Implementation of a Transportation Management System (TMS) to Optimize the Regional Distribution of Antenas y Accesorios AGEV

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INTRODUCTION

In today's competitive environment, the final stage of the supply chain is one of the links with the greatest direct impact on both customer satisfaction and operating cost structures. For small and medium-sized manufacturing enterprises (SMEs), such as Antenas y Accesorios AGEV, finished-product delivery logistics require careful coordination of order receipt, vehicle fleet availability, optimal visit sequencing, and formal recording of proof of delivery.

In smaller organizations, distribution routes are often planned empirically and in a decentralized manner. Decisions draw on drivers' accumulated experience or occasional consultations of personal mapping applications. Although this intuitive approach may suffice for simple daily operations, it has serious limitations as shipment frequency increases: it hinders systematic comparison of routing alternatives, prevents accurate calculation of costs related to vehicle wear and fuel consumption, and leaves the company vulnerable to road disruptions or the absence of key personnel.

To address this problem, adoption of a Transportation Management System (TMS) is emerging as a strategic technological solution. A TMS centrally integrates information from sales orders, vehicle fleet inventories, customer geographic locations, and operating time and distance parameters. By automating route generation and providing visibility into each trip, the platform transforms informal decisions into standardized, traceable, and measurable processes.

From an operations research perspective, route planning belongs to the broad family of Vehicle Routing Problems (VRP). The specialized literature establishes that the primary objective of VRP is to design optimal routes for a fleet serving geographically dispersed customers while minimizing cost functions and strictly respecting vehicle capacity, customer time windows, and working-hour regulations (Toth & Vigo, 2002). When an operation uses a single vehicle departing from a central warehouse and returning to the same origin after completing deliveries, the model resembles the classic Traveling Salesperson Problem (TSP), enhanced with practical capacity and service-time constraints (Google for Developers, n.d.).

For Antenas y Accesorios AGEV, the company considers regional distribution of its product lines using a representative light commercial vehicle: a pickup truck with a nominal one-ton payload capacity. The analysis starts with five geographic locations supplied as potential customers in the state of Puebla. Importantly, these destinations represent potential deliveries and do not imply that every customer requires service on the same trip.

General Objective

To design and illustrate an integrated proposal for implementing a Transportation Management System (TMS) tailored to the regional distribution needs of Antenas y Accesorios AGEV, assessing its ability to optimize the planning, sequencing, and operating cost of a closed route through a reproducible deterministic scenario.

Specific Objectives

• Collect and synthesize methodological and technical evidence on vehicle route optimization through a narrative review inspired by PRISMA 2020.

• Structure the master data catalog required for AGEV logistics operations, including fleet specifications, products, and destinations.

• Formulate explicit rules for order consolidation, filtering, and selection based on geographic, volumetric, and operational constraints.

• Develop a quantitative comparison between intuitive manual route planning and an optimized route based on TMS logic.

• Establish a dashboard of key performance indicators (KPIs) and define the field-validation protocols required before actual implementation.

Working Hypothesis

If Antenas y Accesorios AGEV consolidates and manages information on orders, actual vehicle capacities, verified road-distance matrices, and service times through a TMS architecture, it will be able to select and iterate delivery sequences that significantly reduce total mileage and variable transportation costs compared with traditional manual planning, while maintaining or improving service levels and on-time delivery performance.

METHODS AND MATERIALS

Literature Review Inspired by the Prisma Framework

The PRISMA 2020 statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is a widely recognized international standard for ensuring transparency, reproducibility, and rigor in reporting literature reviews (Page et al., 2021). Although PRISMA was originally designed for systematic reviews and health interventions, its methodological principles are adapted here to systematize the selection of theoretical references on logistics and vehicle routing.

Which optimization criteria, operating constraints, and control models described in the vehicle routing problem (VRP) literature are applicable to designing a TMS for regional distribution companies operating a single cargo vehicle? To answer this question, classic methodological sources on routing (Toth & Vigo, 2002), official technical documentation for widely used logistics optimization engines such as Google OR-Tools (Google for Developers, n.d.), and the PRISMA 2020 guideline were consulted.

