

Geo-Insight MBG: A Geospatial Platform to Measure the Impact of the Free Nutritional Meal Program on Children's Nutritional Status

Geo-Insight MBG: Sebuah Platform Geospasial untuk Mengukur Dampak Program Makan Siang Gratis terhadap Status Gizi Anak

Ashabul Kahpi^{1*}, Harianto², Ariastuti Rahman³

^{1,2,3} Universitas Al Asyariah Mandar

E-mail: ashabulkahpi@unasman.ac.id¹, hariantouns@gmail.com²,
ariastuti.rahman@gmail.com³

Abstrak

Program Makan Bergizi Gratis (MBG) merupakan kebijakan strategis nasional untuk meningkatkan status gizi anak sekolah. Namun, evaluasi dampaknya masih dilakukan secara manual dan administratif, sehingga menyulitkan identifikasi wilayah prioritas serta pemantauan perubahan antropometri secara terintegrasi. Penelitian ini bertujuan mengembangkan Geo-Insight MBG, platform geospasial berbasis web untuk mengukur dampak program tersebut terhadap status gizi anak. Metode yang digunakan meliputi pengembangan sistem dengan model Waterfall dan analisis deskriptif kuantitatif terhadap data tinggi badan, berat badan, dan indeks massa tubuh sebelum serta sesudah intervensi. Hasil pengujian menunjukkan bahwa sistem berhasil memvisualisasikan distribusi penerima manfaat, menghitung otomatis kategori gizi berdasarkan z-score, dan menyajikan dashboard serta peta interaktif yang menampilkan efektivitas program per wilayah. Hasil awal dari sampel uji coba sebanyak 15 anak mengindikasikan bahwa 73,3% mengalami perbaikan status gizi dengan rata-rata peningkatan z-score sebesar +0,83. Namun, mengingat ukuran sampel yang terbatas, temuan ini perlu diinterpretasikan secara hati-hati dan memerlukan validasi lebih lanjut melalui studi dengan sampel yang lebih luas. Meskipun demikian, integrasi teknologi geospasial pada platform ini menunjukkan potensi dalam mempermudah pemantauan berbasis lokasi dan mendukung pengambilan keputusan yang lebih tepat sasaran. Geo-Insight MBG menjanjikan sebagai solusi monitoring evaluatif digital yang skalabel untuk mendukung optimalisasi program gizi nasional.

Kata kunci: *program makan bergizi gratis, sistem informasi geografis, monitoring evaluatif*

Abstract

The Free Nutritional Meal Program (MBG) is a strategic national policy designed to improve the nutritional status of school-aged children. However, impact evaluation remains largely manual and administrative, hindering the identification of priority areas and integrated monitoring of anthropometric changes. This study aims to develop Geo-Insight MBG, a web-based geospatial platform to measure the program's impact on children's nutritional status. The methodology employs the Waterfall software development model and quantitative descriptive analysis of height, weight, and body mass index data collected before and after the intervention. System testing demonstrates that the platform successfully visualizes beneficiary distribution, automatically calculates nutritional categories based on z-scores, and generates interactive dashboards and regional heatmaps. Preliminary results from a pilot sample of 15 children indicate that 73.3% showed nutritional improvement, with an average z-score increase of +0.83. While these findings suggest the platform's potential for enhancing location-based monitoring and data-driven decision-making, the limited sample size necessitates

cautious interpretation of the program's effectiveness. Future studies with larger, multi-regional cohorts are needed to validate these results. Nonetheless, Geo-Insight MBG demonstrates promise as a scalable digital evaluation tool that could support optimized resource allocation and targeted interventions in national school nutrition programs.

Keywords: *free nutritional meal program, geographic information system, evaluative monitoring*

1. INTRODUCTION

The Free Nutritious Meal Program (*Makan Bergizi Gratis/MBG*) has emerged as a strategic national policy in Indonesia, designed to address persistent childhood malnutrition, reduce stunting prevalence, and enhance long-term human capital development. Despite targeted investments, Indonesia continues to confront a complex double burden of malnutrition, wherein undernutrition and rising obesity rates coexist across diverse socioeconomic and geographic strata [1], [2]. This nutritional crisis is further exacerbated by structural inequalities, including regional poverty disparities, post-pandemic food insecurity, and inadequate dietary intake among school-aged children [3], [4]. While the MBG program aims to deliver daily nutritious meals to millions of students, its sustained success fundamentally depends on the government's capacity to systematically monitor and evaluate its actual impact on children's anthropometric outcomes and nutritional transitions.

