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Optimal Location Selection for Mega-Kitchens in the Network Design of Free Lunch Programs in Nusa Tenggara Barat

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Abstract
This study addresses the optimization of the supply chain network for the free lunch program in West Nusa Tenggara, Indonesia, aiming to enhance operational efficiency and service quality. The primary objective was to determine the optimal number and locations of mega-kitchens required to ensure efficient and timely meal delivery to various elementary schools across the region. Employing a combination of Greenfield Analysis (GFA) and simulation techniques within the anyLogistix software, the research systematically improved the supply chain configuration across five iterative simulations. The initial setup, with only one mega-kitchen, resulted in a 45% Expected Lead Time (ELT) Service Level, highlighting significant inefficiencies. Progressive iterations incorporated additional mega-kitchens, leading to substantial improvements in service levels and reductions in transportation costs. By the fifth iteration, the introduction of a fifth mega-kitchen achieved a perfect 100% ELT Service Level, demonstrating optimal operational efficiency with significant cost reductions. The findings confirm that strategic increases in the number of mega-kitchens, coupled with optimal location planning, significantly enhance the service delivery framework, meeting logistic demands while aligning with regional health and nutrition goals. This study illustrates the efficacy of advanced simulation tools in strategic planning and provides a scalable model for similar public health initiatives globally. Future research could explore more complex scenarios, including multi-modal transportation options and variable demand forecasts, to refine the operational efficiencies of such critical service delivery programs further.
Keywords: *greenfield analysis (GFA), mega-kitchen, optimization, service level, simulation*

Abstrak
Penelitian ini mengatasi optimasi jaringan rantai pasok untuk program makan siang gratis di Nusa Tenggara Barat, Indonesia, dengan tujuan untuk meningkatkan efisiensi operasional dan kualitas layanan. Tujuan utama adalah untuk menentukan jumlah dan lokasi *mega-kitchen* yang optimal yang diperlukan untuk memastikan pengiriman makanan yang efisien dan tepat waktu ke berbagai sekolah dasar di seluruh wilayah. Dengan menggunakan kombinasi *Greenfield Analysis* (GFA) dan teknik simulasi dalam perangkat lunak anyLogistix, penelitian ini secara sistematis memperbaiki konfigurasi rantai pasok melalui lima iterasi simulasi. Iterasi awal, hanya dengan satu mega-dapur, menghasilkan ELT *Service Level* sebesar 45%, menyoroti ketidakefisienan yang signifikan. Iterasi berikutnya memasukkan *mega-kitchen* tambahan, mengarah pada peningkatan yang substansial dalam ELT *Service Level* dan pengurangan biaya transportasi. Pada iterasi kelima, dengan lima *mega-kitchen*, mampu mencapai ELT *Service Level* yang sempurna 100%, menunjukkan efisiensi operasional yang optimal dengan pengurangan biaya yang signifikan. Temuan ini mengonfirmasi bahwa peningkatan strategis dalam jumlah mega-kitchen, dikombinasikan dengan perencanaan lokasi yang optimal, secara signifikan meningkatkan *framework* rantai pasok. Penelitian mendatang dapat mengeksplorasi skenario yang lebih kompleks, termasuk pilihan transportasi multi-moda dan *demand forecast* yang bervariasi, untuk lebih menyempurnakan efisiensi operasional program penyampaian layanan kritis tersebut.
Kata Kunci: *greenfield analysis (GFA), mega-kitchen, optimasi, tingkat pelayanan, simulasi*

1. Introduction

Indonesia, which is trying to reach the golden generation of 2045, is encouraged to overcome various problems. One of them is the stunting problem suffered by Indonesia's young generation [1] Stunting is a concrete and urgent problem that must be addressed directly and en masse by the government to ensure the achievement of a good quality of human resources and quality of life. The free lunch program was then proposed by the government to deal with this stunting problem [2]. Nutritional assistance is provided to pregnant women and toddlers across Indonesia to improve health and help the family economy.

The program targets more than 80 million beneficiaries with 100% coverage by 2029 [3]. Thus, the implementation of this program will be carried out in stages based on region and education level. As one of the pilot projects of this program is the West Nusa Tenggara (NTB) region in the districts of North Lombok, Central Lombok, and West Lombok with the education level focused on elementary schools [4]. West Lombok district was selected for several reasons. First, based on e-PPGBM data in 2022, West Lombok District is among the three districts with the highest prevalence of stunting (18.98%) in NTB Province, along with North Lombok District (22.94%) and Central Lombok District (20.81%). Secondly, West Lombok District is one of the districts with the most active progress in implementing Family Posyandu. Third, the support from the West Lombok District Government for the implementation of the Family Posyandu and commitment to efforts to accelerate stunting reduction is very good, making it easier to coordinate with the NTB Province. In total, these three districts account for more than 50% of the number of stunting patients in NTB [5].

Based on the proposed planning document, this program does not yet have a concept of a supply chain network that will be used to distribute food packages to recipients of this service. A good supply chain network concept will determine whether the food packages can be received in good condition in the right quantity and at the right time. Thus, designing an appropriate supply chain network is a vital role for this program.

The concept of a lunch program chain network that can be used as an example has been implemented in the United States. The United States introduced the central kitchen concept to its supply chain network. Central kitchens or mega kitchens are used by restaurant groups and food service providers to prepare and assemble large quantities of food, which are then distributed to various locations. These centralized facilities focus significantly on the preparation and assembly of food components, rather than the full cooking process that takes place at the point of sale or final service location. This centralized approach allows for consistency in food quality and nutritional content when delivered, efficient use of resources, and better management of food costs [6].

