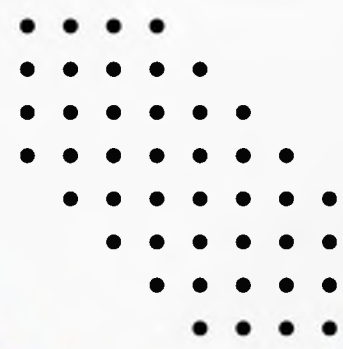


2023 11th International Conference on Cyber and IT Service Management (CITSM) | 979-8-3503-0596-8/23/\$31.00 ©2023 IEEE | DOI: 10.1109/CITSM60085.2023.10455409

CITSM 2023 Proceeding

ISBN

979-8-3503-0596-8



2023 11th International Conference on Cyber and IT Service Management (CITSM)

Makassar, Indonesia
(Hybrid Conference)

November 10-11, 2023

ISBN: 979-8-3503-0596-8

2023 11th International Conference on Cyber and IT Service Management (CITSM)

Makassar, Indonesia (Hybrid)

Phone: +6281384175979

Email: contact.citsm@uinjkt.ac.id

Website: <https://citsm.id>

November 10-11, 2023

ISBN: 979-8-3503-0596-8

2023 11th International Conference on Cyber and IT Service Management (CITSM)

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ISBN: 979-8-3503-0596-8

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Curran Associates, Inc.

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Table of Contents

Online Compulsive Buying Behavior after Outbreak in Java – Big Cities.....	1
<i>Sevenpri Candra, Christian Christian and Leoni Rizki Adlinma</i>	
Information Security Failures Measured and ISO/IEC 27001:2022 Controls Ranked by GDPR Penalty Analysis.....	6
<i>Mikko Suorsa and Petri Helo</i>	
The Success of Higher Education Institutional Policy Is Determined by IT Leadership and IT Infrastructure	11
<i>Herlino Nanang, Husni Teja Sukmana, Yusuf Durachman, Viva Arifin, Dewi Khairani and Siti Ummi Masruroh</i>	
Deep Learning-Based Disaster Sentiment Analysis of Unbalanced Twitter Data: The Case of Indonesia Earthquake	16
<i>Rona Nisa Sofia Amriza and Sena Wijayanto</i>	
Examining the Determinants of Open Government Data Adoption: An Indonesian Case ..	22
<i>Dede Puji Setiono, Evaewero French and Abdul Ilman</i>	
An Analytic Study of Learning Management System in Higher Education	28
<i>Cicilia Sriliasta Bangun, Harmaini Harmaini, Sugeng Santoso, Chandra Lukita, I Komang Mertayasa, Irene Avillya Zahra and Bayu Ajie Putra Seno</i>	
Digital Ringgit: A New Digital Currency with Traditional Attributes.....	33
<i>Nur Azman Abu, Zulkarnain Kedah, Untung Rahardja, Blasius Erik Sibarani, Sandy Kosasi, Susanti Dewi and Ihya Syihabul Fadli</i>	
Renewable Energy Transition Towards Sustainable Development: Benefits, Constraints, and Policy Guidance	39
<i>Ardi Ardi, Imam Ma'Ruf, David Arayoga Saka, Nuke Puji Lestari Santoso, Maulana Yusuf, Po Abas Sunarya and Ida Faridah</i>	
Technology Adaptation for ShopeeFood's Digital Transformation Empowers Driver Partners in Bogor City	46
<i>Musfiah Saidah and Fadhli Naufal</i>	
Systematic Literature Review: User Acceptance Analysis of Digital Banking Applications.	51
<i>Hofifah Isma Adauwiyah, Yusuf Durachman and Muhamad Nur Gunawan</i>	
Digital Transformation in Reading Behavior A Business Model Canvas Approach for Marketing E-Books Library	56
<i>Chandra Lukita, Muhammad Wali, Richard Andre Sunarjo, Eka Purnama Harahap, Fitra Putri Oganda and Nimatul Khojfah</i>	
Implementation of Goods Loss Prevention Tools Using Electronic Article Surveillance (EAS)	64
<i>Mochamad Heru Riza Chakim, Padeli Padeli, Richard Andre Sunarjo, Lisma Nur Azizah, Yulia Putri Ayu Sanjaya and Marviola Hardini</i>	
Covid-19 Systematic Overview Decentralization Using Blockchain Technology	69
<i>Surono Surono, Bob Subhan Riza, Andri Ma'Mun, Ahmad Ramadan, Rosdiana Rosdiana and Natasya Aprila Yusuf</i>	

CCTV Camera With Intelligence Technology to Minimize Chicken Mortality Due to Hazardous Gas	75
<i>Mukti Budiarto, Hindriyanto Dwi Purnomo, Budhi Kristianto, Henderi Henderi, Sedy Zul Friandi and Ananda Alifia Putri</i>	
Comparison Between Bi-Directional LSTM And Transfer Learning in Correcting Typing Errors on Twitter Social Media Posts	82
<i>Arif Lubis, Santi Prayudani and Muhammad Luthfi Hamzah</i>	
Developing Instruments for Digital Talent Competence Using Partial Least Square-Based Models	87
<i>Mochamad Wahyudi, Mochamad Heru Riza Chakim, Henderi Henderi, Sudaryono Sudaryono, Dimas Bagus Saputra, Muhamad Viktor A Sin and Reymund Rahardja</i>	
Comparison of Single Exponential Smoothing And Holt-Winter Exponential Smoothing Methods in Sales Commercial Business	96
<i>Arini Arini, Fahmi Nur Maulana, Hendra Bayu Suseno and Iik Muhamad Malik Matin</i>	
Microfinance Management Strategy Using Poverty Reduction Technology	102
<i>Raden Heriyanto, Tatik Mariyanti and Achani Rahmania Az Zahra</i>	
Analysis of Changes in Sentiment towards COVID-19 Vaccination in Indonesia Using the Convolutional Neural Network	107
<i>Dian Sa'Adillah Maylawati, Muhammad Thariq Sabiq Bilhaq, Agung Wahana, Diena Rauda Ramdania, Eva Nurlatifah and Muhammad Ali Ramdhani</i>	
QR Mobile Payment Adoption Using UTAUT Model Development	113
<i>Asrul Sani, Galih Surono, Nur Nawaningtyas Pusparini, Merliani Ivone, Ade Davy Wiranata and Tri Haryanto</i>	
Analyze and Measure Website Quality Using WebQual 4.0, Importance Performance Analysis Methods and GTMetrix	118
<i>Nia Kumaladewi, Muhammad Muhammad, Elsy Rahajeng and Basyir Arif</i>	
WebQual 4.0 Plus: An Approach to Measure Customer Satisfaction toward Website Quality	124
<i>Qurrotul Aini, Elvi Fetrina and Nadila Chataliya Epriani</i>	
Convolutional Neural Network Algorithm for Yoga Pose Estimation System as an Exercise Assistant	130
<i>Dian Sa'Adillah Maylawati, Difa Andika, Cecep Nurul Alam, Jumadi Jumadi, Ichsan Taufik and Muhammad Ali Ramdhani</i>	
Multilabel Sentiment Analysis of Hate Speech Using the Combination of IndoBERT Lite and Bidirectional LSTM-CNN Methods with Grid Search Hyperparameter Optimization ..	136
<i>Khodijah Hulliyah, Fenty Eka Muzayyanah and Bayu Aji Setyawan</i>	
Analysis of the Successful Implementation of The PeduliLindungi Application Using the Delone & McLean Model	141
<i>Meinarini Catur Utami, Suci Ratnawati and Fifi Alfisa Fitri</i>	
Comparative Analysis of Key Management Service Performance on AWS, Google Cloud, and Oracle Cloud with Load Testing, Stress Testing, and Benchmark Testing	146
<i>Aries Susanto, Ahnaf Hadi Fathulloh, Nuryasin Nuryasin and Aida Fitriyani</i>	

Systematic Literature Review: Key Management Service For Securing Encryption Key ...	152
<i>Aries Susanto, Ahnaf Hadi Fathulloh, Nuryasin Nuryasin and Aida Fitriyani</i>	
Exploring User Behavior of mHealth Application: A Study of Determinants of Continuanance Usage Intention	159
<i>Jason W.Haryanto, Ardi Ardi, Dewi Sri Surya Wuisan, Chandra Lukita and Maulana Yusuf</i>	
Impact of Massive Tourist and Vehicles Flow on Air and Water Quality of Uttarakhand ..	166
<i>Bhupesh Rawat, Ankur Singh Bist, Muhammad Dede Soleman, Hardjanto Nusantoro, Po Abas Sunarya and Iqbal Desam Girinzio</i>	
Identification of Plant Types Based on Leaf Image Using Convolutional Neural Network (CNN)	170
<i>Ichsan Taufik, Hikmatun Nazilah, Nur Lukman, Yana Aditia Gerhana, Jumadi Jumadi and Reisa Permatasari</i>	
Enhancing User Satisfaction with iLearning Education: An Application of the TAM Model.....	175
<i>Chandra Lukita, Qurotul Aini, Kristoko Dwi Hartomo, Muhammad Hairid Zulhi, Nuke Puji Lestari Santoso, Ananda Alifia Putri and Zaharuddin Zaharuddin</i>	
Extraction Features Using Lexicon Embedding On Convolutional Neural Network For Fake Review Detection	181
<i>Arini Arini, Kevin Syam Harira and Yusuf Durachman</i>	
Implementation of Preprocessing in Text Summarization Techniques for Indonesian Language Documents Using the Flax T5 Approach.....	187
<i>Arif Ridho Lubis, Habibi Ramdani Safitri, Irvan Irvan, Muharman Lubis, Al-Khowarizmi Al-Khowarizmi and Okvi Nugroho</i>	
REMAS: Real-Time Emergency and Monitoring Alert System for Baby Incubator using IoT	193
<i>I Komang Agus Ady Aryanto, Dechrit Maneetham, Yamin Thwe and Evi Triandini</i>	
IoT based PID Closed Loop Control System for Baby Incubators	199
<i>I Komang Agus Ady Aryanto, Dechrit Maneetham, Yamin Thwe and Evi Triandini</i>	
Mood of Song Detection Using Mel Frequency Cepstral Coefficient and Convolutional Neural Network with Tuning Hyperparameter	204
<i>Wildan Budiawan Zulfikar, Yana Aditia Gerhana, Aulia Yasmin Putri Almi, Dian Sa'Adillah Maylawati and Muhammad Insan Al Amin</i>	
Authenticity Detection for Mechanical Watch Using Hidden Markov Model	210
<i>Aldy Rialdy Atmadja, Safira Oktarini, Diena Rauda Ramdania, Wisnu Uriawan and Yana Aditia Gerhana</i>	
User Acceptance Analysis of Online Food Delivery Service Application Using The UTAUT 2 Modification Model	215
<i>Nur Aeni Hidayah, Eva Khudzaeva and Puti Riani Frisilia</i>	
The Influence of Delayed-hit on Caching Servers Utilizing Conventional Cache Replacement Methods.....	220
<i>Feri Fahrianto and Noriaki Kamiyama</i>	