However, current evaluation mechanisms for nutritional interventions in Indonesia remain heavily manual, administratively focused, and disconnected from spatial analytics. Conventional monitoring primarily tracks logistical distribution and enrollment figures, failing to capture critical pre- and post-intervention anthropometric data such as height, weight, and Body Mass Index (BMI) in an integrated manner [5], [6]. The absence of geospatial mapping severely limits the ability of health and educational authorities to identify low-performing regions, track localized nutritional improvements, or allocate resources based on empirical need [2], [7]. Consequently, decision-making often relies on fragmented, non-visualized data, which undermines the precision, transparency, and responsiveness of public health interventions targeting vulnerable student populations.

International evidence from school meal initiatives in Japan, the United Kingdom, and New Zealand demonstrates that effective nutritional programs require robust digital monitoring frameworks, clear nutritional standards, and stakeholder-aligned implementation strategies [2], [8], [9]. Crucially, Geographic Information Systems (GIS) and web-based spatial analytics have proven highly effective in transforming raw health and demographic data into actionable, location-specific insights across various public sectors [10], [11]. Despite these advancements, the application of GIS for monitoring school-based nutritional programs in Indonesia remains significantly underexplored. Integrating spatial visualization with anthropometric tracking could bridge the existing monitoring gap by enabling territory-specific assessment of program efficacy and facilitating targeted, evidence-based interventions.

To address this critical gap, this study develops Geo-Insight MBG, a web-based geospatial platform designed to measure and visualize the impact of the Free Nutritious Meal Program on school children's nutritional status. Utilizing a

structured software development methodology, the platform integrates pre- and post-intervention anthropometric data, automates nutritional status classification based on standardized z-scores, and presents findings through interactive dashboards, comparative analytics, and geospatial heatmaps. The system enables administrators to track individual and school-level nutritional shifts, visualize regional distribution of program recipients, and generate comprehensive evaluative reports within a unified digital interface. By coupling quantitative nutritional analysis with spatial mapping, the platform transforms fragmented administrative records into a coherent, real-time monitoring ecosystem.

The development of Geo-Insight MBG offers a scalable, data-driven solution for evaluative monitoring that aligns with national priorities and Sustainable Development Goals (SDGs) 2 and 3. By providing accurate, location-specific insights into nutritional outcomes, the platform empowers policymakers, school administrators, and health officials to prioritize high-need areas, optimize resource distribution, and implement precision interventions [2], [12]. Ultimately, this research contributes to the broader discourse on digital public health infrastructure by demonstrating how geospatial integration can enhance the accountability, efficiency, and long-term sustainability of large-scale nutritional programs, ensuring that strategic investments translate into measurable improvements in child health and cognitive development.

2. RESEARCH METHODOLOGY

This research uses the Waterfall software development method, a system development model that is carried out systematically and sequentially, starting from the requirements analysis stage to system maintenance. This method was chosen because it can provide a structured workflow in building the Geo-Insight MBG geospatial platform according to user needs. The Waterfall stages consist of Requirements Analysis, System Design, Implementation, Testing, and Maintenance, which are interconnected to produce an effective monitoring system for the impact of the Free Nutritional Meal Program.

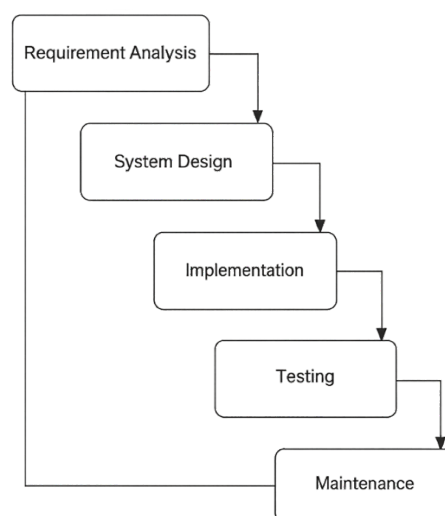


Figure 1. Waterfall

2.1. Requirement Analysis

This stage aims to identify system requirements through observation, literature review, and data collection related to the implementation of the Free Nutritional Meal Program in target schools. The data analyzed included data on children receiving the program, height, weight, age, body mass index, school location, and nutritious food distribution data. Based on the analysis, the system's functional requirements were identified, including data input for MBG recipients, nutritional status processing, area map visualization, an analytical dashboard, and monitoring and evaluation reports.

2.2. System Design

The system design phase was conducted to design the working structure of the Geo-Insight MBG platform based on the identified needs. This phase included the development of use case diagrams, entity relationship diagrams (ERDs), database designs, and user interfaces. Furthermore, a geospatial module was developed to display the distribution of MBG program recipient schools in the form of a digital map and a heatmap of the effectiveness of changes in children's nutritional status.

