PROTOTYPE DESIGN OF CLIENT-SERVER ARCHITECTURE AND GEO-BI TOOLS IN COMMODITY PRICE MONITORING BASED ON PUBLIC PARTICIPATION

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Abstract:
Commodity price stability is a critical pillar in maintaining regional economic resilience and mitigating inflation. However, conventional data collection methods often face significant operational challenges, including high costs, time lags, and limited personnel. This study proposes an innovative, low-cost digital solution by designing a system prototype that integrates a client-server architecture with Geographic Business Intelligence (Geo-BI) tools based on community participation (crowdsourcing). The proposed model utilizes local village officials as enumerators to transmit price data to a Virtual Private Server (VPS) PostgreSQL database, incorporating automated GPS coordinate tracking to ensure spatial validity. Testing using simulated data demonstrates that an intermittent sampling strategy is architecturally capable of capturing macro price trends without overburdening local human resources. Visualizations through an interactive dashboard effectively facilitate early detection of price and spatial anomalies, thereby contributing to public sector transparency and accountability in supporting good governance.
Keywords: Prototype Design; Client-Server Architecture; Geo-BI, Price Monitoring; Good Governance

Abstrak:
Stabilitas harga komoditas merupakan pilar krusial dalam menjaga ketahanan ekonomi daerah dan menekan laju inflasi. Namun, metode pengumpulan data konvensional seringkali terkendala oleh tingginya biaya operasional, jeda waktu pelaporan, dan keterbatasan personil. Penelitian ini mengusulkan solusi digital yang efisien dengan merancang prototipe sistem yang mengintegrasikan arsitektur *client-server* dan *Geographic Business Intelligence* (Geo-BI) berbasis partisipasi masyarakat (*crowdsourcing*). Model yang diusulkan melibatkan perangkat desa sebagai enumerator lokal yang mengirimkan data harga ke basis data *Virtual Private Server* (VPS) PostgreSQL, yang dilengkapi dengan validasi koordinat GPS otomatis untuk menjamin integritas data. Pengujian menggunakan data simulasi menunjukkan bahwa strategi *intermittent sampling* mampu menangkap tren harga makro secara akurat tanpa membebani sumber daya manusia lokal. Visualisasi data melalui dashboard interaktif terbukti efektif dalam deteksi dini anomali harga dan spasial, sehingga mendukung transparansi sektor publik dan akuntabilitas tata kelola pemerintahan yang baik (*good governance*).
Kata Kunci: Perancangan Prototipe; Arsitektur Client-Server; Geo-BI; Pemantauan Harga; Tata Kelola yang Baik

1. Introduction

Commodity price stability is a fundamental pillar in maintaining macroeconomic resilience and social welfare, particularly in developing countries like Indonesia. Uncontrolled food price fluctuations not only trigger regional inflation but also directly erode purchasing power, ultimately threatening the sustainability of Micro, Small, and Medium Enterprises (MSMEs) and regional economic stability (Fitriani et al., 2026).

In the current digital era, mitigating economic volatility requires responsive, accurate, and sustainable market intelligence. Early identification of price anomalies enables governments and monetary authorities to intervene in markets precisely, preventing wider economic distortions. Providing a real-time commodity price monitoring mechanism is crucial for building a resilient and accountable digital economic ecosystem (Moretto et al., 2025).

Conventional public sector data collection frameworks, such as those managed by official agencies like the Central Bureau of Statistics (BPS), often face significant operational constraints. Survey methodologies are highly dependent on enumerators deployed directly to the field, a process requiring high operational costs and complex logistics (Almahdali, 2025). Consequently, data collection often suffers from time lags, resulting in retrospective rather than real-time reporting. Conventional reporting structures generally lack spatial attributes, complicating the analysis of price disparities across geographical regions, especially in markets spread across rural and urban areas. Given the limitations of administrative personnel at the regional level, maintaining continuous annual data collection schedules is highly inefficient and unsustainable.

