Concept for optimizing the scheduling of automated guided vehicles at automated container terminals

MOEPL 2025 Conference

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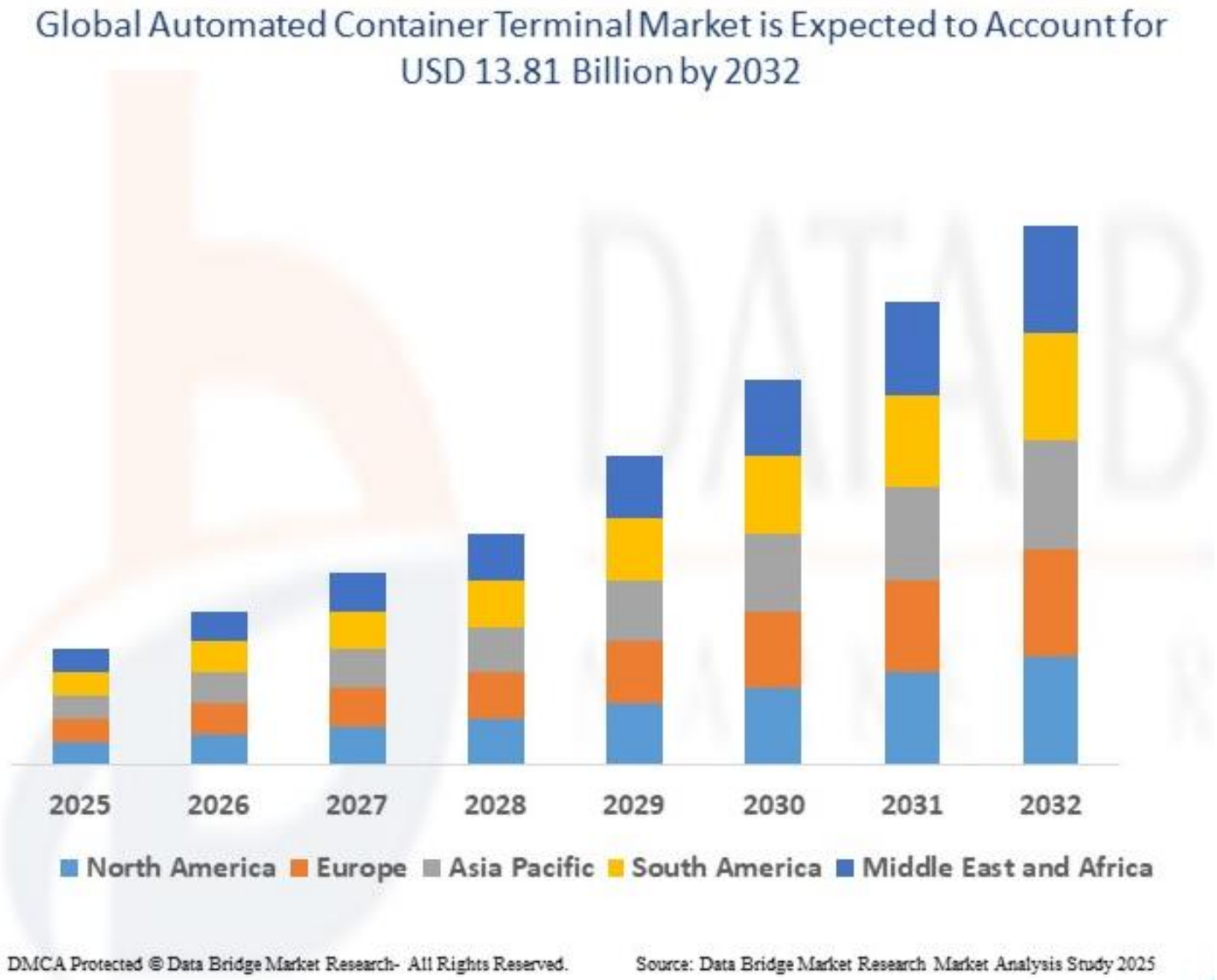
Introduction