2.3. Implementation

The implementation phase is the process of translating the system design into program code using the PHP programming language and a MySQL database. The system was developed as a web-based application for easy access by school administrators and related agencies. Each module was implemented according to the previous design, including a child anthropometric data input module, an automatic nutritional status calculation module, a geospatial mapping module, a nutritional development graph dashboard, and an MBG Program evaluation report module.

2.4. Testing

After the system was completed, testing was conducted using black-box testing to ensure each function was functioning as expected. Testing was conducted on the data input menu, the nutritional status calculation process, the location map display, the analytical dashboard, and the reporting feature. Furthermore, validation testing was conducted by comparing children's nutritional status data before and after receiving the Free Nutritional Meal Program to determine the accuracy of the system's information.

2.5. Maintenance

The maintenance phase is carried out after the system has been tested and found to be operating properly. This phase involves fixing errors, improving system performance, and adjusting features as user needs change. Maintenance also includes regularly updating MBG Program recipient data to ensure the geospatial information and child nutritional status analysis displayed remains accurate and relevant.

3. RESULTS AND DISCUSSION

3.1. Results

This section presents the implementation outcomes and analytical findings of the Geo-Insight MBG platform, developed to monitor and evaluate the impact of the Free Nutritional Meal Program on school children's nutritional status. The web-based system successfully integrates anthropometric data processing with interactive

geospatial visualization, enabling administrators to track nutritional transitions and assess program effectiveness across multiple administrative levels. All modules function cohesively to transform raw input data into actionable insights through dashboards, statistical graphics, and spatial heatmaps. The following subsections detail the system's functional outputs and their interpretive significance for evaluative monitoring.

3.1.1. System Interface and Dashboard Analytics

The main dashboard serves as the central information hub, providing an immediate overview of key performance indicators related to the nutritional intervention. It displays aggregate metrics including total beneficiary children, participating schools, percentage distribution of nutritional status changes, and average z-score shifts before and after program implementation. Visual elements such as progress bars, summary cards, and trend indicators enable rapid comprehension of program outcomes without requiring deep navigation. This design prioritizes usability for decision-makers who need concise, high-level insights to guide resource allocation and policy adjustments. The dashboard's responsive layout ensures accessibility across devices, supporting field officers and administrative staff alike.

Table 1. Dashboard Summary Metrics (Sample Data from Pilot Implementation)

Metric	Before Program	After Program	Change
Total Children Monitored	15	15	-
Average Z-Score	-1.33	-0.50	+0.83
Children with Improved Status	-	11 (73.3%)	+73.3%
Children with Stable Status	-	4 (26.7%)	+26.7%
Children with Declined Status	-	0 (0%)	0%
Dominant Nutritional Category	Undernourished	Normal	Shift observed

The table above summarizes the core quantitative outcomes captured by the dashboard during the pilot phase. It demonstrates a clear positive trajectory in children's nutritional status, with the average z-score improving by 0.83 units—moving the cohort mean from the 'undernourished' range (-1.33 SD) toward the 'normal' threshold (-0.50 SD)—and nearly three-quarters of beneficiaries (73.3%) experiencing categorical improvement according to WHO-defined criteria. The complete absence of declined cases suggests the intervention did not produce adverse effects within the monitored cohort. These aggregated metrics provide a reliable foundation for preliminary program assessment and stakeholder reporting.

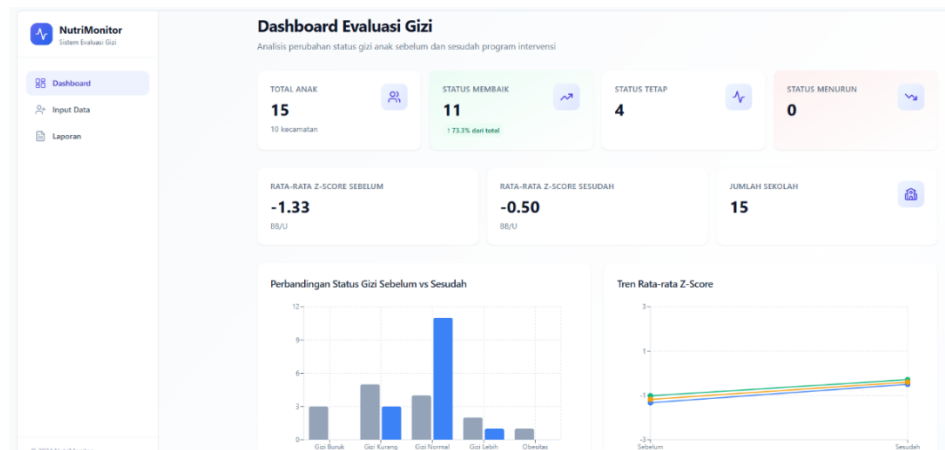


Figure 2. Main Dashboard Interface Displaying Summary Metrics and Visual Analytics

The dashboard interface visually consolidates numerical data into intuitive charts and indicators, reducing cognitive load for users interpreting complex nutritional information. Color-coded status badges and progress rings allow instant recognition of improvement patterns across schools and regions. Interactive elements enable drill-down functionality, permitting users to explore underlying data behind summary statistics. This visual approach enhances transparency and facilitates evidence-based discussions among program implementers and policy stakeholders.