To bridge these operational gaps, this research proposes a low-cost, high-impact digital innovation: an infrastructure that integrates client-server architecture and Geographic Business Intelligence (Geo-BI) tools (Oleś-filiks, 2025) based on community participation (crowdsourcing). Data collection does not involve specialized survey officers; instead, this framework decentralizes data collection by empowering local human resources, specifically village officials, as enumerators in their respective regions. Through the use of mobile-friendly, cloud-based input instruments, data flows directly into a centralized database hosted on a Virtual Private Server (VPS). To ensure public sector accountability and strict data validation, every entry automatically records geolocation coordinates (GPS), effectively minimizing the risk of fictitious reports or incorrect locations.

In the final design stage, the modeled data stream is pushed to an interactive BI Tools visualization engine (Bjerre et al., 2025). This prototype system is designed to transform table figures into anomaly detection maps and temporal trend lines, tested using simulated data. This testing aims to assess visualization reliability if flexible sampling schedules are applied to optimize resource efficiency. By integrating modern IT infrastructure and the concept of active community participation, this research provides a tangible blueprint for evidence-based policy formulation. The objective of this study is to produce a valid, accountable, and resilient prototype design of client-server architecture and Geo-BI to maintain regional economic stability in the digital era.

2. Literature Review

2.1. Economic Resilience, Inflation, and Market Monitoring

The economic resilience of a region is highly influenced by its ability to manage market shocks, such as the volatility of key food prices that trigger inflation. In the digital economy, information asymmetry between wholesalers, speculators, and MSMEs is often the root cause of price distortions in traditional markets, which ultimately reduces the accuracy of statistical estimates in cost-of-living surveys. From an Islamic economic perspective, market monitoring to ensure fair pricing and prevent ikhtikar (hoarding) is known as the concept of Hisbah (Melzatia et al., 2025). In the modern era, Hisbah implementation is no longer manual but transforms using information technology instruments to create price transparency that protects the rights of small producers and consumers. Reliable price monitoring is an absolute prerequisite for formulating targeted monetary and fiscal policies to control regional inflation.

2.2. Digital Public Sector Governance and Community Participation (Crowdsourcing)

Good Governance demands transparency, accountability, and public participation in every evidence-based policy process. The use of information and communication technology (ICT) is proven to build a culture of transparency and minimize reporting manipulation in the public sector. However, public data collection by official agencies like BPS is often constrained by budget and field personnel limitations. As a solution, a voluntary data collection approach or Volunteered Geographic Information (VGI) is proven effective in cutting bureaucracy and operational costs by positioning the community as information sensors. Involving village officials as local enumerators is a form of public sector accounting optimization at the grassroots level. By applying a structured intermittent sampling strategy, data collection can maintain statistical representation of macro data without overburdening local human resource capacity.

2.3. Client-Server Architecture, GIS, and Business Intelligence (BI)

Cloud computing-based client-server architecture, such as the use of a Virtual Private Server (VPS), offers high scalability, bureaucratic efficiency, and data sovereignty for public agencies (Hummel et al., 2021). The use of user-friendly input devices integrated with a centralized database minimizes technical barriers at the end-user level (Moretto et al., 2025). Before data presentation, applying data cleaning formulas is crucial to filter out outliers resulting from input errors. Furthermore, spatial data integration through a Geographic Information System (GIS) provides a new dimension to macro-statistical analysis. The use of Business Intelligence (Geo-BI) tools is capable of converting raw coordinate data and transactional figures into interactive monitoring dashboards (Nuraini & Romadhoni, 2025). Constructing an effective dashboard allows policymakers to understand market situations instantly through comprehensive visual summaries. Automated validation using GPS coordinates ensures that data has a high level of spatial accountability, prevents fictitious reports, and supports digital transparency.

3. Research Methods

3.1. Object, Time, and Place

The object modeled in this prototype is the daily commodity price data structure. This system design and modeling use simulated data. To test its architectural efficiency, the data flow simulation is designed using a combination of a centralized database on a VPS server and Google Sheets. This modeling approach allows the architecture to be simulated within a limited time frame. The spatial model in this prototype is simulated using coordinate points of traditional markets located in the South Brebes region.

