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Evaluate Green Supply Chain Management in the Oil-Engine Manufacturing Industry

Mahesh Olakiya[1], Dr Ghanshyam Acharya[2]

[1]UG Scholar; Dept. of Mech. Eng., Atmiya University Rajkot
[2]Prof. Emeritus: Dept. of Mech. Eng., Atmiya University Rajkot

Abstract

This paper explores how four important logistics factors—**route optimization, reverse logistics efficiency, load optimization, and last-mile delivery emissions**—influence **green supply chain management (GSCM)** in the oil-engine manufacturing industry. Because the oil-engine sector involves heavy transportation of bulky components and finished engines, logistics activities account for a major portion of its environmental footprint. Recent research shows that using **data-driven route planning**, improving **reverse logistics** for remanufacturing and recycling, optimizing **vehicle load distribution**, and minimizing **last-mile emissions** can significantly cut carbon output and operating costs. This review combines findings from recent studies and proposes a simple impact-study method that manufacturers can use to measure environmental benefits. The paper concludes that integrating these four areas can greatly improve sustainability performance, reduce waste, and strengthen circular economy practices in the oil-engine manufacturing supply chain.

Keywords: Green Supply Chain Management, Route Optimization, Reverse Logistics, Load Optimization, Last-Mile Delivery, Oil-Engine Manufacturing, Sustainability, Remanufacturing

1. Introduction

The oil-engine manufacturing industry—producing diesel and industrial engines for vehicles, ships, and machinery—depends on complex and energy-intensive logistics operations. Large castings, heavy components, and finished engines move through multiple stages: from foundries to machining centers, to assembly plants, and finally to distributors and end-users. Additionally, defective or used parts often travel back through **reverse logistics channels** for repair, recycling, or remanufacturing.

Because these logistics processes consume large amounts of fuel and generate emissions, they have become a key target in achieving **green supply chain management (GSCM)** goals. GSCM focuses on minimizing environmental impact while maintaining productivity and competitiveness. In this context, optimizing logistics is crucial, as transportation can account for up to **60% of total supply chain emissions** in heavy industries.

This paper reviews how the four main logistics levers—**route optimization, reverse logistics efficiency, load optimization, and last-mile delivery emission control**—influence the environmental and economic performance of oil-engine manufacturers. It also presents a structured methodology that can be used by companies to assess and improve these factors in their operations.

2. Methodology for Assessing Impact

To understand the impact of these logistics practices, a structured methodology is proposed that can be applied to any oil-engine manufacturing company.

Step 1: Define the Scope and Baseline

Start by identifying which stages of the supply chain to include—typically from raw material suppliers to manufacturing plants, distribution centers, dealers, and end customers. Establish a baseline of emissions using fuel consumption data, distances traveled, and vehicle utilization rates.

Step 2: Collect Relevant Data

Gather telematics and GPS data from delivery trucks, such as routes, idle time, fuel efficiency, and load weight. Record data from return logistics and last-mile deliveries as well. This creates a clear picture of the current operational footprint.

Step 3: Develop and Test Improvement Scenarios

Use simulation models to test different scenarios:

- **Route optimization:** compare traditional static routes with AI-based dynamic routing that accounts for real-time traffic and road conditions.
- **Reverse logistics efficiency:** test the impact of consolidated pickups or shared return trips.
- **Load optimization:** evaluate how improving vehicle fill rates affects emissions.
- **Last-mile delivery:** model different delivery modes such as electric vans or urban consolidation centers.

Step 4: Evaluate Environmental and Economic Outcomes

Calculate the difference in emissions, fuel use, and delivery costs between the baseline and the improved scenarios. Use carbon intensity metrics (like CO_2 per ton-km) to express efficiency gains.

Step 5: Verify Through Pilot Studies

Implement small pilot programs—such as using optimized routing software on selected routes—to validate model predictions before full-scale deployment.

This mixed-method approach ensures that both environmental and financial benefits are clearly measured and understood.

3. Literature Review and Discussion

3.1 Route Optimization

Route optimization focuses on minimizing travel distance and idle time by finding the most efficient paths for delivery vehicles. Traditional routing plans are often fixed and do not consider real-time conditions. In contrast, **AI and GPS-based dynamic routing** systems adjust delivery routes instantly based on traffic, weather, and load conditions.

