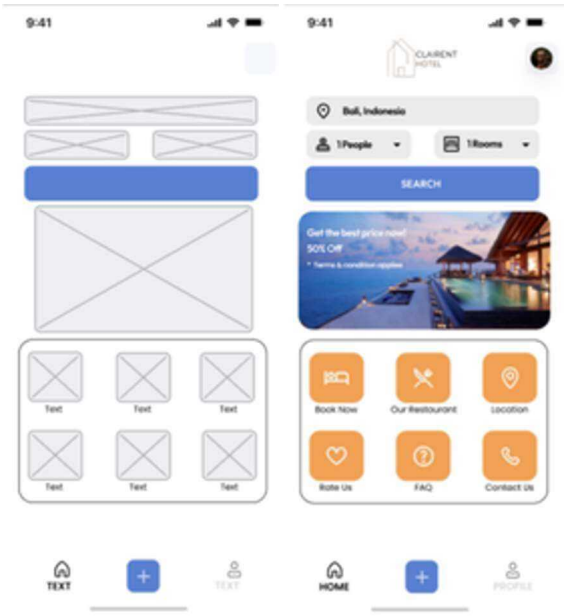


Fig 5. Wireframe Home page

Book Now Page

Next, if the user clicks on the Book Now menu, the Book Now page will appear, where this page is used to book a hotel at Clairent Hotel, the user can see what information is provided such as room prices, room descriptions, choose the date of stay, and the booking now button to book the hotel.

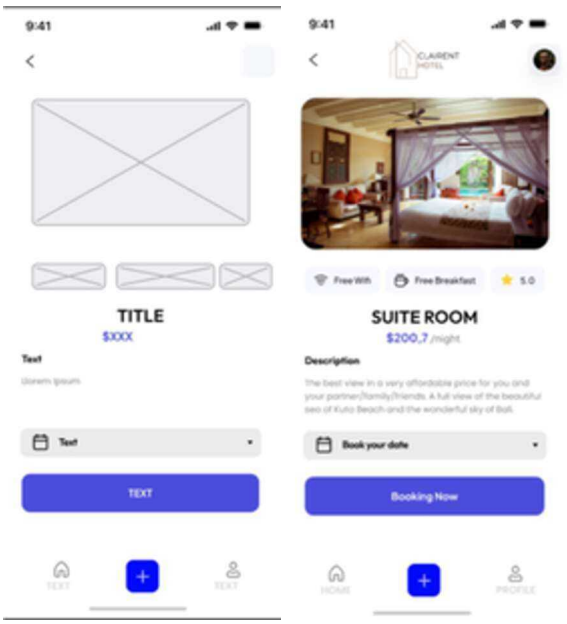
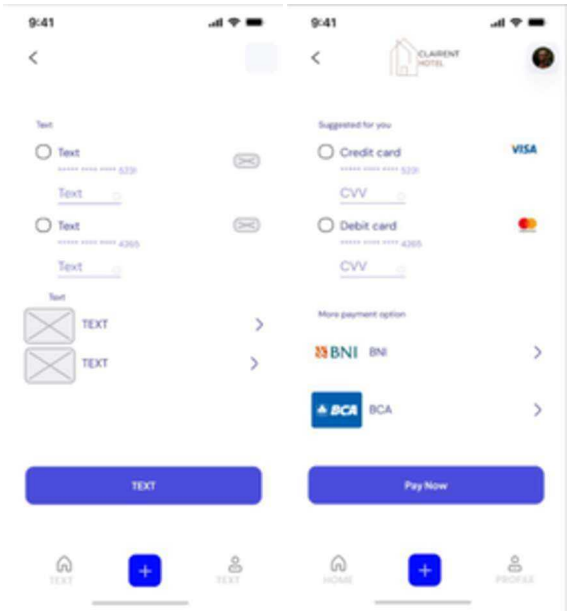


Fig 6. Wireframe Book Now

Payment Page

Then, when the user clicks Booking Now on the Book Now page, continue to the Payment page, where on this page the user can make payments using several options. When the user has entered the required data, the user can click the Pay Now button to pay the bill.



e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig 7. Wireframe Payment Page

Rate Us Page

Then there is the Rate Us page menu, on this page users can review and give ratings to Clairent Hotel, so that other visitors can see and provide suggestions for hotel services to develop.

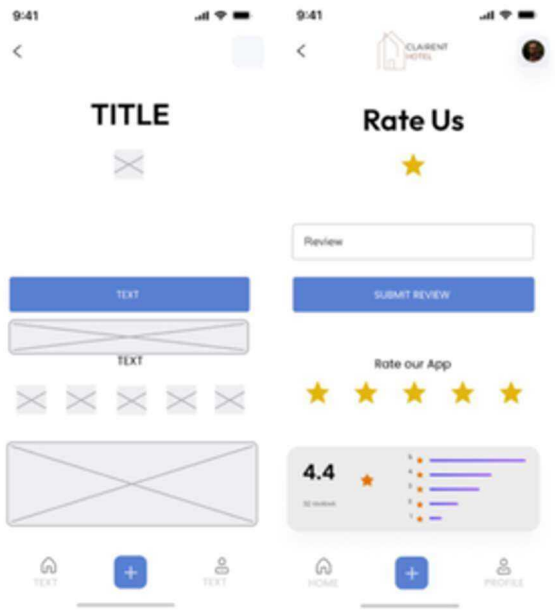


Fig 8. Wireframe Rate us page

FAQ Page

Then next there is the FAQ menu, FAQ or the abbreviation of Frequently Asked Questions is information about questions for customers or users who are confused about ordering or other things. On this page users can see and scroll down to see the answers that have been given by the hotel.

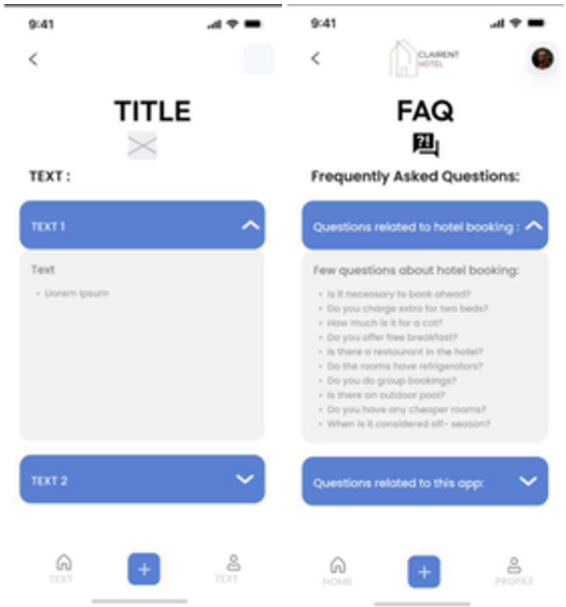


Fig 9. FAQ Page Wireframe

Location Page

Then there is the Location Page menu, on this page users can see the location of the hotel,

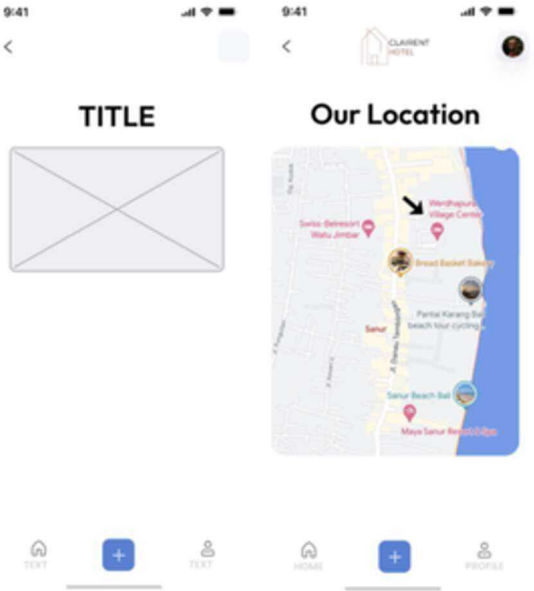


Fig 10. Wireframe Location Page

Our Restaurant Page

Next, there is the Our Restaurant menu, users can see various restaurant choices at Clairent Hotel, according to the atmosphere, then there is a description of the restaurant and there is a hotel customer service number for the restaurant section.