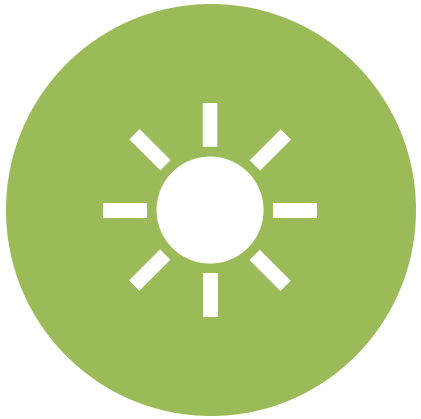
- Rise of ACTs
- AGVs: vital for horizontal transport
- Efficient scheduling = performance + sustainability
- Goal: minimize AGV energy use

Motivation

- Green logistics importance
- Energy varies by state
- Traditional models fall short

Research Objective

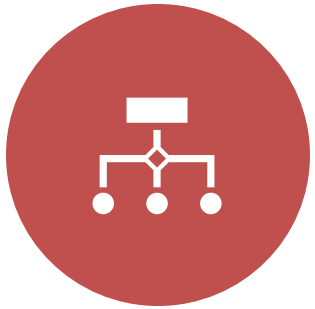
DEVELOP INTELLIGENT MODEL



MINIMIZE AGV ENERGY

SOLVE WITH VNS ALGORITHM

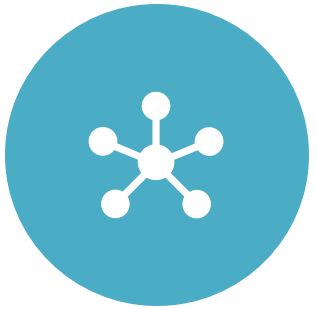
Literature Review Overview



COORDINATION

CHARGING STRATEGIES

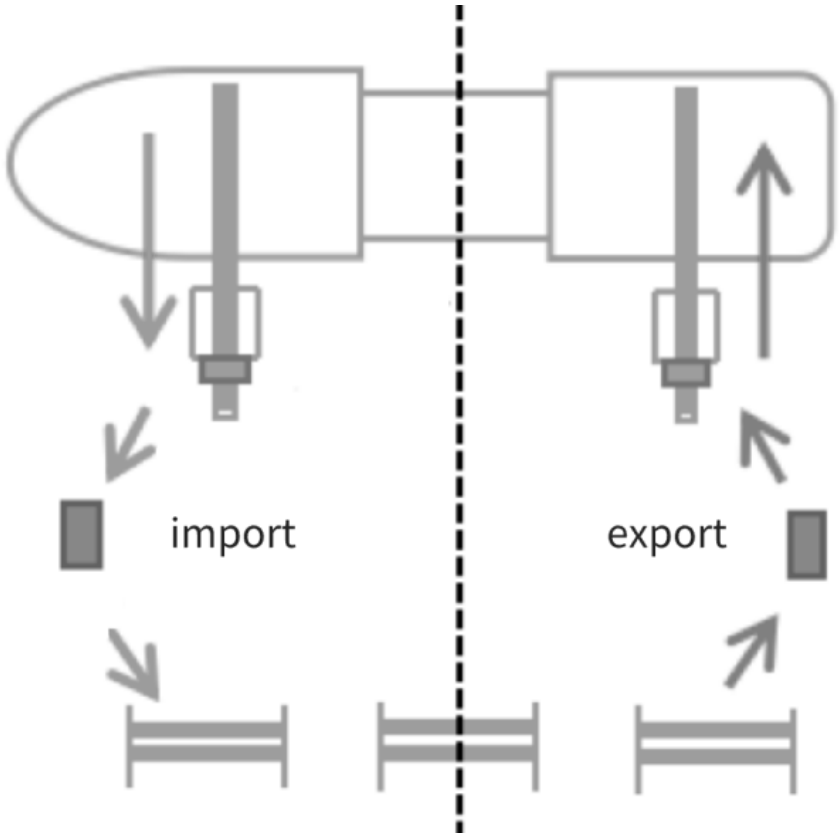
ENERGY FOCUS

