



# IJD SEA

**INTERNATIONAL JOURNAL OF DATA  
SCIENCE, ENGINEERING, AND ANALYTICS**



**Volume 4,  
Number 1,  
May 2024**



**E-ISSN: 2807-1689  
ISSN: 2798-9208  
[ijdasea.upnjatim.ac.id](http://ijdasea.upnjatim.ac.id)**

# Application of Design Thinking on BPD Bali Mobile Banking

Kadek Dwi Natasya Pradnyani<sup>1</sup>, Anindo Saka Fitri<sup>2\*</sup> and Abdul Rezha Efrat Najaf<sup>3</sup>,

<sup>1</sup> Universitas Pembangunan Nasional Veteran Jawa Timur 1;  
dwinatasya45.11@gmail.com

<sup>2</sup> Information System Department, Universitas Pembangunan Nasional Veteran Jawa Timur 2; anindo.saka.si@upnjatim.ac.id

<sup>3</sup> Information System Department, Universitas Pembangunan Nasional Veteran Jawa Timur 3; rezha.efrat.sifo@upnjatim.ac.id

\* Correspondence: anindo.saka.si@upnjatim.ac.id

Vol. 04, No 01, Page 01-11.

Received: 18 April 2024

Accepted: 3 May 2024

Published: 27 May 2024

**Abstract:** The banking company, one of the country's driving forces behind economic growth, continues to innovate for its customers by harnessing technological advancements. Bank BPD Bali has also embraced this progress through the launch of BPD Bali Mobile Banking. In developing this service, it is crucial to consider functionality, usability, needs, and user comfort, including creating a compelling UI/UX design to ensure user satisfaction. In evaluating BPD Bali's mobile banking, an SUS score of 57.19 was obtained. Therefore, redesigning BPD Bali's mobile banking system using design thinking is necessary. This approach enables genuine empathy with target users and effectively develops solutions for user problems and needs. Through five stages—Empathize, Define, Ideate, Prototype, and Test—the final result is a prototype recommendation tested using SUS. The prototype testing achieved a SUS score of 79.69, indicating that users can readily accept the recommendation.

**Keywords:** Design Thinking, Evaluation Usability Testing, SUS

## 1. Introduction

The development of technology today is increasingly rapid, and various innovations in technological development bring society to a new civilization [1]. This technological advancement ushers in a world where everything can be done online and certainly affects all aspects. According to the We Are Social report on [2], internet users have reached 212.9 million as of January 2023, meaning approximately 77% of the population in Indonesia has been using the internet. The continuous advancement of technology is significantly impacting today's dynamic life, where mobility is very high. This trend gradually demands society to effectively and efficiently utilize time by leveraging technology. Enhancing innovation through technology is also being continuously developed by every banking institution to improve performance [3]. According to Piter Abdullah, in an excerpt from [keuangan.kontan.co.id](http://keuangan.kontan.co.id) [4], banking as an intermediary institution contributes 80% of the economy to the cost of consumption and production activities. The importance of banking makes banks take advantage of advances in information technology and the internet by creating innovations.

Mobile banking (m-banking) innovation is one of the opportunities for moving to digital. There are changes each year where customers who use m-banking continue to grow. Based on Bank Indonesia data, the use of mobile banking has grown 67.67% since 2021, which reached 1.90 billion times, to 3.2 billion in May 2022 [5]. Because of this trend opportunity, banks that have not previously provided m-banking services are slowly starting to offer m-banking services as they see an increase in customers using m-banking. Due to the rise in m-banking users, PT Bank Pembangunan Daerah Bali, often called Bank BPD Bali, capitalized on technological developments with the launch of the

e-banking service "BPD Bali Mobile Banking" which was released in 2015 and is available on the Play Store. Using technological developments by creating m-banking is certainly very useful for users. Still, there are complaints or feedback to Bank BPD Bali, which can be seen in the Play Store. Such as "the UI or appearance of the application being less modern, old-fashioned, and less comfortable," "does not support e-money payments such as Shopee, Dana, etc.," "The transaction process is quite complicated, one of which is the transfer feature, which has a complicated process or stage of up to three processes."

Based on the complaints, usability testing was conducted on BPD Bali's mobile banking to gain a clearer understanding. The testing was carried out using the System Usability Scale (SUS) to measure satisfaction levels. It involved a SUS questionnaire consisting of 10 statements rated on a 5-point Likert scale: "strongly disagree," "disagree," "neutral," "agree," and "strongly agree." In the usability testing evaluation, a SUS score of 57.19 was obtained. Based on the Net Promoter Score (NPS), the result falls under the detractor category. This means that consumers are disappointed with the product and will likely give negative recommendations to others [6].

Based on the identified issues, there is a specific need for problem-solving related to the user interface and user experience to delve deeper into user needs and enhance service satisfaction for M-banking BPD Bali in the future. Therefore, it is necessary to improve the user interface of M-banking BPD Bali by conducting analysis and designing UI/UX for mobile banking BPD Bali using design thinking. The design thinking method allows for genuine empathy with the target users and the effective development of solutions to address user needs and create innovation [7]. The UI/UX design in the research will go through 5 stages: Empathize, Define, Ideate, Prototype, and test. The study aims to provide solutions or recommendations to improve the user interface (UI) and user experience (UX) and enhance the m-banking services of BPD Bali.

## 2. Related Works

### 2.1. *UI (User Interface)/ UX (User Experience)*

User interface (UI) focuses on a display's beauty and color selection to create an emotional bond with users through an attractive and beautiful appearance so that the application is pleasing to the eye and users feel comfortable using it [8]. When a user or a person uses a product after using the product or even before using the product, which focuses on understanding consumer preferences and even responses in the form of emotions or physics, then this is called UX or user experience [9].

### 2.2. *Design Thinking*

Design thinking makes it possible to truly empathize with target users, develop solutions that effectively solve user problems and needs, and create innovation. The design thinking method identifies and understands users, user problems, and solutions that enable the author to define the issue from a certain point of view. Thus, it allows for the generation of as many ideas as possible and the development of innovative solutions by democratizing prototype design [10]. Design thinking has five stages: empathize, define, ideate, prototype, and test [7].

#### 2.2.1 *Empathize*

The first stage of design thinking revolves around the need and action to understand the user's problems and to grasp the overall [11]. In this stage, understanding and empathizing with the perspectives and needs of users related to the issue or challenge at hand are conducted. The focus is gathering user information, utilizing various methods and techniques, such as interviews,

observations, direct observations, and in-depth interviews, to collect information about potential users [12].

### 2.2.2 Define

The second stage after empathizing is to analyze and interpret the information gathered. This stage focuses on identifying the existing problems from the empathized results to create a plan to address the needs for the solution to be developed later [11]. The observations gathered during the empathy process are then analyzed to discover/identify the focal points of the problems faced by the users [13].

### 2.2.3 Ideate

The third stage focuses on creating and producing ideas and solutions [14]. Creative thinking at this stage is crucial to discovering innovative solutions and developing realistic solutions [11]. In this stage, efforts are made to generate as many ideas and creative concepts as possible to solve problems or address challenges identified in the defined stage [12].

### 2.2.4 Prototype

The prototype stage in design thinking is the fourth stage in the design thinking process, where models or prototypes are produced from the ideas selected in the ideation stage. These prototypes are physical or visual representations of the planned solutions, which can help understand how the solutions will function in real life [12]. It is the stage where solutions and ideas are implemented into a design that will become a product so that real users can test the resulting prototype [15].

### 2.2.5 Test

The testing stage in design thinking is where researchers test the prototype created in the previous stage, namely the prototype stage, and evaluate the user experience of the application prototype design [12]. The prototype is tested with real users in the final stage of design thinking to gather user experience feedback [15]. This testing is also conducted to assess if the design functions or operates effectively based on user needs and to gather feedback for future application enhancements [14].

## 2.3. SUS (System Usability Scale)

System Usability Scale (SUS) It is a usability test or usability of a system with a questionnaire and focuses on the user's [16]. The use of the SUS questionnaire consists of 10 statements on a 5-point Likert scale, with 5 points being ready to be, "strongly disagree," "disagree," "neutral," "agree," and "strongly agree." The interpretation of the SUS score and the calculation formula can be seen in Figures 1 and 2.