Designing a supply chain network by adopting this concept will start with determining the location and number of facilities [7]. The number and location of facilities play an important role in the success of the supply chain. The location and number of these facilities affect 80% of supply chain costs as they determine the optimization of product flow [7]. This determination will also affect the service level provided to service recipients through delivery time and also from the sustainability aspect, it will also affect the amount of gas emissions released by the supply chain during the delivery process [7].

This research seeks to provide recommendations for the location of the central kitchen and the appropriate number of facilities to minimize distribution costs and ensure that service levels are achieved at 100%. The limitations that must be considered relate to the location of the facilities and the number of facilities established to be able to meet all the needs of the recipients of this service in terms of time and quantity. While the decision taken is the ideal area and number to support this program. Integration of optimization and simulation approaches will be used to solve the problem.

This research applies the integration of optimization and simulation to solve the problem of central kitchen location selection and its ideal number. This integration is able to examine and improve supply chain networks from an end-to-end perspective, including real food supply chains by assessing their feasibility across multiple scenarios based on sustainability and operational resilience metrics. Modern analytical methods and dynamic modeling are able to provide real-time scenario visualization and deeper insights into complex supply chain dynamics that cannot be achieved with conventional solutions in preventing failures and mitigating the negative consequences of the occurrence of risk events in the supply chain [8]. The incorporation of scenario-based simulation makes it possible to assess the effectiveness of optimization under various uncertainty settings, providing a safety net against worst-case scenarios [9]. The integration of these methods is not only about risk management but also about cost efficiency and improved service levels. Greenfield analysis can strategically place distribution centers by minimizing transportation costs and effectively serving customer demand. These simulations can help analyze the impact of different network configurations on distribution effectiveness and costs, thus enabling data-driven decision making [10]. In addition, the combined use of optimization and simulation supports strategic planning in new market conditions [11], according to the conditions of the problem raised.

This study will attempt to answer three research questions, namely: (1) Where to build the central kitchen facility using an optimization approach in NTB? (2) How many should be built to cover the needs of the free lunch program? (3) What is the operational performance of the free lunch supply chain based on the recommended locations and selected quantities using simulation?

Our research has made a very strong contribution to the current free lunch program which still lacks design in many areas including logistics and supply chain. Of course, it provides insight related to the realization of this program in the future. Specifically in terms of the supply chain concept that implements the implementation of the mega kitchen and the ideal location of the mega kitchen establishment. In addition, we also provide analysis using a simulation approach regarding some of the operational performance that can be expected from the results of this design such as the delivery lead time in accordance with the free lunch schedule. Stress testing experiments were also conducted to deepen the insights related to the behavior of our recommended supply chain.

2. Material and Methods

Our work is primarily related to two streams of research. The first examines new food supply chain for meal catering operations, and the second studies location-allocation problem with optimization and simulation.

Food Supply Chain for Meal Catering Operation

Food supply chain is a complex system that connects producers, consumers, to address food safety and value distribution with the aim of balancing food supply and food demand [12]. Food supply chain usually consists of 3 echelons, namely food production facilities, distribution centers for storage, and end consumers [13] [9] [14] [15] [16] [17]. However, there are also those who add suppliers or procurement so that it becomes a 4-echelon supply chain [10] [18]. In the food catering concept, Guidani et al., uses 3 echelons starting from production, central kitchen which is a place to collect food to be delivered to consumers, and end consumers which are usually schools, hospitals, and companies [19] [11].

Food supply chain has various types, ranging from fresh food [9], meat [16] [15] [17], snacks [14], food grains [18], sugar beets [20], table grapes [10], to cooked food [19] [11]. These various types of food cause different handling characteristics. Perishable foods such as fresh food and meat, require special distribution handling that can maintain their freshness [13]. Meanwhile, cooked food that is ready to be consumed usually has time constraints that require food to be delivered on time [11], so strategic facility location determination is needed to be able to optimize costs and distribution routes [19], and even reduce CO_2 emissions [21].

Various research on food supply chains highlights the complexities and uncertainties that affect these networks. Zanjani et al., highlights substantial disruptions such as weather, strikes, and political crises, which require robust and resilient FSC designs to ensure continuity of operations [13]. Guidani et al., added that adaptation to demand fluctuations and efficient cost management are essential to improve network resilience and efficiency [11]. Liu et al., emphasizes the challenges of managing risks associated with transportation costs and demand variability [9], while Vitorino et al. and Aras et al. identify challenges in managing perishability, product freshness, and demand uncertainty in product distribution [14] [10].

In recent years, the focus of development in Food Supply Chains (FSCs) includes various strategies and approaches to improve efficiency, sustainability, and resilience. Zanjani et al., focuses on robust and resilient models by integrating location-allocation and inventory decisions [13]. Guidani et al., focuses on network redesign to effectively manage uncertain demand post-pandemic [19]. Jonkman et al., focuses on improving supply chain configuration by integrating food supply chain characteristics in process design [20]. Mogale et al., focused on optimizing the location and allocation of grain silos to minimize supply chain network costs and total time [18]. Guidani et al., concentrated on the optimization of ready-to-eat food distribution networks from central kitchens to institutional customers such as schools and hospitals. This paper explores the use of a combinative location-routing model to address logistics complexity and ensure distribution efficiency in the context of the COVID-19 pandemic [11].

Location-Allocation Problem with optimization and simulation

Greenfield analysis in the school's meals distribution refers to the evaluation and planning process that focuses on establishing new mega-kitchen facilities and operations in previously undeveloped areas or starting from scratch, often with a focus on environmental sustainability and resource efficiency. Greenfield analysis involves assessing the environmental impact of logistics activities, optimizing resource utilization, and designing operations that minimize negative effects on the environment while meeting the increasing demand for logistics services [22]. In the context of greenfield analysis, the location-allocation problem plays a crucial role in determining the strategic placement of new facilities in undeveloped areas to optimize resource utilization and minimize environmental impact. The location-allocation problem involves determining the optimal placement of facilities and connection location-allocation where material flows between facilities must be routed through connection points to minimize transportation costs and meet customer demand [23]. The primary purpose of location-allocation models, as outlined in the literature, is to optimize various operational and economic objectives. Zanjani et al., aim to maximize total expected profit by balancing operational decisions against potential disruptions [13], while Liu focuses on minimizing worst-case expected costs, incorporating risk management strategies [9]. Similarly, Guidani et al. and Vitorino et al. strive to minimize total costs and ensure efficient service levels across distribution networks, reflecting a strategic focus on cost-efficiency and customer satisfaction [11] [10].