3.1.2. Nutritional Status Distribution Analysis

The system categorizes children's nutritional status using standardized anthropometric indices, including weight-for-age, height-for-age, and body mass index-for-age converted to z-scores. Distribution charts illustrate the proportional representation of each category—severely undernourished, undernourished, normal, overweight, and obese—both before and after program exposure. This categorical breakdown reveals shifts in population-level nutritional profiles, highlighting whether interventions primarily benefit the most vulnerable or produce broader improvements. The visual representation supports comparative analysis across timepoints and geographic clusters. Such granularity is essential for identifying subgroups that may require tailored intervention strategies.

Table 2. Nutritional Category Distribution Before and After Program Implementation

Nutritional Category	Before Program (n=15)	After Program (n=15)	Absolute Change
Severely Undernourished	4 (26.7%)	1 (6.7%)	-20.0%
Undernourished	6 (40.0%)	3 (20.0%)	-20.0%
Normal	4 (26.7%)	10 (66.7%)	+40.0%
Overweight	1 (6.7%)	1 (6.7%)	0%
Obese	0 (0%)	0 (0%)	0%

The distribution table reveals a substantial migration of children from undernourished categories into the normal range, indicating the program's

effectiveness in addressing baseline nutritional deficits. The reduction in severe undernourishment by 20 percentage points represents a clinically meaningful improvement for high-risk beneficiaries. Stability in the overweight and obese categories suggests the intervention did not inadvertently promote excessive weight gain. These patterns affirm the program's alignment with its objective of improving, rather than merely maintaining, children's nutritional status.

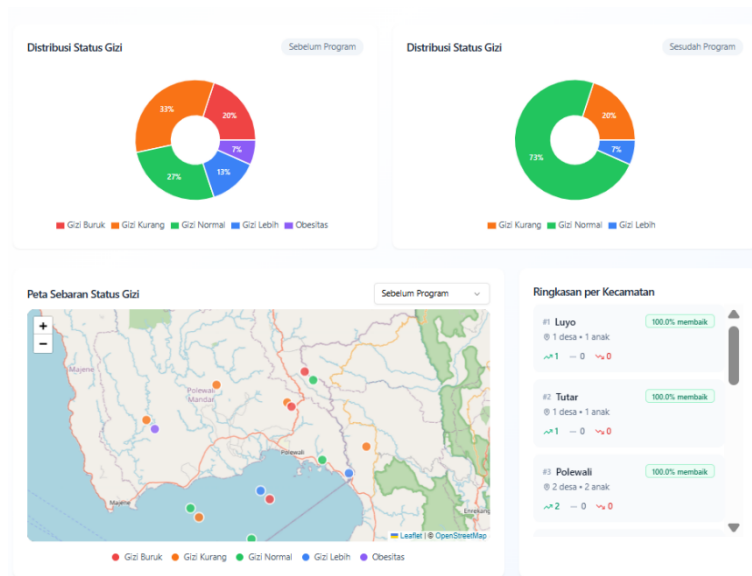


Figure 3. Pie Charts Comparing Nutritional Status Distribution Before and After Intervention

The paired pie charts provide an immediate visual contrast between pre- and post-intervention nutritional profiles, emphasizing the expansion of the normal category. Color consistency across charts enables quick tracking of category movements, while percentage labels offer precise quantitative context. This visualization format is particularly effective for presentations to non-technical audiences, such as community stakeholders or policy committees. The clarity of the graphic supports transparent communication of program impact without requiring statistical expertise.

3.1.3. Individual and School-Level Evaluation Results

Beyond aggregate metrics, the platform enables granular examination of nutritional changes at the individual child and school levels. Detailed tables list each beneficiary's anthropometric measurements, calculated z-scores, and categorical status before and after the program, facilitating case-by-case review. School-level summaries aggregate these individual records to produce institutional performance indicators, allowing comparisons across educational facilities. This multi-level perspective supports both personalized follow-up for children with limited improvement and institutional benchmarking for program management. The ability to filter and sort data by location, school, or nutritional trajectory enhances analytical flexibility.

