DISTRIBUTION SYSTEM MODEL OPTIMIZATION DESIGN OF LAYER SPONGE CAKE PRODUCTS AT PT XYZ

DEANDRA VANYA WISHNU

STUDY PROGRAM OF AGROINDUSTRIAL ENGINEERING
FACULTY OF ENGINEERING AND TECHNOLOGY
IPB UNIVERSITY
BOGOR
2026

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Deandra Vanya Wishnu
F3401221801

ABSTRACT

DEANDRA VANYA WISHNU. Distribution System Model Optimization Design of Layer Sponge Cake Products at PT XYZ. Supervised by MARIMIN.

Efficient distribution planning is essential for reducing transportation costs and improving operational performance in food distribution systems. PT XYZ currently relies on manually planned distribution routes that satisfy operational requirements but have not been systematically optimized. This study aims to analyze the existing distribution system, develop and evaluate a distribution optimization model, and implement the model within a web-based system prototype. The proposed framework integrates the Sweep Algorithm, the Capacitated Vehicle Routing Problem (CVRP), and Mixed Integer Linear Programming (MILP). The Sweep Algorithm was used to group retail stores into geographically compact service areas, while the CVRP with the Nearest Neighbor heuristic generated an initial feasible routing solution. The MILP model subsequently refined customer assignments and delivery sequences to minimize total travel distance while satisfying operational constraints. Compared with the existing distribution system, the optimized model reduced the total travel distance from 275.08 km to 226.47 km (17.67%) and the estimated travel time from 560 minutes to 482 minutes (13.93%). The optimization model was implemented in a Python-based web prototype that supports distribution data management, route optimization, and route visualization. User Acceptance Testing (UAT) produced an acceptance score of 93.75%, indicating that the prototype effectively met user requirements. These findings demonstrate that the proposed optimization framework improves distribution efficiency and supports more systematic and data-driven distribution planning.

Keywords: distribution optimization, Sweep Algorithm, Capacitated Vehicle Routing Problem (CVRP), Mixed Integer Linear Programming (MILP), distribution planning.

ABSTRAK

DEANDRA VANYA WISHNU. Perancangan Model Optimasi Sistem Distribusi Produk Bolu Lapis di PT XYZ. Dibimbing oleh MARIMIN.

Perencanaan distribusi yang efisien berperan penting dalam menurunkan biaya transportasi dan meningkatkan kinerja operasional sistem distribusi pangan. PT XYZ saat ini masih menerapkan perencanaan rute distribusi secara manual yang telah memenuhi kebutuhan operasional, namun belum dioptimalkan secara sistematis. Penelitian ini bertujuan untuk menganalisis sistem distribusi yang berjalan, mengembangkan dan mengevaluasi model optimasi distribusi, serta mengimplementasikan model tersebut ke dalam sebuah prototipe sistem berbasis web. Kerangka optimasi yang diusulkan mengintegrasikan Sweep Algorithm, Capacitated Vehicle Routing Problem (CVRP), dan Mixed Integer Linear Programming (MILP). *Sweep Algorithm* digunakan untuk mengelompokkan toko ritel ke dalam area layanan yang berdekatan secara geografis, sedangkan CVRP dengan heuristik *Nearest Neighbor* digunakan untuk menghasilkan solusi rute awal yang layak. Selanjutnya, model MILP menyempurnakan alokasi pelanggan dan urutan kunjungan guna meminimalkan total jarak tempuh dengan tetap memenuhi seluruh kendala operasional. Dibandingkan dengan sistem distribusi yang ada, model optimasi yang dihasilkan mampu menurunkan total jarak tempuh dari 275,08 km menjadi 226,47 km (17,67%) serta mengurangi estimasi waktu tempuh dari 560 menit menjadi 482 menit (13,93%). Model optimasi tersebut kemudian diimplementasikan dalam prototipe berbasis Python yang mendukung pengelolaan data distribusi, optimasi rute, dan visualisasi hasil optimasi. Pengujian *User Acceptance Testing* (UAT) menghasilkan tingkat penerimaan sebesar 93,75%, yang menunjukkan bahwa prototipe telah memenuhi kebutuhan pengguna. Hasil penelitian menunjukkan bahwa kerangka optimasi yang diusulkan mampu meningkatkan efisiensi distribusi serta mendukung proses perencanaan distribusi yang lebih sistematis dan berbasis data.

Kata kunci: optimasi distribusi, Sweep Algorithm, Capacitated Vehicle Routing Problem (CVRP), Mixed Integer Linear Programming (MILP), perencanaan distribusi.

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DEANDRA VANYA WISHNU

Final Project
as one of the requirements to obtain
A Bachelor's degree in engineering
Agroindustrial Engineering Study Program

PROGRAM STUDY OF AGROINDUSTRIAL ENGINEERING
FACULTY OF ENGINEERING AND TECHNOLOGY
IPB UNIVERSITY
BOGOR
2026

Examining Team for Final Project Examination:

1. Prof. Dr. Eng. Taufik Djatna, S.TP, M.Si.
2. Prof. Dr. Ir. Ono Suparno, S.TP., M.T.

Final Project Title : Distribution System Model Optimization Design of Layer Sponge Cake Products at PT XYZ
Name : Deandra Vanya Wishnu
NIM : F3401221801

Approved by

Supervisor 1:
Prof. Dr. Ir. Marimin, M.Sc.