The proposed new location for mega-kitchen is a crucial and main information that need to be optimal strategically, therefore this study will use the optimization under varied constraints. Optimization plays a pivotal role in enhancing supply chain management by focusing on cost minimization and resource allocation efficiency. According to Zanjani et al., optimization is used to make strategic decisions to enhance resilience and minimize costs [13]. Liu and Mohammed et al., emphasize minimizing risk and expected costs in uncertain environments, showcasing how optimization aids in navigating complex decision-making landscapes [9] [17]. Similarly, Guidani et al. and Vitorino et al. use optimization to adapt distribution networks to changing market demands and minimize logistical costs, respectively [19] [10]. These studies collectively illustrate the critical role of optimization in improving supply chain robustness and responsiveness.

Simulation serves as a complementary tool to optimization by enabling the evaluation of different scenarios and enhancing the robustness of supply chain decisions. Simulation can illustrate the dynamic situation of the supply chain When there is uncertainty with stochastic models. Zanjani et al. and Liu incorporate scenario-based simulations to test the efficacy of their models under various disruption scenarios, enhancing the resilience of supply chains [13] [9]. Similarly, Vitorino et al. employ simulation to analyze the impacts of different network configurations on distribution effectiveness [10]. This strategic use of simulation helps stakeholders visualize potential outcomes and refine strategies, ensuring adaptable and robust supply chain operations. Key Performance Indicators (KPIs) analyzed across these studies include cost efficiency, service level effectiveness, and risk management efficiency. Zanjani et al robustness against disruptions and inventory levels [13], while Liu focuses on cost reduction and the ability to mitigate risks [9]. These indicators help assess the effectiveness of the proposed models in achieving their intended outcomes, providing insights into the operational success and strategic value of location-allocation decisions within supply chains.

The integration of optimization and simulation offers significant advantages, particularly in managing trade-offs and enhancing decision-making under uncertainty. As demonstrated by Zanjani et al. and Liu, this combination allows for a proactive response to disruptions and a structured approach to handling variability in demand and costs [13] [9]. The synergy between these two methods provides a robust framework for strategic decision-making, enabling companies to visualize the effects of different scenarios and make informed, data-driven decisions on network configuration and operational strategies.

Methodology

This study explores the free lunch distribution strategy in NTB Lombok, focusing on optimizing the supply chain network for the program. Based on interviews with supply chain experts and a review of policy documents, this study identified that the location of the central kitchen and the optimal number of facilities are critical to the success of the program.

Data from the 2022 e-PPGBM shows that NTB, with West Lombok, North Lombok and Central Lombok districts, has a high prevalence of stunting. Strong local government support and the active Family Posyandu in West Lombok facilitate coordination and implementation of this program. Therefore, NTB was chosen as the research object.

This study used an integrated optimization and simulation approach to determine the optimal location and number of central kitchen facilities. This approach assesses the feasibility of the supply chain from an end-to-end perspective, including sustainability and operational resilience. The results show that the use of central kitchens can improve food quality consistency, resource use efficiency, and better cost management.

The integration of optimization and simulation methods enables uncertainty-based scenario analysis, providing protection against worst-case scenarios. Thus, this study provides strategic recommendations for the placement of central kitchens and the number of facilities required to minimize distribution costs and ensure optimal service levels, thus supporting the success of the free lunch program in NTB Lombok.

The data includes demand locations and potential mega kitchen locations, transport modes, vehicle types and capacities, time windows for receiving meals. The data used mostly comes from the Ministry of Home Affairs of the Republic of Indonesia, namely data on the location of village points that will be used as demand points, and potential mega kitchen locations. In addition, other data will also be taken through interviews with the respective stakeholders. Besides, some assumptions were also made.

The final destination point of this free lunch distribution is schools which are represented by village location points totaling 262 points. The model built in this research is the distribution of food from the mega kitchen to the schools.

The outbound processing time at the mega kitchen is set as 10 minutes assuming that the free lunch boxes have been staged per vehicle before the outbound process occurs. The inbound processing time at the school is set as 10 minutes per school. Food delivery from the mega kitchen to the schools is done by 1 type of vehicle. Delivery policy used is set to less than truckload (LTL) to allow orders to be delivered no matter if a vehicle is fully loaded or not. Expected lead time (ELT) was prioritized in this case study to ensure high responsiveness. Food distributed to schools should not exceed 11 am so as not to exceed the school break time.

Demand data is taken from the ministry of education's data. The total number of students in the study is 146856 people, so the amount of food to be distributed every day is 146856 packages.

Free lunch distribution to schools is carried out by using blind vans. In the model, the capacity of the vehicle was set at 3557 pieces of lunch box [24]. Vehicle speed was set as 50 km/hr. All customers are served by homogeneous vehicles. Transportation costs are calculated using a "distance-based with fixed cost policy". These vehicles are considered in the same category as small trucks. Variable costs are determined by fuel consumption and electricity consumption, which are directly proportional to the distance traveled. CO_2 emissions are not taken into account in this experiment.