User Satisfaction Analysis of Telecommunication Customer Service Mobile Applications Using the End User Computing Satisfaction (EUCS) Method.....	224
<i>Suci Ratnawati, Elsy Rahajeng and Ridho Dhafi Fauzan</i>	
The Role of Social Media in Knowledge Management: A Comprehensive Literature Review.....	230
<i>Shafira Fatimah Azzahra, Dita Aprillia Rahmani, Tika Astriani, Muharman Lubis and Rosad Ma'Ali El Hadi</i>	
Stakeholder Management and Communication Management Plan on E-Government Project	235
<i>Shafira Fatimah Azzahra, Titisari Ramadhane, Muhammad Fakhrol Safitra, Muharman Lubis and Sinung Suakanto</i>	
Crude Palm Oil Price Forecasting Based on ECoS-MARS: in Data Science Models	240
<i>Al-Khowarizmi Al-Khowarizmi, Fitria Wulandari Ramlan, Syahril Efendi, Arif Ridho Lubis, Ferdy Riza, Amrullah Amrullah and Yoshida Sary</i>	
Gender Recognition Based on Face Image Using Deep Learning Method	245
<i>Mochamad Wahyudi, Waeisul Bismi, Firmansyah Firmansyah, Muqi Raharjo, Untung Rahardja and Lise Pujiastuti</i>	
Performance Analysis of Open Shortest Path First Multiarea Using Virtual Link Method .	251
<i>Mochamad Wahyudi, Firmansyah Firmansyah, Tommi Alfian Armawan Sandi, Waeisul Bismi, Untung Rahardja and Lise Pujiastuti</i>	
Component Level Design in Learning-Based Video Games	256
<i>Yuni Sugiarti, Muhamad Naufal Zulfikar, Nazla Khalisha, E. Oos M Anwas, Khofifa Najma Iftitah and Anggraeni Dian Permatasari</i>	
Impacts of IT Governance Mechanisms on Organizational Agility	260
<i>Sandy Kosasi, Johnny Soetikno, Susanty Margaretha Kuway, I Dewa Ayu Eka Yuliani, Utin Kasma and Budi Susilo</i>	
The Impact of Electronic Word of Mouth on Willingness to Promote the Online Travel Services	266
<i>Dandy Marcelino, Istiharini Istiharini and Astri Wulandari</i>	
Analyzing the Phenomenon of Information and Communication Technology on Online Religious Engagement Among Indonesian Muslim Adolescents	272
<i>Zulkifli Zulkifli, Muhamad Fahri, Nuraeni N and Dhea Urfina Zulkifli</i>	
Strategic Analysis of Green Marketing and Brand Image Towards Purchase Decision Consumer Coffee Shop During Pandemic Covid-19	278
<i>Muhamad Aras and Alfi Rahman</i>	
Impact of Earning Zakat Based on Blockchain Technology on Community Welfare	284
<i>Muhammad Kamil Husain, Tatik Marianti and Muhamad Lutfi Huzairah</i>	
Concept, Technology, Barriers to Smart Village: A Systematic Literature Review	290
<i>Joy Nashar Utamajaya, Meyliana Meyliana, Harjanto Prabowo, Achmad Nizar Hidayanto and Arief Ramadhan</i>	

Server Cloud Based Security Surveillance Systems: a Design Science Research	296
<i>Alexander Nurenie, Arief Ramadhan, Edi Abdurachman, Agung Trisetjarso and Muhammad Zarlis</i>	
Number of Road Accidents Predicting Using Deep Learning-Based LSTM Development Models	302
<i>Joko Siswanto, Hendry Hendry, Untung Rahardja, Irwan Sembiring, Kristoko Dwi Hartomo, Hindriyanto Dwi Purnomo and Ade Iriani</i>	
Hybrid Convolutional Neural Network and Support Vector Machine Based on Model Optimization for Skin Cancer Classification	308
<i>Qorry Aina Fitroh and Shofwatul Uyun</i>	
Unveiling Happiness Disparities: A Machine Learning Approach to City-Village Comparison	314
<i>Bhupesh Rawat, Ankur Singh Bist, Po Abas Sunarya, Marviola Hardini, Nesti Anggraini Santoso and Rasyid Tarmizi</i>	
Development of Case Base Reasoning Recommendation and Sound and Lighting Rental System	319
<i>Calandra Alencia Haryani, Bryan Liming, Andree E. Widjaja and Hery Hery</i>	
Sentiment Analysis of Citizen on Twitter in Accessibility of Disabilities at The Public Space Using Support Vector Machine (SVM) Method with Radial Basis Function (RBF) Kernel	324
<i>Siti Ummi Masruroh, Mitha Rachma Putri, Khodijah Hulliyah, Andrew Fiade, Saepul Aripriyanto and Ahmad Tholabi Kharlie</i>	
Proposing a Novel Framework for Prediction of Stock using Machine Learning	330
<i>Ankur Singh Bist, Bhupesh Rawat, Sandy Kosasi, Qurotul Aini, Fitra Putri Oganda and Ahmad Bayu Yadila</i>	
Improving Universal Rendering Performance on NuxtJS-based Web Application	335
<i>Harta Angkasa, Darren Farell, Erik Hendrawan Putra Wijaya, Said Achmad and Devi Fitriannah</i>	
Usability Evaluation on Website Using the Cognitive Walkthrough Method	341
<i>Yuni Sugiarti, Salma Riyanti Hanifah, E. Oos M. Anwas, Sumanto Sumanto, Saipul Anwar, Anggraeni Dian Permatasari and Evy Nurmiati</i>	
Data Mining to Predict the Ability of Prospective Customer Credit Payments	349
<i>Fifit Alfiah, Usanto S, Ade Setiadi, Ajay Supriadi, Yogasetya Suhandana and Lela Nurlaela</i>	
XOR Encryption based on Index Value Enumeration used in Iot based Healthcare	355
<i>Dendy Jonas, Irwan Sembiring, Adi Setiawan, Danny Manongga, Indrastanti Ratna Widiyasari and Dwi Julianingsih</i>	
The Effect of Perceived Costs on Blockchain Adoption Intention: an Empirical Study	360
<i>Qurotul Aini, Hindriyanto Dwi Purnomo, Iwan Setyawan, Danny Manongga, Hendry, Untung Rahardja, Irwan Sembiring and Sabda Maulana</i>	
Relationship Quality Analysis using Technology in the Business Sector	366
<i>Qurotul Aini, Eko Sedyono, Kristoko Dwi Hartomo, Danny Manongga, Untung Rahardja, Irwan Sembiring and Nesti Anggraini Santoso</i>	

Steganography of Least Significant Bit Algorithm and Combination of Cryptography Vigenère Cipher with Rivest Code 4 for Email Message Security	372
<i>Yana Aditia Gerhana, Aan Adrian Khothibulumam, Ichsan Budiman, Wisnu Uriawan, Dian Sa'Adillah Maylawati and Undang Syaripudin</i>	
Mobile Health Application Design: A User-Centered Approach for Pulmonary Tuberculosis Screening	378
<i>Muhammad Samiaji, Siti Ummi Masruroh, Dewi Khairani, Herlino Nanang, Tabah Rosyadi and Imam Marzuki Shofi</i>	
Analyzing Radicalism-Related Conversation Patterns on Twitter: A Comparative Study of Association Rules with Apriori and FP-Growth Algorithms	385
<i>Iva Alfianti, Dewi Khairani, Khodijah Hulliyah, Jm Muslimin, Feri Fahrianto and Nunung Isnaini Dwi Ningsih</i>	
Comparing GraphQL and ReST Architecture in Arabic Learning Games: A Quality of Service (QoS) Approach	391
<i>Muhammad Arya Dhika, Dewi Khairani, Siti Ummi Masruroh, Andrew Fiade, Viva Arifin and Waki Ats Tsaqofi</i>	
Enhancing User Experience in "Haji Pintar" Mobile App: Implementing Human Interface Guidelines through UCD and PACMAD	396
<i>Atmina Jovanka Azzahra, Dewi Khairani, Nurul Faizah Rozy, Nenny Anggraini, Khodijah Hulliyah and Umi Musyarofah</i>	
User-Centered User Interface Design for Educational Game: Letter and Number Recognition for Slow Learners	401
<i>Farrah Anggiaputri, Dewi Khairani, Fenty Eka Muzayyana Agustin, Saepul Aripriyanto, Nurul Faizah Rozy and Tabah Rosyadi</i>	
Evaluating Usability: Heuristic Analysis of JKN (Indonesia National Health Insurance) Mobile App User Interface	408
<i>Rafif Zaki Fattahaq, Dewi Khairani, Fitri Mintarsih, Herlino Nanang, Nurhayati Nurhayati and Iwan Aminudin</i>	
Optimizing Product Distribution Service Prices: A Fuzzy Mamdani Logic Implementation Case Study at RnD Enterprises Marketing Consultant Office	414
<i>Raffyanda Riskaputra, Siti Ummi Masruroh, Dewi Khairani, Victor Amrizal, Anif Hanifa Setianingrum and Husni Teja Sukmana</i>	
Performance Optimization Of Naïve Bayes Algorithm For Malware Detection On Android Operating Systems With Particle Swarm Optimization	420
<i>Nenny Anggraini, Muhammad Sigit Tri Pamungkas and Nurul Faizah Rozy</i>	
Exploring User Experience in Mobile Applications: A Systematic Literature Review	425
<i>Fildzah Waalidein Syukron, Husni Teja Sukmana, Dewi Khairani, Muhammad Azhari, Andrew Fiade and Saepul Aripriyanto</i>	
Green Energy Harvest Monitoring of Watering System for Smart Farming Using IoT	432
<i>Ignatius Agus Supriyono, Eko Sedyono, Iwan Setyawan, Ivanna K. Timotius and Muchlishina Madani</i>	