Inclusion criteria covered peer-reviewed academic publications, technical manuals for recognized optimization software, and standardized reporting guidelines published between 2000 and 2026 in Spanish or English. Commercial articles lacking explicit mathematical foundations, technology vendor websites without algorithmic details, and VRP studies focusing exclusively on large urban fleets with hundreds of vehicles were excluded because they differ substantially from the operating conditions of regional SMEs.

The following matrix brings together the sources and assessments from the supplementary literature review document. Its content is retained as reference material; quantitative claims attributed to each source must be checked against the original publications before submission to a journal.

Table 1. Literature Review Matrix Based on PRISMA 2020

Article Title / Source	Main Objective	Methods and Approach	Key Findings	Identified Limitations
The vehicle routing problem	Provide a rigorous mathematical foundation for the	Mixed-integer linear programming (MILP), exact	Showed that optimal node sequencing	Exact models face combinatorial explosion in large

(Toth & Vigo, 2002 / SIAM)	Vehicle Routing Problem (VRP) family to optimize distribution logistics.	algorithms (Branch-and-Cut), and local-search heuristics.	reduces overall distance by 15% to 25% compared with empirical or unstructured sequences.	NP-hard problems, requiring metaheuristics for real-time operation.
The PRISMA 2020 statement: An updated guideline for reporting systematic reviews (Page et al., 2021 / BMJ)	Establish a standardized 27-item guideline and flowchart to ensure transparency and reproducibility in systematic literature reviews.	International consensus methodology for structuring source identification, screening, eligibility, and inclusion.	Standardized transparent reporting of selection bias and exclusion criteria in engineering and applied science articles.	Originally designed for biomedicine; requires conceptual adaptation for software or logistics optimization reviews.
OR-Tools: Vehicle Routing Problem with Capacity Constraints (Google for Developers, s. f. / 2024)	Provide an open-source combinatorial optimization suite capable of solving vehicle routing problems with capacity constraints and time windows.	Heuristic and metaheuristic search algorithms (Guided Local Search and Tabu Search) integrated in C++ with Python interfaces.	Can solve CVRP and VRPTW instances with hundreds of nodes in seconds, approaching global optima with low computational effort.	Requires prior cleaning, normalization, and accurate geocoding of addresses to avoid erroneous distance matrices.
A Systematic Literature Review of Vehicle Routing Problems with Time Windows (Braekers et al. / ResearchGate, 2023)	Synthesize and classify the state of the art in VRP variants with time windows (VRPTW) published over the past decade.	Systematic review strictly based on PRISMA methodology, analyzing 93 articles selected from Scopus and Web of Science.	Identified a trend toward hybrid models combining metaheuristics and machine learning to predict traffic.	Most studies assume symmetric distance matrices and constant speeds, unlike actual urban congestion.
Review of research on dynamic vehicle routing problems (Hao et al., 2024 / SPIE Digital Library)	Analyze real-time route updates in response to unexpected changes in demand or road congestion (DVRP).	Systematic literature review of deep reinforcement learning algorithms and adaptive metaheuristics.	Reported that modern TMS systems reduce delays by 30% when dynamically reoptimizing routes in response to actual traffic.	Requires costly IoT infrastructure (continuous GPS telematics and 4G/5G connectivity), challenging for resource-constrained SMEs.
Vehicle routing optimization problem in logistics and supply chain management (Đurđev, M., 2025 / ResearchGate)	Assess the economic and environmental impact of route optimization in regional and last-mile supply chains.	Comparative modeling of Traveling Salesperson Problem (TSP), Capacitated VRP (CVRP), and Green VRP (GVRP), focusing on fuel consumption.	Reported simultaneous reductions in variable transportation costs ($/km) and CO2 emissions of comparable magnitude (15–20%).	Assumes homogeneous fixed fuel costs without sudden changes in diesel/gasoline prices or tolls.

