Minimizing Cost of Intra-Yard Finished Vehicle Logistics Through Automation and Optimization

BUSINESS PROBLEM

An OEM seeks to transform its finished vehicle logistics through automation, where newly manufactured vehicles drive themselves within the plant environment using Vehicle Plug-In (VPI) units. However, the company faces significant uncertainty in optimizing these operations. Key challenges include determining optimal VPI inventory levels (initially estimated at 300 units), identifying potential bottlenecks in the workflows, validating safety performance against human drivers, and evaluating whether mid-lifecycle LIDAR sensor upgrades would be cost-effective. These unknowns create financial planning challenges and operational risks.

APPROACH

The research applies a three-layered systems engineering methodology: operational modeling using FlexSim simulation to optimize VPI inventory and replenishment cycles; safety analysis using Bayesian Networks to validate performance against human benchmarks; and technology evaluation to assess sensor architecture and potential upgrades throughout the system lifecycle.

DATA SOURCES

Two-week yard movement data from the OEM's Yard Management System tracking vehicle movements; direct observations from the OEM's R&D team showing autonomous technology performance; commercial research on sensor technologies and tow truck specifications; and stakeholder interviews with FVL, Mobility and Innovation, and technical teams providing operational context and requirements.

Data Types and Format

Time-series vehicle movement data from the OEM's Yard Management System; autonomous system performance probability metrics; sensor and tow truck cost estimates; interview notes and flow diagrams.

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IMPACT

The three-layered systems engineering analysis validates the system's operational viability while revealing critical implementation parameters. Operational modeling demonstrates that 750 VPI units (significantly higher than initial 300-unit estimates), with 6-hour replenishment cycles, minimizes cost considering replenishment labor and depreciation factors. This modeling identifies a key bottleneck in stock lot VPI collection, where the current individual retrieval approach extends replenishment time to nearly two hours. Safety analysis using Bayesian Networks confirms system performance exceeds human driver benchmarks with 99.999% probability of accident-free operation, providing quantifiable risk metrics for decision-making. The technical evaluation establishes LIDAR-equipped RSUs as the optimal sensor architecture while determining that mid-lifecycle sensor upgrades yield a slightly negative NPV, indicating upgrades may become viable with further technology improvements. The implementation adds only 4.6% capacity impact to the existing End-of-Assembly Line (EOAL) workforce, minimizing operational disruption. Beyond immediate benefits, this framework positions Nissan for predictable intra-yard automation, and establishes a foundation for expanding autonomous systems throughout their manufacturing ecosystem. In effect, creating a bridge between controlled-environment autonomy and broader mobility applications.

DRIVERS	Industry trends toward manufacturing automation and the growing Automated Valet Parking market (projected to reach $42.38 billion by 2028) created competitive pressure and opportunity. The OEM's leadership mandated increased automation and asset optimization while creating higher-value jobs, providing executive sponsorship for implementation.
BARRIERS	Acquisition delays for an initial simulation tool required shifting to FlexSim after legal reviews. Computing power limitations prevented using actual OEM CAD files in simulations. Incomplete tracking data for accessory install operations required developing scaling factors for accurate processing time estimation. Geographic dispersion of teams created communication challenges affecting information gathering and stakeholder alignment.
ENABLERS	The controlled manufacturing environment avoided regulatory challenges of public-road implementation. The OEM's R&D team provided autonomous system expertise while yard operations staff offered process insights. MIT's operations management frameworks and FlexSim's simulation capabilities supported complex modeling, while leadership's automation vision provided organizational support.
ACTIONS	Developed a three-layered systems engineering approach to validate Nissan's automated yard operations. Conducted yard movement data analysis using Python, created FlexSim simulation models for VPI inventory optimization, implemented Bayesian Network safety analysis to quantify accident probabilities, and evaluated sensor technologies through technical assessment and NPV analysis.
INNOVATION	The integrated three-layered systems engineering approach connects operational modeling, safety analysis, and technology strategy to optimize multiple dimensions simultaneously. The modified inventory model extends Economic Order Quantity theory to account for circular VPI flow in autonomous logistics. The Bayesian Network safety validation provides quantifiable metrics directly integrating financial implications for NPV calculations.
IMPROVEMENT	Analysis established optimal parameters: 750 VPI units with 6-hour replenishment cycles maintaining 100 vehicles/hour throughput—far above initial 300-unit estimates. Safety validation confirmed 99.999% probability of accident-free operation, exceeding human benchmarks. Validated the implementation requires only 4.6% capacity impact to existing workforce at End-of-Assembly-Line (EOAL).
BEST PRACTICES	Begin with detailed process mapping before simulation development. Develop comprehensive stakeholder engagement spanning operational, technical, and management teams. Use multi-method validation combining simulation, probabilistic modeling, and financial analysis. Structure models with modular components for easier modification.
OTHER APPLICATIONS	The methodology can also apply to inbound logistics management, parts delivery, and carrier loading in automotive manufacturing. Similar approaches benefit port operations, distribution centers, and fulfillment operations. Beyond automotive, applications include pharmaceutical manufacturing logistics, airport baggage handling, and mining operations—all controlled environments suitable for autonomous vehicle technology.