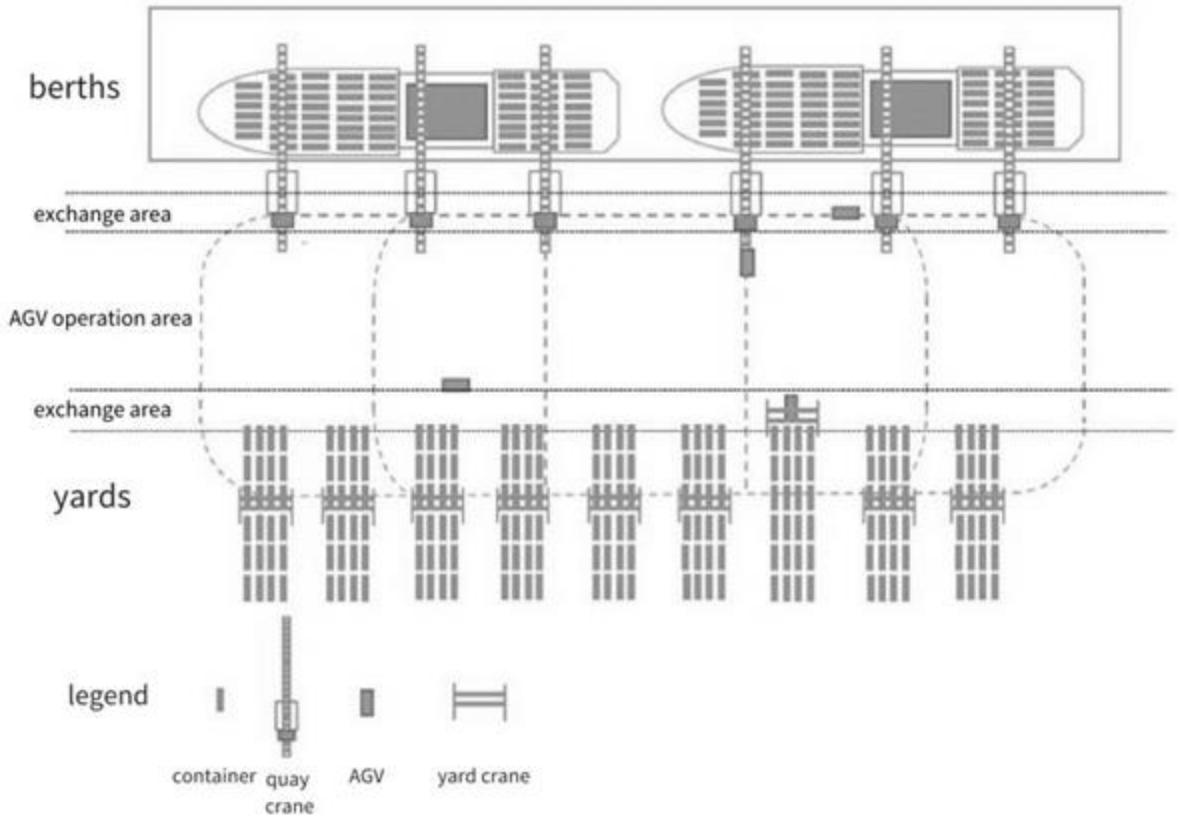


GAPS: ENERGY STATES, SCHEDULING SYNERGY

AGV Operation Flow

- Terminal: Quay → AGV → Yard
- Import/Export workflows

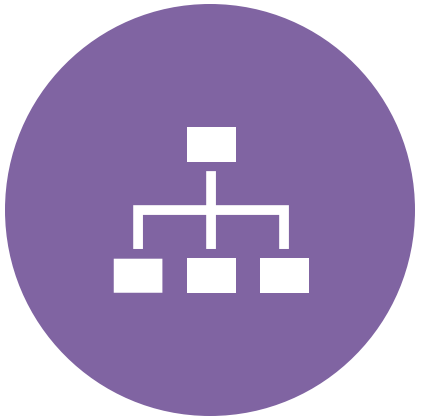




Problem Definition

3 STATES: LOADING, UNLOADING, WAITING

CRANE CONFLICT



COORDINATION REQUIRED

Optimization Model

3 STATES:
- LOADING, UNLOADING, WAITING
- CRANE CONFLICT
- COORDINATION REQUIRED

Objective Function:

$$\min \sum_{i \in \mathcal{A}} \sum_{j \in \mathcal{T}} \left(E_{ij}^{\text{load}} + E_{ij}^{\text{unload}} + E_{ij}^{\text{wait}} \right)$$