$\bar{x} = \frac{\sum x}{n}$	<p><math>\bar{x}</math> = Average SUS score</p> <p><math>\sum x</math> = Total SUS score</p> <p><math>n</math> = Total Respondents</p>
------------------------------	--

**Figure 1.** SUS Calculation Formula

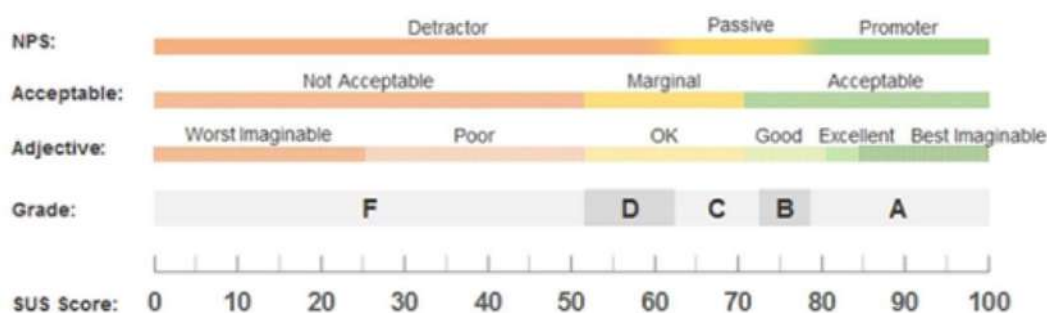


Figure 2. Score Result Interpretation SUS

#### 2.4. Figma

Figma is a graphic design application designed specifically to create prototypes and user interfaces for applications and websites [17]. It is a free design tool that can be accessed online, making it accessible even with a lower-end computer. Figma also has a supportive community that offers numerous plugins, templates, and designs to assist in building prototypes, as well as features specifically for designing prototypes or user interfaces [17].

### 3. Experiment and Analysis

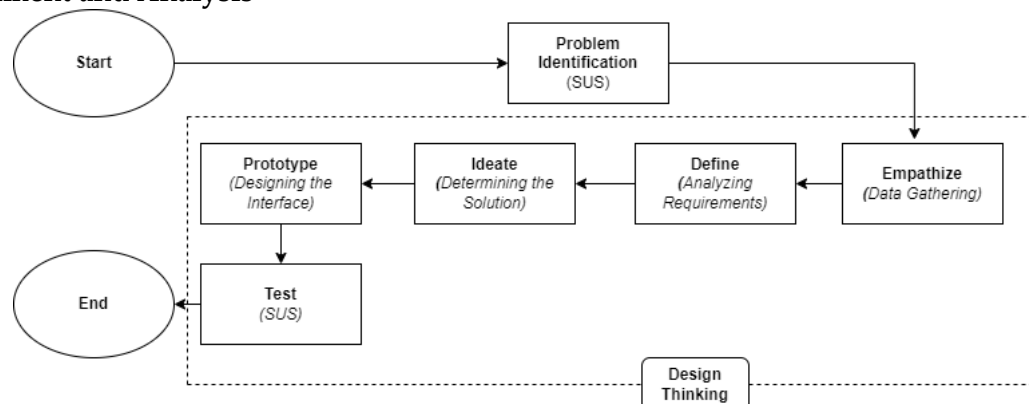


Figure 3. Methodology

This research consists of several stages or process flows carried out, as shown in Figure 3:

#### 3.1. Problem Identification

The identification process and usability testing evaluation are carried out, evaluating BPD Bali m-banking using the SUS (System Usability Scale). According to Nielsen in the quote Field [18], In the usability testing evaluation, the respondents can be five people; 5 respondents are enough to do a usability test. In testing the usability testing evaluation in this study, using 8 respondents who are customers of Bank BPD Bali.

Based on the testing conducted on BPD Bali's mobile banking, the recapitulation results can be seen in Table 1. The SUS score for BPD Bali's mobile banking in the usability testing evaluation phase is 57.19 (grade D). From the SUS score, it can be concluded that based on the adjective approach, BPD Bali's mobile banking service still falls into the OK category, with an acceptance level that is still acceptable to BPD Bali's customers. However, based on the NPS interpretation approach, the



identifying user problems by creating a user persona or a description of a user type that is fictional yet realistic according to the collected data. The user persona results can be seen in Figure 5.



**Background**  
Bintang is a civil servant who has worked in one of the government agencies for 10 years. Apart from being a civil servant, he is also a father of two children who are now in junior high school. Bintang is a man of principles, a little old-fashioned, but he is open to change.

**Usia** 39  
**Jenis Kelamin** Male  
**Status** Married  
**Pekerjaan** Civil Servant

## Bintang Angkasa

**Frustrations**

- Had a frustrating experience when purchasing PLN, as it could not find the token code, resulting in a loss. (M9)
- This application is still complicated, because you have to log in manually, and view mutations or history must always set the time manually. (M10, M5, M4)
- This application is boring because, the design is still old school and does not keep up with the times and some buttons are less visible making it difficult to find buttons. (M2, M3)
- Sometimes confused because there are too many transaction processes, such as the transfer of funds that must go through many processes. (M6, M13)

**Needs**

- Easy login (fingerprint / face id / username is displayed so that only enter the password) (M4)
- Innovative display or interface (modern design, menus using icons and grammar that are short and easy to understand, service menus directly displayed on the home page, more appropriate button size) (M1, M2, M3, M7, M11, M12)
- The transaction process in m-banking is more effective and efficient (reducing or shortening unnecessary pages, displaying transaction code information on transaction evidence, adding features that can facilitate transactions, etc.) (M1, M5, M6, M9, M10)

**Goals**

BPD Bali's innovative M-banking application keeps up with the times and offers a more efficient transaction process, making it easier for users without burdening them during transactions.

Figure 5. User Persona

### 3.4. Ideate

In the ideate stage, the process involves finding solutions or designing strategies for existing problems in the form of a user journey map and user flow.

#### 3.4.1. User Journey Map

The user journey map focuses on visualizing the flow of a customer's journey to achieve their goals in using a product or service. It is useful for understanding and addressing user needs and issues. The results of the user journey map can be seen in Figure 6.

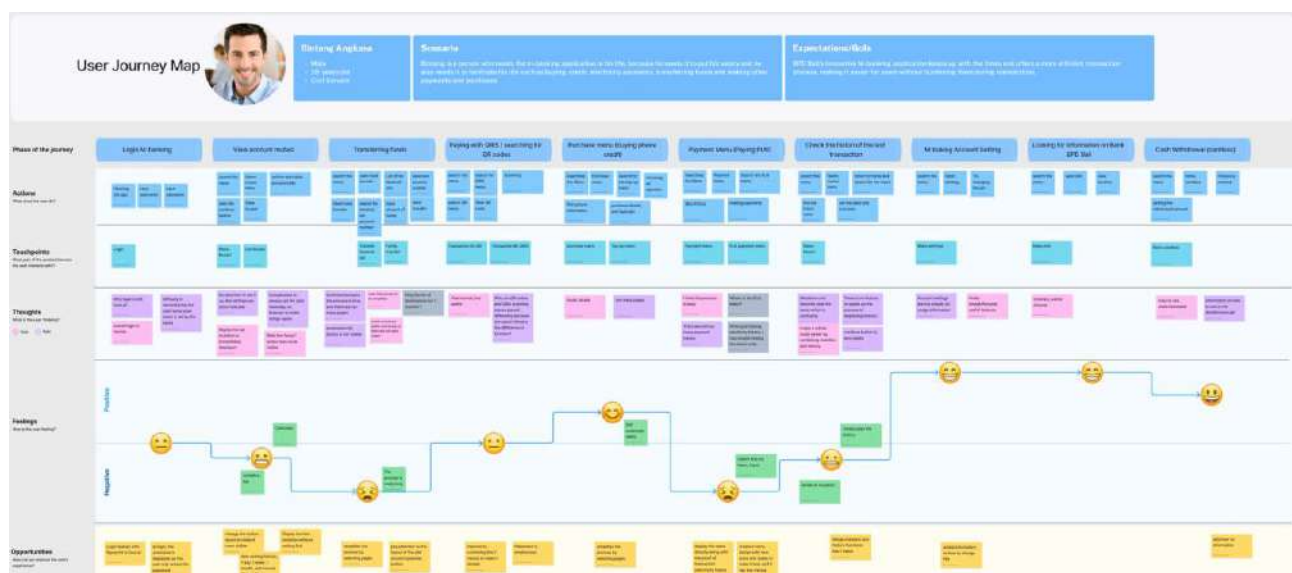


Figure 6. User Journey

Based on the findings from developing the User Journey Map, here is a detailed explanation of the revamp plan for BPD Bali's mobile banking interface, incorporating user input as depicted in Table 2.