A Review of Last-Mile Delivery Optimization Strategies and Technologies (ResearchGate, 2025)	Examine emerging last-mile logistics technologies, including TMS algorithms, drones, and experience-based routing.	Qualitative and quantitative analysis of mathematical programming models combined with historical driving behavior data.	Reported that incorporating drivers' tacit knowledge into TMS algorithms increases route acceptance to 85%.	Integrating unstructured driver data requires extended training and software calibration.
Top 5 features to look for in a Transportation Management System (TMS) (Abivin / ABI-VN, 2024)	Identify critical features that commercial TMS software should offer to maximize return on investment for SMEs.	Operational case study and comparative analysis of leading TMS platforms in distribution and third-party logistics (3PL).	Established load optimization and dynamic routing as two major drivers of financial savings.	Advanced commercial platforms are often costly or rigid, requiring customized software for microenterprises.

AGEV Case Study Context

Dispatch Origin, Logistics Vehicle, and Cargo Characteristics

Antenas y Accesorios AGEV manufactures and sells telecommunications equipment, receiving/transmitting antennas, and mounting hardware. For the proposed distribution model, the central operations and dispatch facility is assumed to be located in Pachuca de Soto, Hidalgo, from which routes must depart toward customer facilities and consumption centers.

The fleet assigned to this logistics corridor consists of a commercial delivery truck with a nominal payload capacity of 1,000 kg (one ton). In actual logistics operations, however, effective vehicle capacity is not determined by weight alone. AGEV productsparticularly large antennas and mounting masts—occupy considerable volume relative to their weight, making usable cargo-space volume (measured in cubic meters) and packaging configuration critical constraints that must be incorporated into the TMS.

Commercial management identified five potential delivery destinations in different municipalities of Puebla. The following table presents their codes and descriptions:

Table 2. Portfolio of Potential Destinations

ID	Provided Destination / Location	Use in Illustrative Scenario	Logistics Notes
A	Jilotepec, 75160 San Salvador el Seco, Puebla	Selected (Active Route)	Intermediate point along the eastern corridor.
B	73996 San José Alchichica, Puebla	Reserve / Next Trip	Remote location toward northeastern Puebla.
C	Xalapa–Puebla Highway 112, Bypass, Acatzingo, Puebla	Selected (Active Route)	Strategic commercial destination in Acatzingo.
D	3rd West Boulevard, San Antonio, Acatzingo, Puebla	Selected (Active Route)	Urban delivery point in the municipality of Acatzingo.

E	Puebla–Tehuacán Federal Highway km 5, Huixcolotla, Puebla	Reserve / Next Trip	Commercial logistics hub in the southeastern area.

It is essential to note that the transcribed addresses represent preliminary commercial information. A core module of the proposed TMS is address normalization and geocoding, through which text addresses are converted into precise geographic coordinates (latitude and longitude). This step resolves ambiguities in references such as "Jilotepec" or "San José Alchichica" and ensures that the routing engine calculates actual drivable distances rather than straight-line distances.

Order Selection and Consolidation Rules

In modern transportation management, route optimization is not simply about finding the shortest path between an arbitrary set of points; it first requires deciding which orders should be consolidated into a single route. For this comparative scenario, customers A, C, and D were selected based on a geographic consolidation assumption along the logistics corridor toward Acatzingo.

For the TMS to approve the inclusion of a set of orders in the same vehicle departure, the algorithm must simultaneously verify the following operating constraints:

1. Weight Constraint: The sum of the gross weights of orders must not exceed the vehicle's legal and technical payload capacity (≤ 1,000 kg).
2. Volume Constraint: Total volume occupied by boxes or pallets must be less than the usable internal volume of the truck.
3. Load Stability and Compatibility: Physical loading arrangements must prevent damage to fragile components (e.g., antenna dishes).
4. Time Windows and Working Hours: Total time (driving plus unloading operations) must remain within the driver's permitted shift.
5. Commercial Priority: Urgent orders or orders past their delivery deadline must receive priority in route assignment.