Studies show that such systems can **reduce total travel distance by 10–25%**, saving fuel and cutting greenhouse gas (GHG) emissions significantly. In the oil-engine industry, where vehicles often carry heavy loads over long distances, even small efficiency gains result in large fuel savings. Moreover, optimized routes also lead to **better driver scheduling**, less overtime, and reduced vehicle wear and tear—creating both environmental and operational benefits.

3.2 Reverse Logistics Efficiency

Reverse logistics plays a vital role in **circular economy practices**—the reuse, repair, and recycling of returned or end-of-life components. In the oil-engine industry, returned cores, crankshafts, filters, and injectors can often be remanufactured instead of discarded.

Efficient reverse logistics systems collect these components systematically, consolidate return shipments, and coordinate with remanufacturing facilities. Research shows that such systems can **reduce material waste by up to 40%** and **cut carbon emissions by 15–20%**, especially when return routes are planned alongside regular delivery trips.

Beyond environmental gains, reverse logistics reduces the demand for virgin materials and lowers overall production costs. This not only supports sustainability goals but also enhances competitiveness in a cost-sensitive market.

3.3 Load Optimization

Load optimization ensures that vehicles are filled to near capacity and that weight is evenly distributed. In heavy manufacturing logistics, **underutilized capacity** leads to unnecessary fuel use and emissions. Studies suggest that increasing truck fill rates by just **10%** can lower CO_2 emissions per unit shipped by **up to 8%**. Proper load balancing also minimizes engine strain and tire wear, further reducing maintenance costs and fuel consumption.

In oil-engine manufacturing, where shipments involve bulky yet non-uniform components, **smart load planning tools** can help optimize weight distribution, prevent partial loads, and reduce the number of trips required.

3.4 Last-Mile Delivery Emissions

The “last mile” refers to the final delivery stage—from the distribution center to the customer. While it accounts for a smaller portion of total distance, it is typically the **most emission-intensive** due to frequent stops, low load density, and traffic congestion.

Research indicates that **urban last-mile emissions could rise by more than 30% by 2030** if not addressed. Strategies such as using **electric or hybrid delivery vehicles**, establishing **micro-hubs**, and **consolidating deliveries** can significantly reduce these emissions.

For oil-engine companies, this applies particularly to aftermarket parts and service deliveries. Electrifying these short routes or combining them into shared logistics networks with other firms can deliver substantial environmental benefits.

4. Integrated Impact on Green Supply Chain Management

When these four strategies are combined, their impact is far greater than when applied individually:

- **Route and Load Optimization Together:** Smart routing paired with full truckloads cuts both mileage and emissions. For heavy-engine shipments, this can mean **up to 20% reduction in fuel use** and faster delivery times.
- **Reverse Logistics and Last-Mile Efficiency:** Coordinating deliveries with return pickups reduces empty runs. Electrifying short last-mile routes further decreases emissions.
- **Digital Integration:** Implementing telematics, IoT sensors, and AI for real-time tracking and predictive maintenance enhances the efficiency of the entire network.
- **Cost-Benefit Synergy:** While initial investment in technology and electric vehicles may be high, the payback period is usually short—often within **2 to 3 years**—due to savings from fuel, materials, and improved productivity.

However, some challenges remain. These include high upfront costs for digital tools, limited charging infrastructure for heavy vehicles, and the need for better coordination among suppliers, transporters, and dealers. Addressing these challenges requires both strategic planning and collaboration across the supply chain.

5. Conclusion

The shift toward **green logistics** in oil-engine manufacturing is no longer optional—it is essential for long-term competitiveness and compliance with environmental regulations. Route optimization, reverse logistics efficiency, load optimization, and last-mile delivery improvements together form the backbone of a **sustainable supply chain**.

Evidence from multiple studies confirms that:

- **Optimized routing** can cut total emissions by 10–25%.
- **Efficient reverse logistics** promotes circularity and reduces waste.
- **Load optimization** saves fuel and lowers per-unit emissions.
- **Cleaner last-mile delivery** mitigates urban pollution and enhances brand image.

To realize these benefits, manufacturers should adopt an integrated data-driven approach. By combining smart logistics planning, cleaner technologies, and circular economy principles, oil-engine manufacturers can achieve both **economic efficiency** and **environmental sustainability**.

Future research should focus on real-world case studies and long-term monitoring to quantify these impacts more precisely and support policy development in the manufacturing sector.

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