**Table 2.** Improvement Plan

<b>Problem</b>	<b>Improvement Plan</b>
<ul style="list-style-type: none"> <li>• "Transfer dana" has long transaction steps</li> <li>• The '+' add destination button is not visible.</li> </ul>	<ul style="list-style-type: none"> <li>• Simplifying the "transfer dana" process by streamlining the page.</li> <li>• Improving the layout of the add destination account button.</li> </ul>
<ul style="list-style-type: none"> <li>• The payment menu has a large menu.</li> <li>• The placement of the electricity token code information is not efficient.</li> </ul>	<ul style="list-style-type: none"> <li>• Create a menu design with new icons and styles to make it appear more concise.</li> <li>• Display the token code simultaneously with the transaction proof (electricity token).</li> </ul>
<ul style="list-style-type: none"> <li>• "Mutation Menu" is less efficient, setting the date manually.</li> <li>• There is no speed up time setting feature.</li> </ul>	<ul style="list-style-type: none"> <li>• Displaying the latest mutation without time settings in the mutation menu.</li> <li>• Rearranging the button layout for better visibility.</li> <li>• Combining the mutation and history functions into a single "activity" menu.</li> <li>• Adding date settings feature: 1 day, 1 week, 1 month, and manual date setting.</li> </ul>
<ul style="list-style-type: none"> <li>• Menu history is less efficient, setting the date manually.</li> <li>• The position of the 'lanjut' button is not visible.</li> <li>• Similarity of Mutation and History functions creates confusion.</li> </ul>	
<ul style="list-style-type: none"> <li>• Manual login, and no easy features.</li> <li>• the login username is difficult to recall.</li> </ul>	<ul style="list-style-type: none"> <li>• Username at login is displayed by default, so only enter the password.</li> <li>• Login feature with fingerprint or face id</li> </ul>
<ul style="list-style-type: none"> <li>• The similarity of the transaction menu functions by QR and by QRIS, where users are more familiar with QRIS.</li> </ul>	<ul style="list-style-type: none"> <li>• Placement is more emphasized.</li> <li>• Combining the 2 menus to make it simpler and easier to find.</li> </ul>
<ul style="list-style-type: none"> <li>• The purchasing menu has a lengthy process page.</li> </ul>	<ul style="list-style-type: none"> <li>• Simplify the process by selecting pages</li> </ul>
<ul style="list-style-type: none"> <li>• Cardless lacks information on how to utilize its features.</li> </ul>	<ul style="list-style-type: none"> <li>• Update information on how to use</li> </ul>
<ul style="list-style-type: none"> <li>• Simple setup, no usage information available to change PIN or Password</li> </ul>	<ul style="list-style-type: none"> <li>• Addition of instructions on how to change PIN or Password</li> </ul>

### 3.4.2. User Flow

The user flow focuses on depicting the sequence of steps taken by customers to accomplish their goals. In Figure 7, one of the user flows has been created to illustrate the steps users take when logging in. There are 2 representations of user flows: the original one (user flow in the previous m-banking) and the recommended one after the changes, which aligns the login process with user



needs. This includes adding the feature of using fingerprint/face ID and displaying the username by default, so users only need to enter their m-banking password.

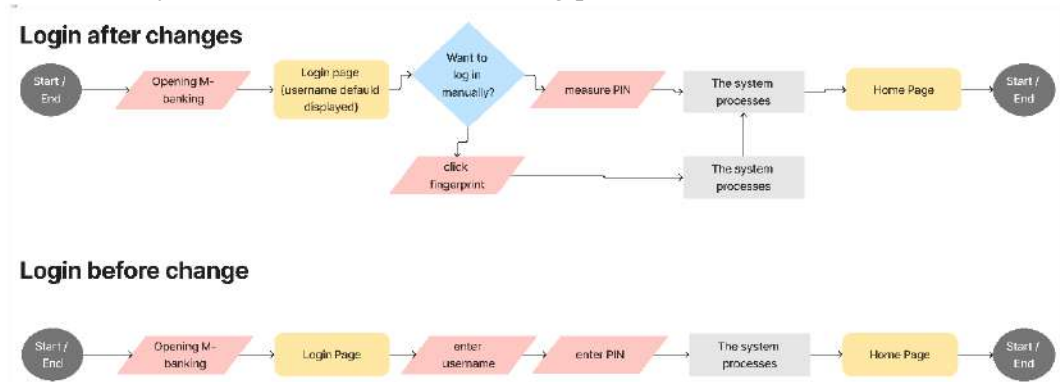


Figure 7. User Flow

### 3.5. Prototype

The prototype stage process is the phase where the redesign process of BPD Bali m-banking begins based on a collection of ideas or solutions after conducting the data collection process at the empathize, define, and ideate stages. At this stage, a high-fidelity prototype is made using Figma. According to Sommerville in the quote [16], a Prototype is used to explain a concept, trial system design, and find a problem to find the most appropriate solution. The results can be seen in Figure 8.

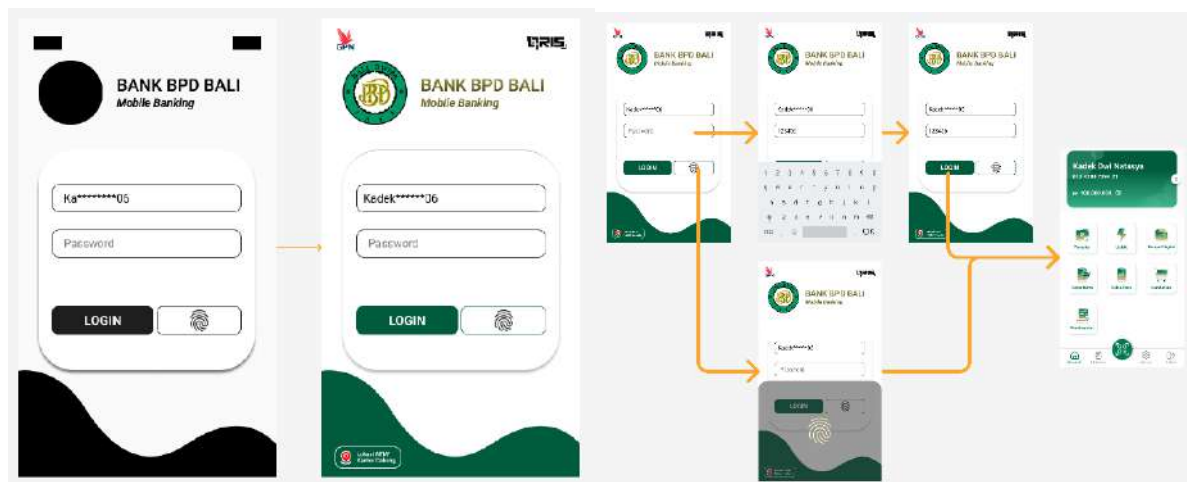


Figure 8. Prototype

### 3.6. Test

In the test stage process, the testing process is carried out on the prototype of the redesigned BPD Bali m-banking design. Testing is done using the same techniques as in usability testing evaluation. Based on the results of testing the BPD mobile banking redesign design, using think-aloud, all users gave a positive response and had a SUS value of 79.69 (grade A-), adjective, Good category, and NPS, classified as Promoter, this Promoter condition is a condition where consumers are enthusiastic about the products offered and are also interested in recommending to others [6], the SUS results can be seen in Table 3.