The research flow starts with problem identification, followed by a literature review to understand the existing theory and find gaps that need to be researched. After that, a mathematical model is developed, and data is collected after knowing the inputs of the mathematical model to support the model. The model is then designed in software. The verification process ensures the model functions correctly, while validation ensures the model reflects reality. Once the model was validated, the number of mega-kitchen locations was determined and optimized using Greenfield Analysis (GFA). The results from the GFA optimization are tested and analyzed through simulation. If the food delivery is not completed before 11am, the number of mega-kitchen locations is increased, and the optimization and simulation process is repeated. If the delivery was on time before 11am, the results were analyzed based on the key performance indicators of time and cost. The research flow can be seen in the following **Figure 1**.

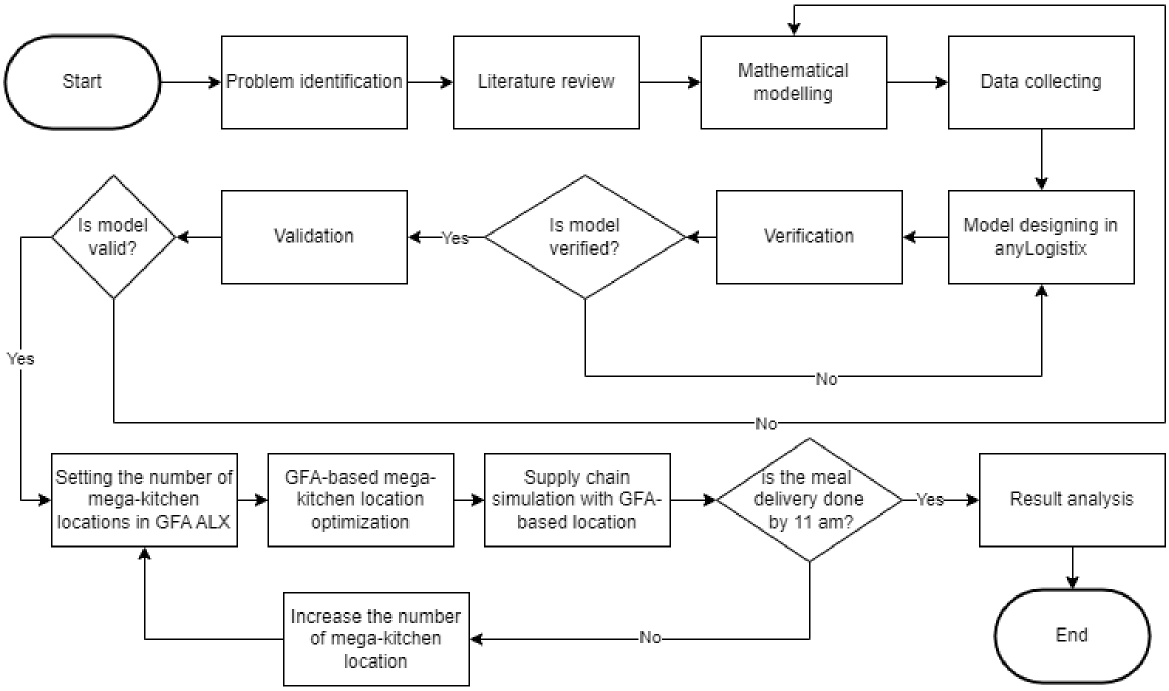

Figure 1. Research Flowchart

Optimization of locations in this study using greenfield analysis (GFA) or center of gravity analysis GFA has been integrated into one of the modules in anyLogistix. GFA is commonly used in the early stages of supply chain planning. GFA can be used to determine the optimal location and number of mega-kitchens. GFA was chosen as the approach in this study because the free lunch supply chain is a new supply chain that requires a new network overview [24]. The optimization mathematical model used in this GFA is adapted from [25] as follows.

Minimize $\sum_{i\in I}\sum_{j\in J} dist_{i,j} d_j Y_{i,j}$

Subject to:

$$\sum_{i\epsilon} Y_{i,j} = 1 \; ; \; \forall j \in J \quad (1)$$

$$\sum_{i\epsilon I} X_i = P \quad (2)$$

$$Y_{i,j} \le X_i \; ; \; \forall i \in I, \forall j \in J \quad (3)$$

$$Y_{i,j} \in \{0,1\} \; ; \; \forall i \in I, \forall j \in J \quad (4)$$

$$X_i \in \{0,1\} \; ; \; \forall i \in I \quad (5)$$

Notation description:

Sets:

Set J : set of villages that represent elementary schools as demand points

Set I : set of villages that represent potential mega kitchen locations

Input parameters:

d_j : total demand in village j (pcs)

$dist_{i,j}$: distance from the village of mega-kitchen to village of elementary school (km)

P : number of mega-kitchens (unit)

Decision variables:

$Y_{i,j}$: $\begin{cases} 1, if\ mega - kitchen\ i\ will\ service\ elementary\ school\ j \\ 0, if\ otherwise \end{cases}$

X_i : $\begin{cases} 1, if\ mega - kitchen\ i\ is\ opened \\ 0, if\ otherwise \end{cases}$

The objective function in this model is to minimize the distance by considering the weight of demand quantity to be delivered. Constraint (1) ensures that each district must be served by one mega-kitchen. Constraint (2) limits the number of mega-kitchens opened to equals P. Constraint (3) ensures that each demand point is not assigned to an unopened mega-kitchen. Constraints (4) and (5) illustrate that the two decision variables are binary numbers. It should be noted that the location point used in this model is the midpoint of the village. The villages considered are those on the main island of Lombok, for the districts of North, West, and Central Lombok as explained in the introduction. Based on data from the Ministry of Home Affairs of the Republic of Indonesia, there are 33 villages in North Lombok district, 150 villages in Central Lombok district, and 101 villages in West Lombok district [26]. However, it should be limited that this study does not consider villages located outside Lombok main Island. This is a challenge in itself, as it involves sea transportation modes.