Known by

Head of the study program:
Prof. Dr. Ir. Ono Suparno, S.TP., M.T.
NIP 197212031997021001

Exam Date:
21 July 2026

Graduation Date:

FOREWORD

All praise and gratitude be to Allah Subhanahu wa Ta'ala for His blessings, mercy, and guidance, which have enabled the author to complete this undergraduate final project. This research was conducted from February 2026 to June 2026 under the theme of distribution system optimization, entitled "Distribution System Model Optimization Design of Layer Sponge Cake Products at PT XYZ."

The author would like to express sincere gratitude to Prof. Dr. Ir. Marimin, M.Sc. and Prof. Dr. Ir. Ono Suparno, S.TP., M.T. for their invaluable guidance, encouragement, constructive suggestions, and continuous support throughout the completion of this research. The author also extends appreciation to the academic advisor, seminar moderator, and final project examiner for their valuable comments and recommendations that have contributed to the improvement of this final project.

The author would also like to express sincere appreciation to PT XYZ, particularly the distribution supervisor, human resources development manager, and all staff members who granted permission to conduct this research, guided the author, and provided the necessary data and assistance throughout the research process. Appreciation is also extended to the lecturers and administrative staff of the Program Study of Agroindustrial Engineering, Faculty of Engineering and Technology, IPB University, for their support and guidance during the author's academic journey.

Finally, the author wishes to express heartfelt gratitude to beloved parents, family, and friends for their endless prayers, encouragement, understanding, and unwavering support throughout the completion of this study. Appreciation is also extended to everyone who has contributed, directly or indirectly, to the completion of this final project.

The author realizes that this final project is not without limitations. Therefore, constructive criticism and suggestions are sincerely welcomed for future improvement. It is hoped that this research will contribute to the advancement of knowledge in agroindustrial logistics and distribution optimization and provide useful references for future studies.

Bogor, July 2026

Deandra Vanya Wishnu

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GLOSSARY

3PL	: Third party logistics or 3PL is an external logistics provider responsible for supplying delivery vehicles and transportation services for product distribution.
BPMN	: Business Process Model and Notation (BPMN) is a standardized graphical notation used to model and visualize business processes, illustrating the sequence of activities, decision points, and interactions between users and the system.
CVRP	: Capacitated Vehicle Routing Problem (CVRP) is a variant of the Vehicle Routing Problem in which each vehicle has a limited carrying capacity. The objective is to determine delivery routes that minimize travel distance while ensuring that total customer demand assigned to each vehicle does not exceed its capacity.
Cluster	: A group of geographically adjacent customers assigned to the same delivery vehicle during the clustering stage.
Depot	: The central distribution facility from which all delivery vehicles depart and to which they return after completing their assigned routes.
Distance Matrix	: A matrix containing pairwise travel distances between all locations in the distribution network, generated using the Open-Source Routing Machine (OSRM) based on actual road networks.
Geographical Coordinates	: Latitude and longitude values representing the physical locations of the depot and retail stores, used as spatial inputs for clustering and routing.
MILP	: Mixed Integer Linear Programming is a mathematical optimization technique that solves linear objective functions subject to linear constraints, where some decision variables are restricted to integer values.
MTZ Constraint	: Miller-Tucker Zemlin constraint is a subtour elimination constraint used in MILP formulations to prevent disconnected cycles and ensure continuous delivery routes.
OSRM	: Open-Source Routing Machine or OSRM is an open-source routing engine that calculates realistic travel distances and routes using the existing road network rather than straight-line (Euclidean) distances.
Operational Constraint	: Practical limitations imposed by the company, including vehicle capacity, maximum delivery stops per trip, and monthly trip requirements, which must be satisfied during optimization.

Polar Angle	: The angle measured between the depot and each customer location relative to a reference axis. It is used by the Sweep Algorithm to sequentially group geographically adjacent customers.
Prototype	: An initial working version of an information system developed to demonstrate system functionality, gather user feedback, and support iterative system refinement before full implementation.
Prototype Model	: A System Development Life Cycle (SDLC) model that emphasizes iterative development through repeated design, prototype evaluation, and refinement based on user feedback until the system satisfies user requirements.
Rapid Design	: An SDLC Prototype phase in which the initial system structure, interface, and workflow are designed to support the development of a functional prototype.
Route Optimization	: The process of identifying delivery routes that minimize travel distance or travel time while satisfying operational constraints.
Service Area	: A geographical region or group of customers assigned to a specific delivery vehicle for distribution activities.
Subtour	: A disconnected cycle that does not include the depot and represents an infeasible route in vehicle routing optimization.
Sweep Algorithm	: A clustering heuristic that groups customers according to their polar angles relative to the depot while considering vehicle capacity and operational constraints.
SDLC	: System Development Life Cycle is a structured methodology for developing information systems through systematic phases, including requirements analysis, design, implementation, testing, development, and maintenance.
Use Case Diagram	: A Unified Modeling Language (UML) diagram that illustrates the interactions between system users (actors) and the functions provided by the system.
UAT	: User Acceptance Testing is a software testing method performed by end users to evaluate whether a developed system satisfies user requirements and functions appropriately in operational conditions before deployment.
Vehicle Capacity	: The maximum quantity of products that can be transported by a delivery vehicle in one trip.
Vehicle Routing Problem (VRP)	: A combinatorial optimization problem that determines the optimal routes for a fleet of vehicles serving a set of customers while satisfying operational constraints.
Vehicle Utilization	: The proportion of a vehicle's carrying capacity that is used during a delivery trip, expressed as a percentage of the total capacity.