**Table 3.** Test Results With SUS

		SUS										Score	
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total	Grade
Respondent	R1	4	3	4	3	4	3	4	3	4	0	32	80
	R2	4	4	4	4	4	4	4	4	4	4	40	100
	R3	3	4	4	3	3	3	3	3	3	1	30	75
	R4	4	3	3	3	3	3	3	3	3	2	30	75
	R5	3	3	3	3	3	3	3	3	3	3	30	75
	R6	4	4	4	4	3	4	3	4	4	1	35	87,5
	R7	3	3	3	2	3	3	4	3	4	1	29	72,5
	R8	4	4	3	2	3	3	3	3	3	1	29	72,5
		<b>Score SUS</b>										<b>79,69</b>	

#### 4. Conclusions

Based on the research results, it can be concluded that the redesign of BPD Bali's mobile banking using the design thinking method went through 5 design processes: empathize, define, ideate, prototype, and test. The research resulted in a design solution, where the prototype testing of M-banking BPD Bali obtained a SUS score of 79.69 (grade A-), indicating that consumers are enthusiastic about the offered product and are interested in recommending it to others. In comparison, the SUS score evaluation resulted in a score of 57.19 (grade D), indicating consumer disappointment with the product and the potential for negative recommendations. Therefore, it can be concluded that the design of BPD Bali's mobile banking has been well executed and is acceptable to users, which means that the design is ready to be used as a recommendation for BPD Bali.

Drawing on the study that has been done, it is suggested that to get comprehensive results and cover all the bases, more assessment tools should be added during the testing phase. The suggested outcomes may be turned into an application or used as guidance when BPD Bali's mobile banking is built in the future.

#### References

- [1] baktikominfo.id, "DAMPAK POSITIF DAN NEGATIF PERKEMBANGAN TEKNOLOGI KOMUNIKASI DI ERA DIGITAL," 10 05 2019. [Online]. Available: [https://www.baktikominfo.id/en/informasi/pengetahuan/dampak\\_positif\\_danneгатif\\_perkembangan\\_teknologi\\_komunikasi\\_di\\_era\\_digital-806](https://www.baktikominfo.id/en/informasi/pengetahuan/dampak_positif_danneгатif_perkembangan_teknologi_komunikasi_di_era_digital-806).
- [2] dataindonesia.id, "Pengguna Internet di Indonesia Sentuh 212 Juta pada 2023," dataindonesia.id, 2023.

- 
- [3] Imamah, "PENGARUH MOBILE BANKING TERHADAP PROFITABILITAS BANK DI BURSA EFEK INDONESIA," *Jurnal Administrasi Bisnis*, vol. 15, 2021.
- [4] keuangan.kontan.co.id, "Peran perbankan sangat besar dalam menggerakkan ekonomi nasional," 17 08 2020. [Online]. Available: <https://keuangan.kontan.co.id/news/peran-perbankan-sangat-besar-dalam-menggerakkan-ekonomi-nasional>.
- [5] keuangan.kontan.co.id, "BI Catat Transaksi Mobile Banking Tembus Rp 3.888,09 Triliun hingga Mei 2022," 11 08 2022. [Online]. Available: <https://keuangan.kontan.co.id/news/bi-catat-transaksi-mobile-banking-tembus-rp-388809-triliun-hingga-mei-2022>.
- [6] B. T. Simarmata, "MENGUKUR TINGKAT KEPUASAN NASABAH DENGAN NET PROMOTER," *Jurnal Ilmiah Skylandsea*, p. 261, 2019.
- [7] A. Tankó, "Design and Development of a User Centered Mobile Application for Intermodal Public Transit in Bangkok A Design Thinking Approach," *Special Issue of the Infocommunication Journal*, 2022.
- [8] D. Yogi Irdes, KONSEP INTERAKSI MANUSIA DAN KOMPUTER, Lakeisha, 2022.
- [9] A. P. K. M. A. A. Muhammad Azmi, "Evaluasi User Experience Aplikasi Mobile Pemesanan Makanan Online dengan Metode Design Thinking (Studi Kasus GrabFood)," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer (J-PTIHK) - Vol 3 No 8*, 2019.
- [10] P. N. Winda Suci Lestari Nasution, "UI/UX Design Web-Based Learning Application Using Design," *ARRUS Journal of Engineering and Technology*, vol. 01, pp. 28-27, 2021.
- [11] D. Darma Paramartha, "Perancangan Ui/Ux Aplikasi Banten Online Menggunakan Metode Design Thinking," *Jurnal Teknologi Informasi dan Komputer - Vol. 9 No. 2*, 2023.
- [12] P. R. Muhammad Fadil Ardiansyah, "Perancangan UI/UX Aplikasi Pengolahan Limbah Anorganik Menggunakan Metode Design Thinking," *LOGIC : Jurnal Ilmu Komputer dan Pendidikan*, vol. 1, p. 842, 2023.
- [13] A. M. W. S. Sri Soedewi, "Penerapan Metode Design Thinking Pada Perancangan Website UMKMKirihuci," vol. 10, p. 85, 2022.
- [14] Y. R. R. ., T. I. H. Muhammad Adhitya, "Rancangan UI/UX Design Aplikasi Pembelajaran Bahasa Jepang Pada Sekolah Menengah Atas Menggunakan Metode Design Thinking," *JURIKOM (Jurnal Riset Komputer) - Vol. 9 No. 4*, 2022.
- [15] D. Diva Kurnia, "Implementation Of User Interface And User Experience Car Wash Service Provider Android Based Application "Spotless" Using Design Thinking Method," *Jurnal Teknik Informatika (JUTIF) - Vol.3, No. 6*, 2022.
- [16] D. Ilham Hananto, "Analisis dan Perbaikan Usability Situs Halo FILKOM menggunakan Metode Design Thinking dan System Usability Scale," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer (J-PTIHK) - Vol 6 No 11*, 2022.
- [17] Jubilee, Desain UI/UX dengan Figma dari Nol, Jubilee Digital, 2021.
- [18] M. U. A. Iryanto, "Evaluasi Usability Aplikasi SIAP TARIK Dengan Menggunakan Metode Usability Testing dan System Usability Scale (SUS) Pada Puskesmas Tarik Sidoarjo," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer*, p. 7097, 2019.

- [19] D. Dara Adhelia, "Perancangan User Experience Aplikasi Mobile Lelonesia menggunakan Metode Desain Thinking," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer (J-PTIIK)* - Vol 3 No 11, 2019.

# Prediction of the Islamic Stock Price Index and Risk of Loss Using the LSTM (Long Short-Term Memory) and VaR (Value at Risk) Methods

Ikbar Athallah Taufik<sup>1</sup>, Trimono<sup>1\*</sup> and Amri Muhaimin<sup>1</sup>

<sup>1</sup> Universitas Pembangunan Nasional "Veteran" Jawa Timur; 20083010027@student.upnjatim.ac.id

\* Correspondence: trimono.stat@upnjatim.ac.id

Vol 4, No 1, 11-22

Received: 3 April 2024

Accepted: 5 May 2024

Published: 27 May 2024

**Abstract:** Investment aims to increase the value of capital or earn additional income through asset growth, dividends or profits. One investment instrument that is in demand, especially among the Muslim community, is Islamic stocks, which are in accordance with Islamic principles that focus on a healthy economy. This research is focused on predicting Islamic stock prices using the Long Short-Term Memory (LSTM) method and measuring risk with Value at Risk (VaR) using the Cornish-Fisher Expansion (ECF) method. Stock price data from the food sector (PT Indofood), technology sector (Telkom Indonesia), and construction sector (Indocement) for the period 2018-2023 were analyzed. The results show that the ADAM model provides the best performance with the lowest prediction error rates for INTP and TLKM stocks (around 1.22%, 1.98%, and 1.41%). In addition, the SGD model shows limitations in accurate predictions with an error rate above 12%. VaR analysis reveals a slightly higher level of risk in INTP stocks, with a VaR value of around 2.85% at the 95% confidence level. Meanwhile, TLKM stock shows a lower level of risk, with a VaR of around 2.25% at the same confidence level. An in-depth understanding of the risk and growth characteristics of each stock, as well as the selection of the optimization model, are key in making wise investment decisions.

**Keywords:** Prediction; Deep Learning; LSTM (Long Short-Term Memory); Investment Risk; Value at Risk (VaR); Islamic Stock Price Index.