3.2. Data Collection Techniques

Data collection in this study utilizes simulated data (dummy data) sourced from *https://www.kaggle.com/code/mochamadraivaldy/bawang-merah-price/input*. This dataset was subsequently interpolated into a weekly format to align with the proposed intermittent sampling strategy. Finally, the data was ingested into a database structured according to the standard data format of the Indonesian Central Bureau of Statistics (BPS).

3.3. Data Analysis Techniques

The prototype development and analysis methods are illustrated in **Figure 1**. The figure is explained as follows:

A. Client-Server Architecture Design

The initial stage focuses on modeling the network infrastructure and data flow to support community-based (crowdsourcing) price monitoring.

- Client-Side (Input): Designing a web-mobile-based input instrument optimized for operation by village officials (local enumerators) in the field. This instrument is designed to capture daily commodity price data, physical photo evidence, and automatically track GPS coordinates.
- Server-Side (Storage): Organizing a relational database using PostgreSQL with the PostGIS extension hosted on a Virtual Private Server (VPS). This architecture ensures data sovereignty and independent spatial processing capabilities.

B. Proses Extract, Transform, Load (ETL) Data

This stage governs how raw data from enumerators is processed until it is ready to be consumed by Business Intelligence (BI) tools. The ETL process in this system is designed in two layers (multi-tier). The first layer (Server-Side) focuses on injecting survey data from the mobile application into the PostgreSQL database on the VPS through table relationalization. The second layer (Client-Side) is performed within the Geo-BI tools through a Data Modeling process, integrating transactional data from PostgreSQL with master data from Google Sheets. The transformation process in the second layer includes data cleansing, schema relationalization, and the implementation of analytical logic using Data Analysis Expressions (DAX) and the integration of Python scripts for more precise statistical modeling (EMA).