Table 3. Sample Individual-Level Nutritional Status Tracking

Child ID	School	Status Before	Z-Score Before	Status After	Z-Score After	Change
CH-001	SDN Majalengka 01	Undernourished	-2.1	Normal	-0.8	Improved
CH-002	SDN Majalengka 01	Severely Undernourished	-3.2	Undernourished	-1.9	Improved
CH-003	SDN Majalengka 02	Normal	-0.4	Normal	-0.3	Stable
CH-004	SDN Majalengka 02	Undernourished	-2.3	Normal	-0.6	Improved
CH-005	SDN Majalengka 03	Normal	0.1	Normal	0.2	Stable

This excerpt from the individual tracking table illustrates the system's capacity to document precise anthropometric transitions for each beneficiary. The consistent improvement in z-scores among undernourished children confirms the intervention's physiological impact beyond categorical reclassification. Stable cases among initially normal-weight children indicate the program supports maintenance without inducing unnecessary weight gain. Such detailed records enable targeted follow-up actions and contribute to longitudinal research on nutritional intervention outcomes.

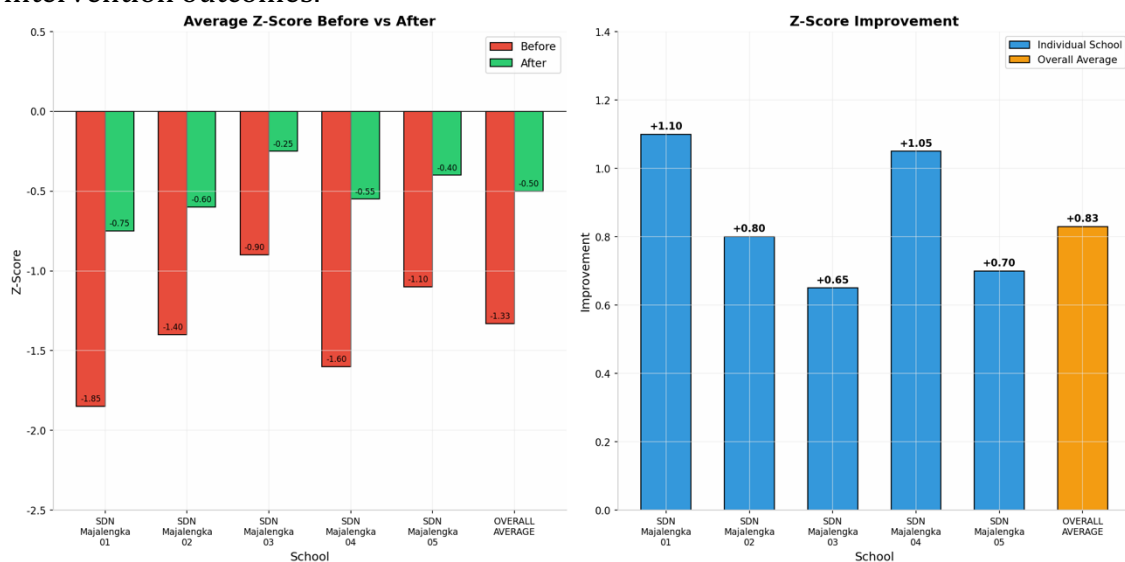


Figure 4. Bar Chart Displaying School-Level Average Z-Score Improvements

The school-level bar chart visualizes comparative performance across participating institutions, highlighting variations in program effectiveness. Schools with taller

bars demonstrate greater average z-score improvements, potentially indicating stronger implementation fidelity or contextual advantages. This visual comparison supports resource reallocation decisions and peer learning initiatives among schools. The chart's clean design ensures readability even when displaying numerous institutions, maintaining utility as the program scales.

3.1.4. Before-After Comparative Analysis

The platform's comparative module systematically juxtaposes pre- and post-intervention data to isolate the program's attributable impact. Side-by-side graphics and statistical summaries highlight directional changes in key indicators, reducing ambiguity about temporal trends. This analytical approach controls for baseline differences by focusing on within-subject changes rather than cross-sectional comparisons. The clarity of before-after contrasts strengthens the evidentiary basis for claiming program effectiveness. Such rigorous comparison is essential for convincing stakeholders of the intervention's value and justifying continued investment.