---

## 1. Introduction

Investment serves the purpose of increasing capital value or generating additional income through asset value growth or earnings such as interest, dividends, and capital gains [1]. Investment characteristics include the need for relatively small capital, enabling individuals with various income levels to participate. There is a swift turnover of money, with investment instruments being bought and sold in the stock market daily, providing investors with quick access and flexibility to adjust portfolios as needed. In the digital era, online platforms and financial intermediary apps make various investment instruments easily accessible, allowing for swift and straightforward investment without complex processes [2].

One impactful investment instrument is stocks, issued by companies to raise additional capital for operational and performance growth [3]. This includes Sharia stocks in Indonesia, adhering to Islamic principles and gaining popularity among the Muslim community for contributing to a healthy and Islamic-values-aligned economy.

Sharia stocks not only serve as investment tools but also play a role in inclusive and sustainable economic development, positively impacting corporate governance and business transparency [4]. However, stock prices are dynamic, leading to fluctuations, necessitating modeling to aid investors in predicting price changes.

In addition to predicting stock prices, this study focuses on predicting Value at Risk (VaR) using the Cornish-Fisher Expansion (ECF) method. VaR measures and manages potential investment risks, calculating potential losses within a specific time frame and confidence level [5]. While investment holds strong financial appeal, it is crucial to acknowledge the inherent risks (Maruddani & Astuti, 2021). The research also delves into predicting VaR risk, crucial in aiding investors to make informed decisions by integrating risk factors into their investment strategies.

Previous studies on LSTM and VaR have been conducted, emphasizing the importance of selecting the right model for risk estimation, such as the Cornish-Fisher Expansion (ECF), which considers skewness and kurtosis [6]. The research aims to deepen understanding and provide insights into the integration of risk in investment decision-making, facilitating wiser strategies and more informed choices for investors. The Sharia stock price index data for this study comes from three sectors: food (PT Indofood), technology (Telkom Indonesia), and construction (Indocement), spanning from 2018 to 2023.

## 2. Related Works

There are some methods and approaches to create a forecast model. Such as linear and non-linear. The first study titled "Analysis of Banking Sector Stock Price Prediction Using Long-Short Term Memory (LSTM) Algorithm" by Prismahardi Aji Riyantoko, presented in the Proceedings of the 2020 National Informatics Seminar (SEMNASIF 2020), focuses on utilizing LSTM for predicting stock prices in the banking sector. The author collected stock data from BRI, BNI, BTN, and Mandiri, employing LSTM as the prediction model after preprocessing the dataset, consisting of 1257 rows and 7 columns. The findings emphasized the impact of epoch variations on computational time, with larger epochs requiring more computation time. Additionally, the optimization model significantly influenced the outcomes in terms of loss and accuracy at various epoch values [7].

The second study, "Prediction of Sharia Stock Prices Using Long Short-Term Memory (LSTM)" by Gunawan Budiprasetyo, Mamluatul Hani'ah, Darin Zahira Aflah, published in the National Journal of Technology and Information System, explores the application of LSTM in predicting daily closing stock prices of five Sharia emitters. The research involved normalization, LSTM model creation, denormalization, and model evaluation. The findings revealed accurate predictive performance for all five emitters, as indicated by the obtained MAPE values [8].

Feby Seru's study, "Analysis of VAR and CVAR Risk on the Prediction of Astra International Tbk Stock Prices," published in the Journal of Silogisme - Mathematical Sciences and Learning Studies, investigates the use of Geometric Brownian Motion for predicting PT. Astra International Tbk stock prices. The study incorporates Value at Risk (VaR) and Conditional Value at Risk (CVaR) for risk prediction. The findings highlighted the VaR and CVaR values at different confidence levels, indicating a proportional relationship between risk and confidence level.

Nikanor Goreglyad's work, "The LSTM Approach for Value at Risk Prediction," conducted at Charles University, presents an approach to forecasting Value at Risk (VaR) using LSTM and compares it with traditional models such as FIGARCH and EVT-POT. The study showcased the competitive forecasting capabilities of the LSTM approach during normal volatility periods, despite the need for certain assumptions during VaR estimation.

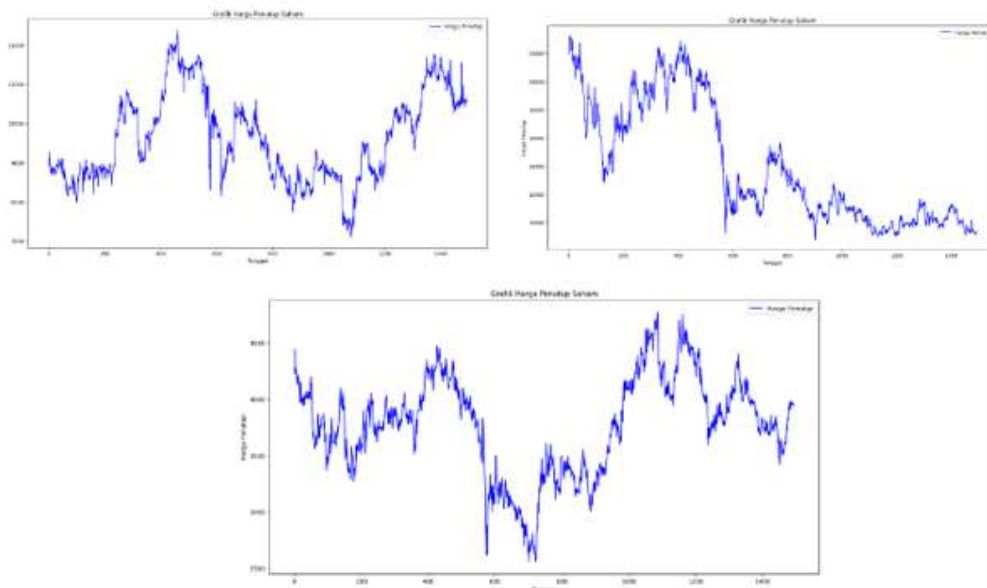
Lastly, "Optimization of Stock Portfolio with Monte Carlo Simulation for Value at Risk (VaR) Measurement" by Sarah Hardiana, Muhammad Subhan, Dewi Murni, published in UNPjoMath, delves into portfolio optimization using Monte Carlo simulation. The study used return data from LQ-45 stocks and the Composite Stock Price Index, involving various steps such as data normalization, model creation, and risk measurement. The findings revealed the optimal portfolio composition and associated risks, providing insights for investors seeking to balance risk and return in their portfolios [9].

### 3. Experiment and Analysis

The experiments conducted were to compare the optimiser in the LSTM model and perform risk prediction. Experiments included pre-processing the data, splitting the data, modelling and determining the parameters in building the LSTM model. Also, calculating the return value and calculating risk predictions for a certain period. Each treatment is carried out using stock data from three sectors, namely, ICBP, INTP and TLKM. Furthermore, the evaluation results of the computational validation of the LSTM model are shown and the risk prediction results are also displayed. Additional information that will be obtained is the best optimiser to build the LSTM model and the risk of stock losses.

#### 3.1. Dataset

In this study, stock price data from three sectors are used. The data used are the daily time series data of the stock price index from 2018 to 2023. This study uses stock price data from three sectors. The data used are daily time series data of the stock price index from 2018 to 2023. Figure 1 shows the time series of the closing variable. It also shows the graph pattern of the dataset.



**Figure 1.** ICBP, INTP, TLKM Stocks Dataset Graph

The dataset graphs show fluctuating chart patterns for the three stocks - ICBP, INTP and TLKM - within their respective sectors. Each stock index has its own unique characteristics and potential for gains or losses, and this common occurrence in stock prices reflects dynamic changes and fluctuations over time. The ICBP, INTP and TLKM stocks exhibit fluctuating data, commonly referred to as price volatility, which affects the values calculated in the model and results in different outcomes. These graphs provide valuable insight into the dynamic nature of stock prices by illustrating patterns of data that show increases, decreases or consistency over a period of time.