Thailand Carbon Dioxide Emissions Forecasting Using Stacked LSTM-based Prediction Model.....	438
<i>Yamin Thwe, Dechrit Maneetham, Padma Nyoman Crisnapati and Myo Min Aung</i>	
Business Sub-Process Analysis and Redesign of Counseling Week (Pekan Konseling) at Career Center Services using Business Process Improvement (BPI)	444
<i>Bayu Waspodo and Irfan Nur Rizki</i>	
Solar Powered RT-Bot: River Trash Collecting Robot	451
<i>Chanida Tangjai, Benchalak Maungmeesri and Dechrit Maneetham</i>	
Automatic Buffalo Feeding and Monitoring System Using NodeMCU ESP8266 based on Internet of Things.....	457
<i>Sirintorn Thawechart, Benchalak Maungmeesri, Chanokporn Smuthkalin and Dechrit Maneetham</i>	
Analysis Of Continuance Use Intention In BNI Mobile Banking Using The Expectation-Confirmation Model (ECM)	463
<i>Nurbojatmiko Nurbojatmiko, Eva Khudzaeva, Syopiansyah Jaya Putra, Yusuf Durachman and Muhammad Noor Rokhim</i>	
Implementation of Fuzzy K-Nearest Neighbor Method in Dengue Disease Classification ...	471
<i>Asrar Aspia Manurung, Marah Doly Nasution, Al-Khowarizmi Al-Khowarizmi and Indah Purnama Sari</i>	
Evaluation of User Satisfaction with Mobile-Based E-Wallet Platforms Using the Delone & Mclean Model (Case Study: Sakuku)	475
<i>Muhammad Dizza Aliefa Rachman, Yusuf Durachman and Eva Khudzaeva</i>	
Detection of Alzheimer’s Disease in Magnetic Resonance Imaging Images Using Machine Learning with the Convolutional Neural Network Method	481
<i>Ambran Hartono, Elvan Yuniarti, Muhammad Adi Wirya and Salsabila Tahta Hirani Putri</i>	
Design and Development of the Unicycle Balancing Robot Using Linear Slider	486
<i>Kaung Soe Thar, Dechrit Maneetham, Myo Min Aung and Tenzin Rabgyal</i>	
Mobile Academic Information Systems for Students: Measuring End-User Computing Satisfaction (EUCS)	492
<i>Muhammad Qomarul Huda, Nuryasin Nuryasin, Juli Adi Prasetyo, Nia Kumaladewi, Suci Ratnawati and Mona Alyami</i>	
Development of a PID Controller-Based Portable Seeder Design for Corn Seeds.....	498
<i>Somsamai Boonkon, Benchalak Maungmeesri and Dechrit Maneetham</i>	
Design and Development of An Automated Mobile Robot for Hospital Care Services.....	503
<i>Chaiwut Boonhane, Benchalak Muangmeesri and Dechrit Manetham</i>	
Enhancing Gimbal Stabilization Using DMP and Kalman Filter: A Low-Cost Approach with MPU6050 Sensor	509
<i>Padma Nyoman Crisnapati, Dechrit Maneetham, Yamin Thwe and Myo Min Aung</i>	
Enhancing Outdoor Warehouse Operations: Design and Development of GPS and Compass-Guided Automatic Vehicles	514
<i>Singhanart Ketsayom, Dechrit Maneetham, Myo Min Aung and Wichian Srichaipanya</i>	

Responding to the Digital Transformation: The Implications of Transformational Leadership to Predict MSMEs Learning Agility.....	519
<i>Chwen-Li Chang, Edgar Octoyuda and Ivon Arisanti</i>	
Analysis Adoption of Information Technology Using the UTAUT Method on Poultry Farmers in Indonesia.....	525
<i>Evi Triandini, I Gusti Ngurah Satria Wijaya, I Ketut Putu Suniantara, Wayan Cahya Ayu Pratami, Riza Wulandari, Sugiarto Sugiarto, Ahmad Rosadi Djarkasih, Agnesia Candra Sulyani and Niken Larasati</i>	
Smart Parking System With Background Subtraction Algorithm Using Progressive Web Apps (PWAs) Technology on Raspberry Pi 4.....	531
<i>Nenny Anggraini, Awiez Fathwa Zein, Luh Kesuma Wardhani and Khair Fadhillah</i>	
Enhancing Loan Application Business Process Model with Multi-perspective Process Mining.....	537
<i>Rizal Broer Bahaweres and Humaira Zakiyyah</i>	
Analyzing the Financial Implications of Increasing Renewable Energy Penetration in Indonesia's Power System.....	543
<i>Umi Rusilowati, Nuke Puji Lestari Santoso, Aulia Azmi, Sabda Maulana and Adam Faturahman</i>	
Quantifying the Effects of Renewable Energy Advancement: A Statistical Analysis Method.....	547
<i>Mochamad Heru Riza Chakim, Qurotul Aini, Ninda Lutfiani, Nova Ramadhona, Ferry Ariyanto and Marviola Hardini</i>	
Optimizing Animation of Adolescents learning materials as Moral Education.....	554
<i>Noorlela Marcheta, Anggita Rahma Inayatullah, Malisa Huzaiifa and Mira Rosalina</i>	
Evaluating User Perception of Online Pharmacy Application in Indonesia.....	559
<i>Rosa Adelina, Annisya Ayu, Reyhan Diva Zaafira and Siti Ummi Masruroh</i>	
A Novel Stair-Climbing Robot Controlled Using the Internet of Things.....	564
<i>Pharan Chawaphan, Dechrit Maneetham, Padma Nyoman Crisnapati and Ren Jean Liou</i>	
Design and Development of an IoT Enabled CNC Machine.....	571
<i>Tawan Katduang, Dechrit Maneetham, Elang Parikesit and Tenzin Rabgyal</i>	
The Solar Panels Cleaning Robot Control via IOT.....	577
<i>Borwornyot Sutam, Dechrit Maneetham, Padma Nyoman Crisnapati and Wichian Srichaipanya</i>	
Development of PID Control System for a Smart Leg Splint using Sensor Technology.....	583
<i>Sasiwimol Sukket, Dechrit Maneetham and Niyom Laoopugsin</i>	
Feedback Control System for Angular Position Locking Fork of Forklifts.....	589
<i>Sillapachai Klinklai, Dechrit Maneetham, Sasiwimol Sukket and Petrus Sutyasadi</i>	
Bridging Tradition and Technology: Enabling Thai Temple Bell Beater Control through IoT.....	595
<i>Samart Rungcharoen, Benchalak Maungmeesri and Dechrit Maneetham</i>	

Application of Long Short-Term Memory (LSTM) and Gated Recurrent Unit (GRU) Algorithm in Gold Price Prediction	602
<i>Ni Putu Juni Rahayu Dewi, Ni Luh Wiwik Sri Rahayu Ginantra, I Wayan Agus Surya Darma and I Gusti Agung Indrawan</i>	
Evaluation of Public Health Centers Performance through Sentiment Analysis using LSTM in Bali Province, Indonesia	608
<i>I Gede Bintang Arya Budaya, I Komang Dharmendra, Dedy Panji Agustino, I Gede Harsemadi, I Made Pasek Pradnyana Wijaya and I Gede Putra Mas Yusadara</i>	
Analysis of Factors Influencing the Use of QRIS on Museum Visitors with the Extended TAM Model.....	614
<i>Drajad Wiryawan, Devyano Luhukay, Joni Suhartono, Anwar Allah Pitchay, Yuwaraj Ganesan and Anderes Gui</i>	
Design and Development of Leg Splint Rehabilitation Monitoring System via IoT.....	620
<i>Sasiwimol Sukket, Dechrit Maneetham and Tenzin Rabgyal</i>	
E-Commerce Website Quality: Usability, Information, Service Interaction & Visual Quality on Customer Satisfaction	626
<i>Widya Sastika, Fanni Husnul Hanifa, Krishna Kusumahadi and Dandy Marcelino</i>	
Decision Support System for Government Aid Resipient using SMART Method.....	633
<i>Asep Taufik Muharram, Rizki Elisa Nalawati, Alifah Fadiyah, Iik Muhamad Malik Matin and Bambang Warsuta</i>	
Cross-Industry Standard Process For Data Mining (CRISP-DM) For Discovering Association Rules in Graduate Tracer Study Data of Islamic Higher Education Institution	638
<i>Ari Lathifah, Zainul Arham, Nidaul Hasanati, Zulfiandri Zulfiandri and Evy Nurmiati</i>	
Evaluation Model The Successful Use of Information Technology in Distance Learning at State Islamic Universities (PTKIN).....	644
<i>Eva Khudzaeva, Nur Aeni Hidayah and Qurrotul Aini</i>	
Reducing Internet Gaming Disorder in Adolescents: Analysis of Gaming-Contingent of Self-Worth, Loneliness and Peer Attachment	651
<i>Aprily Eka Asri and Rena Latifa</i>	
Enhancing English Students' Writing Skills with Technology Tools: A Qualitative Study..	656
<i>Ratna Sari Dewi, Didin Nuruddin Hidayat and Siti Zulfa</i>	
Speech Recognition of Sundanese Dialect Using Convolutional Neural Network Method with Mel-Spectrogram Feature Extraction	661
<i>Anif Hanifa Setianingrum, Khodijah Hulliyah and Muhammad Fitroh Amrilla</i>	
Control Improvements of an Electromyography-Based Lower Limb Gait Trainer	666
<i>Elang Parikesit, Dechrit Maneetham and Petrus Sutiyasadi</i>	
A Deep Learning Approach to Outbreak Virus Classification: Utilizing Bidirectional GRU on DNA Sequence of SARS-CoV-2, Zika, Ebola, and MERS	671
<i>William Santoso, Khodijah Hulliyah, Wilda Nurjannah and Anif Hanifa Setianingrum</i>	