Proposed TMS Model

To meet AGEV's operating needs without incurring disproportionate software costs, a scalable modular architecture consisting of six interconnected modules is designed:

Table 3. Minimum Functional System Architecture

Functional Module	Required Input Data	Generated Operational Output
1. Order Management	Order number, customer, items, weight, volume, promised date.	List of eligible and priority deliveries.
2. Destination Master Data	Postal address, delivery references, geocoding (lat/long).	Database of validated logistics nodes.
3. Fleet Management	Usable capacity (kg/m³), fuel efficiency, cost/km.	Vehicle specifications and availability.
4. Planning and Routing	Road-distance/time matrix, consolidation rules.	Proposed optimal delivery sequence.
5. Execution and Tracking	Departure time, GPS tracking, incidents en route.	Real-time monitoring and proof of delivery (POD).

6. Analytics and Indicators	Actual mileage, fuel, time, and completed delivery records.	Logistics KPI report and performance assessment.

Route Planning Procedure

The workflow within the proposed TMS follows a standardized five-step logical sequence:

- Step 1: Capture and import confirmed sales orders for the following day.
- Step 2: Automatically validate and geocode the delivery addresses of selected customers.
- Step 3: Calculate the matrix of actual road distances and travel times between the origin (Pachuca) and selected nodes using digital mapping services.
- Step 4: Run the optimization algorithm to evaluate possible visit permutations and select the lowest-total-cost sequence satisfying all constraints.
- Step 5: Issue the digital route sheet to the driver and enable electronic proof of delivery (POD).

Simplified Mathematical Formulation of the Model

Mathematically, optimizing the sequence of a closed route consisting of several stops can be represented by a complete graph. Let R = (0, 1, 2, ..., n, 0) denote the ordered visit sequence, where index "0" represents the origin and return point in Pachuca and {1, ..., n} represents assigned customers.

The total distance traveled along route D(R) is defined by:

$D(R) = \Sigma\, d(i, j)$ for every consecutive segment (i, j) on route R,

where d(i, j) is the road distance in kilometers between nodes i and j.

The direct variable cost of the trip, CV(R), is calculated by multiplying the total distance by the operating cost per kilometer (c_{km}): $CV(R) = D(R) \times c_{km}$

The estimated total time required to complete route T(R) combines road travel times and fixed handling and service times at each customer facility:

$T(R) = \Sigma\, t(i, j) + \Sigma\, s_i$

where t(i, j) represents driving time between points i and j (obtained from average speed or traffic matrices), and s_i represents the service or unloading time at customer i.

Technological Alternatives for Implementation

Implementing this model does not require high enterprise software licensing costs from the outset. AGEV can adopt a phased technology scaling strategy:

1. Initial Stage (Basic Phase): Use a spreadsheet tool (e.g., Microsoft Excel or Google Sheets) connected through macros or scripts to the Google Maps or OpenStreetMap geocoding API, using built-in linear optimization engines (Solver).
2. Intermediate Stage (Professional Phase): Integrate world-class open-source optimization libraries such as Google OR-Tools. This suite allows complex vehicle routing models with capacity constraints (CVRP) and time windows (VRPTW) to be programmed in Python with high algorithmic performance (Google for Developers, n.d.).
3. Advanced Stage (Corporate Phase): Migrate to a commercial cloud-based TMS platform (SaaS), natively integrated with the company's ERP system and equipped with driver mobile applications and real-time GPS telematics tracking.

Construction of the Comparative Scenario

To quantitatively illustrate the TMS methodology and compare its performance with traditional manual planning, a deterministic scenario is constructed using a hypothetical symmetric road-distance matrix between Pachuca (0) and stops A, C, and D. These distances are for demonstration purposes only and do not constitute a definitive navigation plan.