The horizontal line represents the date and the vertical line represents the closing price when interpreting the data graph. The date does not follow the day/month/year format. Instead, it indicates the number of changes in the closing price or the sequential occurrence of closing prices over time. The closing prices of each stock index are shown on the vertical lines. In particular, the ICBP reaches a high above 12000 and a low below 7000; the INTP reaches a high above 22000 and a low below 10000; and the TLKM reaches a high above 4500 and a low below 2500.

### 3.2. Methodology

The research methodology that has been determined will then be implemented in stages and done using the python programming language. The results and discussion of the coding work will be discussed in the section below. Starting with the stages of doing the stock price prediction process until the visual results of the prediction using LSTM, then continued with the stages of predicting risk using VaR ECF method.

In the LSTM process, the initial stage involves separating information from  $C_{t-1}$  using a forget gate. The task of this gate is to check the values of  $s_{t-1}$  and  $x_t$ , producing a value between 0 and 1 for each element in  $C_{t-1}$ . In formulation, it is as described [7], as follows:

$$f_t = \sigma(W_f \cdot [s_{t-1}, x_t] + b_f) \quad (1)$$

For elements in  $C_{t-1}$ , temporary subject information can be stored, allowing the use of appropriate pronouns. When facing a new subject, the old elements in  $C_{t-1}$  can be removed. The next stage involves an input gate that determines the values to be updated. Next, the hyperbolic tangent layer (tanh) generates a new context candidate vector, namely  $\tilde{C}_t$  (C tilde). Next, these two pieces of information are combined to update the context, and in this context, the process can be explained as follows:

$$i_t = \sigma(W_i \cdot [s_{t-1}, x_t] + b_i) \quad (2)$$

$$C_t = \tanh(W_c \cdot [s_{t-1}, x_t] + b_c) \quad (3)$$

At this time, the step to be taken is to update the old context  $C_{t-1}$  into the new context,  $C_t$ . To remove information that is no longer needed, the forget gate ( $f_t$ ) in equation (1) is used to multiply with the old context as in equation (2) and equation (3). This results in a new equation as follows:

$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t \quad (4)$$

In the output gate stage, updates will be applied to the cells and sigmoid layers to determine which parts of the context to generate. This results in the following equation:

$$o_t = \sigma(W_o \cdot [s_{t-1}, x_t] + b_o) \quad (5)$$

$$s_t = o_t * \tanh(C_t) \quad (6)$$



With:

$f_t$ : Forget gate

$i_t$ : Input gate

$o_t$ : Output gate

$c_t$ : Cell state

$s_t$ : Hidden state

$s_{t-1}$ : hidden state

$C_t$ : new candidate cell state

$\sigma$ : Sigmoid

$b_f, b_i, b_c, b_o$ : bias vector

$s_{t-1}, x_t$ : Combined value of previous hidden state and current input data

$W_i, W_f, W_c, W_o$ : Weight matrix

$\tanh$ : Target activation function with value range (-1, 1))

In conducting research on the LSTM program carried out in the python programming language, the first step is to import the required library, then retrieve or input the data that has been obtained, then perform pre-processing on the input data, then correct missing data, filtering to select appropriate features, the selected feature is the closing price on the stock price index dataset, the next process is to normalize the data with the aim of helping the features to run well when modeling and avoiding inappropriate scales.

Before entering into the computational process, the inputted dataset is divided into 2 parts, the first part for training data, and the second for test data. The training data is divided into 80% and the test data is 20%. After the data is divided into 2 parts, the next step is to make LSTM modelling. Here the model is formed and adjusted its parameters so that it can perform good computation and produce validation of training data and test data and their predictions.

To find out how well the model runs or during computing data, loss is used which is calculated using MSE. The results of loss validation are shown to see how good the model is during computation. Models that have successfully performed computations produce predicted values, to measure how well the model is in making predictions using MAPE calculations.

$$MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{Y_i - \hat{Y}_i}{Y_i} \right| \times 100 \quad (7)$$

Where:

- $n$  is the number of observations,
- $Y_i$  is the actual value, and
- $\hat{Y}_i$  is the predicted value.

**Table 1.** MAPE Evaluation

MAPE	Kategori
< 10	Accurate prediction model performance
10 – 20	Good prediction model performance
20 – 50	The performance of the prediction model is decent
21 > 50	Inaccurate prediction model performance

This table provides a general guide for evaluating model performance. The lower the MAPE value, the better the model is at predicting the data. This categorisation aids the interpretation of the evaluation results by giving an idea of how accurate the model is in terms of the percentage error relative to the actual values [8].

$$MSE = \frac{1}{n} \sum_{i=1}^n (y_i - \hat{y}_i)^2 \quad (8)$$

$n$  = Number of data samples

$y_i$  = True value of the  $i$ -th observation

$\hat{y}_i$  = Predicted value for the  $i$ -th observation given by the model.

MSE measures the average of the squared difference between the true value and the predicted value. The smaller the value of MSE, the better a model is in performing the computational process to produce predicted values [10].

Value at Risk (VaR) is a method used to measure and manage risk in investment and portfolio management. VaR describes the extent to which the value of an investment or portfolio can fluctuate in a given period of time with a certain level of confidence [11]. The basis of VaR is the recognition that all investments involve risk, and it is important for investors and risk managers to have an understanding of the extent to which potential losses can occur [6]. VaR with a confidence level of  $100(1 - \alpha)\%$  is calculated using the ECF formula :

$$S = \frac{M^3}{s^3} = \frac{\frac{1}{n} \sum_{i=1}^n (X_i - \bar{X})^3}{s^3} \quad (9)$$

$$K = \frac{M^4}{s^4} = \frac{\frac{1}{n} \sum_{i=1}^n (X_i - \bar{X})^4}{s^4} \quad (10)$$

Where:

$S$ : A measure of the degree of skewness

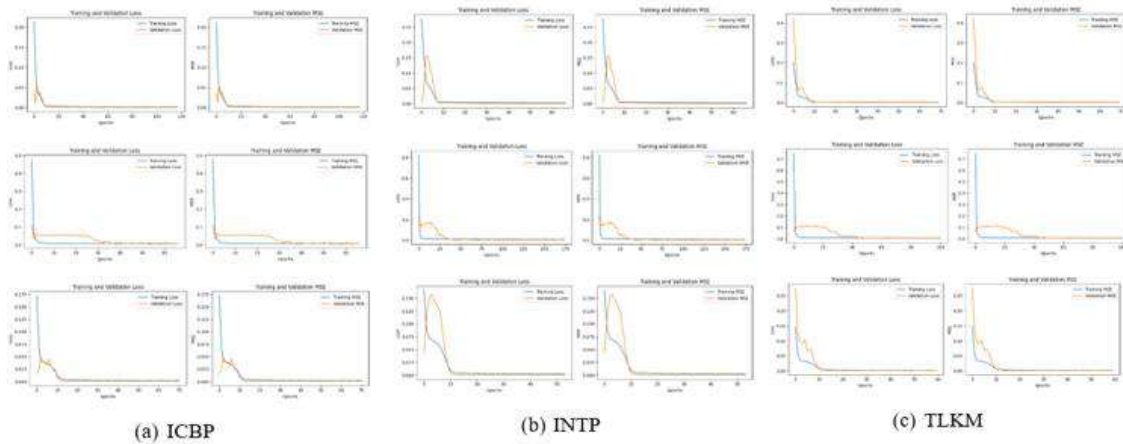
$K$ : A measure of the degree of skewness