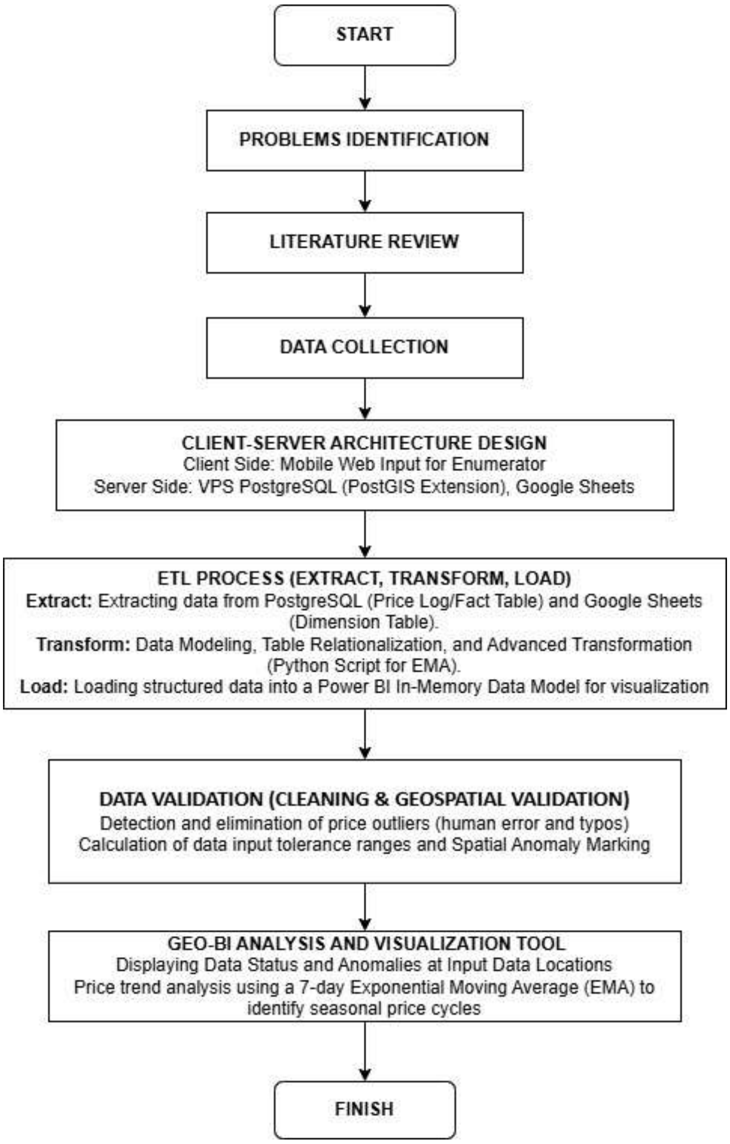

Figure 1. Client-Server and Geo-BI architecture design stages

C. Data Cleansing and Coordinate Anomaly Analysis

To ensure public sector accountability and data validity before reaching the modeling stage, strict filtering is applied:

1. Implementing extreme value detection formulas (outliers) within the database or BI tools to filter out price typographical errors made by enumerators, including cleaning incomplete data. The price input cleaning formulation uses the Interquartile Range (IQR) method. First, we divide the data into four equal parts to obtain Quartile 1 (Q1 or the 25th percentile) and Quartile 3 (Q3 or the 75th percentile).

   Calculate the Quartile Range (IQR):

   $$IQR = Q_3 - Q_1$$

   Determine the Lower Bound:

   $$Lower\ Bound = Q_1 - (1.5\ x\ IQR)$$

   Determine the Upper Bound:

   $$Upper\ Bound = Q_3 + (1.5\ x\ IQR)$$

   All data whose value is less than the Lower Limit or more than the Upper Limit will be immediately filtered as typo or outlier data.

2. Coordinate Anomaly Analysis uses spatial-based geofencing logic. The system calculates the geometric distance between the enumerator's input coordinates and the registered market reference coordinates. If the data row distance exceeds a predetermined tolerance radius, the dashboard displays the data as a Spatial Anomaly to detect fraudulent reports. To identify the validity of the input coordinates, each market data set is assigned a permissible spatial tolerance radius (τ). The classification of data as normal or anomalous is determined based on the following condition function:

$$Status = \{Anomali, jika\ D > \tau\ ;\ Normal, jika\ D \leq \tau$$

The variable *D* represents the distance between the input data and the market coordinate location. To measure the geometric distance *D* between the two points, the Euclidean distance formula is used:

$$D = \sqrt{(X_1 - X_2)^2 + (Y_1 - Y_2)^2}$$

Where X_1 and Y_1 are the input coordinate points, while X_2 and Y_2 are the reference coordinate points (the market location).

The use of the Euclidean distance formula simplifies the architectural design prototype in this case study. A distance tolerance of 50 to 100 meters is representative for this formula. Geographic coordinates (lat/long) are spherical (spherical/curved), not flat (Euclidean). Using Euclidean distance on lat/long coordinates produces less accurate results for long distances.

D. Geo-BI Analysis and Visualization

Data that has undergone cleaning and input anomaly detection is then displayed on the dashboard. The data displayed includes:

1. Total data count (Total Data)
2. Input location status matrix table (normal and anomalous)
3. Data status matrix table (normal and outliers)
4. Input status anomaly map (routes maps)
5. Weekly commodity price graph (total data)
6. Main table displaying visit ID, recording date, enumerator name, market ID, market name, commodity category, commodity name, price, unit, tolerance radius, distance, input location status, and data status
7. Commodity price trend analysis (shallots)

In this study, the Exponential Moving Average (EMA) method was used to analyze commodity price trends. EMA was chosen as a data smoothing technique to identify shallot price trends. The selection of EMA is based on the characteristics of commodity price data, which is volatile and influenced by current market conditions. Unlike the Simple Moving Average (SMA), the EMA assigns exponentially decreasing weight to older observations, resulting in a trendline that is more responsive to recent price changes without ignoring seasonal patterns.