Subject to Constraints:

1. Assignment Constraint:

$$\sum_{i \in \mathcal{A}} x_{ij} = 1, \quad \forall j \in \mathcal{T}$$

2. Capacity Constraint:

Each AGV carries only one container at a time

3. Timing Constraint:

$$s_j \geq a_j, \quad \forall j \in \mathcal{T}$$

4. Precedence Constraint:

$s_{j+1} \geq s_j + d_j$, if task j precedes $j+1$ for AGV i

Decision Variables:

AGV Assignment:

$x_{ij} \in \{0,1\}$ AGV i is assigned to task j

Start Time:

s_j Start time of task j

Duration:

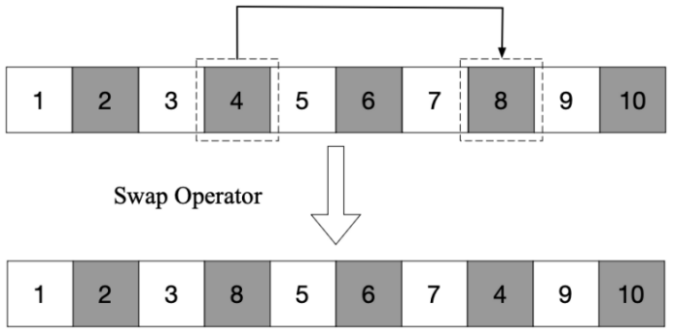
d_j Duration of task j

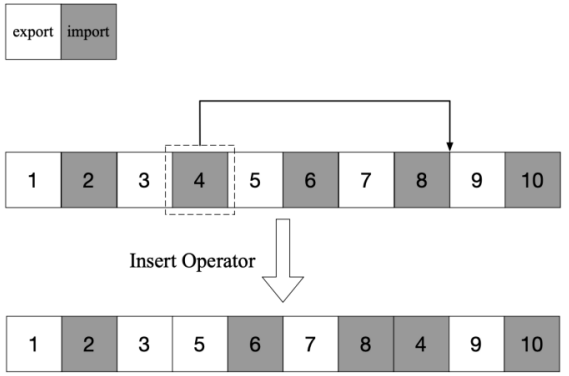
Solution: VNS Algorithm

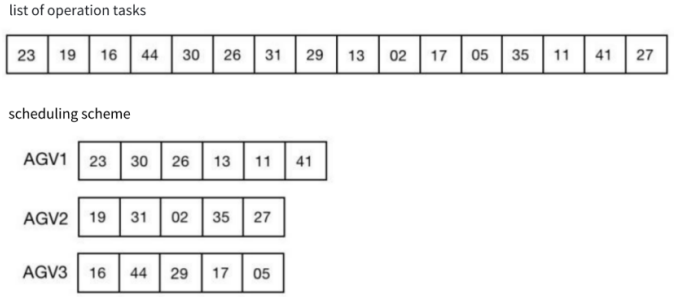
- Escapes local optima
- Better than GA
- Robust and scalable

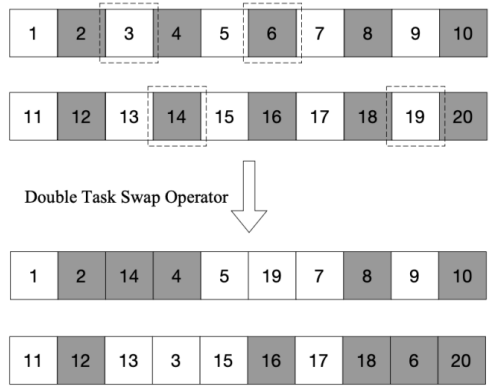
VNS Design

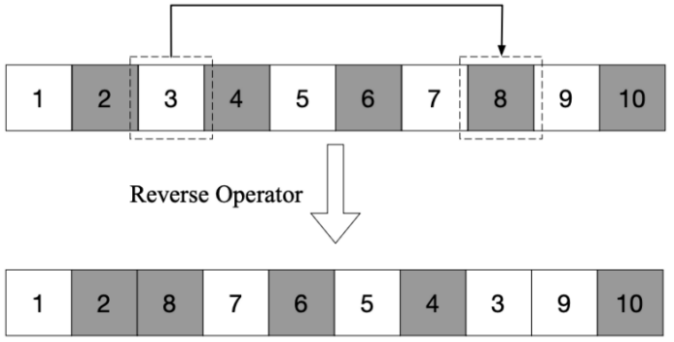
- Chromosomes = container tasks per AGV
- 5 neighborhood operators