At present, this research will only focus on village areas that can be reached by land transportation modes, given the availability of data as well. In addition, there are also some villages that have incomplete population documentation so the demand data cannot be found. Therefore, there are 262 village locations that will be processed as demand points and potential mega-kitchen location points. The demand data or the number of students per village is obtained from the ministry of education's data. The total number of students in the study is 146.856 people so there are 146.856 lunch packages that will be delivered every day [27].

After optimization, the supply chain network is simulated with the following conceptual model in **Figure 2**. The simulation flow in this study starts from the mega kitchen, which is a large-scale kitchen facility designed to produce large quantities of food with high efficiency. In this context, the mega kitchen is in charge of producing food which is then distributed to various schools.

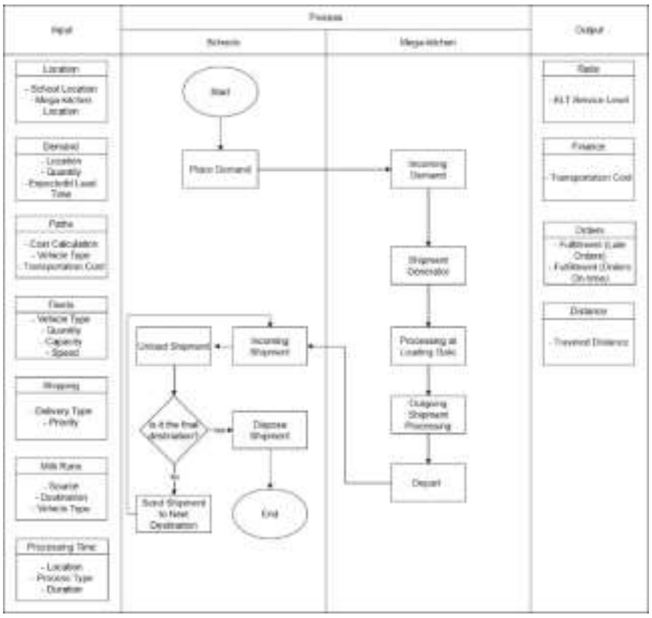

Figure 2. Conceptual Model

The schools connected to the mega kitchen are the final receiving entities in this supply chain. Food distributed to schools should not exceed 11 am so as not to exceed the school break time. If the simulation results show that there is still food distributed later than 11 am, then this research will re-optimize the mega kitchen using GFA until it is found that all food has been distributed no later than 11 am. The proposed supply chain network can be seen in **Figure 3**.

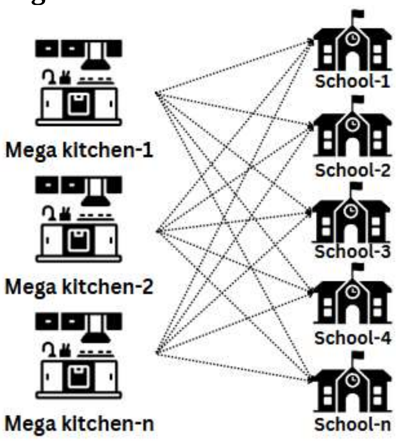

Figure 3. Proposed Network Design

Parameters Setting and Assumptions

This research uses the anyLogistix academic edition 3.2 software. In this paper, we investigate the value of GFA-based mega-kitchen location and the number of mega-kitchens in the West Nusa Tenggara school's meals catering supply chain on its performance and sustainability with optimization-simulation. This research uses two anyLogistix modules. starting with GFA and continuing with SIM. Some of the parameters used to conduct experiments in this study involve several entities. The first entity is the consumer. The parameters that will be applied to consumers include the determination of demand quantity, location, time windows. The information we use as a reference in setting parameters on consumers comes from data on the projected number of elementary school students per village in West Lombok, North Lombok and Central Lombok districts collected from various official government information sources. The second is the parameters applied to mega kitchen.

Parameters on mega kitchen are related to transportation policies and loading and unloading processes. Regarding transportation policy, the parameters set are the application of the less-than load (LTL) policy and the shipping time parameter which is defined as the time level at which the vehicle starts operating on anyLogistix. The loading and unloading policy include loading time at the mega kitchen and unloading time at each school. The determination of the number of each parameter can be seen in **Table 1**.

Table 1. Parameter Data Sources

Data Type	Parameter	Source
Demand and location points of customers	262 locations	[29] [27] [28]
Demand of customers	146856 lunch boxes/weekday	[29] [27] [28]
Active Fleets Operating	50 fleets	Trial and error experiment
Transportation Variable Cost	IDR 740 per km	[30] [31]
Shipping Time	08.00 am – 14.30 pm	[24]
Receiving Process Time Window	11.00 am – 12.30 pm	[32]
Vehicle Capacity	3557 lunch boxes per vehicle	[24]
Vehicle Speed (Triangular Dist.)	(30, 80, 40) km/h	

3. Results and Discussion

This research focuses on finding the optimal strategy for food supply chain management in the free lunch program in the NTB region, in accordance with the concept of community-based food security. The management strategies reviewed consider the current situation, using an integrated approach of optimization and simulation, as well as transportation policies that consider financial aspects. The ability to manage food distribution is assumed to develop gradually with a baseline from 2024 to 2025, in accordance with regional policies and mega-kitchen implementation strategies in the food supply chain.

Green Field Analysis (GFA)

From GFA, the optimal number of mega kitchens and their location can be determined. The results from 5 iterations are as follows.