The mathematical formula used to calculate the EMA value is:

$$EMA_t = (P_t . \alpha) + (EMA_{t-1} . (1 - \alpha)$$

Where the smoothing factor (α) is determined by the time period (span) used, with the formula:

$$\alpha = \frac{2}{span + 1}$$

- $EMA_t : EMA\ value\ at\ time\ t$
- $P_t : Actual\ price\ at\ time\ t$
- $EMA_{t-1} : EMA\ value\ at\ previous\ time$
- $span : Time\ window\ period$

4. Result and Discussion

4.1. Research Result

A. Client-Server Architecture Design and BI Tools Model

This study has successfully built a client-server architecture prototype in an agile and cost-efficient manner. Based on internal testing, the data migration flow from the mobile application (client-side) to the Virtual Private Server (VPS) database was successful. The implementation of this independent VPS model conceptually proves that the public sector can possess full, secure, and independent data sovereignty.

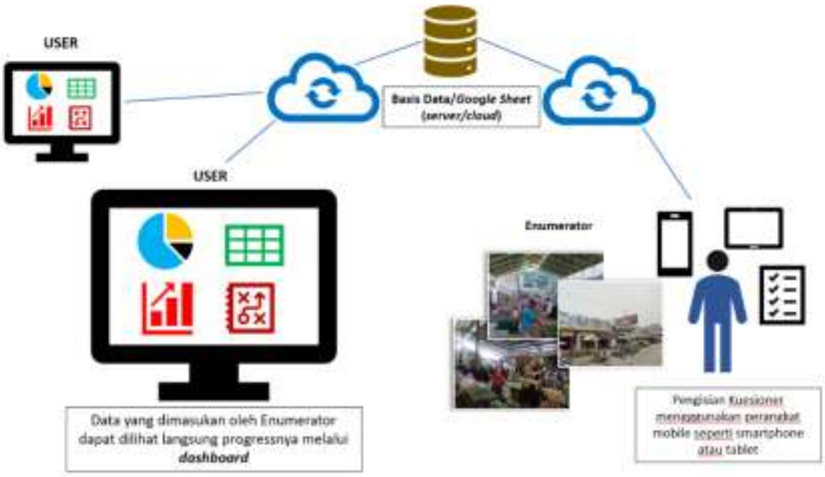

Figure 2. Client-Server architecture

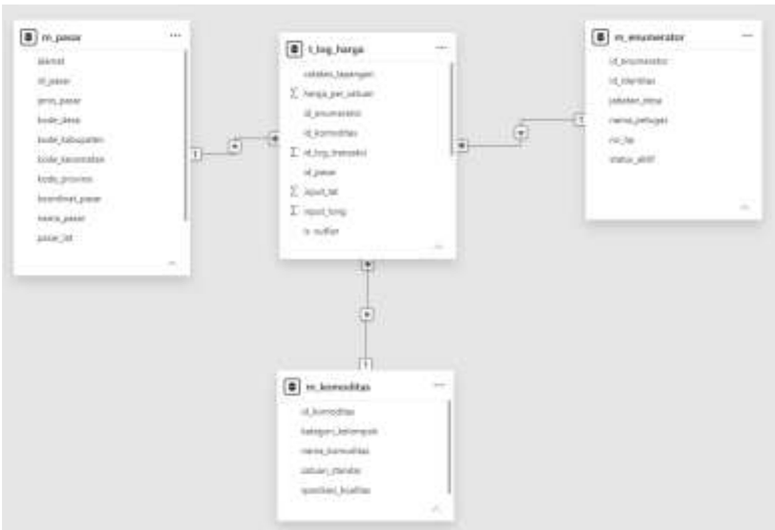

Figure 3. BI tools system modeling

B. Data Visualization Using Geo-BI Tools

The database prototype on the VPS was successfully connected in real-time to Power BI. Visualization testing results show that the Executive Dashboard is able to instantly summarize simulated data into two main components: a GPS coordinate-based spatial map and a Temporal Trend Chart (weekly fluctuation trends). This indicates that the Geo-BI tools are ready to be integrated to accelerate the public institution's response in detecting market anomalies.