The Automatic Steering Control System for Local Small Tractor by Encoder Tracking System.....	677
<i>Phummarin Thavitchasri, Dechrit Maneetham, Benchalak Maungmeesri and Tenzin Rabgyal</i>	
Analysis of Strengths and Weaknesses of Software Testing Strategies: Systematic Literature Review.....	682
<i>Syopiansyah Jaya Putra, Yuni Sugiarti, Bagas Yana Prayoga, Dizar Wangsa Samudera and Dewi Khairani</i>	
Improvement Control of a Three Axis Articulated Robotic Arm Using PID Cascade Control.....	687
<i>Petrus Sutiyasadi, Martinus Bagus Wicaksono and Dechrit Maneetham</i>	
Improving the Quality of P4AI Mobile Apps through User Interface Results and User Experience Surveys.....	691
<i>Yasinta Indrianti, Sasmoko Sasmoko, Sonya Rapinta Manalu and Lukas Kurniawan</i>	
Relation Classification in Scientific Article Abstracts using SciBERT with Entity Marker .	696
<i>Nur Inayah, Muhaza Liebenlito, Nina Fitriyati, Muhammad Manaqib and Nabila Aryanti</i>	
Implementation of the K-means Clustering Algorithm for Targeting Ads. Case Study: IBM Watson Analytics Car Insurance Customer Data.....	701
<i>Siti Ummi Masrurroh, Asyifa Tasya Fadilah, Khodijah Hulliyah, Ahmad Fadlan Ramadhan, Rizka Amalia Putri and Mohamad Ali Irfan</i>	
Sentiment Analysis on News Headlines of Nation’s Capital Relocation Using CNN and SVM.....	704
<i>Nidaul Hasanati, Tania Syifa Utami and Rinda Hesti Kusumaningtyas</i>	
IoT-based Alcohol Detection Prototype for Public Transportation Drivers.....	710
<i>Muhamad Haikal Ardiyansah, Luh Kesuma Wardhani and Arini Arini</i>	
Enhancing Small Dataset Performance: Data Augmentation and Transfer Learning in Indonesian Traditional Foods Classification.....	716
<i>Nurhayati Nurhayati, Zulfiandri Zulfiandri, Wilda Nurjannah and Anggita Maharani Gumay Putri Gumay Putri</i>	
Predicting Loneliness using SVM, Logistic Regression and Decision Tree in Thailand.....	722
<i>Chai Meenornngwar and Choosak Nithikathkulb</i>	
The Impact of Technological Readiness Factors on User Satisfaction in The Indonesian Local Government Employee Service System.....	728
<i>Syopiansyah Jaya Putra, Ismail Khalil, Ahmad Cucus and Azizah Nurfauziah Yusril</i>	
Enhancing Student Engagement in Computational Physics through Project-Based Learning: An Exploration of VBA Physics Simulation.....	733
<i>Dzikri Rahmat Romadhon, Maila Rahiem, Ratna Faeruz, Evi Muliyah, Asmui Asmui and Nurbaini Futuhat Wulansari</i>	
Evaluating SVOD User Experiences: Insights from the UEQ Method.....	739
<i>Shinta Oktaviana R, Retno Dwi Wulandari and Dwiza Riana</i>	

Vehicle Number Plate Recognition in Intelligent Transportation System using YOLO v8 and EasyOCR	744
<i>Rizki Elisa Nalawati, Dewi Yanti Liliana, Ratna Widya Iswara, Muhammad Dzaky Nashshar, Rumika Damayanti M.S. and Rahma Maulida Shaliha</i>	
Exploring the Role of Information Technology in Analyzing the Choice to Attend a Master's Program in Management during COVID-19: A Financial Perspective	749
<i>Nardi Sunardi, A Kadim, Asep Sutarman, Ilamsyah Ilamsyah and Mustofa Kamal</i>	
Leveraging IT for Optimizing Employee Performance via Work Culture and Quality Management in BUMD Enterprises.....	754
<i>Asep Sutarman, A Kadim, Nardi Sunardi, Meri Mayang Sari and Yusuf Febriansyah</i>	
Comparison of the Indobert Optimization Hyperparameter Algorithm for Radicalism Sentiment Analysis.....	760
<i>Fenty Eka Muzayyana Agustin, Khodijah Hulliyah, Frido Arifadilah, Imam Marzuki Shofi and Nafia Wafiqni</i>	
Enhancing Breeding Control: The IoT-Driven Automated System for Budgie Farming	766
<i>Saranpong Nooyimsai, Jarinya Thaloy, Parinya Jansengrat, Weena Janratchakool, Jaturapith Krohkaew, Padma Nyoman Crisnapati and Yamin Thwe</i>	
Evaluation of Human Resource Information System Implementation Success and Technology Trust Factors in the Context of a Manufacturing Company	772
<i>Sarah Astiti, Khairun Nisa Meiah Ngafidin and Muhammad Mahendra</i>	
Improving Digital Literacy of Rural Women Entrepreneurs in Indonesia	778
<i>Amelia Fauzia and Sri Hidayati</i>	
Adopting Five Planes Framework for Developing User Interface based on User Experience Aspects	783
<i>Aang Subiyakto, Devika Putri Utami, Evy Nurmiati, Dwi Yuniarto, Ajang Sopandi and Faiz Muqorrrir Kaffah</i>	
Evaluating Effectiveness and Efficiency of A Website Using Cognitive Walkthrough Method	789
<i>Tri Haryanto, Mar'Atus Sholihah, Dwi Yuniarto, Ajang Sopandi, Faiz Muqorrrir Kaffah and Aang Subiyakto</i>	
Comparative Analysis of Time Series Methods for Stock Market Index Forecasting.....	795
<i>Elvi Fetrina, Meinarini Catur Utami and Fakhri Arizki</i>	
Implementation of LoRaWAN Routing Protocol in Wireless Sensor Network for Smart Compost System with LoRa Communication Module.....	801
<i>Nenny Anggraini, Syaifan Fadlan Riady Bachri and Muhammad Tabah Rosyadi</i>	
The SEM-PLS Analysis for Testing Questionnaire: Software Developer Productivity Based on Religiosity and Work Behavior	806
<i>Meinarini Catur Utami, Dede Rosyada, Erma Suryani, Nashrul Hakiem, Didin Saepudin and Maswani Maswani</i>	
Analysis of Website Quality Using Webqual 4.0 Method and Importance Performance Analysis (IPA)	811
<i>Suci Ratnawati, Arif Zamhari, Nidaul Hasanati and Rafi Nabil Muktabar</i>	

Design and Build a Web-Based e-Learning System using ReactJS Framework	817
<i>Nia Kumaladewi, Getar Nuansa Refardi, Muhamad Nur Gunawan and Zulkifli Zulkifli</i>	
Continuance Use Intention Analysis on Paid Streaming Service Using Expectation-Confirmation Model (ECM)	823
<i>Muhammad Qomarul Huda, Alda Wahyufebrian, Nuryasin Nuryasin, Evy Nurmiati, Noor Azura Zakaria and Suci Ratnawati</i>	
Student Perceptions of User Satisfaction and User Loyalty of Website Based E-Learning ..	829
<i>Nur Aeni Hidayah, Muhamad Nur Gunawan, Dyah Kusumawati, Maswani Maswani, Rizqi Handayani and Suparto Suparto</i>	
Decision Support System Mapping of Information Technology Training for Students with Blind Disabilities	835
<i>Siti Ummi Masruroh, Dede Rosyada, Ahmad Tholabi, Ahmad Arya Sawraja, Nurul Faizah Rozy, Rizka Amalia Putri and Imam Subchi</i>	
Development Of A Question Answering Model Using The Indobert Algorithm To Evaluate Website Content In Indonesian Language	840
<i>Siti Ummi Masruroh, Kirana Humaira Putri, Khodijah Hulliyah, Imam Marzuki Shofi and Victor Amrizal</i>	

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Author Index

Abas Sunarya, Po	166
Abdurachman, Edi	296
Abu, Nur Azman	33
Achmad, Said	335
Adauwiyah, Hofifah Isma	51
Adelina, Rosa	559
Aditia Gerhana, Yana	170, 372
Adlinma, Leoni Rizki	1
Agustin, Fenty Eka Muzayyana	401, 760
Agustino, Dedy Panji	608
Aini, Qurotul	175, 330, 360, 366, 547
Aini, Qurrotul	124, 644
Al Amin, Muhammad Insan	204
Al-Khowarizmi, Al-Khowarizmi	187, 240, 471
Alam, Cecep Nurul	130
Alfiah, Fifit	349
Alfianti, Iva	385
Aliefa Rachman, Muhammad Dizza	475
Almi, Aulia Yasmin Putri	204
Alyami, Mona	492
Aminudin, Iwan	408
Amrilla, Muhammad Fitroh	661
Amriza, Rona Nisa Sofia	16
Amrizal, Victor	414, 840
Amrullah, Amrullah	240
Andika, Difa	130
Anggiaputri, Farrah	401
Anggraini, Nenny	396, 420, 531, 801
Angkasa, Harta	335
Anwar, Saipul	341
Anwas, E. Oos M	256
Aprila Yusuf, Natasya	69
Aras, Muhamad	278
Arayoga Saka, David	39
Ardi, Ardi	39, 159
Ardiyansah, Muhamad Haikal	710
Arham, Zainul	638
Arif, Basyir	118
Arifadilah, Frido	760
Arifn, Viva	11, 391
Arini, Arini	96, 181, 710
Aripiyanto, Saepul	324, 401, 425
Arisanti, Ivon	519
Ariyanto, Ferry	547