Table 4. Road-Distance Matrix Assumptions

Logistics Segment / Node Connection	Assumed Distance (km)	Type of Segment
Pachuca (0) – Jilotepec (A)	155	Outbound segment / initial connection
Pachuca (0) – Acatzingo C	175	Outbound segment / direct connection
Pachuca (0) – Acatzingo D	179	Outbound segment / direct connection
Jilotepec (A) – Acatzingo C	65	Regional connection
Jilotepec (A) – Acatzingo D	69	Regional connection
Acatzingo C – Acatzingo D	4	Local urban travel (same municipality)

Comparison of Routing Sequences (Manual vs. TMS)

Two sequencing approaches are evaluated for the three selected customers (A, C, and D):

• Manual Planning (Traditional Sequence): Represents an intuitive method in which the operator first schedules delivery to company C in Acatzingo, then travels north to Jilotepec (A), and finally returns toward Acatzingo to serve customer D before returning to Pachuca. Sequence: 0 → C → A → D → 0.

• TMS Proposal (Optimized Sequence): Represents the algorithmic solution in which the system identifies that Jilotepec (A) lies geographically before Acatzingo along the route from Pachuca and that customers C and D are only 4 km apart within Acatzingo. The TMS proposes the continuous sequence: 0 → A → C → D → 0.

Calculation of Distance in Manual Planning:

Distance = (0→C) + (C→A) + (A→D) + (D→0)
Distance = 175 km + 65 km + 69 km + 179 km = 488 km.

Calculation of Distance in the TMS Proposal:

Distance = (0→A) + (A→C) + (C→D) + (D→0)
Distance = 155 km + 65 km + 4 km + 179 km = 403 km.

Assumed Economic and Operating Parameters

To complement the physical comparison with a financial and time analysis, the following reference operating parameters were established:

• Variable cost rate per kilometer: MXN $4.50/km (including allocated fuel consumption, lubricants, and cumulative tire and brake wear).
• Average driving speed: 65 km/h (weighted average for federal highways and urban access roads).
• Fixed customer service and unloading time (s_i): 25 minutes per stop (0.416 hours per customer). Total for 3 customers: 75 minutes (1.25 hours).

Scenario Results

Assessment of Mileage, Variable Cost, and Total Time

Processing both sequences using the same equations and parameters yields the comparative results shown in Table 5

Table 5. Assessment of Mileage, Variable Cost, and Total Time

Operating / Financial Indicator	Manual Planning	TMS Proposal	Absolute Difference	Relative Savings (%)
Total trip distance (km)	488.00 km	403.00 km	-85.00 km	-17.4 %
Direct variable cost (MXN)	$2,196.00	$1,813.50	-$382.50	-17.4 %
Estimated driving time (h)	7.51 h	6.20 h	-1.31 h (-78 min)	-17.4 %
Customer service time (h)	1.25 h	1.25 h	0.00 h	0.0 %
Total workday time (h)	8.76 h	7.45 h	-1.31 h (-78 min)	-15.0 %

The data show that the sequence generated by the TMS eliminates the unnecessary back-and-forth segment between Acatzingo and Jilotepec. This physical optimization translates into 85 fewer kilometers traveled, representing savings of 17.4% in both distance and variable cost. Driving time is also reduced by 1 hour and 18 minutes, allowing the full workday to decrease from 8.76 to 7.45 hours and the driver to finish the shift within the regulatory framework without overtime.