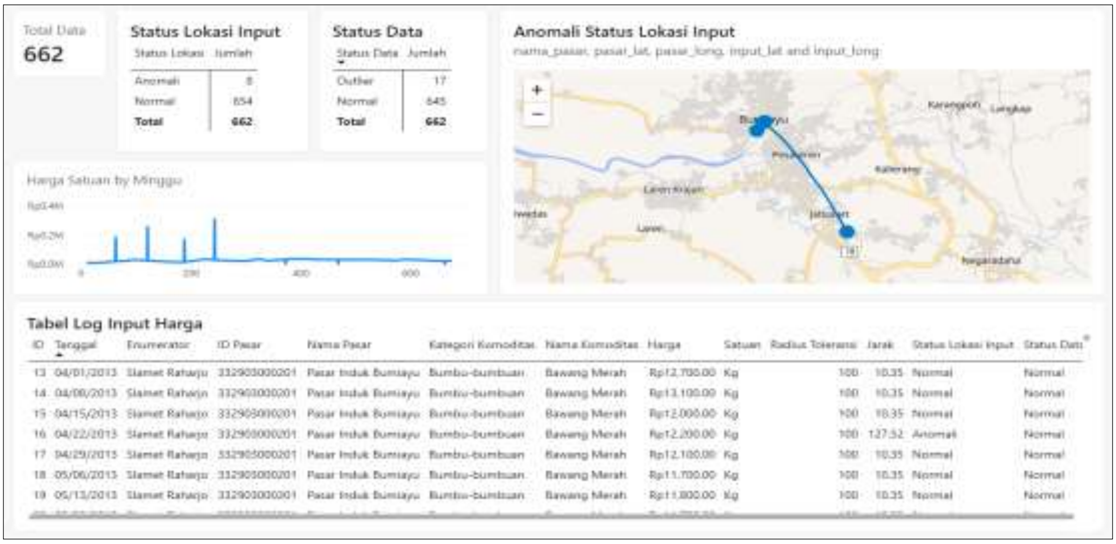

Figure 4. Main dashboard view

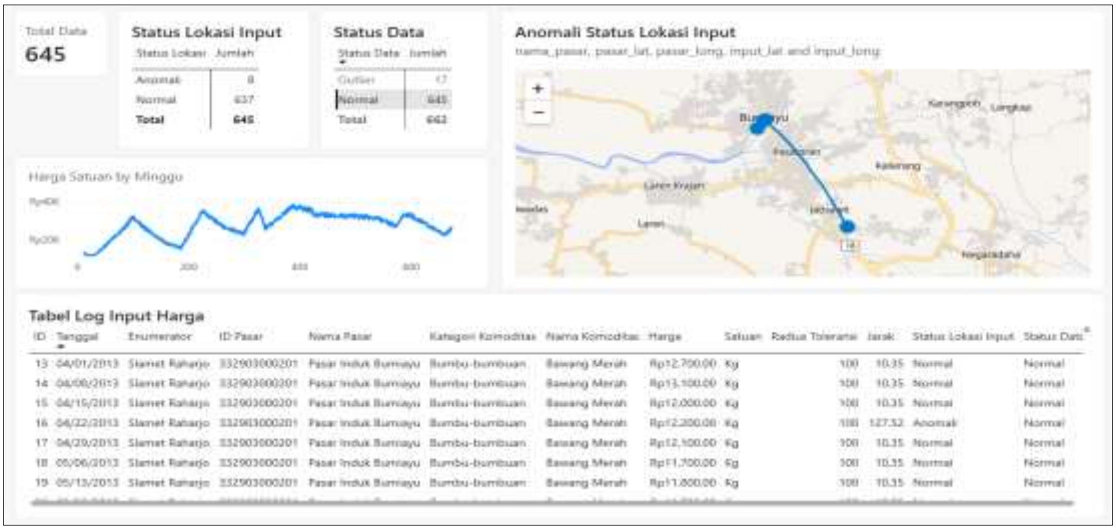

Figure 5. Dashboard view for normal data status

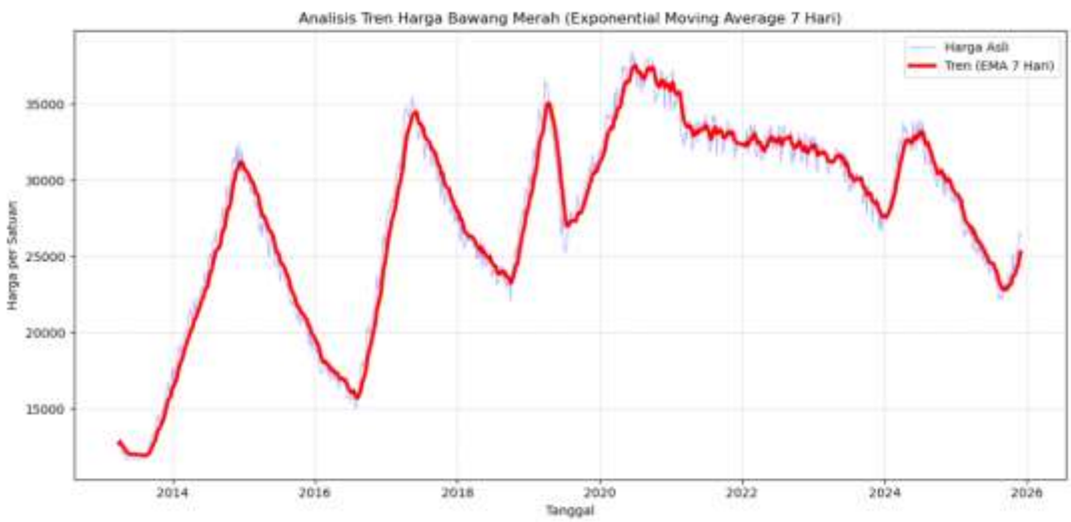

Figure 6. Onion price trend analysis display using EMA (7 days)

4.2. Discussion

A. Feasibility Analysis of Intermittent Sampling Strategy

Based on functional testing using simulated data, the dashboard's chart visualization remains capable of accurately displaying macro fluctuation trends even when using periodic (weekly) data input. This theoretical finding confirms that, architecturally, this model can be a resolution to conventional reporting problems at BPS or the Department of Trade, which often experience budget limitations and staff burnout (survey fatigue). Crowdsourcing utilization through village officials is proven technically feasible as a cost-efficient alternative for data collection.

B. Spatial Accountability Logic Validation

The discussion on the Good Governance aspect of this prototype focuses on the reliability of the GPS coordinate filtering feature. When simulating data input with dummy coordinates outside the market range, the rule system on the BI Tools successfully isolated the data as fictitious reports (anomalies). This logic testing proves that the designed architectural model has built-in mechanisms to minimize information asymmetry and maintain report integrity before being presented to decision-makers.

C. Price Trend Analysis in the Geo-BI Tools Prototype