Arizki, Fakhri	795
Armawan Sandi, Tommi Alfian	251
Aryanti, Nabila	696
Aryanto, I Komang Agus Ady	193, 199
Asmui, Asmui	733
Astiti, Sarah	772
Astriani, Tika	230
Atmadja, Aldy Rialdy	210
Ats Tsaqofi, Waki	391
Aung, Myo Min	438, 486, 509, 514
Ayu Pratami, Wayan Cahya	525
Ayu Sanjaya, Yulia Putri	64
Ayu, Annisya	559
Azhari, Muhammad	425
Azizah, Lisma Nur	64
Azmi, Aulia	543
Azzahra, Atmina Jovanka	396
Azzahra, Shafira Fatimah	230, 235
Bagus Saputra, Dimas	87
Bahaweres, Rizal Broer	537
Bayu Suseno, Hendra	96
Bilhaq, Muhammad Thariq Sabiq	107
Bismi, Waeisul	245, 251
Bist, Ankur Singh	166, 314, 330
Boonhane, Chaiwut	503
Boonkon, Somsamai	498
Budaya, I Gede Bintang Arya	608
Budiarto, Mukti	75
Budiawan Zulfikar, Wildan	204
Budiman, Ichsan	372
Candra Sulyani, Agnesia	525
Candra, Sevenpri	1
Catur Utami, Meinarini	795
Chang, Chwen-Li	519
Chawaphan, Pharan	564
Christian, Christian	1
Crisnapati, Padma Nyoman	438, 564, 766
Cucus, Ahmad	728
Damayanti M.S., Rumika	744
Darma, I Wayan Agus Surya	602
Dewi, Ni Putu Juni Rahayu	602
Dewi, Ratna Sari	656
Dewi, Susanti	33
Dharmendra, I Komang	608
Dhika, Muhammad Arya	391

Dian Permatasari, Anggraeni	256, 341
Durachman, Yusuf	11, 51, 181, 463, 475
Dwi Wulandari, Retno	739
E. Widjaja, Andree	319
Efendi, Syahril	240
Eka Asri, Aprily	651
El Hadi, Rosad Ma'Ali	230
Elisa Nalawati, Rizki	633
Epriani, Nadila Chataliya	124
Fadhillah, Khair	531
Fadilah, Asyifa Tasya	701
Fadiyah, Alifah	633
Fadlan Riady Bachri, Syaifan	801
Fadli, Ihya Syihabul	33
Faeruz, Ratna	733
Fahri, Muhamad	272
Fahrianto, Feri	220, 385
Farell, Darren	335
Faridah, Ida	39
Fattahaq, Rafif Zaki	408
Faturahman, Adam	543
Fauzan, Ridho Dhafi	224
Fauzia, Amelia	778
Febriansyah, Yusuf	754
Fetrina, Elvi	124, 795
Fiade, Andrew	324, 391, 425
Firmansyah, Firmansyah	245, 251
Fitri, Fifi Alfisa	141
Fitrianah, Devi	335
Fitriyani, Aida	146, 152
Fitriyati, Nina	696
Fitroh, Qorry Aina	308
French, Evaewero	22
Friandi, Sendy Zul	75
Ganesan, Yuvaraj	614
Gerhana, Yana Aditia	204, 210
Ginatra, Ni Luh Wiwik Sri Rahayu	602
Girinzio, Iqbal Desam	166
Gui, Anderes	614
Gumay Putri, Anggita Maharani Gumay Putri	716
Gunawan, Muhamad Nur	51, 817, 829
Hadi Fathulloh, Ahnaf	146, 152
Hakim, Nashrul	806
Hamzah, Muhammad Luthfi	82

Handayani, Rizqi	829
Hanifa Setianingrum, Anif	671
Hanifa, Fanni Husnul	626
Harahap, Eka Purnama	56
Hardini, Marviola	64, 314, 547
Harmaini, Harmaini	28
Harsemadi, I Gede	608
Hartomo, Kristoko Dwi	175, 302, 366
Hartono, Ambran	481
Haryani, Calandra Alencia	319
Haryanto, Tri	113, 789
Hasanati, Nidaul	638, 704, 811
Helo, Petri	6
Henderi, Henderi	75, 87
Hendrawan Putra Wijaya, Erik	335
Hendry,	360
Hendry, Hendry	302
Heriyanto, Raden	102
Heru Riza Chakim, Mochamad	87, 547
Hery, Hery	319
Hidayah, Nur Aeni	215, 644, 829
Hidayanto, Achmad Nizar	290
Hidayat, Didin Nuruddin	656
Hidayati, Sri	778
Huda, Muhammad Qomarul	492, 823
Hulliyah, Khodijah	136, 324, 385, 396, 661, 671, 701 760, 840
Husain, Muhammad Kamil	284
Huzaifa, Malisa	554
Huzaifah, Muhamad Lutfi	284
Ilamsyah, Ilamsyah	749
Ilman, Abdul	22
Inayah, Nur	696
Indrawan, I Gusti Agung	602
Indrianti, Yasinta	691
Irfan, Mohamad Ali	701
Iriani, Ade	302
Irvan, Irvan	187
Isnaini Dwi Ningsih, Nunung	385
Istiharini, Istiharini	266
Iswara, Ratna Widya	744
Ivone, Merliani	113
Janratchakool, Weena	766
Jansengrat, Parinya	766
Jean Liou, Ren	564
Jonas, Dendy	355

Julianingsih, Dwi	355
Jumadi, Jumadi	130, 170
Kadim, A	749, 754
Kamal, Mustofa	749
Kamiyama, Noriaki	220
Kasma, Utin	260
Katduang, Tawan	571
Kedah, Zulkarnain	33
Ketsayom, Singhanart	514
Khairani, Dewi	11, 378, 385, 391, 396, 401, 408 414, 425, 682
Khalil, Ismail	728
Khalisha, Nazla	256
Kharlie, Ahmad Tholabi	324
Khoffah, Nimatul	56
Khothibulumam, Aan Adrian	372
Khudzaeva, Eva	215, 463, 475, 644
Klinklai, Sillapachai	589
Kosasi, Sandy	33, 260, 330
Kristianto, Budhi	75
Krohkaew, Jaturapith	766
Kumaladewi, Nia	118, 492, 817
Kurniawan, Lukas	691
Kusumahadi, Krishna	626
Kusumaningtyas, Rinda Hesti	704
Kusumawati, Dyah	829
Kuway, Susanty Margaretha	260
Laoopugsin, Niyom	583
Larasati, Niken	525
Lathifah, Ari	638
Latifa, Rena	651
Lestari Santoso, Nuke Puji	39
Liebenlito, Muhaza	696
Liliana, Dewi Yanti	744
Liming, Bryan	319
Lubis, Arif	82
Lubis, Arif Ridho	187, 240
Lubis, Muharman	187, 230, 235
Luhukay, Devyano	614
Lukita, Chandra	28, 56, 159, 175
Lukman, Nur	170
Lutfiani, Ninda	547
M. Anwas, E. Oos	341
Ma'Mun, Andri	69
Ma'Ruf, Imam	39

Madani, Muchlishina	432
Mahendra, Muhammad	772
Manalu, Sonya Rapinta	691
Manaqib, Muhammad	696
Maneetham, Dechrit	193, 199, 438, 451, 457, 486, 498 509, 514, 564, 571, 577, 583, 589 595, 620, 666, 677, 687
Manetham, Dechrit	503
Manongga, Danny	355, 360, 366
Manurung, Asrar Aspia	471
Marcelino, Dandy	266, 626
Marcheta, Noorlela	554
Marianti, Tatik	284
Mariyanti, Tatik	102
Marzuki Shofi, Imam	378
Masruroh, Siti Ummi	11, 324, 378, 391, 414, 559, 701 835, 840
Maswani, Maswani	806, 829
Matin, Iik Muhamad Malik	633
Maulana, Sabda	360, 543
Maungmeesri, Benchalak	451, 457, 498, 595, 677
Maylawati, Dian Sa'Adillah	107, 130, 204, 372
Meenorngwar, Chai	722
Mertayasa, I Komang	28
Meyliana, Meyliana	290
Mintarsih, Fitri	408
Muangmeesri, Benchalak	503
Muhamad Malik Matin, Iik	96
Muhammad, Muhammad	118
Muktabar, Rafi Nabil	811
Muliyah, Evi	733
Muqorrrir Kaffah, Faiz	783, 789
Muslimin, Jm	385
Musyarofah, Umi	396
Muzayyanah, Fenty Eka	136
N, Nuraeni	272
Najma Iftitah, Khofifa	256
Nalawati, Rizki Elisa	744
Nanang, Herlino	11, 378, 408
Nashshar, Muhammad Dzaky	744
Nasution, Marah Doly	471
Naufal Zulfikar, Muhamad	256
Naufal, Fadhli	46
Nazilah, Hikmatun	170
Ngafidin, Khairun Nisa Meiah	772
Nithikathkulb, Choosak	722
Nooyimsai, Saranpong	766