To evaluate how financial savings respond to fuel price fluctuations or changes in maintenance costs, a sensitivity analysis was conducted using three per-kilometer rate scenarios (MXN $3.50, $4.50, and $5.50/km):

Table 6. Economic Sensitivity Analysis

Assumed Rate per Km (MXN)	**Manual Route Cost**	**Proposed TMS Route Cost**	**Net Savings per Trip (MXN)**
$3.50 / km (Low-Cost / Economic Scenario)	$1,708.00	$1,410.50	$297.50
$4.50 / km (Baseline / Standard Scenario)	$2,196.00	$1,813.50	$382.50
$5.50 / km (High-Inflation Scenario)	$2,684.00	$2,216.50	$467.50

The analysis shows that the absolute financial benefit increases in direct proportion to the cost per kilometer. In high-inflation or expensive-fuel scenarios ($5.50/km), savings for each typical Pachuca–Puebla trip reach MXN $467.50, which could represent significant resources for the company when projected across annual operations.

Interpretation and Scope of Results

These findings must be interpreted rigorously: the greatest value of a TMS for Antenas y Accesorios AGEV is not simply "saving kilometers" on a single three-stop route, but institutionalizing a decision-making system. The TMS provides a structure in which each trip is documented, costs are predicted before dispatch, and deviations are audited at the end of the day.

DISCUSSION

The results of the deterministic scenario are consistent with established theories in the Vehicle Routing Problem (VRP) literature. As Toth and Vigo (2002) note, visit sequence has a major impact on distribution logistics efficiency when fleet size and demand remain constant.

However, the limitations of the deterministic model must be considered in relation to AGEV's actual operations. In practice, customer selection cannot always be based strictly on geographic criteria. For example, if customer B in San José Alchichica had a critically urgent order or contractual late-delivery penalties, the company would have to include that customer in the route even if overall mileage increased.

Special attention must also be paid to the physical characteristics of AGEV merchandise. Antennas and metal structures have irregular volumes. A truck with a nominal 1,000 kg capacity could fill 100% of its cargo volume before reaching 50% of its weight limit. Therefore, recording dimensions in the TMS product catalog is essential to avoid actual dispatch failures.

Implementation of Risks and Barriers in an SME

Transitioning from manual routing to a digital environment involves operational and organizational risks that must be managed proactively:

• Master data quality: If addresses are not correctly geocoded or product weights are inaccurate, the system will generate infeasible routes.
• Staff resistance to change: Drivers may perceive GPS and strict route sheets as punitive monitoring rather than workplace support tools.
• Dependence on key personnel: If software management rests with a single operator without trained backups, operations become vulnerable.

To measure the effectiveness of TMS implementation and ensure continuous improvement, the following logistics KPI system is proposed:

Table 7. Key Performance Indicator (KPI) Dashboard

Key Indicator (KPI)	Calculation Formula / Record	Measurement Frequency	Performance Target
Cost per Delivery	Total Trip Cost / Completed Deliveries	Per Trip / Weekly	Gradual reduction of 10–15%
Kilometers per Delivery	Actual GPS Kilometers / Completed Deliveries	Per Trip	Minimize km/delivery ratio
On-Time Delivery (OTD)	(On-Time Deliveries / Committed Deliveries) × 100	Weekly	≥ 95% on-time deliveries
Capacity Utilization	(Loaded Weight or Volume / Usable Capacity) × 100	Per Trip	≥ 80% vehicle utilization

Route Deviation	| Actual GPS km − TMS Planned km |	Per Trip	Deviation ≤ 5%
On-Time In-Full Delivery Index (OTIF)	(Orders Delivered Without Shortages / Total Orders) × 100	Weekly / Monthly	≥ 98% effectiveness

Excel–Python Synchronization Algorithm

The file sincronizar agev.py implements a bidirectional editing and updating interface with desktop Excel, displaying sales by month, category, and salesperson. Changes made in the workbook can be reflected in Python while the program is running, and vice versa. Within a TMS architecture, its role would be to provide order and sales activity data after converting sales into logistics orders with addresses, weight, volume, priority, and delivery dates.

Pseudocode A — Commercial Information Synchronization:

START: open the Excel workbook and establish a connection with the Python interface.

WHILE the application is active: read modified cells and update the view.

IF the user edits an allowed value in Python: write the change to Excel.

RECALCULATE indicators and refresh sales charts.

ON EXIT: save the workbook and close the connection.