Table 2. GFA Results per Iteration

Iteration	Name	Latitude	Longitude
1	Megakitchen 1	-8,647575426	116,2593206
2	Megakitchen 1	-8,420944766	116,1803918
	Megakitchen 2	-8,682743019	116,2718743
3	Megakitchen 1	-8,680852807	116,3103774
	Megakitchen 2	-8,654392799	116,1575705
	Megakitchen 3	-8,357500796	116,2466423
4	Megakitchen 1	-8,762823714	116,2819579
	Megakitchen 2	-8,631612694	116,1497866
	Megakitchen 3	-8,342344644	116,253217
	Megakitchen 4	-8,623490272	116,3174229
5	Megakitchen 1	-8,765590467	116,3074401
	Megakitchen 2	-8,306982312	116,3040542
	Megakitchen 3	-8,680323291	116,1711839
	Megakitchen 4	-8,518634521	116,1091196
	Megakitchen 5	-8,619630191	116,3157523

Source: Authors' Data Processing Results

From the **Table 2** above, there are 5 scenarios of mega kitchens locations that can be used for distributing school's meals. The locations of the mega kitchens are spread across different latitudes and longitudes, indicating an expansion in geographical coverage. As the iterations progress, the addition of new mega kitchens seems to cover more regions, suggesting an effort to optimize coverage and reduce travel distances for supply chain efficiency or customer reach. The locations of existing mega kitchens also change. This could indicate a process of optimization to better serve the demand areas or improve logistical efficiency.

From this optimization process, there are some key points that can be taken into account. First, the inclusion of new locations in each iteration indicates an attempt to optimize geographic coverage, hence minimize delivery times or operational costs. Second, the changes in the locations of existing mega kitchens (e.g., Megakitchen 1 in different iterations) might indicate attempts to find optimal sites that balance various factors such as proximity to supply chains, accessibility, and cost-effectiveness. This happens because the optimal number of mega kitchens depends on factors such as demand density, geographic size of the service area, and logistical constraints.

Simulation

The simulation results from the Greenfield Analysis (GFA) provide insights into operational efficiency and service quality improvements. The results from GFA are simulated so the key performance indicators of each scenario can be analyzed, including ELT service level by orders, fulfillment orders, traveled distance, and transportation cost. The ELT service level by orders results can be seen as follows.

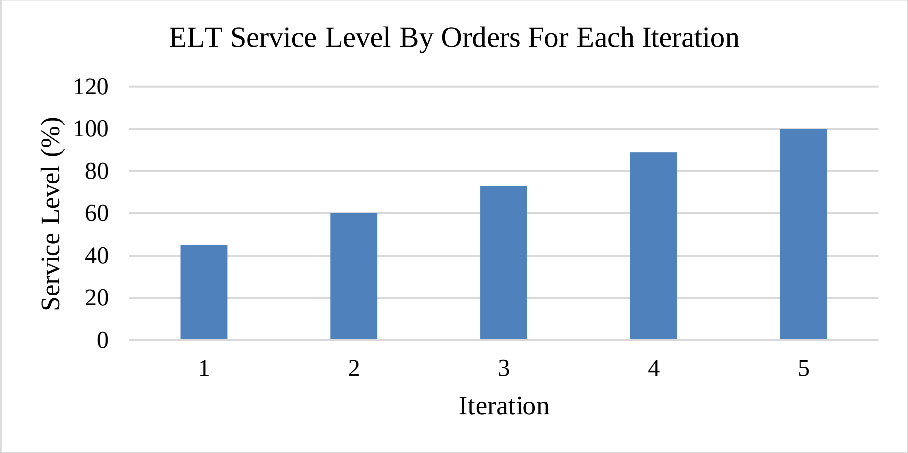

Figure 4. ELT Service Level By Orders For Comparisons

The Expected Lead Time (ELT) Service Level by Orders throughout the five stages of the simulation shows a steady progress within the supply chain network tailored for the free lunch program. Initially, with a service level starting at 45% in the first iteration and only one mega-kitchen, there were clear signs of initial inefficiencies, highlighting the need for strategic modifications in facility placement or logistical operations. Progress was evident in subsequent iterations, as the service level climbed to 60% in the second iteration with the addition of a second mega-kitchen, signifying considerable enhancements. The third iteration saw a further rise to 73% service level with three mega-kitchens, indicating that continuous refinements were successfully meeting the logistical requirements of the service areas. The trend of improvement persisted, with the fourth iteration achieving an 89% service level with four mega-kitchens, focusing on refining existing configurations to eliminate minor discrepancies.

The series of adjustments reached its peak in the fifth iteration, with five mega-kitchens achieving an optimal 100% service level, demonstrating that the arrangement and operation of the mega kitchens were perfectly aligned to efficiently meet demand. Securing a 100% service level in the final iteration not only establishes a standard for operational excellence but also sets a strong foundation for future enhancements. As the network expanded and the locations of the mega kitchens were optimized through each iteration, there was a marked and consistent enhancement in ELT Service Level. The addition of more mega kitchens significantly reduced the travel distance and time required for the food to reach its recipients, thereby decreasing potential delays.

The graph **Figure 5** illustrates a significant transformation in the operational dynamics of the supply chain network for the free lunch program. Starting with the first iteration, the delivery system showed substantial room for improvement, with only 181 on-time deliveries against 151 late deliveries, reflecting initial logistical inefficiencies and challenges in meeting delivery schedules, because there was only 1 mega-kitchen. As the simulation progresses to the second iteration, with 2 mega-kitchen, there is a marked improvement, with on-time deliveries increasing to 198, and late deliveries decreasing to 129. This shift suggests that the initial adjustments made—possibly in the routing algorithms, scheduling, or coordination among the supply chain nodes—began to positively impact delivery performance. The trend of improvement is even more pronounced by the third iteration, with 3 mega-kitchens, where on-time deliveries rise to 260, significantly outnumbering the 97 late deliveries. The continued optimization efforts appear to be refining the network's efficiency further, enhancing the timeliness of the deliveries. By the fourth iteration, with 4 mega-kitchens, the data indicates a near-optimal performance with 394 on-time deliveries compared to just 50 late ones.