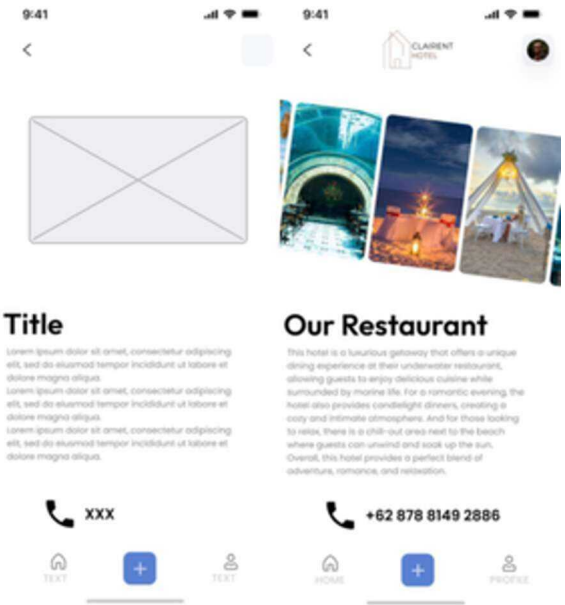


Fig 11. Wireframe Our Restaurant Page

Contact Us Page

Then, there is a Contact Us menu, on this page if the user feels confused about hotel reservations, or what facilities are provided at Clairent Hotel, they can contact the hotel's Customer Service. There is the location of Clairent Hotel, the hotel's customer service number, Clairent Hotel email, or you can contact the hotel's social media.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

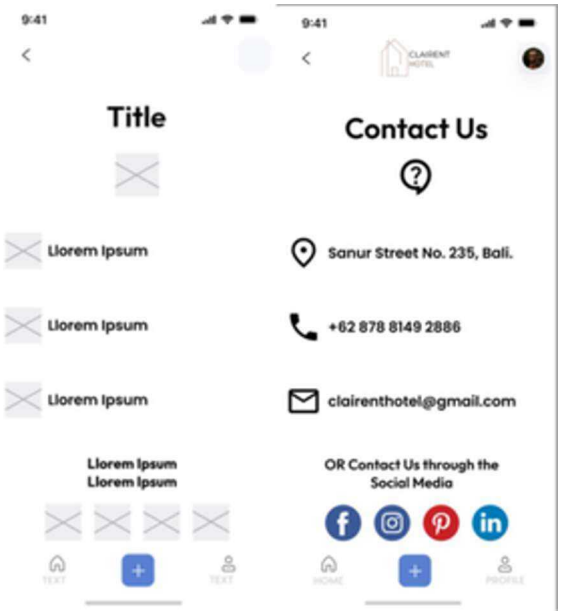


Fig12. Wireframe Contact Us

Profile Page

Finally, there is bottom navigation to go to the profile page, where on this page, there is user account data, starting from profile photo, user username, user date of birth, and user email. Users can also add user social media, then the last is the Log Out button, where this button functions for users when they want to exit the Clairent Hotel application, for a moment when Log Out, then the splash screen will appear again, then go to the Login Page again.

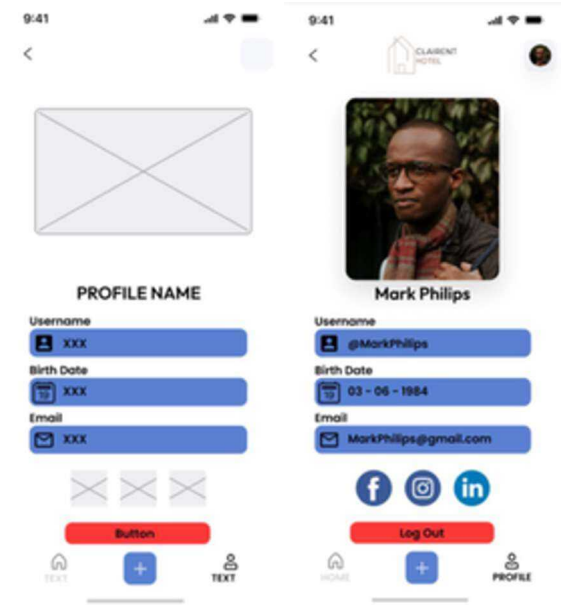


Fig 13. Profile Page Wireframe

.

The findings from this research on the design of the Clairent Hotel application underscore the importance of employing a structured approach, such as the design thinking method, in the development of user interfaces and experiences. The resulting application not only facilitates the hotel reservation process but also emphasizes the value of a simple and organized design. Based on these insights, it is recommended that future app designs prioritize user-centric principles, ensuring that the UI/UX is intuitive and accessible. By adhering to these recommendations, developers can create applications that effectively meet user needs and enhance overall satisfaction.

IV. CONCLUSION

Based on the results of the discussion that has been carried out on the design of the UI/UX design for the Clairent Hotel application, there are several things that can be concluded, including: (1) This discussion resulted in a UI/UX design and prototype of the Clairent Hotel website, (2) The results of this development are still in the form of designs and prototypes to provide an overview of the hotel application before being implemented by the development team.

Future works for researcher may conduct extensive user testing with a diverse group of participants to gather feedback on the prototypes. This would provide insights into real user interactions, preferences, and pain points, enabling iterative improvements to the design.

REFERENCES

[1] A. A. Krishnavarty, M. Defriani, and T. I. Hermanto, "UI/UX Design for Language Learning Mobile Application Chob Learn Thai Using the Design Thinking Method," *SinkrOn*, 2022, doi: 10.33395/sinkron.v7i3.11585.

[2] N. Rösch, V. Tiberius, and S. Kraus, "Design thinking for innovation: context factors, process, and outcomes," *Eur. J. Innov. Manag.*, 2023, doi: 10.1108/EJIM-03-2022-0164.

[3] K. Roth, D. Globocnik, C. Rau, and A. K. Neyer, "Living up to the expectations: The effect of design thinking on project success," *Creat. Innov. Manag.*, 2020, doi: 10.1111/caim.12408.

[4] C. Y. Huang, L. Y. Tsai, C. H. Chung, F. F. Shih, and Y. M. Wang, "The effect of design thinking approach in interprofessional education programme of human sexuality course: A quasi-experimental design," *Nurs. Open*, 2023, doi: 10.1002/nop2.1363.

[5] I. Darmawan, M. S. Anwar, A. Rahmatulloh, and H. Sulastri, "Design Thinking Approach for User Interface Design and User Experience on Campus Academic Information Systems," *Int. J. Informatics Vis.*, 2022, doi: 10.30630/joiv.6.2.997.

[6] M. Pande and S. V. Bharathi, "Theoretical foundations of design thinking – A constructivism learning approach to design thinking," *Think. Ski. Creat.*, vol. 36, no. February, p. 100637, 2020, doi: 10.1016/j.tsc.2020.100637.

[7] S. Milda Puspita and N. Apriyanti, "The UI/UX Design with Design Thinking Method for The University Complaint Website," *Inf. Technol. Int. J.*, 2023, doi: 10.33005/itij.v1i1.2.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

[8] C. Jiang and Y. Pang, "Enhancing design thinking in engineering students with project-based learning," *Comput. Appl. Eng. Educ.*, 2023, doi: 10.1002/cae.22608.

[9] B. J. M. Robertson, "Combining Design Thinking and Systems Engineering to Improve Customer Outcomes," *Des. J.*, 2020, doi: 10.1080/14606925.2020.1822046.

[10] E. Coleman, T. Shealy, J. Grohs, and A. Godwin, "Design thinking among first-year and senior engineering students: A cross-sectional, national study measuring perceived ability," *J. Eng. Educ.*, 2020, doi: 10.1002/jee.20298.

[11] T. Buphate and R. H. Esteban, "Using Ideation Discussion Activities in Design Thinking to Develop EFL Students' Speaking and Critical Thinking Abilities," *Learn J. Lang. Educ. Acquis. Res. Netw.*, 2022.