Expected outcome: updated commercial information available for subsequent delivery planning; the current file is not assumed to include geocoding, GPS tracking, or a routing engine.

Proposed Route Optimization Algorithm

The second component would use Python to construct a road-distance matrix between Pachuca and customers with confirmed orders, assess constraints on capacity (nominally 1,000 kg), volume, and service times, and compare feasible sequences for a single vehicle returning to its origin. With a small number of stops, enumerating permutations allows selection of the shortest distance; larger instances could use OR-Tools.

Pseudocode B — Closed-Route Planning:

INPUT: confirmed orders, validated locations, weights, volumes, priorities, and road-distance matrix.

FILTER: select orders compatible with capacity, volume, and workday constraints.

GENERATE: visit sequences starting and ending in Pachuca.

FOR EACH feasible sequence: sum distances, times, and estimated cost.

SELECT: the lowest-cost sequence subject to constraints.

OUTPUT: itinerary, mileage, expected cost, and indicators for comparison with the manual route.

Expected outcome: a technically feasible delivery route and a reproducible comparison with manual planning. The proposed 403 km and the traditional scenario’s 488 km described in this article come from an assumed matrix and do not constitute road validation or results from executing the Python algorithm.

Integration and Validation

To connect both components, the data workbook would need a unique order identifier, verifiable address, promised delivery date, quantity, weight, and volume. The routing algorithm would then generate a route sheet and store actual distances and times to update KPIs. The proposal requires a pilot test with real AGEV data before operational savings can be attributed to it.

Implementation Proposal and Conclusions

To ensure successful, low-risk deployment at Antenas y Accesorios AGEV, a structured plan consisting of five successive phases is proposed:

Table 7. Phased Technology Adoption Plan

Project Phase	Main Activities to Be Performed	Acceptance Criterion / Deliverable
Phase 1: Diagnosis	Collect delivery history, clean customer master data, and audit fuel costs.	Clean database and baseline cost report.
Phase 2: Configuration	Configure the fleet in the TMS, enter volume constraints, and define speed matrices.	Configured and validated TMS.
Phase 3: Pilot Test	Run parallel tests (traditional method vs. TMS) on the Pachuca–Puebla route for 4 weeks.	Performance report with actual GPS data.
Phase 4: Evaluation	Compare actual KPIs with company baselines and adjust service-time parameters.	Evaluation report and management approval.
Phase 5: Scaling	Formally integrate the TMS with billing/ERP and fully train operating personnel.	Fully digitalized and independently managed operations.

CONCLUSIONS

This research analyzed the importance of implementing a Transportation Management System (TMS) as a technological tool to improve the efficiency of logistics processes at Antenas y Accesorios AGEV. Through the study of regional distribution from Pachuca de Soto, Hidalgo, to different destinations in Puebla, route planning, strategic customer selection, and efficient resource utilization were identified as key factors in reducing operating costs, optimizing delivery times, and strengthening the company's responsiveness.

Through a literature review based on PRISMA 2020 principles, different approaches to TMS, route optimization models, and digital tools in logistics management were identified. Analysis of these studies provided theoretical and methodological foundations for proposing a system tailored to AGEV's operating needs, considering product characteristics, a one-ton truck, and a distribution route with multiple potential destinations. The incorporation of information technologies also supports data-driven decision-making and helps replace empirical procedures with more structured planning methods.

Regarding route assessment, the comparative scenario showed that proper delivery sequencing can generate economic and operational benefits. Under the stated assumptions, the traditionally planned route covered 488 kilometers, while the TMS-based optimized proposal reduced the distance to 403 kilometers, an estimated 17.4% decrease. This difference represents savings of 85 kilometers and a reduction in variable transportation costs from MXN $2,196.00 to $1,813.50 per trip. Although these results are simulated and require validation through actual trips, they demonstrate the potential of route optimization to improve fuel efficiency, reduce unnecessary travel, and support more efficient distribution.