The implementation of the 7-day Exponential Moving Average (EMA) method in this prototype's analytics module is designed to support transparent, data-driven commodity price monitoring. In the developed client-server architecture, the resulting trend visualization serves as an information layer that helps both community participants and supervisors interpret price fluctuations in real time.

Based on the prototype's analysis results graph, the following is a discussion of the model's relevance to system functions:

1. Trend Interpretation Capabilities for the Community. The integration of the EMA model on the client side allows users to separate data noise from the main price trend. With smooth yet responsive visualizations, community participants in price monitoring can easily identify the direction of price movements without requiring in-depth statistical technical expertise. This reinforces the user-friendliness aspect of the Geo-BI Tools prototype design.
2. Support for Monitoring Functions. The use of this model has proven effective in mapping recurring price cycles. In the designed Geo-BI architecture, the system's ability to systematically identify periods of price increases or decreases allows supervisors to provide early warnings if price anomalies occur that deviate from expected seasonal patterns, thus maintaining commodity price transparency.
3. Data Reliability in the Geo-BI Architecture. In the context of a client-server architecture, selecting a reliable EMA model—compared to polynomial regression, which is prone to overfitting—ensures that the data sent from the server to the client remains consistent and valid. This is crucial in a public participation-based system, where information accuracy is key to maintaining public trust in the price monitoring platform being developed.