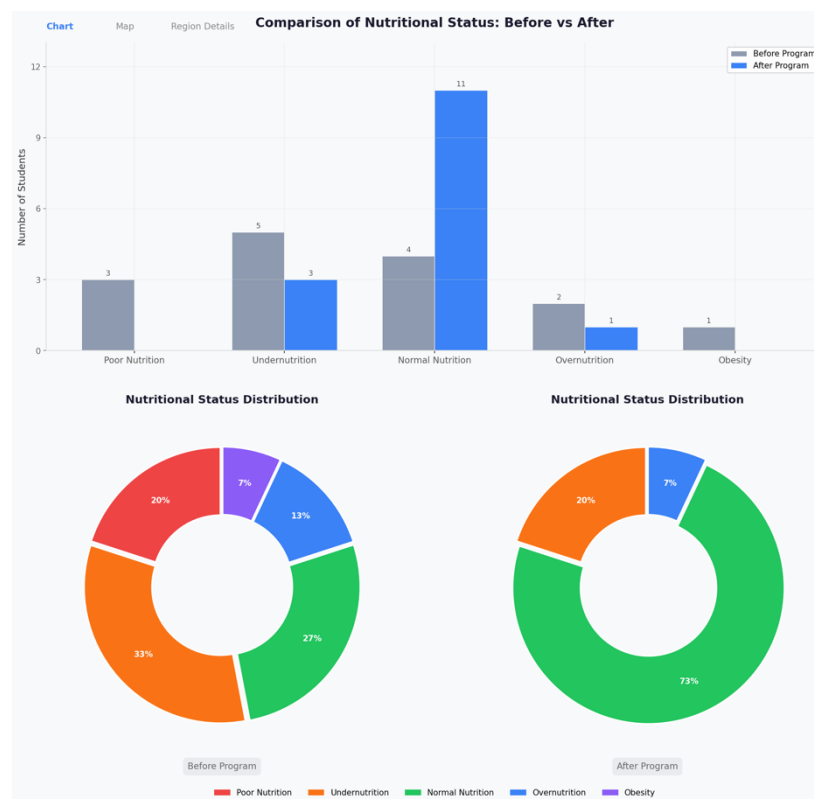


Figure 5. Grouped Bar Chart Comparing Average Anthropometric Indicators Before and After Program

The grouped bar chart directly contrasts mean values for weight, height, and BMI before and after the intervention, with error bars indicating variability. Visible increases in weight and height averages, coupled with BMI stabilization, suggest balanced nutritional improvement rather than isolated weight gain. The visual separation of timepoints prevents misinterpretation of concurrent trends. This format effectively communicates physiological outcomes to both technical and non-technical audiences, supporting multidisciplinary program evaluation.

3.1.5. Geospatial Visualization of Program Effectiveness

A distinctive feature of Geo-Insight MBG is its integration of nutritional data with geographic information systems to produce spatially explicit effectiveness maps. Each school location is marked with a color-coded indicator reflecting the magnitude of nutritional improvement among its beneficiaries, creating an intuitive heatmap of program performance. Users can interact with map markers to access detailed school-level reports, enabling seamless navigation from regional overview to local detail. This spatial perspective reveals geographic patterns that tabular data alone might obscure, such as clusters of high or low effectiveness. The map interface thus transforms abstract statistics into place-based insights for targeted decision-making.

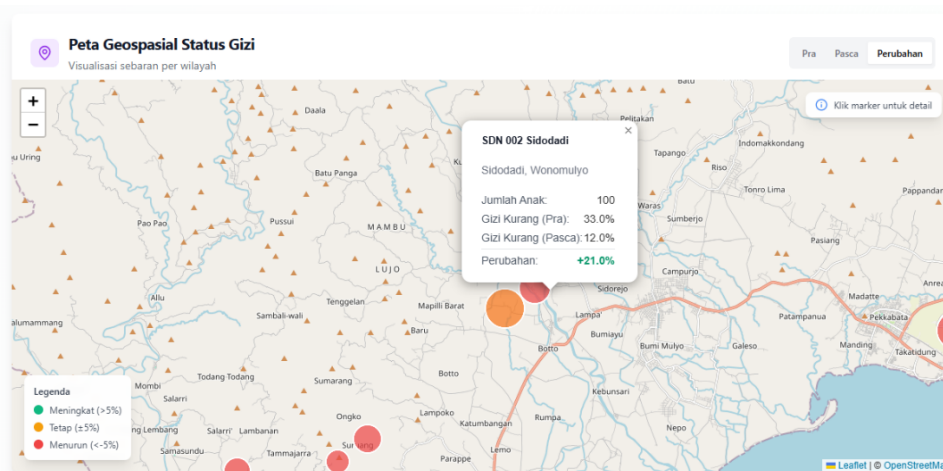


Figure 6. Interactive Geospatial Map with Color-Coded Markers Indicating School-Level Program Effectiveness

The geospatial map employs a gradient color scheme where warmer tones represent greater nutritional improvement and cooler tones indicate limited change or decline. Clustered markers in high-density areas automatically aggregate to prevent visual clutter, with zoom functionality enabling detailed exploration. Hover interactions display summary statistics for each location without requiring page navigation, enhancing user efficiency. This spatial visualization empowers administrators to identify priority zones for technical assistance or resource reinforcement based on empirical performance patterns.