[12] R. Bender-Salazar, "Design thinking as an effective method for problem-setting and needfinding for entrepreneurial teams addressing wicked problems," *J. Innov. Entrep.*, 2023, doi: 10.1186/s13731-023-00291-2.

[13] W. Chanpuypetch and D. Kritchanchai, "A design thinking framework and design patterns for hospital pharmacy management," *Int. J. Healthc. Manag.*, 2020, doi: 10.1080/20479700.2017.1389479.

[14] C. Wrigley, G. Mosely, and M. Mosely, "Defining Military Design Thinking: An Extensive, Critical Literature Review," *She Ji*, 2021, doi: 10.1016/j.sheji.2020.12.002.

[15] N. D. Fila, S. McKIlligan, and K. Guerin, "Design thinking in engineering course design," in *ASEE Annual Conference and Exposition, Conference Proceedings*, 2018. doi: 10.18260/1-2--30271.

[16] L. M. Simon and D. C. Cox, "The role of prototyping in mathematical design thinking," *J. Math. Behav.*, 2019, doi: 10.1016/j.jmathb.2019.100724.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Ethereal Lenscraft Company Profile *UI/UX* Design Using *Design Thinking* Approach

[1]Zulkifli Azis, [2]Rulliansyah Sugianto
[1,2]Informatics Engineering Study Program, Faculty of Creative Industries and Telematics, Trilogi University
Zulkifli.azis@trilogi.ac.id, rulliansyah.sugianto@trilogi.ac.id

Abstract – Ethereal Lenscraft is a company specializing in photography and videography, with its company profile designed to effectively market its services. The primary focus of the website is to enhance user interactivity and satisfaction for those seeking documentation services for their events. Therefore, it is essential to conduct research from a design perspective, particularly in terms of UI/UX. This study employs the Design Thinking methodology to enhance the user interface (UI) and user experience (UX) of the "Ethereal Lenscraft" website, which offers photography and videography services tailored to specific events. The research follows the Design Thinking steps, including empathy, definition, ideation, prototyping, and testing, to ensure that the user experience aligns with expectations and leaves a lasting impression. Additionally, the photography industry entails technical complexities and various supporting elements, including equipment and personnel. Photography and videography works are categorized into commercial, journalistic, and artistic/expression genres. The outcomes of this study will serve as a benchmark for enhancing user experience and fostering deeper interactions on the "Ethereal Lenscraft" company profile website.

Keywords : Design Thinking, User Interface Design, User Experience.

I. INTRODUCTION

The rapid advancements in technology, particularly in the domains of information and communication systems, have significantly enhanced the capabilities to meet the diverse needs of various industries [1],[2]. User Interface (UI) and User Experience (UX) exemplify this swift technological evolution [3], enabling individuals to leverage digital media—both online and offline—to design products that are visually appealing and user-friendly, thereby enhancing user comfort and convenience[4].

Creative industries, such as photography and videography, exhibit unique characteristics influenced by various technical aspects that shape their development. Numerous supporting elements, including equipment and human resources, play crucial roles in this sector, with essential tools comprising cameras, lenses, tripods, lighting, and more [5]. Traditionally, the process of ordering photography and videography services required customers to either visit a studio or contact available photographers directly, as there were no applications on platforms like the Play Store or App Store, nor websites offering reservation services for these services. This approach proved inefficient, as customers had to physically visit studios to coordinate schedules and locations with photographers.

Ethereal Lenscraft is a company that specializes in providing professional photography and videography services to fulfill visual documentation needs. However, the design of the company's website is deemed suboptimal, necessitating the application of the Design Thinking methodology to enhance the User Interface (UI) and User Experience (UX) on the "Ethereal Lenscraft" website.

Consequently, the objective of this research is to develop a design model for User Interface and User Experience by implementing innovations in the form of a company profile website using the Design Thinking method. This methodology is considered effective in addressing existing challenges[6],[7], [8], particularly in enhancing UI and UX to foster deeper interactions with users and ensure an optimal user experience.

II. RESEARCH METHODS

This study uses the design thinking method. The reason is that the company profile website must support customer desires with every problem, especially in the fields of photography and videography. Design thinking itself is a method known as a comprehensive thinking process that concentrates on creating solutions that begin with the process of empathy for a particular need that is centered on humans (human centered) towards a sustainable innovation based on the needs of its users[9],[10].

Fig 1. ***Design Thinking Method.***

This method has 5 stages[11],[12], namely: Empathize which aims to find out user needs based on their views, define which aims to describe each problem based on empathize, ideate is the part where ideas and solutions obtained from each problem in define become the basic reference for making a prototype, prototype is the stage where ideas and solutions in ideate are implemented in the form of user interface or UI designs that can solve the

e-ISSN: 2614-8404
p-ISSN: 2776-3234

problems defined, test is the last stage where the prototype is run by the user in real time which is expected to produce feedback or input for the development of the Ethereal lenscraft company profile website.

1. Empathize
   Empathize means relating to user feelings, empathy, emotions, views, and user experiences with system designers. An approach taken with users to understand and explain the problems they have and what needs they want to fulfill. This stage will focus on users who need professional documentation services with many choices and support customization according to their wishes[13]. The problem comes from the geographical location of the user where photo studios can be much more difficult to find even though their location offers natural beauty. There is also a problem where lay people in photography and videography want to just learn but do not know the equipment and techniques in the world of photography and videography.

2. Define
   At the level *Design Thinking*, *Define* is the second step after the level *Empathize*. On the step *Define*, the research team formulates a clear and concrete problem statement based on the insights and understanding gained from the previous stage. The purpose of this stage *Define* is to identify precisely and specifically what needs to be solved or addressed in the design process. By formulating the right problem statement, the research team will have a clear focus in finding innovative and effective solutions [14]. And the problems that arise in the empathize stage divide several categories of users into several parts, as follows:
   a. Lay users who are aged 18-40 and male or female. In this user category, the website must be made to support easy understanding if it is intended for reference for learning photography and videography. Using easy language so that men and women can increase the speed of user understanding.
   b. Users who live in big cities and have middle to upper incomes. Users in this category specialize in a service that requires user trust in a company through a previously created portfolio.
   c. Users with extrovert personalities, have an interest in art & culture, uphold aesthetic values, and quality. These users require the company profile website to show a more open design and insert artistic and cultural values with aesthetics and quality.
   d. Users with positive traits and willing to accept new things. For this one user, a website is needed that uses language that is not considered indoctrinating but still directs users according to their needs.

3. Ideate
In this third step, researchers can generate ideas for problem solutions by conducting *brainstorming* with the team and stakeholders [15]. Ideas obtained through brainstorming will produce ideas in the form of solutions to problems faced by users. And after each problem from the above categories has been defined, the solution is as follows:
a. Creating a company profile website has informative tips and tricks that people aged 18-40 can quickly understand.
b. Create a portfolio that can illustrate the professionalism of the company ethereal lenscraft.
c. Beautify the design of the company profile according to artistic and cultural values but without eliminating the elements of aesthetics and quality.
d. Using language that describes ethereal lenscraft does not indoctrinate or patronize users in order to create comfortable user interaction.

4. Prototype
This stage is an initial representation or model created to realize ideas or solutions resulting from the process of understanding, observation, and ideation. *Prototype* is an important step in the exploration and experimentation phase of design to test and develop the concepts that have been generated before they are fully implemented. *Prototype* can take various forms, from physical prototypes (real or printed models) to digital prototypes (in the form of wireframes, mockups, or working software). The purpose of creating a prototype is to obtain responses and feedback from users. Thus, the prototype allows for necessary changes and improvements before the final product or service is implemented. Based on the previous 3 stages, the designs offered are as follows:

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig 2.*Wireframe* Home Page.

Fig 3. *Wireframe* Page *About*.

Fig 4.*Wireframe* Tips & Tricks Page.

Fig 5.*Wireframe* Gallery Page.

Fig 6.*Wireframe* Page *Booking*.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

5. Testing
Testing is a validation step if the solution design that has been implemented is correct and is able to solve user problems or needs further development. After the prototype has been produced, this stage uses the feedback method via Google Form which is published to prospective users and is expected to be shared with friends or family of the user.