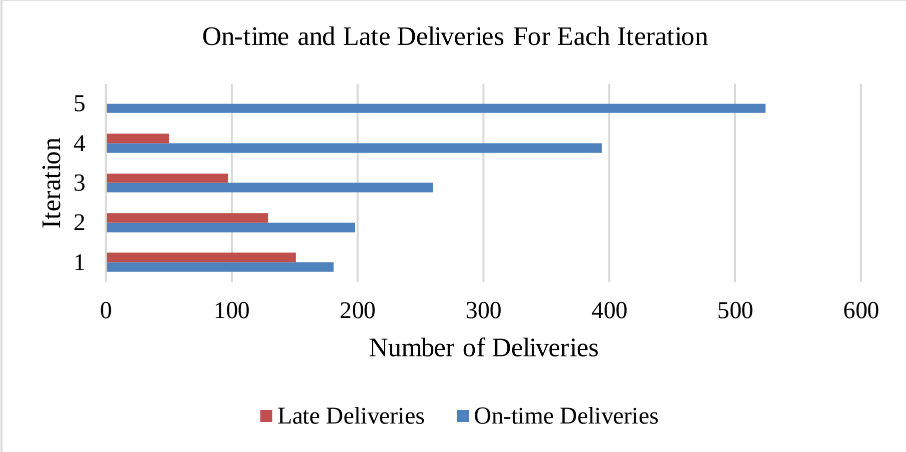

Figure 5. Fulfillment Orders Comparisons

This iteration likely capitalized on the cumulative learnings and adjustments from previous iterations, optimizing routes, and perhaps improving real-time logistics management. The pinnacle of performance is observed in the fifth iteration, with 5 mega-kitchens, where all 524 deliveries are made on-time with zero late deliveries. This perfect score in the final iteration demonstrates that the supply chain network has been optimized to an ideal state, where operational efficiency ensures that all deliveries meet their scheduled times, a crucial factor for the success of any program reliant on timely service delivery. As the number of mega kitchens increased and their locations were optimized over each iteration, we observed a consistent rise in the fulfillment of orders. The addition of mega kitchens enhances the supply chain's capacity and reduces the distance food needs to travel to reach the recipients, which in turn decreases the chances of delays.

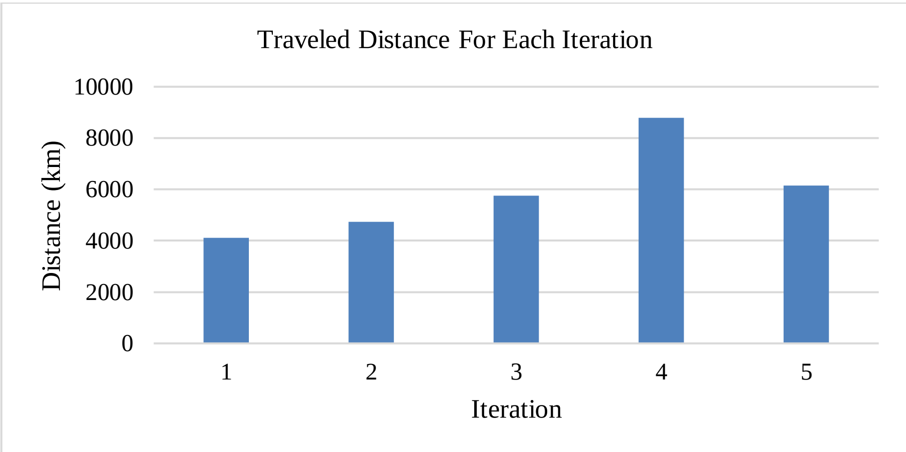

Figure 6. Traveled Distance Comparisons

The graph illustrates the total traveled distance for each iteration, showing the effects of varying the number of mega-kitchens on the distance covered for distributing meals. The traveled distance is 4,108 km with 1 mega-kitchen. With 2 mega-kitchens, the traveled distance increases to 4,746 km. The traveled distance further increases to 5,750 km with 3 mega-kitchens. The highest traveled distance, 8,794 km, occurs with 4 mega-kitchens. With 5 mega-kitchens, the traveled distance slightly decreases to 6,146 km.

The analysis of the transportation cost for each iteration, as shown in the provided graph, demonstrates the impact of increasing the number of mega-kitchens on the total transportation cost for the program. With only 1 mega-kitchen, the transportation cost is the highest, amounting to IDR 7,888,614.41. This high cost is likely due to the extensive distances that need to be covered to deliver meals to various locations from a single central point. When the number of mega-kitchens increases to 2, the transportation cost significantly decreases to IDR 4,008,043.10. This reduction suggests a more efficient distribution network with reduced travel distances, leading to lower transportation expenses. Adding a third mega-kitchen results in a slight increase in transportation costs to IDR 5,188,602. With 4 mega-kitchens, the transportation cost rises further to IDR 6,430,607. Interestingly, with 5 mega-kitchens, the transportation cost decreases again to IDR 4,494,152. The data suggests that having 2 mega-kitchens offers the most cost-

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effective solution for this program, as it significantly reduces costs without the diminishing returns seen in subsequent iterations.

