Microscopic Traffic Simulation for Evaluating Multimodal Logistics Hubs

Master's Thesis of Carl Alkai

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Research Context

The Challenge: Urban logistics faces congestion, emissions (15-20% of city center total), and space constraints.

The Solution: Strategically placed micro-hubs with shared cargo bike infrastructure.

The promise: Maximize efficiency, lower emissions, ease congestion.

Comparing diesel vans vs. cargo bikes in Munich's urban core around the historic Paketposthalle

Figure 1: Paketposthalle Munich: Heritage Meets Urbanism

Objectives

- Compare delivery performance metrics
- Assess environmental impacts
- Evaluate economic viability
- Analyze urban space consumption
- Test system sensitivity to operational parameters

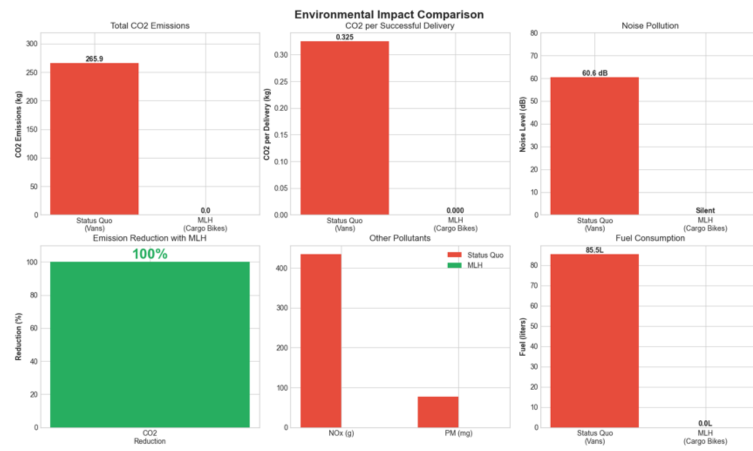
Methodology

Simulation : SUMO microscopic traffic model
Duration: 24-hour operations
Network: Munich city center (calibrated with Oct 2024 detector data)

Figure 2: Modern Multi-Modal Transit Center

Metric	Status Quo	MLH
Vehicles	10 vans	63 bikes
Capacity	100 pkg	15 pkg
Start time	5:00 AM	6:00 AM
Fuel type	Diesel	Electric

Environmental Impact



100%
Emissions Reduction

Daily CO_2: 265.9 kg → 0 kg
NOx: 434.6 g → 0 g
PM: 7,697 mg → 0 mg

Annual savings:
79.8 tons CO_2
25,650 L diesel
€40,509 fuel cost

Operational Efficiency

Average Speed Advantage (km/h): 6.8 (bikes) vs 3.7 km/h = **+82.8%**
Labor Productivity (pkg/hr): 10.2 vs 8.29 = **+23%**

Service Quality

Status Quo	MLH
90.4%	96.7%
Completion Rate	Completion Rate
CV: 0.311 (31% variability)	CV: 0.138 (14% variability)

+68 packages delivered daily with **55% better time predictability**

Urban Space Consumption

92%
Space-Time Reduction
82,425 m²·min → 6,659 m²·min per day
Equivalent to: 10 hours across 62 parking spaces freed for pedestrian areas, or green infrastructure

Economic Performance

Cost/Delivery:
Status Quo: €2.85
MLH: €3.06
+7.4% premium

Within consumer acceptance:
35% willing to pay extra for eco-delivery
Future carbon pricing (€145-160/ton by 2030) may eliminate premium

Sensitivity Analysis

Capacity Testing: Cargo bikes show non-linear scaling
•**15 pkg minimum** for economic viability (46.2% margin at 10 pkg)
•**20 pkg optimal** for cost parity with vans (€2.57 vs €2.49)
Temporal Testing: Cargo bikes maintain **97% accessibility** across all operating windows (timing-independent)

Key Findings

- ✓ Accessibility > Capacity in dense urban cores
- ✓ 100% direct emissions elimination achieved
- ✓ 92% urban space freed for community use
- ✓ 7.4% cost premium within market acceptance
- ✓ Timing-independent operations enable policy flexibility

Critical Insights

Distance Paradox: 67% more distance traveled but zero environmental impact challenges traditional "minimize distance = optimize sustainability" thinking

Infrastructure Matters: 87 van-inaccessible addresses due to parking constraints, not routing inefficiency

Policy Implications

•**Smart interventions:** Preferential parking, micro-hub site allocation, capacity subsidies (15+ pkg)
•**Peak-hour restrictions:** Cargo bike timing independence enables van restrictions without service loss
•**Hybrid approaches:** Vans for urgent deliveries, bikes for consolidated peak runs
•**Social equity:** Improved accessibility benefits elderly & disabled populations

Limitations

•Ideal weather conditions assumed
•Homogeneous package characteristics
•Partial network calibration (71 detectors)
•Munich-specific infrastructure (bike lanes, topology)
•No seasonal variations modeled

Conclusions

Micro-hub cargo bike systems achieve sustainability without trade-offs - simultaneously addressing emissions, space constraints, accessibility, and equity.

The 7.4% cost premium is a **strategic investment** in urban problem-solving. Carbon pricing trajectories suggest **natural market adoption by 2030**.