$n$ : Number of data

$X_i$ : The  $i$ -th data

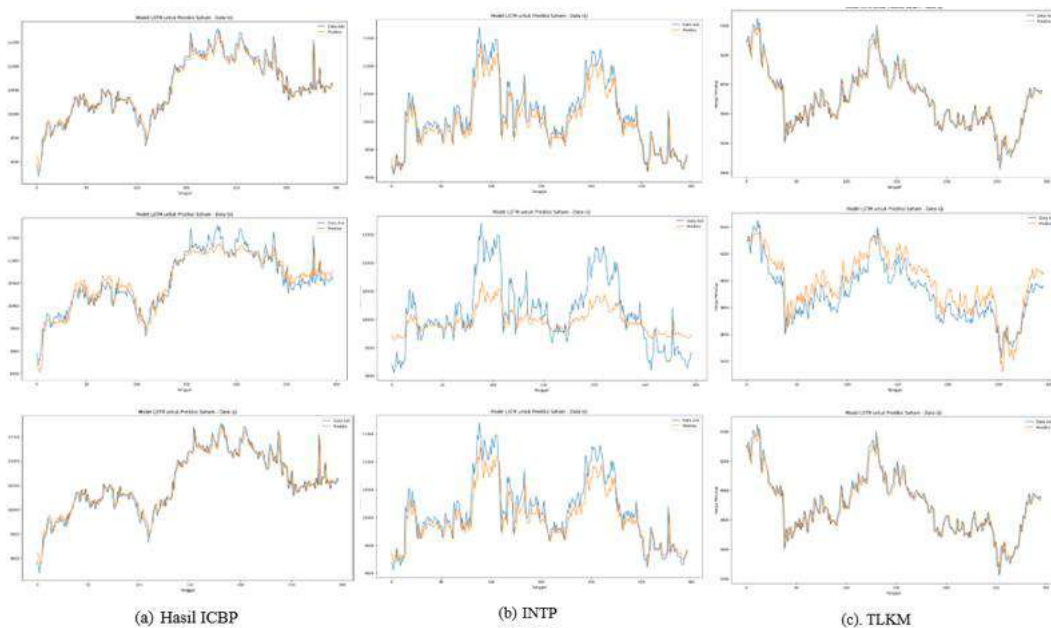
$s$ : Standard deviation

### 3.3 Prediction Using LSTM



**Figure 2.** Model validation results on the training data

From figure 2. the top result is the ADAM optimiser, the middle is SGD, and the bottom is RMSprop, these are the validation results on the training data. Optimisations such as ADAM, SGD, and RMSprop were evaluated for three stocks: ICBP, INTP, and TLKM. RMSprop showed the best performance on ICBP stock with a MAPE of 1.27% and MSE of 0.0019, while ADAM had the smallest MAPE of 1.22%. On INTP stock, ADAM has the lowest MAPE of 1.98%, although the MSE is quite high at 0.0023. For TLKM stock, ADAM came back with the smallest MAPE of 1.41% and MSE of 0.0017. However, SGD showed the poorest performance across all stocks with a MAPE above 12%, showing limitations in better prediction.



**Figure 3.** Prediction Results

From the prediction results of the test data, various optimisation models such as ADAM, SGD, and RMSprop were evaluated for ICBP, INTP, and TLKM stocks. For ICBP stock, RMSprop has a slightly lower MAPE than ADAM, which is 2.03%, and MSE 0.00091. For INTP stocks, ADAM has the lowest MAPE of 2.63%, with a lower MSE than SGD and RMSprop, which is 0.0024. For TLKM stock, ADAM returns as the optimiser with the smallest MAPE, 1.30%, and MSE of 0.0006. It should be noted that SGD showed the lowest performance with a significant MAPE, the lowest in the test data validation results of 30.25%, indicating the limitations of the model in predicting the test data, although it has not reached the desired level of accuracy.

The following are the results of the training and test data presented in table form to see the overall evaluation more easily, as follows:

**Tabel 2.** Training Data Evaluation Results on 3 Stocks

Model	ICBP			INTP			TLKM		
	Loss	MAPE	MSE	Loss	MAPE	MSE	Loss	MAPE	MSE
<b>ADAM</b>	0.0018	1.22 %	0.0018	0.0023	1.98%	0.0023	0.0017	1.41 %	0.0017
<b>SGD</b>	0.0070	12.69%	0.0070	0.0066	14.51%	0.0066	0.0048	13.18%	0.0048
<b>RMSprop</b>	0.0019	1.27%	0.0019	0.0027	2.39%	0.0027	0.0019	1.54%	0.0019

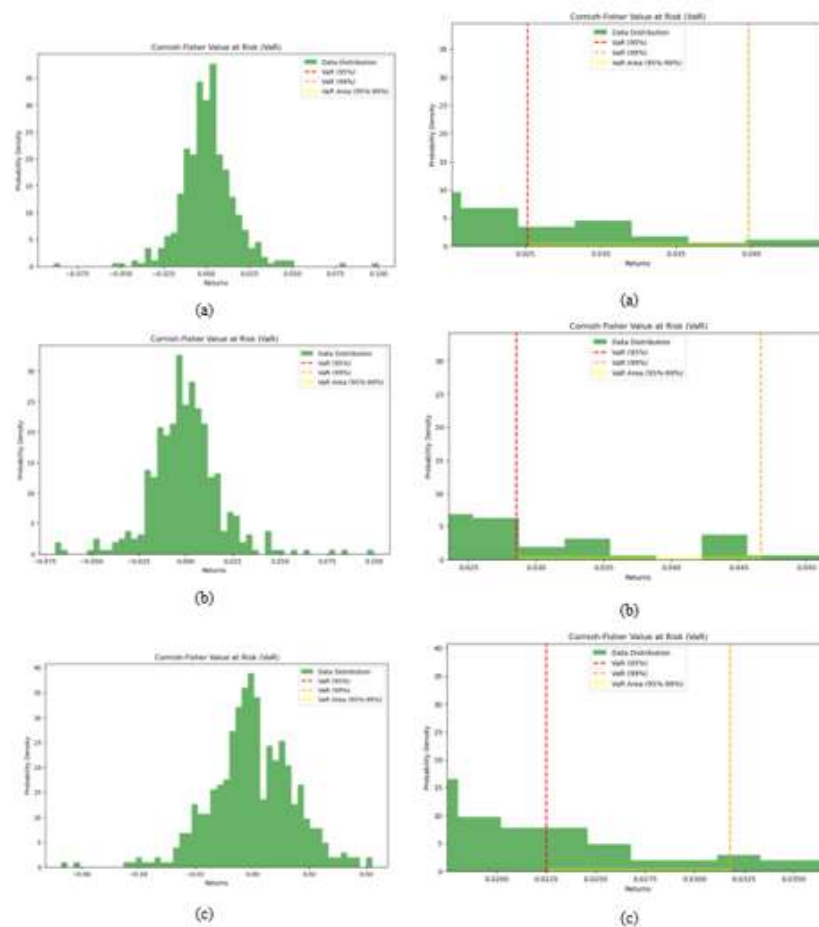
**Tabel 3.** Test Data Evaluation Results on 3 Stocks

Model	ICBP			INTP			TLKM		
	Loss	MAPE	MSE	Loss	MAPE	MSE	Loss	MAPE	MSE
<b>ADAM</b>	0.00092	2.04%	0.00092	0,0024	2.63%	0,0024	0.0006	1.30%	0.0006
<b>SGD</b>	0.0013	11.47%	0.0013	0,0088	30,25%	0,0088	0.0025	20.44%	0.0025
<b>RMSprop</b>	0,00091	2.03%	0,00091	0,00029	3.78%	0,00029	0.0007	1.41%	0.0007

From the training data validation table, the evaluation of various optimisation models such as ADAM, SGD, and RMSprop for ICBP, INTP, and TLKM stocks revealed that RMSprop showed the best performance on ICBP with a MAPE of 1.27% and MSE of 0.0019, while ADAM had the smallest MAPE of 1.22%. On INTP, ADAM has the lowest MAPE of 1.98%, albeit with a fairly high MSE of 0.0023. For TLKM, ADAM returns as the optimiser with the smallest MAPE of 1.41% and MSE of 0.0017. Nonetheless, SGD showed the poorest performance across all stocks with a MAPE above 12%, indicating limitations in better prediction. Reviewing the test data validation results, RMSprop was slightly lower than ADAM on ICBP, with a MAPE of 2.03% and MSE of 0.00091. On INTP, ADAM has the lowest MAPE of 2.63%, with a lower MSE than SGD and RMSprop, at 0.0024. For TLKM, ADAM returns as the optimiser with the smallest MAPE of 1.30% and MSE of 0.0006. It should be noted that SGD showed the lowest performance with a significant MAPE, the lowest in the test data validation result of 30.25%, indicating the model's limitation in predicting the test data, although it has not reached the desired level of accuracy.