Nuansa Refardi, Getar	817
Nugroho, Okvi	187
Nur Maulana, Fahmi	96
Nurbojatmiko, Nurbojatmiko	463
Nurenie, Alexander	296
Nurhayati, Nurhayati	408, 716
Nurjannah, Wilda	671, 716
Nurlaela, Lela	349
Nurlatifah, Eva	107
Nurmiati, Evy	341, 638, 783, 823
Nuryasin, Nuryasin	146, 152, 492, 823
Nusantoro, Hardjanto	166
Nyoman Crisnapati, Padma	509, 577
Octoyuda, Edgar	519
Oganda, Fitra Putri	56, 330
Oktarini, Safira	210
Oktaviana R, Shinta	739
Padeli, Padeli	64
Pamungkas, Muhammad Sigit Tri	420
Parikesit, Elang	571, 666
Permatasari, Reisa	170
Pitchay, Anwar Allah	614
Prabowo, Harjanto	290
Prasetyo, Juli Adi	492
Prayoga, Bagas Yana	682
Prayudani, Santi	82
Pujiastuti, Lise	245, 251
Purnomo, Hindriyanto Dwi	75, 302, 360
Pusparini, Nur Nawaningtyas	113
Putra Seno, Bayu Ajie	28
Putra, Syopiansyah Jaya	463, 682, 728
Putri Utami, Devika	783
Putri, Ananda Alifia	75, 175
Putri, Kirana Humaira	840
Putri, Mitha Rachma	324
Putri, Rizka Amalia	701, 835
Putri, Salsabila Tahta Hirani	481
Rabgyal, Tenzin	486, 571, 620, 677
Rahajeng, Elsy	118, 224
Rahardja, Reymund	87
Rahardja, Untung	33, 245, 251, 302, 360, 366
Raharjo, Mugi	245
Rahiem, Maila	733
Rahma Inayatullah, Anggita	554
Rahman, Alfi	278

Rahmani, Dita Aprillia	230
Rahmania Az Zahra, Achani	102
Ramadan, Ahmad	69
Ramadhan, Ahmad Fadlan	701
Ramadhan, Arief	290, 296
Ramadhane, Titisari	235
Ramadhona, Nova	547
Ramdania, Diena Rauda	107, 210
Ramdhani, Muhammad Ali	107, 130
Ramlan, Fitria Wulandari	240
Ratnawati, Suci	141, 224, 492, 811, 823
Rawat, Bhupesh	166, 314, 330
Riana, Dwiza	739
Riani Frisilia, Puti	215
Riskaputra, Raffyanda	414
Riyanti Hanifah, Salma	341
Riza Chakim, Mochamad Heru	64
Riza, Ferdy	240
Rizki, Irfan Nur	444
Rokhim, Muhammad Noor	463
Romadhon, Dzikri Rahmat	733
Rosadi Djarkasih, Ahmad	525
Rosalina, Mira	554
Rosdiana, Rosdiana	69
Rosyada, Dede	806, 835
Rosyadi, Tabah	378, 401
Rozy, Nurul Faizah	396, 401, 420, 835
Rungcharoen, Samart	595
Rusilowati, Umi	543
S, Usanto	349
Saepudin, Didin	806
Safitra, Muhammad Fakhrol	235
Safitri, Habibi Ramdani	187
Saidah, Musfiah	46
Samiaji, Muhammad	378
Samudera, Dizar Wangsa	682
Sani, Asrul	113
Santoso, Nesti Anggraini	314, 366
Santoso, Nuke Puji Lestari	175, 543
Santoso, Sugeng	28
Santoso, William	671
Sari, Indah Purnama	471
Sari, Meri Mayang	754
Sary, Yoshida	240
Sasmoko, Sasmoko	691
Sastika, Widya	626
Satria Wijaya, I Gusti Ngurah	525

Sawraja, Ahmad Arya	835
Sediyono, Eko	366, 432
Sembiring, Irwan	302, 355, 360, 366
Setiadi, Ade	349
Setianingrum, Anif Hanifa	414, 661
Setiawan, Adi	355
Setiono, Dede Puji	22
Setyawan, Bayu Aji	136
Setyawan, Iwan	360, 432
Shaliha, Rahma Maulida	744
Shofi, Imam Marzuki	760, 840
Sholihah, Mar'Atus	789
Sibarani, Blasius Erik	33
Siswanto, Joko	302
Smuthkalin, Chanokporn	457
Soetikno, Johnny	260
Soleman, Muhammad Dede	166
Sopandi, Ajang	783, 789
Srichaipanya, Wichian	514, 577
Sriliasta Bangun, Cicilia	28
Suakanto, Sinung	235
Subchi, Imam	835
Subhan Riza, Bob	69
Subiyakto, Aang	783, 789
Sudaryono, Sudaryono	87
Sugiarti, Yuni	256, 341, 682
Sugiarto, Sugiarto	525
Suhandha, Yogasetya	349
Suhartono, Joni	614
Sukket, Sasiwimol	583, 589, 620
Sukmana, Husni Teja	11, 414, 425
Sumanto, Sumanto	341
Sunardi, Nardi	749, 754
Sunarjo, Richard Andre	56, 64
Sunarya, Po Abas	39, 314
Suniantara, I Ketut Putu	525
Suorsa, Mikko	6
Suparto, Suparto	829
Supriadi, Ajay	349
Supriyono, Ignatius Agus	432
Surono, Galih	113
Surono, Surono	69
Suryani, Erma	806
Susanto, Aries	146, 152
Susilo, Budi	260
Sutam, Borwornyot	577
Sutarman, Asep	749, 754
Sutyasadi, Petrus	589, 666, 687

Syam Harira, Kevin	181
Syaripudin, Undang	372
Syukron, Fildzah Waalidein	425
Tabah Rosyadi, Muhammad	801
Tangjai, Chanida	451
Tarmizi, Rasyid	314
Taufik Muharram, Asep	633
Taufik, Ichsan	130, 170
Thaloy, Jarinya	766
Thar, Kaung Soe	486
Thavitchasri, Phummarin	677
Thaweechart, Sirintorn	457
Tholabi, Ahmad	835
Thwe, Yamin	193, 199, 438, 509, 766
Timotius, Ivanna K.	432
Triandini, Evi	193, 199, 525
Trisetyarso, Agung	296
Uriawan, Wisnu	210, 372
Utamajaya, Joy Nashar	290
Utami, Meinarini Catur	141, 806
Utami, Tania Syifa	704
Uyun, Shofwatul	308
Viktor A Sin, Muhamad	87
W.Haryanto, Jason	159
Wafiqni, Nafia	760
Wahana, Agung	107
Wahyudi, Mochamad	87, 245, 251
Wahyufebrian, Alda	823
Wali, Muhammad	56
Wardhani, Luh Kesuma	531, 710
Warsuta, Bambang	633
Waspodo, Bayu	444
Wicaksono, Martinus Bagus	687
Widiasari, Indrastanti Ratna	355
Wijaya, I Made Pasek Pradnyana	608
Wijayanto, Sena	16
Wiranata, Ade Davy	113
Wirya, Muhammad Adi	481
Wiryawan, Drajad	614
Wuisan, Dewi Sri Surya	159
Wulandari, Astri	266
Wulandari, Riza	525
Wulansari, Nurbaini Futuhat	733

Yadila, Ahmad Bayu	330
Yuliani, I Dewa Ayu Eka	260
Yuniarti, Elvan	481
Yuniarto, Dwi	783, 789
Yusadara, I Gede Putra Mas	608
Yusril, Azizah Nurfauziah	728
Yusuf, Maulana	39, 159
Zaafira, Reyhan Diva	559
Zaharuddin, Zaharuddin	175
Zahra, Irene Avillya	28
Zakaria, Noor Azura	823
Zakiyyah, Humaira	537
Zamhari, Arif	811
Zarlis, Muhammad	296
Zein, Awiez Fathwa	531
Zulfa, Siti	656
Zulfiandri, Zulfiandri	638, 716
Zulhi, Muhammad Hairid	175
Zulkifli, Dhea Urfina	272
Zulkifli, Zulkifli	272, 817

Comparative Analysis of Key Management Service Performance on AWS, Google Cloud, and Oracle Cloud with Performance Testing

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Abstract—Although switching to cloud technology for free exclusive can give cost advantage and efficiency, it requires policies, processes, and practices best security level business calculated. Based on survey to industry experts, available problem security in cloud computing, including data breaches identified as a problem security top need _ attention more. Most entry way sense to prevent data breach involves practice security in data storage, for example data encryption. But if happen lost key encryption, then it will also data loss. It supported by abundance data breaches that have occurred in the last 5 years recently, especially in Indonesia. To overcome security and management issues key encryption, some cloud providers provide Key Management Services (KMS) services. This research will compare the performance of Key Management Services from cloud providers AWS, Google Cloud, and Oracle Cloud with load testing methods, stress testing, and benchmark testing. The parameters assessed from this research are response time, error rate, throughput, and latency. The resulting research results are recommendations for the best cloud providers in Key Management Services. The result shows AWS can say better compared Google Cloud and Oracle because constant error rate lower from Google Cloud and Oracle, competitive response time and latency. Throughput (requests per second) obtained almost always more excels at every testing.

Keywords— *Performance Analysis, Cloud Computing, Cloud Security, Data Breaches, JMeter*

I. INTRODUCTION

In recent years, the demand for data has increased drastically as has the number of online users. Therefore, an external storage system is required to store data. Traditional computing is unable to handle the increasing number of online users due to the growth of the global internet. A new concept in data storage systems appears, namely cloud computing [1].

Cloud computing is a model of easy resource access and can be delivered on demand [2]. In cloud computing, customers only pay for services used with the PAYG model. Benefits include flexibility in customizing software, storage, development platforms, and computing resources [3].

In Indonesia, there have been several cases of user data violations on cloud service platforms such as Bukalapak, Tokopedia, and BPJS [4]. These cases show that inadequate implementation of encryption can lead to leaking of user data [15]. To address security issues and management of

encryption keys, several cloud service providers provide Key Management Services (KMS) services. KMS is a system that leverages cryptography and key lifecycle management functionality to connect applications and services, and automate key management processes [5].