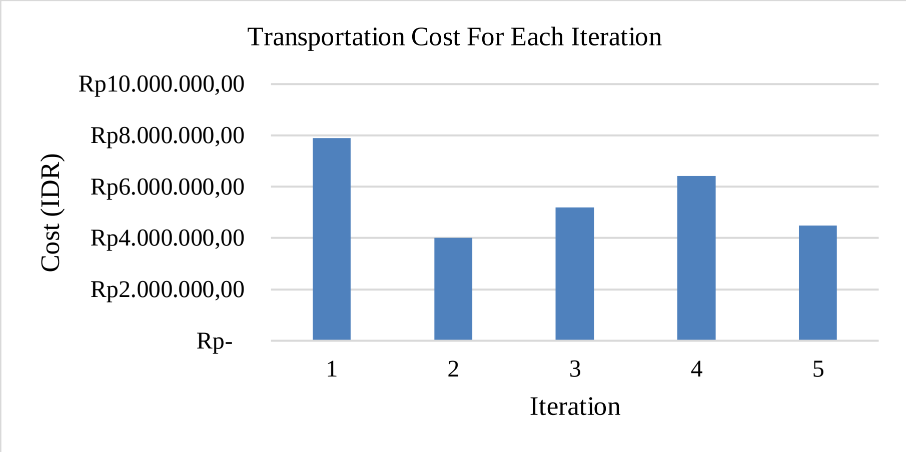

Figure 7. Transportation Cost Comparisons

From the single mega kitchen scenario, the initial setup is in a relatively low service level (45%) and high transportation costs, indicating inefficiencies in coverage. The high number of late deliveries suggests that a single location cannot effectively serve the entire region within desired time frames. The addition of a second mega kitchen improves the service level to 60%, reduces transportation costs significantly, and slightly decreases the number of late deliveries. The traveled distance increases slightly, possibly due to more extensive coverage, but overall efficiency improves. Introducing a third mega kitchen further increases the service level to 73%, with a substantial reduction in late deliveries. However, both the traveled distance and transportation costs rise, indicating a trade-off between increased coverage and operational expenses. With four mega kitchens, the service level jumps to 89%, showing a marked improvement in timely deliveries. The traveled distance and transportation costs are significantly higher, suggesting an extensive coverage area and possibly more complex logistics. Finally, with five mega kitchens, a 100% service level is achieved, with all deliveries on time and no late orders. The transportation cost decreases compared to the fourth iteration, suggesting an optimal configuration that balances coverage and efficiency. The traveled distance data is missing, but the reduced transportation cost indicates a more efficient routing or distribution network.

The results indicate a clear trend for improved service levels and on-time deliveries with each additional mega kitchen. However, the increase in the number of mega kitchens also leads to rising transportation costs and traveled distances, particularly noticeable up to the fourth iteration. The fifth iteration represents an optimal point where 100% of orders are delivered on time, and costs are reduced compared to the previous iteration, indicating an effective balance between service quality and operational costs. The missing traveled distance data in the fifth iteration should be noted, but the overall trend suggests that five mega kitchens provide the best configuration under the given parameters.

Managerial implications

The analysis of the Greenfield Analysis (GFA) results and the subsequent simulation outcomes provides several managerial implications that can guide strategic decision-making. First, the progression from one to five mega kitchens shows a clear improvement in the service level, resulting in a 100% on-time delivery rate with five mega kitchens. This implies that increasing the number of strategically placed mega kitchens can significantly enhance customer satisfaction by ensuring timely deliveries. The network of mega kitchens can be used to improve service reliability and customer experience, especially in regions where demand is high or spread out. Second, while the addition of more mega kitchens improves service levels, it also impacts transportation costs and traveled distances. The data suggest a non-linear relationship between the number of mega kitchens and operational costs. Initially, adding more locations reduces costs, but beyond a certain point, costs start to increase again due to greater coverage and complexity in logistics. It's important to carefully balance the trade-off between improving service levels and managing operational costs. The significant drop in transportation costs in the fifth iteration, despite an increased number of mega kitchens, suggests that there might be an optimal configuration that minimizes costs while maximizing service quality. Third, the changing locations of mega kitchens across iterations highlight the importance of strategic placement. As the network grows, the choice of locations should not only focus on current demand patterns but also consider future scalability and flexibility to adjust to changing demand conditions. Data-driven approaches are preferred in order to select optimal sites for new mega kitchens, ensuring they are well-positioned to serve both current and potential future demand efficiently.

4. Conclusion

This study focused on improving the operational effectiveness and service quality of the free lunch initiative in West Nusa Tenggara, Indonesia, by utilizing advanced optimization and simulation strategies within the supply chain. The main goals were to pinpoint the ideal number and placement of mega-kitchens to ensure timely and efficient meal delivery to various primary schools throughout the area. Utilizing a blend of Greenfield Analysis (GFA) and simulations via the anyLogistix software, we methodically enhanced the supply chain setup to achieve these aims. The deployment of the fifth mega-kitchen culminated in a flawless 100% ELT Service Level and the most reduced transportation expenses observed in the iterations involving an expansion of mega-kitchens, indicating superior operational effectiveness. The study verified that the strategic augmentation of mega-kitchen numbers and their thoughtful placement markedly elevated the service quality and efficiency of the meal distribution network. Adding more kitchens substantially lessened the travel distance for the meals, thereby cutting down on possible delays and boosting the reliability of the service.

This refinement not only satisfied logistical requirements but also supported regional objectives to enhance child nutrition and health outcomes. The research further emphasized the value of adaptable strategies in supply chain management, showing that the capability to modify the number and locations of facilities in response to continuous performance indicators like service levels and costs offers a strong framework for overseeing extensive public service endeavors. These results highlight the critical role of employing sophisticated optimization and simulation models in designing and implementing effective supply chain strategies. Future projects could adapt this model to different settings and regions, potentially expanding the influence of optimized supply chain strategies on global public health initiatives. Additional studies might explore more intricate scenarios, including the use of multi-modal transportation solutions and fluctuating demand projections, to sharpen the operational efficiencies of such essential service delivery programs.

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6. Abbreviations

NTB	Nusa Tenggara Barat / West Nusa Tenggara
GFA	Greenfield Analysis
ELT	Expected Lead Time
LTL	Less Than Truckload
e-PPGBM	elektronik-Pencatatan dan Pelaporan Gizi Berbasis Masyarakat

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