### 3.3 Risk Prediction Using VaR

The second programme is to measure the level of risk present in the stock data. However, before getting the results of risk prediction or Value at Risk value, there are several processes and programming that must be carried out. These processes are, importing the library needed to run the programme, retrieving the return value of the close variable in the database, the dataset to be used is determined in the 2022-2023 period only, this is done because the desired result is the result of risk prediction with new data information so as to produce the latest value and the latest risk information. Calculate the VaR function, using Cornish-Fisher Expansion. Then, calculate VaR with a certain level of confidence, namely, 95% and 99%. Next, display the visualisation results and the VaR area results.



**Figure 4.** (a) ICBP VaR Result, (b) INTP VaR Result, (c) TLKM VaR Result

In the Value at Risk (VaR) prediction analysis for ICBP, INTP, and TLKM stocks at the 95% and 99% confidence levels, it can be seen that ICBP stocks show a well-controlled level of risk. The VaR at the 95% confidence level is 0.0251 and 99% is 0.0398, indicating that the daily loss at the 95% confidence level is not expected to exceed 2.51% of the portfolio value, while at the 99% confidence level, the daily loss limit is not expected to exceed 3.98%. The histogram analysis of returns is also supportive, showing the majority distribution is on the positive side, reflecting positive growth with reasonable fluctuations. In contrast, INTP stock has a slightly higher level of risk, with a VaR at the 95% confidence level of 0.0285 and 99% of 0.0466. Nonetheless, the return histogram shows significant positive growth, providing a balanced picture between risk and potential gain.

When VaR is applied to TLKM shares, a lower level of risk can be seen with VaR at 95% confidence level of 0.0225 and 99% of 0.0318. This indicates that at the 95% confidence level, the daily loss of TLKM stock is not expected to exceed 2.25% of the portfolio value, and at the 99% confidence level, the daily loss limit is not expected to exceed 3.18%. The return histogram also shows a distribution of values that are mostly on the positive side. Overall, VaR analysis and return histograms provide useful information for investors to make wiser investment decisions, considering the level of risk and potential profit in accordance with their respective preferences.

#### 4. Conclusion

Based on the research of stock price prediction using deep learning LSTM architecture model on ICBP, INTP, and TLKM stocks, as well as risk analysis using Value at Risk Cornish-Fisher Expansion method, some important findings can be concluded. First, the performance of the LSTM model is strongly influenced by the choice of optimiser, where ADAM generally gives the best results and is better than RMSprop and SGD which need further improvement. Secondly, VaR analysis at 95% and 99% confidence level shows that ICBP and TLKM stocks have a controlled risk level, while INTP stocks have a slightly higher risk level.

For further development, research can focus efforts on improving the LSTM model by exploring various hyperparameter settings and model structures. More diverse hyperparameter tuning processes, including learning rate tuning, can be applied to improve model performance. In addition, other strategies in the use of VaR can be explored, or alternative VaR methods can be used to compare the risk analysis results of various approaches. These steps can further contribute to the understanding and development of stock price prediction and risk management in financial markets.

**Author Contributions:** Athallah Taufik is the person who wrote this paper and analysed the LSTM and VaR methods. The concept of this paper came from Trimono. In addition, Muhaimin provided input and improvements to the model.

**Funding:** This research received no external funding.

**Data Availability Statement:** This data is collected by expert investment managers. Access to this data can be checked at <https://finance.yahoo.com>

**Acknowledgment:** Thanks to everyone who always be there for me, especially my parents.

**Conflict of Interest:** The authors declare no conflict of interest.

---

**References**

- [1] D. Tambunan, "Investasi Saham di Masa Pandemi COVID-19," *Widya Cipta J. Sekr. dan Manaj.*, vol. 4, no. 2, pp. 117–123, 2020, doi: 10.31294/widyacipta.v4i2.8564.
- [2] D. Chandra, A. T. Ramaningtyas, and L. Hakim, "Penerapan Breadth First Search Untuk Mengelola Keuangan Dengan Menentukan Karakteristik Investasi Individu," *J. Tek. Inform. UNIKA St. Thomas*, vol. 06, pp. 395–402, 2021, doi: 10.54367/jtiust.v6i2.1561.
- [3] S. Elviani, R. Simbolon, and S. P. Dewi, "Faktor-Faktor Yang Mempengaruhi Harga Saham Perusahaan Telekomunikasi," *J. Ris. Akunt. Multiparadigma*, vol. 6, no. 1, pp. 29–39, 2019.
- [4] Via Sukmaningati and Fadlilatul Ulya, "Keuntungan Investasi di saham syariah," *J. Investasi Islam*, vol. 5, no. 1, pp. 59–68, 2021, doi: 10.32505/jii.v5i1.1648.
- [5] Q. P. Nguyen, Z. Dai, B. K. H. Low, and P. Jaillet, "Value-at-Risk Optimization with Gaussian Processes," *Proc. Mach. Learn. Res.*, vol. 139, pp. 8063–8072, 2021.
- [6] R. Andespa, D. A. I. Maruddani, and T. Tarno, "Expected Shortfall Dengan Ekspansi Cornish-Fisher Untuk Analisis Risiko Investasi Sebelum Dan Sesudah Pandemi Covid-19 Dilengkapi Gui R," *J. Gaussian*, vol. 11, no. 2, pp. 173–182, 2022, doi: 10.14710/j.gauss.v11i2.35457.
- [7] P. A. Riyantoko, T. M. Fahrudin, and K. Maulida, "ANALISIS PREDIKSI HARGA SAHAM SEKTOR PERBANKAN MENGGUNAKAN ALGORITMA LONG-SHORT TERMS MEMORY," vol. 2020, no. Semnasif, pp. 427–435, 2020.
- [8] G. Budiprasetyo, M. Hani'ah, and D. Z. Aflah, "Prediksi Harga Saham Syariah Menggunakan Algoritma Long Short-Term Memory (LSTM)," *J. Nas. Teknol. dan Sist. Inf.*, vol. 8, no. 3, pp. 164–172, 2023, doi: 10.25077/teknosi.v8i3.2022.164-172.
- [9] B. R. Zain, C. D. Indrawati, and P. S. Murdapa, "Analisis Simulasi Monte Carlo VAR ( Value at Risk ) dan Maximum Entropy Bootstrap untuk Menghitung Total Loss pada Kasus PT . X," *Semin. dan Konf. Nas. IDEC*, no. 2010, p. E03.1-E03.6, 2021.
- [10] H. Mustafidah and S. N. Rohman, "Mean Square Error pada Metode Random dan Nguyen Widrow dalam Jaringan Syaraf Tiruan Mean Square Error on Random and Nguyen Widrow Method on Artificial Neural Networks," *Sainteks*, vol. 20, no. 2, pp. 133–142, 2023, doi: 10.30595/sainteks.v20i2.19516.
- [11] A. Arimond, D. Borth, A. G. F. Hoepner, M. Klawunn, and S. Weisheit, "Neural Networks and Value at Risk," *SSRN Electron. J.*, 2020, doi: 10.2139/ssrn.3591996.
- [12] Sethia, A., & Raut, P. (n.d.). Application of LSTM , GRU and ICA for Stock Price Prediction. Springer Singapore. <https://doi.org/10.1007/978-981-13-1747-7>
- [13] Shrestha, A., & Mahmood, A. (2019). Review of deep learning algorithms and architectures. *IEEE Access*, 7, 53040–53065. <https://doi.org/10.1109/ACCESS.2019.2912200>
- [14] Tambunan, D. (2020). Investasi Saham di Masa Pandemi COVID-19. *Widya Cipta: Jurnal Sekretari Dan Manajemen*, 4(2), 117–123. <https://doi.org/10.31294/widyacipta.v4i2.8564>
- [15] Via Sukmaningati, & Fadlilatul Ulya. (2021). Keuntungan Investasi di saham syariah. *Jurnal Investasi Islam*, 5(1), 59–68. <https://doi.org/10.32505/jii.v5i1.1648>
- [16] Zain, B. R., Indrawati, C. D., & Murdapa, P. S. (2021). Analisis Simulasi Monte Carlo VAR ( Value at Risk ) dan Maximum Entropy Bootstrap untuk Menghitung Total Loss pada Kasus PT . X. *Seminar Dan Konferensi Nasional IDEC, 2010, E03.1-E03.6*.