Cloud service providers such as Amazon Web Services (AWS), Google Cloud, and Oracle Cloud are recognized as leaders in cloud platform infrastructure and services [6]. They have invested heavily in building data centres and offering on-premises services, as well as offering a wide range of services, tools and support to their customers [6], [7].

Based on the importance of key management in cryptography and the need to reduce the impact of data breaches, the author will conduct research that focuses on comparative analysis of Key Management Service (KMS) performance on AWS, Google Cloud, and Oracle Cloud using load testing, stress testing, and benchmark testing methods.

II. RELATED WORK

A. Key Management Service

Key Management Service (KMS) is system that utilizes functionality cryptography and management cycle life key to connect applications and services. Functions too expanded to manage secrets and certificates. NIST defines KMS as a system for management key cryptography and its metadata, include various processes such as creation, distribution, storage, backup, archiving, restoration, use, revocation, and destruction key. KMS got used in a manner automation to oversee, automate, and secure management processes key [8].

B. Load Testing

Load testing is a method of performance testing that involves the continuous operation of a system within the pressure it can withstand. The purpose is to test the stability of the system by ensuring the system can run consistently under these stresses. *Load testing* helps understand the performance capacity of the system and can be used as a basis for performance tuning [16]. It is important to distinguish *load testing* from *stress testing*, in which *stress testing* involves evaluating a system's performance beyond its normal capacity. *Load testing* is part of performance testing that ensures testing is carried out within the specified resource capacity [9], [10].

C. Stress Testing

Stress testing is a performance testing method that involves continuously increasing pressure on the system under test until the system fails. The goal is to test the maximum pressure that the system can withstand. *Stress testing* involves a gradual increase in system load to test for changes in system performance and determine conditions under which the system fails to deliver the maximum level of performance service. The difference with *load testing* is that in *stress testing*, the test is carried out at the maximum pressure that the system can withstand [9].

D. Benchmark Testing

Overall, *benchmark testing* is a performance testing method that involves measuring and comparing system performance using standardized tests [11]. The purpose of benchmark testing is to provide a standardized and objective way to evaluate and compare the performance of different computer systems, as well as identify performance bottlenecks that can be optimized to improve system performance. *Benchmark testing* is used in a variety of fields, including computer architecture, hardware and software design, and system optimization [11].

E. Apache JMeter

Apache JMeter is a desktop application used to test and

III. RESEARCH METHOD

A. Method Data Analysis

At stage analysis performance, this study uses three method testing that is *load testing*, *stress testing*, and *benchmark testing*. *Load testing* is carried out to test the stability of the system by running operations continuously within the pressure limit that can be withheld. Apache JMeter is used as a tool testing with a test plan.

TABLE I Load Test Plan Scenario 1

Group Threads	name	Load Test Scenario 1
Thread Properties	Number of threads	100
	Ramp-up Period (in seconds)	1
	Loop Count	10

TABLE II Load Test Plan Scenario 2

Group Threads	name	Load Test Scenario 2
Thread Properties	Number of threads	250
	Ramp-up Period (in seconds)	1
	Loop Count	10

Stress testing is performed to test changes in system performance by gradually increasing system load. The pressure on the system is tested continuously until the system collapses or is unable to withstand the applied load. Apache JMeter is used for measurements in stress testing with a test plan.

TABLE III Stress Test Plan Scenario 1

Group Threads	name	Stress Test Scenario 1
Thread Properties	Number of threads	5000
	Ramp-up Period (in seconds)	1
	Loop Count	10

measure the performance and functional behavior of client/server applications, such as web applications or FTP applications. As one of the most popular *open-source testing applications*, JMeter is designed in Java and has expandability via a provided API. By acting as the "client side" of a "client/server" application, JMeter measures response time and server resources such as CPU load, memory usage, and other resource usage. This enables automated functional testing [10].

JMeter can be used to test the performance of static and dynamic resources such as static files, *Servlets*, *FTP servers*, *Databases*, and *queries*. To test and measure the robustness of *HTTP or FTP servers* or networks, JMeter users can simulate various types of loads on the tested system. With its graphical tools, JMeter facilitates better performance analysis in heavy load situations [10].

F. Similar Literature

After determining the topic of research and the formulation of the problem, the author collects data by reading and studying books, journals, and also thesis which is used as a reference in order to obtain a theoretical basis regarding the problem to be studied. Similar literature can be seen in Table I

Group Threads	name	Stress Test Scenario 2
Thread Properties	Number of threads	10000
	Ramp-up Period (in seconds)	1
	Loop Count	10

TABLE IV Stress Test Plan Scenario 2

Group Threads	name	Benchmark Test Plan
Thread Properties	Number of threads	10
	Ramp-up Period (in seconds)	1
	Loop Count	1

Benchmark testing is a performance testing methodology that involves measuring and comparing system performance using a series of standardized tests known as benchmarks. At this stage, the system is tested by encrypting files of various sizes and the results are compared. Apache JMeter is also used to perform benchmark testing with the test plan listed in the table.

TABLE V Benchmark Test Input Plan

No	file sizes	Number of threads	Extension
1	100 kb	10	pdf
2	1mb	10	pdf
3	10mb	10	pdf

TABLE VI Benchmark Test Plan

Group Threads	name	Benchmark Test Plan
Thread Properties	Number of threads	10
	Ramp-up Period (in seconds)	1
	Loop Count	1

The output of the test is in the form of response time, error rate, throughput, and latency which will be compared.

IV. RESULTS

A. Load Testing

1) Average Response Time

Table 8 is comparison of the average *response time load testing* function encryption and function Key Management Service decryption from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle providers. The smallest average *response time* from the encryption function is obtained by AWS in scenario 1 and scenario 2. The largest average *response time* from scenario 1 for the encryption function is obtained by Google Cloud, in scenario 2 is obtained by Oracle. In the decryption function, the least average *response time* from scenario 1 and scenario 2 is obtained by AWS, and the largest average *response time* from scenario 1 and scenario 2 is obtained by Oracle.

TABLE VII COMPARISON OF AVERAGE RESPONSE TIME LOAD TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	197	402
	Google Cloud	1124	2694
	Oracles	978	2920
Decrypt function	AWS	230	295
	Google Cloud	1245	2336
	Oracles	1370	2560

2) Minimum Response Time

Table 9 is comparison *minimum response time load testing* function encryption and function Key Management Service decryption from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle providers. *The minimum response time* for the encryption function is obtained by Oracle in scenario 1 and scenario 2. *The minimum response time* for scenario 1 is obtained by AWS and scenario 2 is obtained by Oracle.

TABLE VIII COMPARISON OF MINIMUM RESPONSE TIME LOAD TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	65	85
	Google Cloud	74	71
	Oracles	56	63
Decrypt function	AWS	34	90
	Google Cloud	79	73
	Oracles	101	70

3) Maximum Response Time

Table 10 is comparison *maximum response time load testing* function encryption and function Key Management Service decryption from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle providers. *The minimum maximum response time* of the encryption and decryption functions is obtained by AWS in scenario 1 and scenario 2. *The maximum maximum response time* of the encryption and decryption functions is obtained by Oracle in scenario 1 and scenario 2.

TABLE IX COMPARISON OF MAXIMUM RESPONSE TIME LOAD TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	2790	715
	Google Cloud	7170	21069
	Oracles	7623	16355
Decrypt function	AWS	2417	537
	Google Cloud	7404	21063
	Oracles	7706	21411

4) Error

Table 11 is *error comparisons load testing* the encryption function and decryption function Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle providers. The fewest errors in the encryption and decryption functions in scenario 1 and scenario 2 were obtained by AWS. The biggest error from the encryption function in scenario 2 is obtained by Google Cloud. The biggest error from the decryption function in scenario 2 is obtained by Oracle.

TABLE X COMPARISON OF ERROR LOAD TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	2790	715
	Google Cloud	7170	21069
	Oracles	7623	16355
Decrypt function	AWS	2417	537
	Google Cloud	7404	21063
	Oracles	7706	21411

5) Throughput

Table 12 is *throughput comparisons load testing* the encryption function and decryption function Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle providers. *The greatest throughput* of scenario 1 and scenario 2 encryption and decryption functions was obtained by AWS. The smallest *throughput of the scenario 1 encryption function* is obtained by Google Cloud and *the scenario 2 encryption function* is obtained by Oracle. In the decryption function the smallest *throughput from scenarios 1 and 2* is obtained by Google Cloud.

TABLE XI COMPARISON OF THROUGHPUT LOAD TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	161.81	524.21
	Google Cloud	65.6	68.51
	Oracles	76.3	63.38
Decrypt function	AWS	169.3	651.04
	Google Cloud	63.2	73.40
	Oracles	64.3	78.21

6) Latency

Table 13 is comparison *latency load testing* function encryption and function decryption Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle providers. Least *latency* on functions encryption and function decryption Scenario 1 and Scenario 2 are obtained by AWS. The biggest *latency on the function encryption* Scenario 1 is obtained by Google Cloud and scenario 2 is obtained by Oracle. In the decryption function, the greatest *latency in scenario 1 and scenario 2* is obtained by Oracle.

TABLE XII COMPARISON OF LATENCY LOAD TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	197.059	402.628
	Google Cloud	1124.52	2694.68
	Oracles	978.498	2920.76
Decrypt function	AWS	230.262	295.8836
	Google Cloud	1245.82	2336.78
	Oracles	1370.435	2560.05

B. Stress Testing

1) Average Response Time

Table 14 is a comparison of the average *response time stress testing* the encryption function and decryption function Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle *providers*. In scenario 1 and scenario 2, the smallest average *response time* obtained by Oracle is 6687 ms and 6877 ms. Meanwhile, the largest average *response time* in scenario 1 encryption function was obtained by Google Cloud at 15673 ms and in scenario 2 encryption function obtained by AWS. In the scenario 1 decryption function, the smallest average *response time* is obtained by AWS of 6093 and in scenario 2 obtained by Oracle is 5576 ms. While the highest average *response time* in the scenario 1 and scenario 2 decryption function was obtained by Google Cloud at 13859 ms and 9705 ms.