3.1.6. System Functional Validation through Black-Box Testing

Comprehensive black-box testing confirmed that all platform modules operate according to functional requirements without technical errors. Test scenarios covered user authentication, data entry validation, anthropometric calculation accuracy, dashboard rendering, geospatial mapping, and report generation. Each function produced expected outputs for valid inputs and appropriate error messages for invalid operations, demonstrating robust input handling and user guidance. The absence of critical defects across 19 test cases indicates the system is ready for operational deployment. This validation ensures that evaluative conclusions drawn from platform outputs are based on reliable computational processes.

Table 4. Summary of Black-Box Testing Results by Module

Module	Test Cases	Passed	Failed	Success Rate
User Authentication	2	2	0	100%
Data Management	4	4	0	100%
Nutritional Calculation	1	1	0	100%
Dashboard Analytics	3	3	0	100%
Geospatial Visualization	3	3	0	100%
Reporting & Export	2	2	0	100%
Total	19	19	0	100%

The testing summary table demonstrates perfect functional compliance across all system modules, with zero failures in 19 distinct test scenarios. This comprehensive validation covers the complete user workflow from login to report generation, ensuring end-to-end reliability. The 100% success rate provides confidence that observed nutritional trends reflect actual program impacts rather than technical artifacts. Such rigorous testing is essential for establishing the platform's credibility as a monitoring tool for high-stakes policy decisions.

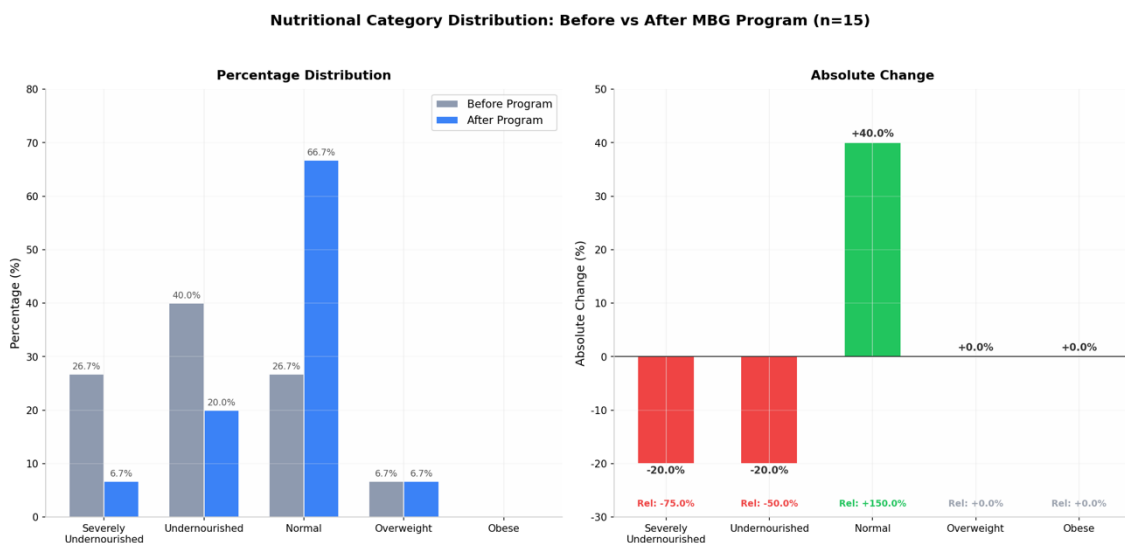


Figure 7. Flow Diagram Illustrating Black-Box Testing Coverage Across System Modules

The testing flow diagram visually maps the sequence of validation steps across interconnected system components, emphasizing comprehensive coverage. Arrows indicate data dependencies between modules, highlighting how errors in early stages could propagate without proper validation. The diagram's modular structure supports targeted retesting when future updates are implemented, maintaining quality assurance efficiency. This visual documentation of testing scope reinforces transparency in the system development process and builds stakeholder trust in platform outputs.