III. RESULT AND DISCUSSION

Based on the survey conducted previously, it produced complete data regarding the need for improving the design of the Ethereal Lenscraft company profile website. The data includes:

Table 1. Questionnaire rating data

No	Age	Residential area	rating about responsiveness and ease of navigating the web				
Stay safe	22	Bekasi	5	4	4	5	4
Ibn	22	Bekasi	4	3	4	4	4
English: Anggiet Harjo Baskoro	19	Jakarta	3	4	4	3	3
Adzra Inas Shafira	20	Depok	5	4	5	5	5
English: Hendrawan Sito Lukmana	19	Sragen	4	3	4	4	5
Achmad Fauzie Tri Kurniawan	28	Jakarta	4	4	5	4	4
Medina Kamelia	13	South Jakarta	4	4	4	3	4
Bagasse	25	Bekasi	5	5	5	5	5
Alif Mahesha	21	Bekasi	5	5	5	5	5
Azhar Maulana Abdillah	20	Bekasi	5	5	5	5	5
Zita Fauziah	2	Bekasi	4	4	3	4	4
Afif Khairul Umam	21	Bekasi	4	3	4	5	3
Abdul Aziz	26	Tangerang	2	2	2	2	2
Muhammad Fadhil Musyaffa	21	Depok	4	4	4	3	4
Princess Alifvia Sugianto	20	Bekasi	5	5	5	5	5
Love Faeruziani	21	East Jakarta	4	4	3	3	4
fault	19	Bekasi	5	5	5	5	5
The Star of the Empress	20	Bekasi	4	4	3	4	4
zya	19	Bekasi	4	4	4	4	4
Vienta Andini Febriana	21	East Jakarta	5	4	5	5	5

Table 2. Continuation of questionnaire rating data

No	rating regarding all the information that we have displayed on the website				rating of the overall visual design of the website		
Stay safe	5	5	5	5	5	4	5
Ibn	4	4	4	4	4	4	4
English: Anggiet Harjo Baskoro	4	4	3	3	4	4	4
Adzra Inas Shafira	4	4	3	5	3	5	4
English: Hendrawan Sito Lukmana	4	4	4	3	3	4	3
Achmad Fauzie Tri Kurniawan	4	4	4	4	4	4	4
Medina Kamelia	4	4	4	4	4	4	4
Bagasse	5	5	5	5	5	5	5
Alif Mahesha	5	5	5	5	5	5	5
Azhar Maulana Abdillah	5	5	5	5	5	5	5
Zita Fauziah	5	4	4	5	5	5	4
Afif Khairul Umam	5	4	3	4	4	3	5
Abdul Aziz	3	3	2	2	3	3	2
Muhammad Fadhil Musyaffa	3	4	4	3	3	4	4
Princess Alifvia Sugianto	5	5	5	5	4	5	5
Love Faeruziani	4	4	4	3	3	4	4
fault	5	5	5	5	4	4	5
The Star of the Empress	4	4	3	4	4	4	4
zya	4	4	4	4	4	4	4

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Vienta Andini Febriana	5	5	5	5	5	5	5

From the data above, there are also several comments given by respondents, such as:

- The design is considered too quiet
- The gallery is too monotonous
- Coloring that is less cohesive with the photographic context

To see everything more clearly, you can access the forms we have created by using:

- https://forms.gle/gdu6RoaEhRS3qoCN9

Based on the problems above we redesign the website using design thinking phases such as :

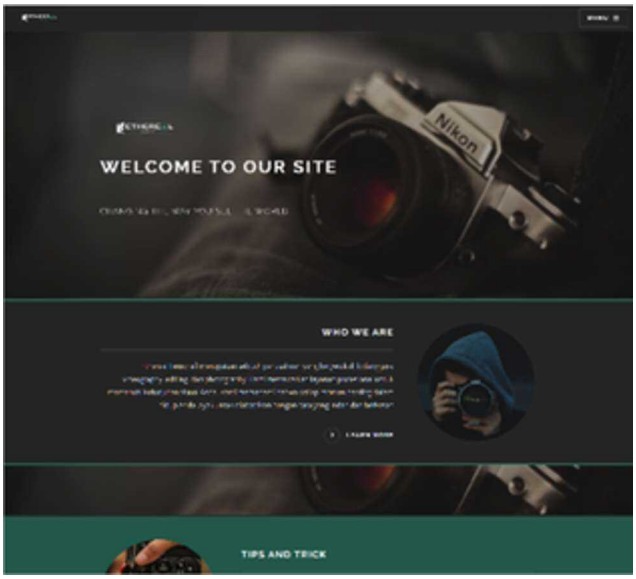
1. Empathize
   At this stage will focus on users where they need professional documentation services with many choices and support customization according to their wishes. The problem comes in the layout and coloring of the website.

2. Define
   The problems that arise in the empathize stage divide several categories of users into several parts, as follows:
   a. Ordinary users who are aged 13-28 and male or female. They think that the design is good but the coloring and layout are still lacking.

3. Ideate
   After each problem from the above categories has been defined, the solution is as follows:
   a. Create a company profile website that has a layout and colors that people in the 18-40 age range like.

4. Prototype
   Based on the previous 3 stages, the design before and after the upgrade is as follows:

Fig 7. Front page (before).



e-ISSN: 2614-8404
p-ISSN: 2776-3234

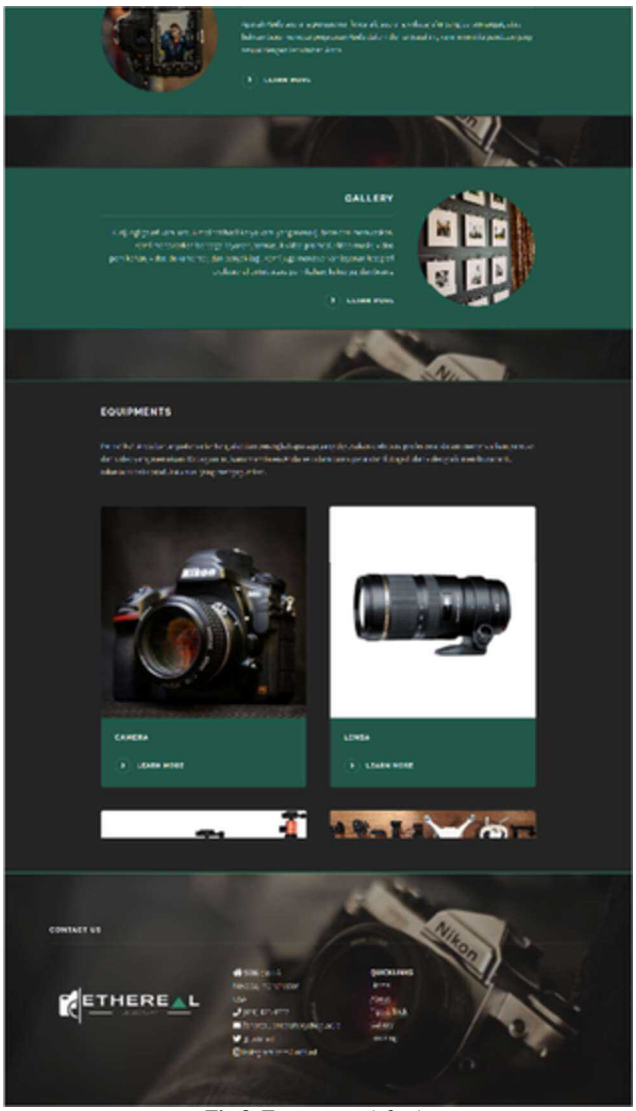
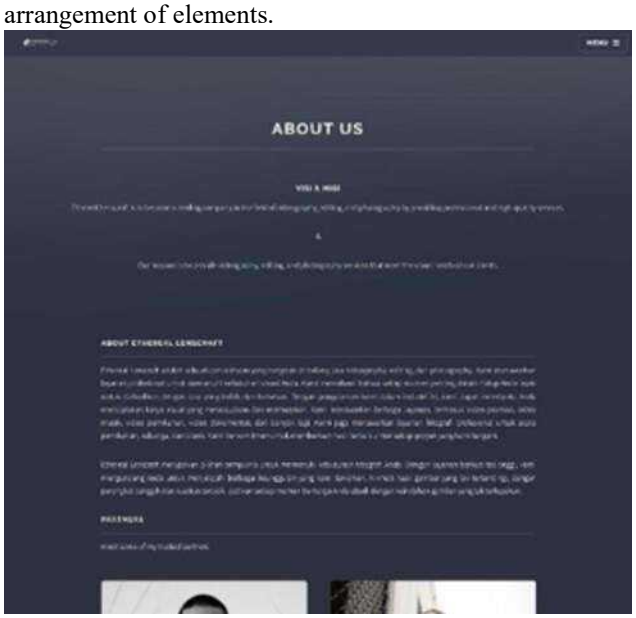


Fig 8. Front page (after).