4.3. Relevance to Research Objectives

The integration of the client-server architecture and Geo-BI tools provides a robust framework for evidence-based decision-making in regional economic governance. The prototype’s functionality directly addresses the identified research objectives, demonstrating both technical viability and socioeconomic utility. The relevance of the system to the research objectives is outlined as follows:

1. The implementation of the client-server architecture and Geo-BI tools has proven relevant and meets the primary research objective, which is to provide a low-cost, fast, and accurate price monitoring system.
2. Price transparency presented on the dashboard protects market traders and MSMEs (entrepreneurs) from information asymmetry and price speculation.
3. It provides a tool for public policymakers (Regional Governments/BPS) to monitor food inflation rates in real time based on valid and accountable spatial data.

Consequently, these outcomes underscore the system's capacity to transform manual reporting into an automated, transparent, and accountable digital workflow.

4. Conclusion

5.1 Conclusion

This research successfully compiled and tested a prototype design of a VPS PostgreSQL (PostGIS) client-server architecture integrated with Geo-BI tools (Power BI). Through testing using simulated data, this system model is technically proven capable of performing commodity price monitoring functions independently and cost-efficiently. The zigzag-patterned intermittent sampling design and the utilization of the village official crowdsourcing mechanism are conceptually viable solutions to address the logistical limitations of agencies like BPS. Coupled with a reliable GPS coordinate validation system, this architectural blueprint is ready to support the implementation of Good Governance and transparency in the digital era.

5.2 Recomendation

Based on the research results and system trials conducted, several recommendations can be proposed:

1. Further development can add simple Machine Learning features (such as time-series forecasting) on the Power BI dashboard to predict commodity price spikes in the coming weeks before anomalies occur in the market.
2. The web-based mobile application can be upgraded to a dedicated Android or iOS application that is more flexible for data collection in remote areas (with poor signal).

Bibliography

Almahdali, H. (2025). *Tantangan dan Peluang Inovasi Pelayanan Publik di Era Revolusi Industri 4 . 0 (Challenges and Opportunities for Public Service Innovation in the Industrial Revolution 4 . 0 Era)*. *4*(2), 63–73.

Bjerre, J., Clausen, B., Møller, C., Boye, C., & Lundgaard, S. (2025). Self-service business intelligence systems in production domains : Introducing data democratization and mass customizable mashups $. *Digital Business*, *5*(2), 100156. https://doi.org/10.1016/j.digbus.2025.100156

Fitriani, R. D., Zahra, A., Fadhilah, R. A., & Bahtiar, M. Y. (2026). *Dampak Inflasi terhadap Keuntungan Usaha Mikro (UMKM) di Lingkungan Pasar Teori inflasi Inflasi didefinisikan sebagai kenaikan tingkat harga umum yang berlangsung terus-*. 1–5.

Hummel, P., Braun, M., Tretter, M., & Dabrock, P. (2021). *Data sovereignty : A review*. https://doi.org/10.1177/2053951720982012

Melzatia, S., Daryanto, E., & Setiono, K. Y. (2025). *Digitalisation of Islamic Economy and Maqasid Sharia for Social Resilience and Welfare*. *13*(1), 89–102. https://doi.org/10.55960/jlri.v13i1.1153

Moretto, M., Delucchi, L., Zorer, R., Moser, D., Micheli, F., Paoli, A., & Franceschi, P. (2025). DigiAgriApp : a client-server application to monitor field activities. *Environmental Modelling and Software*, *192*(January), 106528. https://doi.org/10.1016/j.envsoft.2025.106528

Nuraini, S. S., & Romadhoni, A. M. (2025). *Pemanfaatan Visualisasi Data dalam Business Intelligence untuk Strategi Bisnis Perusahaan Retail*.

Oleś-filiks, M. (2025). ScienceDirect The essence of the use of business analytics and business intelligence systems in supporting managerial decision-making in organisations. *Procedia Computer Science*, *270*, 36–47. https://doi.org/10.1016/j.procs.2025.09.122