Furthermore, integrating Microsoft Excel and Python offers an accessible technological alternative for strengthening data analysis and process automation within AGEV. Linking these tools makes it possible to organize and update sales records, analyze sales behavior, and obtain useful information for logistics planning. In addition, a proposed Python route optimization algorithm could process customer locations, distances, load capacity, and transportation costs to identify more suitable distribution sequences. This integration provides a foundation for progressively developing a TMS that connects commercial information with transportation decisions.

Similarly, the use of key performance indicators (KPIs) is essential for evaluating the effectiveness of proposed improvements. Monitoring distance traveled, cost per kilometer, total distribution time, fuel consumption, and delivery compliance would help identify deviations, compare outcomes, and establish continuous improvement actions. Systematic collection of these data would also provide historical information for future decisions on order scheduling, load consolidation, and resource allocation.

Finally, the gradual implementation of a TMS, supported by data analysis tools and Python optimization algorithms, is a viable alternative for modernizing transportation management at Antenas y Accesorios AGEV. Its application could lead to more organized, measurable, and evidence-based distribution, supporting economic efficiency and better use of available resources. Nevertheless, confirming the estimated benefits will require pilot testing, verification of actual travel distances and times, evaluation of vehicle operating conditions, and collection of historical delivery information. The proposal therefore provides a methodological and technological foundation for strengthening the company's competitiveness and promoting continuous improvement in its transportation and distribution operations.

REFERENCES

1. Braekers, K., Ramaekers, K., & Van Nieuwenhuyse, I. (2016). The vehicle routing problem: State of the art classification and review. Computers & Industrial Engineering, 99, 300–313. https://doi.org/10.1016/j.cie.2015.12.007
2. Clarke, G., & Wright, J. W. (1964). Scheduling of vehicles from a central depot to a number of delivery points. Operations Research, 12(4), 568–581. https://doi.org/10.1287/opre.12.4.568
3. Dantzig, G. B., & Ramser, J. H. (1959). The truck dispatching problem. Management Science, 6(1), 80–91. https://doi.org/10.1287/mnsc.6.1.80
4. Laporte, G. (2009). Fifty years of vehicle routing. Transportation Science, 43(4), 408–416. https://doi.org/10.1287/trsc.1090.0301
5. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372, Article n71. https://doi.org/10.1136/bmj.n71
6. Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: Updated guidance and exemplars for reporting systematic reviews. BMJ, 372, Article n160. https://doi.org/10.1136/bmj.n160
7. Pillac, V., Gendreau, M., Guéret, C., & Medaglia, A. L. (2013). A review of dynamic vehicle routing problems. European Journal of Operational Research, 225(1), 1–11. https://doi.org/10.1016/j.ejor.2012.08.015
8. Toth, P., & Vigo, D. (Eds.). (2014). Vehicle routing: Problems, methods, and applications (2nd ed.). Society for Industrial and Applied Mathematics. https://doi.org/10.1137/1.9781611973594
9. Vidal, T. (2022). Hybrid genetic search for the CVRP: Open-source implementation and SWAP* neighborhood. Computers & Operations Research, 140, Article 105643. https://doi.org/10.1016/j.cor.2021.105643
10. Google for Developers. (n.d.-a). Capacity constraints. OR-Tools Documentation. Retrieved from https://developers.google.com/optimization/routing/cvrp

11. Google for Developers. (n.d.-b). Vehicle routing. OR-Tools Documentation. Retrieved from https://developers.google.com/optimization/routing
12. Google for Developers. (n.d.-c). Vehicle routing problem. OR-Tools Documentation. Retrieved from https://developers.google.com/optimization/routing/vrp
13. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. BMJ, 372(n71), 1–9. https://doi.org/10.1136/bmj.n71
14. Toth, P., & Vigo, D. (Eds.). (2002). The vehicle routing problem. Society for Industrial and Applied Mathematics (SIAM). https://doi.org/10.1137/1.9780898718515