The front page has been redesigned with coloring and design that adapts to customer desires and a neater arrangement of elements.



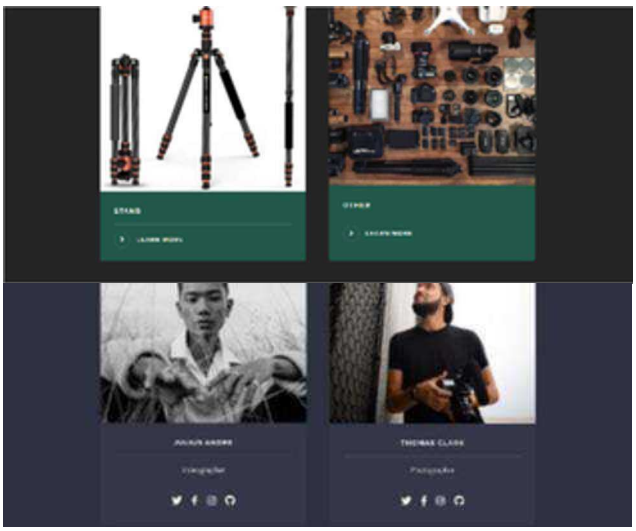


Fig 9. About page (before).

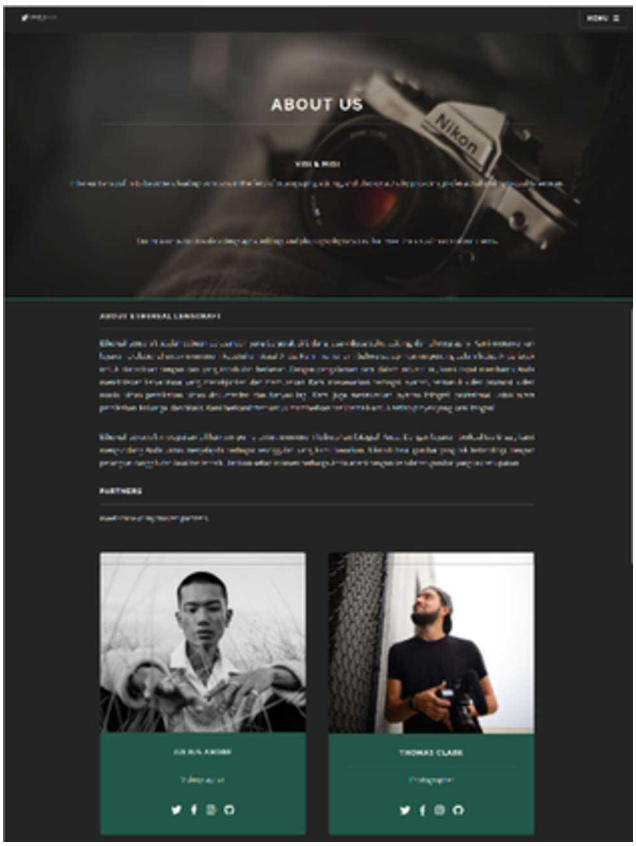


Fig 10. About page (after).

The about section is the same as the front page section where the design of both the layout and coloring are improved as well as the presentation of several explanations to reduce the level of boredom in users in order to create a longer interaction duration.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig 11. Tips And Tricks page (before).

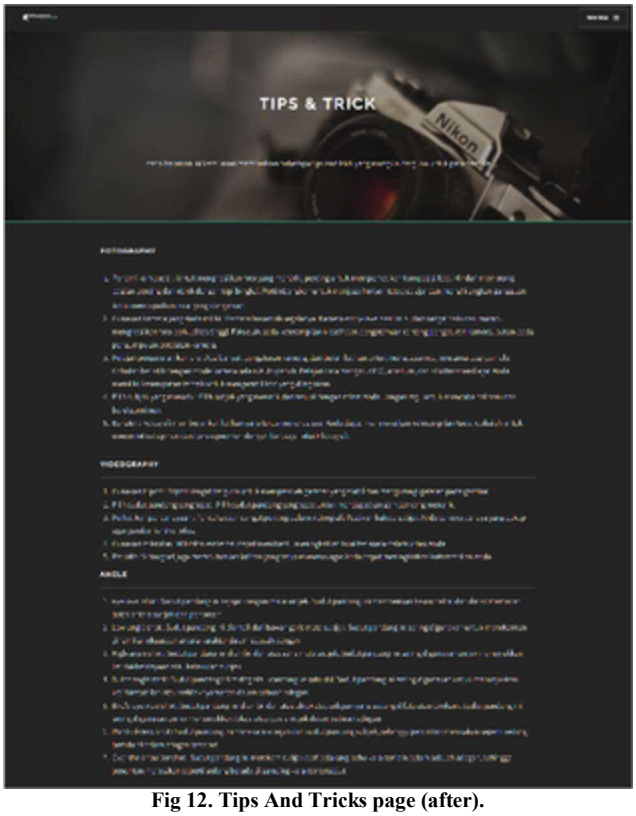
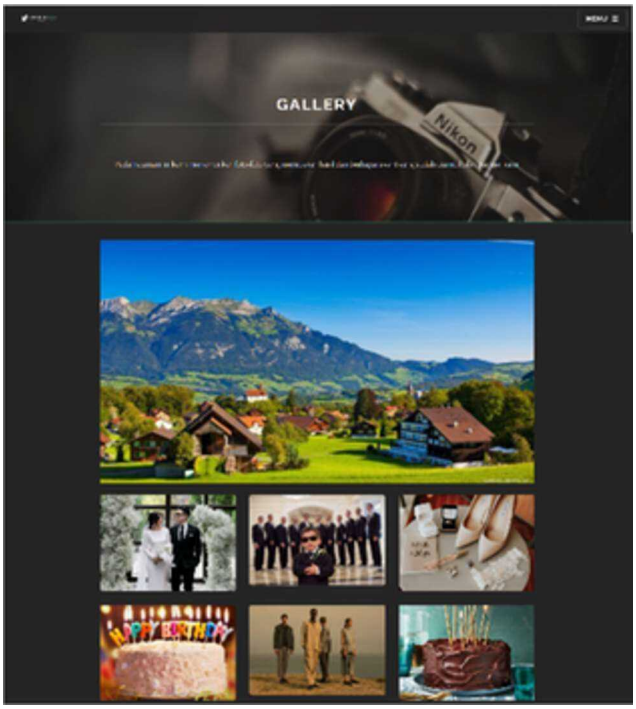


Fig 12. Tips And Tricks page (after).

Tips and tricks are one of the parts that are highlighted for improvement, this makes users want to learn a lot through the Ethereal Lenscraft company profile. Therefore, the design that was previously offered was improved to be more friendly to read for a long time and does not make people dizzy because of the contrast of the writing with the previous background.

Fig 13. Gallery page (before).



e-ISSN: 2614-8404
p-ISSN: 2776-3234

Fig 14. Gallery page (after).

The gallery page also gets a spotlight which makes the arrangement of the displayed photos larger so that users can enjoy them better.