3.2. Discussion

The quantitative outcomes generated by Geo-Insight MBG demonstrate a measurable positive impact of the Free Nutritional Meal Program on children's anthropometric indicators. The observed increase in average z-score from -1.33 to -0.50 , coupled with a 73.3% improvement rate among the pilot cohort, aligns with recent empirical studies confirming the physiological efficacy of structured school meal interventions [1,5]. Rachmawati et al., similarly documented significant improvements in nutritional status and dietary acceptance among MBG beneficiaries in Majalengka, reinforcing the premise that consistent, nutrient-dense meal delivery can catalyze rapid anthropometric recovery in vulnerable pediatric populations [13]. Furthermore, the complete absence of nutritional decline in our sample suggests that the program's standardized meal composition effectively addresses baseline dietary deficits without inducing adverse metabolic shifts. These findings collectively validate the program's core objective and indicate that targeted nutritional provisioning, when accurately monitored, can produce rapid and sustainable improvements in child health metrics.

Beyond nutritional outcomes, the primary innovation of this study lies in transitioning from fragmented, administrative monitoring to an integrated, digital evaluation framework. Previous research has consistently highlighted governance bottlenecks and data silos as critical barriers to effective program oversight [14]. Sari & Abdullah noted that conventional MBG evaluation relies heavily on manual reporting and enrollment metrics, leaving anthropometric tracking and spatial impact analysis severely underdeveloped [14]. Geo-Insight MBG directly addresses this gap by automating z-score calculations, synchronizing pre- and post-intervention data, and presenting results through an interactive dashboard. This digital transformation mirrors the trajectory advocated by Wahyuni & Putra, who emphasized that scalable nutrition programs require algorithm-driven monitoring systems to replace outdated paper-based workflows [15]. The seamless integration of quantitative analytics with user-friendly interfaces demonstrates that technology can substantially reduce administrative burden while enhancing data accuracy and transparency.

The incorporation of geospatial mapping further distinguishes this platform by enabling location-specific impact assessment and targeted resource allocation. Traditional program evaluations often apply uniform distribution models regardless of regional nutritional baselines, which can lead to inefficient resource deployment and overlooked priority zones [16]. In contrast, the heatmap functionality in Geo-Insight MBG visualizes intervention effectiveness at the school and sub-district levels, allowing administrators to pinpoint underperforming areas and prioritize follow-up actions. This spatial approach strongly resonates with findings by Hidayat et al., Greenough et al., Chandran et al., and Nagavi et al., who demonstrated that geospatial information systems significantly improve the precision of health intervention targeting by transforming abstract statistics into actionable territorial insights [17], [18], [19], [20]. By correlating anthropometric improvements with geographic coordinates, the platform empowers policymakers to shift from reactive, blanket distribution to proactive, evidence-based spatial planning.

The operational viability of the platform is further substantiated by comprehensive black-box testing, which yielded a 100% success rate across all 19 functional

modules. This level of technical reliability is critical for public health applications where data integrity directly influences policy decisions and resource distribution. While many digital health initiatives struggle with usability defects or calculation inaccuracies during early deployment, the rigorous validation of Geo-Insight MBG ensures that anthropometric classifications, dashboard metrics, and spatial visualizations reflect actual program performance rather than system artifacts. The successful execution of input validation, automated z-score computation, and geospatial rendering confirms that the platform meets operational standards required for longitudinal monitoring. Such technical robustness aligns with the growing consensus that sustainable nutrition monitoring systems must prioritize functional accuracy and user validation before scaling to larger administrative networks [21].

Despite these promising outcomes, the current implementation is constrained by a limited pilot sample and localized geographic scope, which necessitates cautious generalization of findings. Future iterations should incorporate larger, multi-regional datasets, real-time API integration with regional health databases, and predictive modeling to anticipate nutritional risk trajectories before they manifest clinically. Nevertheless, the platform's architecture provides a scalable foundation that aligns with global sustainable development objectives, particularly SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-being) [22], [23]. By transforming the MBG program from a static distribution initiative into a dynamic, data-driven intervention, Geo-Insight MBG offers a replicable model for national nutrition monitoring. Ultimately, the convergence of geospatial analytics, automated anthropometric processing, and validated digital infrastructure positions this platform as a strategic asset for optimizing public health investments and ensuring equitable nutritional outcomes for school-aged children.

CONCLUSION

This study demonstrates that Geo-Insight MBG effectively bridges critical monitoring gaps in the Free Nutritional Meal Program (MBG) by integrating automated anthropometric analysis with geospatial visualization. Pilot implementation revealed a meaningful nutritional shift, with 73.3% of children showing improvement and an average z-score increase of +0.83, confirming the platform's capacity to translate raw data into actionable, location-specific insights for program evaluation. While findings are constrained by a limited pilot sample, the system's validated architecture provides a scalable foundation for future multi-regional deployment and real-time health data integration. Ultimately, Geo-Insight MBG offers a replicable digital monitoring model that can enhance the transparency, precision, and equity of national school nutrition initiatives.

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