TABLE XIII COMPARISON OF AVERAGE RESPONSE TIME STRESS TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	7047	12858
	Google Cloud	15673	9828
	Oracles	6687	6877
Decrypt function	AWS	6093	8574
	Google Cloud	13859	9705
	Oracles	6635	5576

2) Minimum Response Time

Table 15 is minimum *response time comparison stress testing* function encryption and function decryption Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle *providers*. Oracle gets the smallest minimum *response time* on the encryption and decryption functions in scenario 1. There are several *minimum response times* that produce a value of 0 so that it is not visible on the graph. This is because there are so many *errors that occur at once that the request* is immediately countered.

TABLE XIV COMPARISON OF MINIMUM RESPONSE TIME STRESS TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	851	0
	Google Cloud	0	0
	Oracles	63	0
Decrypt function	AWS	909	0
	Google Cloud	0	0
	Oracles	61	0

3) Maximum Response Time

Table 16 is comparison maximum *response time stress testing* function encryption and function decryption Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle *providers*. AWS gets the smallest result the maximum *response time* of function encryption and decryption in scenario 1, but in scenario 2 it functions encryption, AWS maximum *response time increases* substantially drastic up to 320678 ms.

TABLE XV COMPARISON OF MAXIMUM RESPONSE TIME STRESS TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	21250	320678
	Google Cloud	45262	50427
	Oracles	57959	107945

Decrypt function	AWS	10529	75578
	Google Cloud	101837	72516
	Oracles	81213	71820

4) Error

Table 17 is a comparison of the percentage error *stress testing* of the encryption function and the decryption function Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle *providers*. In the scenario 1 encryption and decryption function, AWS gets the least percentage of errors, namely 0.995% and 0.747%. But in scenario 2, the percentage of AWS errors rises to the range of 46% to 53%. Google Cloud and Oracle got somewhat consistent results in the range of 76% to 93% in scenario 1 and scenario 2.

TABLE XVI COMPARISON OF ERROR STRESS TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	0.995	46.743
	Google Cloud	78.638	91.292
	Oracles	89.943	90.994
Decrypt function	AWS	0.747	53.568
	Google Cloud	76.06	92.195
	Oracles	90.374	93.77

5) Throughput

Table 18 is *throughput comparisons stress testing* the encryption function and decryption function Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle *providers*. AWS got the highest *throughput result on scenario 1 encryption function, and scenario 1 and scenario 2 decryption function*. Google Cloud got results highest *throughput* on function encryption scenario 2.

TABLE XVII COMPARISON OF THROUGHPUT STRESS TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	701.1285	554.8832
	Google Cloud	278.369	582.5547
	Oracles	514.774	457.2054
Decrypt function	AWS	808.5473	916.5491
	Google Cloud	298.9898	644.1867
	Oracles	498.4205	817.0162

6) Latency

Table 19 is comparison of the average *latency* of the test *stress testing* function encryption and function decryption Key Management Service from scenario 1 and scenario 2 on AWS, Google Cloud, and Oracle *providers*. AWS got the lowest average *latency on scenario 1 encryption function, scenario 1 and scenario 2 decryption function*. Oracle got the lowest average *latency on scenario 2 encryption function*.

TABLE XVIII COMPARISON OF LATENCY STRESS TESTING

Label	Provider	Scenario 1	Scenario 2
Encrypt Function	AWS	7076.899	21624.73
	Google Cloud	19552.47	23219.05
	Oracles	19814.49	20406
Decrypt function	AWS	6108.458	17165.57
	Google Cloud	16974.61	22899.32
	Oracles	20140.7	18436.87

C. Benchmark Testing

1) Average Response Time

Table 20 is comparison of the average *response time* of testing *benchmark testing* of the function encryption and function decryption Key Management Service on the insert file sizes 100KB, 1MB, and 10MB. In the 100KB file encryption function, AWS gets an average response time of less than Google Cloud. Meanwhile, the 1MB and 10MB file encryption, Google Cloud has an average response time that is lower than AWS. Oracle Cloud produces a constant *average response time* of 0 ms due to unsuccessful *benchmark testing*.

TABLE XIX COMPARISON OF AVERAGE RESPONSE TIME BENCHMARK TESTING

Label	Cloud Provider	Average Response Time (ms)
Encrypt Files 100KB	AWS	97
	Google Cloud	133
	Oracles	0
Encrypt Files 1MB	AWS	192
	Google Cloud	147
	Oracles	0
Encrypt Files 10MB	AWS	2117
	Google Cloud	1023
	Oracles	0

2) Minimum Response Time

Table 21 is comparison of minimum *response time* testing *benchmark testing* function encryption and function decryption Key Management Service on the insert file sizes 100KB, 1MB, and 10MB. At 100 KB file encryption, AWS gets minimum *response time* results more A little compared to Google Cloud. Meanwhile, at 1 MB and 10 MB file encryption, Google Cloud gets minimum *response time* results are more A little compared to AWS. Oracle Cloud generates a constant *minimum response time* of 0 ms due to unsuccessful *benchmark testing*.

TABLE XX COMPARISON OF MINIMUM RESPONSE TIME BENCHMARK TESTING

Label	Cloud Provider	Min Response Time (ms)
Encrypt Files 100KB	AWS	88
	Google Cloud	102
	Oracles	0
Encrypt Files 1MB	AWS	162
	Google Cloud	123
	Oracles	0
Encrypt Files 10MB	AWS	781
	Google Cloud	534
	Oracles	0

3) Error

Table 22 is comparison error presentation testing *benchmark testing* function encryption and function decryption Key Management Service on the insert file sizes 100KB, 1MB, and 10MB. From pictures we can conclude that there are none of the errors generated at the time testing good *benchmark testing* from AWS or Google Cloud *providers*. Especially for Oracle Cloud, it produces a constant error of 0% due to unsuccessful *benchmark testing*.

TABLE XXI COMPARISON OF ERROR BENCHMARK TESTING

Label	Cloud Provider	Error %
	AWS	0

Encrypt Files 100KB	Google Cloud	0
	Oracles	0
Encrypt Files 1MB	AWS	0
	Google Cloud	0
	Oracles	0
Encrypt Files 10MB	AWS	0
	Google Cloud	0
	Oracles	0

4) Throughput

Table 23 is a comparison of *throughput for benchmark testing* of the encryption function and decryption function Key Management Service in the file enter size 100KB, 1MB, and 10MB. At 100 KB file encryption, AWS gets slightly more *throughput* than Google Cloud. Meanwhile, for 1 MB and 10 MB file encryption, Google Cloud gets greater *throughput than AWS*. Oracle Cloud generates a constant *throughput* of 0 requests per second due to unsuccessful *benchmark testing*.

TABLE XXIII COMPARISON OF THROUGHPUT BENCHMARK TESTING

Label	Cloud Provider	Throughput(s)
Encrypt Files 100KB	AWS	10.04016
	Google Cloud	9.8912
	Oracles	0
Encrypt Files 1MB	AWS	9.43396
	Google Cloud	9.68054
	Oracles	0
Encrypt Files 10MB	AWS	2.6462
	Google Cloud	4.58926
	Oracles	0

5) Latency

Table 24 is comparison of the average latency of benchmark testing function testing encryption and function decrypt Key Management Service in the insert file sizes 100KB, 1MB, and 10MB. At 100 KB file encryption, AWS gets more latency results A little compared to Google Cloud. However, at 1 MB file encryption and 10 MB Google Cloud gain more latency results A little compared to AWS. Oracle Cloud produces an average constant latency of 0 ms due to unsuccessful *benchmark testing*.

TABLE XXIII COMPARISON OF LATENCY BENCHMARK TESTING

Label	Cloud Provider	Latency (ms)
Encrypt Files 100KB	AWS	97.1
	Google Cloud	133.4
	Oracles	0
Encrypt Files 1MB	AWS	171
	Google Cloud	142.9
	Oracles	0
Encrypt Files 10MB	AWS	1774.4
	Google Cloud	975.3
	Oracles	0

V. CONCLUSION

Based on results analysis Key Management Service performance on AWS, Google Cloud, and Oracle using load testing methods, stress testing, and benchmark testing, can concluded things following:

1. In the load testing test, AWS shows the best results compared to Google Cloud and Oracle. AWS has more response time, throughput, and latency well, as well No generates an error in the load testing test. Google Cloud and Oracle experienced an error rate of 0.44% to 2.44%.

2. In stress testing, the percentage of errors is a determining factor for the success of requests. AWS has more error percentage low than Google Cloud and Oracle, while the best latency, throughput, and response time alternate between AWS, Google Cloud, and Oracle.
3. In benchmark testing, AWS has more results good at encrypting file sizes of 100 KB, while Google Cloud is more both in encryption file size of 1 MB and 10 MB in terms of response time, throughput, and latency. No, there is an error that occurs in benchmark testing.
4. Based on testing whole, author recommend AWS provider in implementing Key Management Service because more error rate low, competitive response time and latency, as well as more throughput superior.

ACKNOWLEDGMENT

The author would like to thank various parties who have supported the author in completing this research as well as possible.

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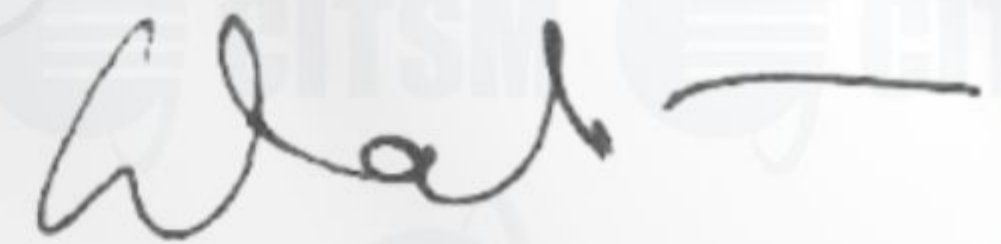
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