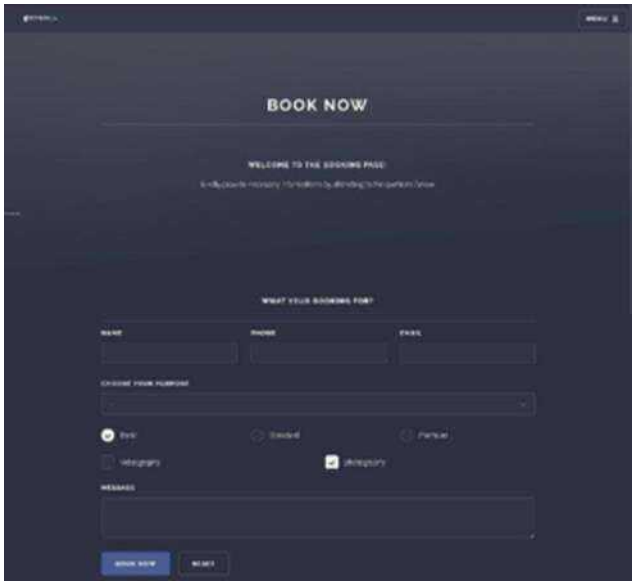


Fig 15. Booking page (before).

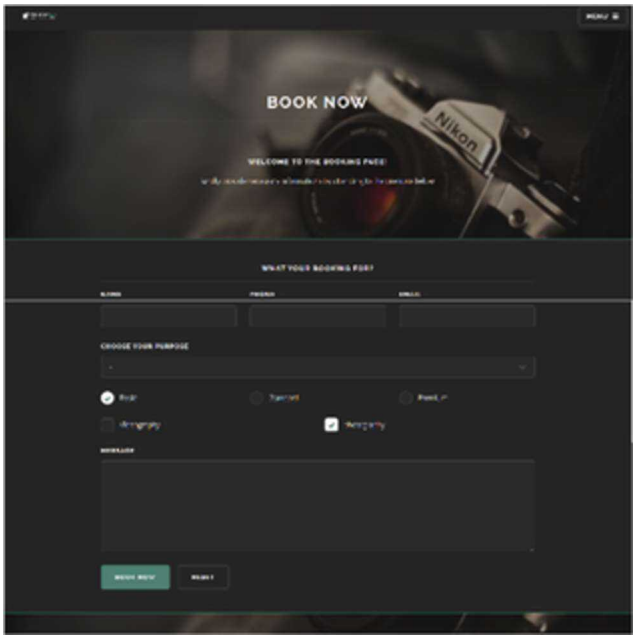


Fig16. Booking page (after).

The last figure 16 is the booking page where more or less at least 1 respondent focused on the price that will be offered, but because the improvement focuses on the part that is often glanced at, the booking section has not changed much, but it is hoped that there will be a similar improvement after some time.

The design above has adjusted to the respondents' requests and is considered better than the previous design. With this, the improvement of the UI/UX design on the Etherreal Lenscraft company profile website is declared complete because it has been accepted by the respondents.

IV CONCLUSION

In designing UI/UX design for a website, using the design thinking method is one way to ensure that the UI/UX design has good quality and has an attractive appearance and can help users when using the photography service reservation application.

By designing a Company Profile media website that has an attractive value, enhances our company image, namely Ethereal Lenscraft, and can also support promotional programs that are able to display the company's image, and have aspects of appearance, image and structured visual elements. By providing a touch of the characteristics of our company, for example the company's color identity, company logo, company motto and so on, it can create an information and promotional media that is in accordance with the company's image.

And with the results that have been listed previously, hopefully it can be a consideration for improving UI and UX for the Ethereal Lenscraft company profile. Respondents from this research are used as a reference for improving UI/UX in the future.

REFERENCES

[1] Faraz Ahmed Wajidi, Eruj Wajidi Rehan, Mahwish Saeed, Kamila Mariam Iftikhar, and Anosh Tahir, "Technology Trends and Their Impact on the E-commerce Industry," *Int. J. Soc. Sci. Entrep.*, 2023, doi: 10.58661/ijsse.v3i4.227.

[2] Hamed Taherdoost, "An Overview of Trends in Information Systems: Emerging Technologies that Transform the Information Technology Industry," *Cloud Comput. Data Sci.*, 2022, doi: 10.37256/ccds.4120231653.

[3] H. Joo, "A study on understanding of UI and UX, and understanding of design according to user interface change," *Int. J. Appl. Eng. Res.*, 2017.

[4] H. Ilham, B. Wijayanto, and S. P. Rahayu, "ANALYSIS AND DESIGN OF USER INTERFACE/USER EXPERIENCE WITH THE DESIGN THINKING METHOD IN THE ACADEMIC INFORMATION SYSTEM OF JENDERAL SOEDIRMAN UNIVERSITY," *J.*

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Tek. Inform., 2021, doi: 10.20884/1.jutif.2021.2.1.30.

[5] T. Antopani, "FOTOGRAFI, PARIWISATA, DAN MEDIA AKTUALISASI DIRI," *REKAM J. Fotogr. Telev. dan Animasi*, 2016, doi: 10.24821/rekam.v11i1.1293.

[6] M. Pande and S. V. Bharathi, "Theoretical foundations of design thinking – A constructivism learning approach to design thinking," *Think. Ski. Creat.*, 2020, doi: 10.1016/j.tsc.2020.100637.

[7] R. Bender-Salazar, "Design thinking as an effective method for problem-setting and needfinding for entrepreneurial teams addressing wicked problems," *J. Innov. Entrep.*, 2023, doi: 10.1186/s13731-023-00291-2.

[8] R. Pérez-rodríguez *et al.*, "Usability, user experience, and acceptance evaluation of capacity: A technological ecosystem for remote follow-up of frailty," *Sensors*, 2021, doi: 10.3390/s21196458.

[9] R. Bartlett, J. A. Boyle, J. Simons Smith, N. Khan, T. Robinson, and R. Ramaswamy, "Evaluating human-centred design for public health: a case study on developing a healthcare app with refugee communities," *Res. Involv. Engagem.*, 2021, doi: 10.1186/s40900-021-00273-2.

[10] I. Göttgens and S. Oertelt-Prigione, "The Application of Human-Centered Design Approaches in Health Research and Innovation: A Narrative Review of Current Practices," *JMIR mHealth and uHealth*. 2021. doi: 10.2196/28102.

[11] I. Darmawan, M. S. Anwar, A. Rahmatulloh, and H. Sulastri, "Design Thinking Approach for User Interface Design and User Experience on Campus Academic Information Systems," *Int. J. Informatics Vis.*, 2022, doi: 10.30630/joiv.6.2.997.

[12] A. A. Krishnavarty, M. Defriani, and T. I. Hermanto, "UI/UX Design for Language Learning Mobile Application Chob Learn Thai Using the Design Thinking Method," *SinkrOn*, 2022, doi: 10.33395/sinkron.v7i3.11585.

[13] D. Saputra and R. Kania, "Designing User Interface of a Mobile Learning Application by Using a Design Thinking Approach: A Case Study on UNI Course," *J. Mark. Innov.*, 2022, doi: 10.35313/jmi.v2i2.36.

[14] A. Efeoğlu and C. Moller, "Redesigning design thinking for codesign with nondesigners: a method efficiency perspective," *Des. Sci.*, 2023, doi: 10.1017/dsj.2023.11.

[15] E. Z. Dewi, M. Fransisca, R. I. Handayani, and F. L. D. Cahyanti, "Analysis and Design of UI/UX Mobile Applications for Marketing of UMKM Products Using Design Thinking Method," *Sinkron*, 2022, doi: 10.33395/sinkron.v7i4.11505.

e-ISSN: 2614-8404
p-ISSN: 2776-3234

UI/UX Design Using Design Thinking Method Based on Website Unload Repair

Anggiet Harjo Baskoro Bonari[1*)], Fajar Ariya Putra[2]
[1,2]Program Studi Teknik Informatika,Universitas Trilogi
Email:[1]anggiet.harjo@trilogi.ac.id [2]fajar.ariya@trilogi.ac.id

Abstract – Unload Repair is a PC repair service that can solve problems with computers or laptops. However, the current problem is that marketing through social media tends to be a little bit about information about service services, making it difficult for customers to receive the information. This study aims to create a User Interface (UI) and User Experience (UX) design that can make it easier for customers to see what services are provided by Unload Repair and help customers in ordering repair services using the Design Thinking method. Design Thinking is a method that involves users in every stage of design, starting from a deep understanding of their needs, to producing a prototype that can be tested to measure the effectiveness of the design. Design thinking includes the Empathize, Define, Ideate, Prototype and Testing stages. The Design Thinking method used is to create solutions based on problems in order to create designs that are easy to use and understand for users. The design was tested using Usability testing on 50 respondents, thus it was concluded that the UI/UX design on the Unload Repair website in the city of Jakarta can be used easily by users and has a positive experience based on the results of the respondents obtained and gets good satisfaction from Unload Repair website users.

Keywords – User Interface, User Experience, Website, Design Thinking.

I. INTRODUCTION

Technological progress continues to grow rapidly, with more and more tools available to people in the era of globalization. Businesses and industries related to personal and social welfare are growing due to technological progress. One of the most effective components of new development is information technology, which allows individuals to access various services provided by technology. With technological progress and the increasing need for information, the internet has experienced significant growth [1], [2] .

Website ownership has become a necessity for business people and companies in this digital era. Websites function as internet technology that can be used to promote product and service sales and convey information online[3],[4],[5]. The importance of building a strong identity that can support the existence of the company to ensure its continuity. Therefore, a media profile is needed as an identification and a way to introduce the company itself. A company profile is one type of media profile that most businesses have [6],[7], without a company profile website, Unload Repair will face several significant challenges. The company's ability to contact potential customers and build trust may be hampered by a lack of web visibility. Important information such as types of services, prices, client testimonials, and contact information will be difficult to obtain, hindering the decision-making process of potential customers. In addition, the difficulty of building business networks with potential partners and the lack of brand recognition may be significant obstacles. Unload Repair may have difficulty reaching target consumers such as students and office workers who are digitally active if they do not have a strong web presence. All of this can stimulate the growth of the company and reduce the company's capacity to operate in a competitive market.

Design Thinking is an approach that can solve various difficulties, such as making it easier for consumers to use prototypes or creating a positive user experience[8],[9],[10],[11]. Based on the problems identified in Unload Repair, it can be concluded that it is necessary to design the UI/UX of the Unload Repair Company Profile Website to make it easier for clients to find out more about the services and information offered by Unload Repair..

II. RESEARCH METHODOLOGY

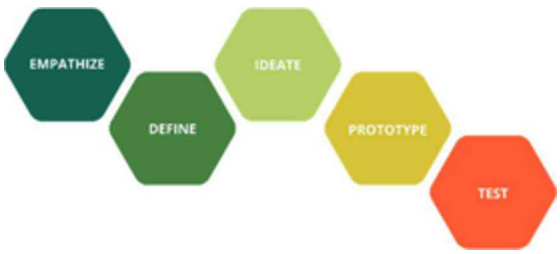


Fig 1 Design Thinking Process

Design thinking is a creative approach used to solve problems and create innovative solutions. This method focuses on deeply understanding the end user, creating new ideas, and testing those ideas to produce solutions that meet the user's needs[12],[13],[14].

e-ISSN: 2614-8404
p-ISSN: 2776-3234

The Design Thinking method is very suitable for use in the development stage of the Company Profile Unload Repair website because design thinking is very flexible to use in the design stage of this website. This stage will determine what is needed by the Company Profile Unload Repair website and adjust user needs well so as to minimize errors that occur during prototyping.

The Design Thinking approach method consists of five stages, namely Empathize, Define, Ideate, Prototype, and Test.[15]

A. Empathize
The design thinking method emphasizes human values as users as its focus. The Empathize stage, which is the foundation of design thinking, aims to identify problems and understand the needs of users and related target audiences. Empathize means understanding and sharing the feelings of the people involved to uncover the core of the problem and the needs they desire. The results of the Empathize process are data that is then used as a basis for formulating problem statements obtained through direct surveys to related parties.

B. Define
After understanding user needs, the define stage is the next step where designers develop ideas that form the basis of the product. This stage includes writing a list of user needs. Here, data from interviews is processed into statements using the HMW (How Might We) method. The HMW approach is used to formulate the core of the problem into a clear statement. The results of this define process will be a guide in building a system according to user needs.

C. Ideate
In this phase, the designer conducts an evaluation through a brainstorming process that will form the basic framework of the system. Collaboration of ideas with the team will produce solutions. The ideas collected will be represented in the form of user flow and site map to visualize the application usage pattern.

D. Prototype
Prototype is a stage in the development process that produces a visualization of the product and allows developers and consumers to be involved before the product becomes a final system. This is a prototype of the design that will be used to test the product. This prototype is then transformed into a visual representation for use in the testing phase.

E. Test
This step is a test of the prototype to determine the level of user satisfaction.

Testing provides a greater opportunity to understand user needs, thereby accelerating the improvement process according to their needs.

III. RESULT AND DISCUSSION

This research is conducted in accordance with the stages of Design Thinking, applying the method to produce appropriate results from the Company Profile Unload Repair website research for Laptop or Computer Service. The following are the stages carried out in the design thinking method in the Company Profile Unload Repair Website research:

1. Proses Empathize

The first step in designing a company profile website for Unload Repair laptop service is to understand the needs and expectations of customers regarding the services offered. The author conducted an analysis involving concerns encountered by students, school children, and office workers regarding prices and offers that are not in line with laptop service services, as well as their difficulties in finding websites about laptop services. As an adjustment, Unload Repair realizes that laptop service customers also want clarity regarding repair prices, as well as ease in viewing complete information through an attractive website so that customers can easily find out what services are provided, and also customers can easily contact Customer Service from the Unload Repair Team.

Therefore, Unload Repair is committed to understanding and meeting customer needs. Through the company profile website, Unload Repair will provide transparent information regarding what services are provided, contact customer service, and provide service offers that suit the needs of users, such as fast repair services or affordable repair service options, and users can also contact the unload repair admin easily.

Table 1. Information Collection on Concerns

No	List of Concerns
1	Limited Access to Information.
2	The Difficulty of Building a Business Network
3	Lack of trust in relatively expensive laptop service.

2. Define

After "empathize", the next step is "define". At this stage, the main goal is to determine more specific problems and determine user needs. Based on the concerns found at the empathize stage, several user needs can be identified as follows:

Table 2. User Requirement List

No.	User Requirements List
1.	The Need for Easy Access to Information

e-ISSN: 2614-8404
p-ISSN: 2776-3234

2.	The Need to Build Trust and Brand Recognition
3.	The Need to Reach Digital Consumers
4.	The Need to Build a Business Network
5.	The Need for Online Visibility

3. Ideate

In this study, the Ideate stage, where solution ideas are presented through the design team's assessment and the creativity of each application designer, is realized in images using a low-fidelity design framework as an initial step to facilitate the layout creation process for Android-based mobile applications. To avoid significant changes, this design mockup was tested with partners before the final layout design stage.

Fig 2. Design Low Fidelity Website Unload Repair

Figure 1 shows a low fidelity design or early prototype of an Unload Repair company profile website. This design consists of several pages that can be accessed by application users. Here is an explanation of each page in the design:

1. Home: is the initial display on the Unload Repair website that will appear when users access the website for the first time. On this page, the slogan of an Unload Repair website will appear.
2. Service: is a display where Unload Repair provides what services it does. In this display, it will display an explanation of services such as Thermal Paste replacement, Operating System Installation, etc.
3. Portfolio: is a display where what services have been done by the service provider, namely Unload Repair. In this display, the services that have been done will be displayed in the form of documentation and explanations of the images.
4. About: is a display that contains explanations about Unload Repair. What is Unload Repair, when was it formed, and what services does it provide.
5. Team: is a display that contains the team members working on the Unload Repair, as well as the job descriptions of its members.
6. Contact: is a display that contains a message form. This display functions if there are customers who want to require Unload Repair services.

Before proceeding with development, a low-fidelity design or early prototype is usually used to assess and test the basic features of the application. In the next stage of development, this design can be changed or adjusted according to user feedback and needs.

4. Prototype

Prototype process is the process of implementing previously created idea into an application that can be tested. This stage produces a scenario of how the application is used. The image below is the result of the prototype design that was created in the previous idea.

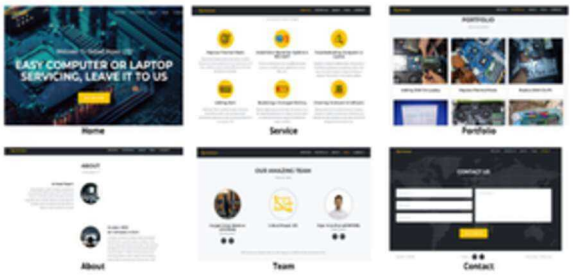


Fig 3. High Fidelity UI/UX Design Results for Unload Repair Website

The process of the Company Profile Unload Repair Website is as follows:

1. The “Home” display is the “initial” display that will first appear when a user opens the Unload Repair website.
2. The “Service” display is a display that shows what services are provided by Unload Repair, so that customers can immediately find out what services can be done by the Unload Repair Team.
3. The “Portfolio” display is a display that shows the results of work that has been done by the Unload Repair team, so that in this display customers can be confident when they want to order services from the Unload Repair Company.
4. The “About” display is a display that tells the history of the establishment of the Unload Repair company, so that prospective customers can find out the background of the Unload Repair Company.
5. The “Team” view is a view that provides team information from Unload Repair.
6. The “Contact” display is a display that is intended for prospective customers if they are sure to order services from the Company Unload Repair. There is a text field that they can fill in to make an order, after they have made an order, the admin from Unload repair will reconfirm to the Customer.

5. Testing

The testing component is part of the system testing process, which focuses on testing the application interface components. The results show that each element and menu button function according to its purpose. The SUS (System Usability Scale) method is used to test the Unload Repair

e-ISSN: 2614-8404
p-ISSN: 2776-3234

Website to assess the level of user satisfaction and ease of use. The score from the questionnaire is used to assess the ease of use of the website according to user perception. The results of the questionnaire are used to determine how easy it is to use the system or application. The SUS method can be used to assess the design thinking of the Unload Repair website and find out how users rate its ease of use. The following table contains details of the SUS method questions:

Table 3. SUS Questions

No.	Question
1.	Do you know what this website is for?
2.	Do you like the design of the main page?

The next system testing process in Unload Repair is carried out through the use of the UEQ (User Experience Questionnaire) method in gform. The main focus of testing is on Component testing, which aims to examine the components in the system, especially in terms of the interface.

Testing using the UEQ method aims to assess the overall user experience related to the functionality of the interface that has been created. From the results of this test, it can be concluded that all menu components and buttons in the application successfully direct users to the right page and operate according to their functions. For EUQ method questions can be seen in the table below:

Table 4. UEQ Method Questionnaire

No.	Question
1.	Bagaimana pendapat anda mengenai tata letak dari desain website kami? 1 2 3 4 5 Sangat Suka ○ ○ ○ ○ ○ Sangat Tidak Suka
2.	Apakah Desainnya membuat anda tertarik untuk menjelajahi lebih banyak? 1 2 3 4 5 Sangat Suka ○ ○ ○ ○ ○ Sangat Tidak Suka
3.	Seberapa mudah menavigasi website kami? 1 2 3 4 5 Sangat Suka ○ ○ ○ ○ ○ Sangat Tidak Suka
4.	Bagaimana pendaat anda mengenai desain visual pada halaman utama dan halaman service? 1 2 3 4 5 Sangat Suka ○ ○ ○ ○ ○ Sangat Tidak Suka

Table 2 List of UEQ Questions

The questionnaire consisted of 20 respondents with 30% aged 19 years, 35% aged 20 years, 15% aged 21 years, and 20% aged over 21 years. So the results for each aspect of UEQ are Attraction 1.375 clarity 1.552, efficiency 1.354, accuracy 1.377, stimulation 1.346, and authenticity 0.8555.

IV. CONCLUSION

This study found that the Unload Repair website, which was created using the Design Thinking method and evaluated using the SUS and UEQ methods, successfully passed the trial stage with positive results. By using an online questionnaire, satisfactory results were found. From these results, it is recommended to continue the development to improve the UEQ score on the novelty aspect and pay further attention to security and different appearances in website creation. In addition, it is necessary to expand the scope of the test to include more diverse respondents such as from more specific groups and from various ages.

REFERENCES

[1] S. S. S. Syahyono, "The Effect Of Structural Capital And Creative Innovation On Increasing Business Performance Of The Cibaduyut Shoes Fashion Industry In Bandung City," *Fair Value J. Ilm. Akunt. dan Keuang.*, 2019, doi: 10.32670/fairvalue.v1i2.1192.

[2] E. V. Soboleva, T. N. Suvorova, S. V. Zenkina, and M. I. Bocharov, "Developing Computational Thinking of Specialists of the Future Through Designing Computer Games for Educational Purposes," *Eur. J. Contemp. Educ.*, 2021, doi: 10.13187/ejced.2021.2.462.

[3] J. West and M. J. Malatji, "Technology Integration in Higher Education: The use of Website Design Pedagogy to Promote Quality Teaching and Learning," *Electron. J. e-Learning*, 2021, doi: 10.34190/ejel.19.6.2557.

[4] B. Liang and Y. Wang, "Using integrated marketing communications to promote country personality via government websites," *Place Brand. Public Dipl.*, 2023, doi: 10.1057/s41254-021-00221-7.

[5] H. C. L. Hsieh and H. H. Yang, "Incorporating gamification into website design to facilitate effective communication," *Theor. Issues Ergon. Sci.*, 2020, doi: 10.1080/1463922X.2019.1645920.

[6] A. Korombel and O. Ławińska, "Impact of an enterprise's company profile on social media on purchasing decisions of representatives of generation Z," *IBIMA Business Review*. 2019. doi: 10.5171/2019.671964.

[7] P. Riyadi, N. W Respati, and A. Oktaviani, "Profitability, Leverage, Firm Size and Enviromental Performance Moderated Company Profile in Company CSR Disclosure," *Int. J. Manag. Bus. Appl.*, 2022, doi: 10.54099/ijmba.v1i1.95.

[8] A. Efeoğlu and C. Moller, "Redesigning design thinking for codesign with nondesigners: a method efficiency perspective," *Des. Sci.*, 2023, doi: 10.1017/dsj.2023.11.

[9] C. Y. Huang, L. Y. Tsai, C. H. Chung, F. F. Shih, and Y. M. Wang, "The effect of design thinking

e-ISSN: 2614-8404
p-ISSN: 2776-3234

approach in interprofessional education programme of human sexuality course: A quasi-experimental design," *Nurs. Open*, 2023, doi: 10.1002/nop2.1363.

[10] K. Roth, D. Globocnik, C. Rau, and A. K. Neyer, "Living up to the expectations: The effect of design thinking on project success," *Creat. Innov. Manag.*, 2020, doi: 10.1111/caim.12408.

[11] P. Casadei, D. Gilbert, and L. Lazzeretti, "Urban Fashion Formations in the Twenty-First Century: Weberian Ideal Types as a Heuristic Device to Unravel the Fashion City," *Int. J. Urban Reg. Res.*, 2021, doi: 10.1111/1468-2427.12961.

[12] I. Darmawan, M. S. Anwar, A. Rahmatulloh, and H. Sulastri, "Design Thinking Approach for User Interface Design and User Experience on Campus Academic Information Systems," *Int. J. Informatics Vis.*, 2022, doi: 10.30630/joiv.6.2.997.

[13] A. A. Krishnavarty, M. Defriani, and T. I. Hermanto, "UI/UX Design for Language Learning Mobile Application Chob Learn Thai Using the Design Thinking Method," *SinkrOn*, 2022, doi: 10.33395/sinkron.v7i3.11585.

[14] I. Holeman and D. Kane, "Human-centered design for global health equity," *Inf. Technol. Dev.*, 2020, doi: 10.1080/02681102.2019.1667289.

[15] T. Buphate and R. H. Esteban, "Using Ideation Discussion Activities in Design Thinking to Develop EFL Students' Speaking and Critical Thinking Abilities," *Learn J. Lang. Educ. Acquis. Res. Netw.*, 2022.