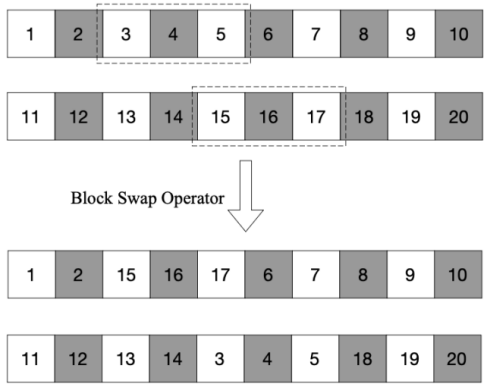




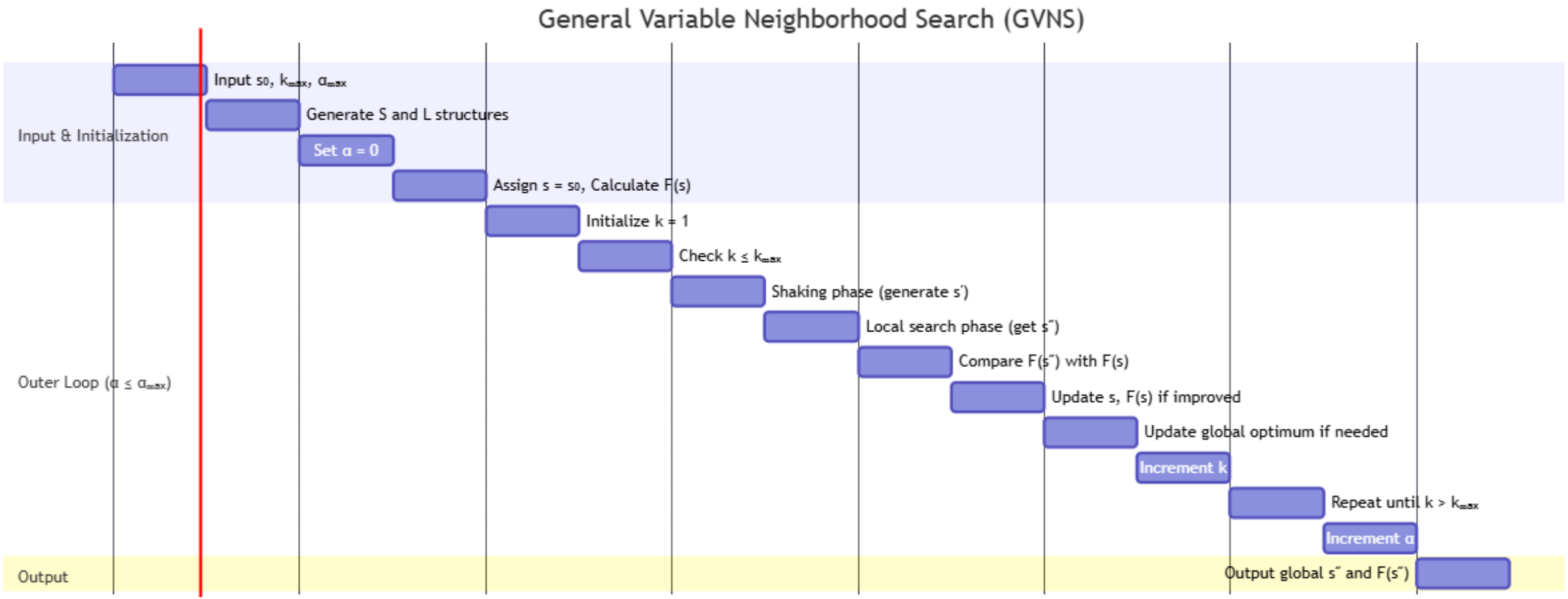






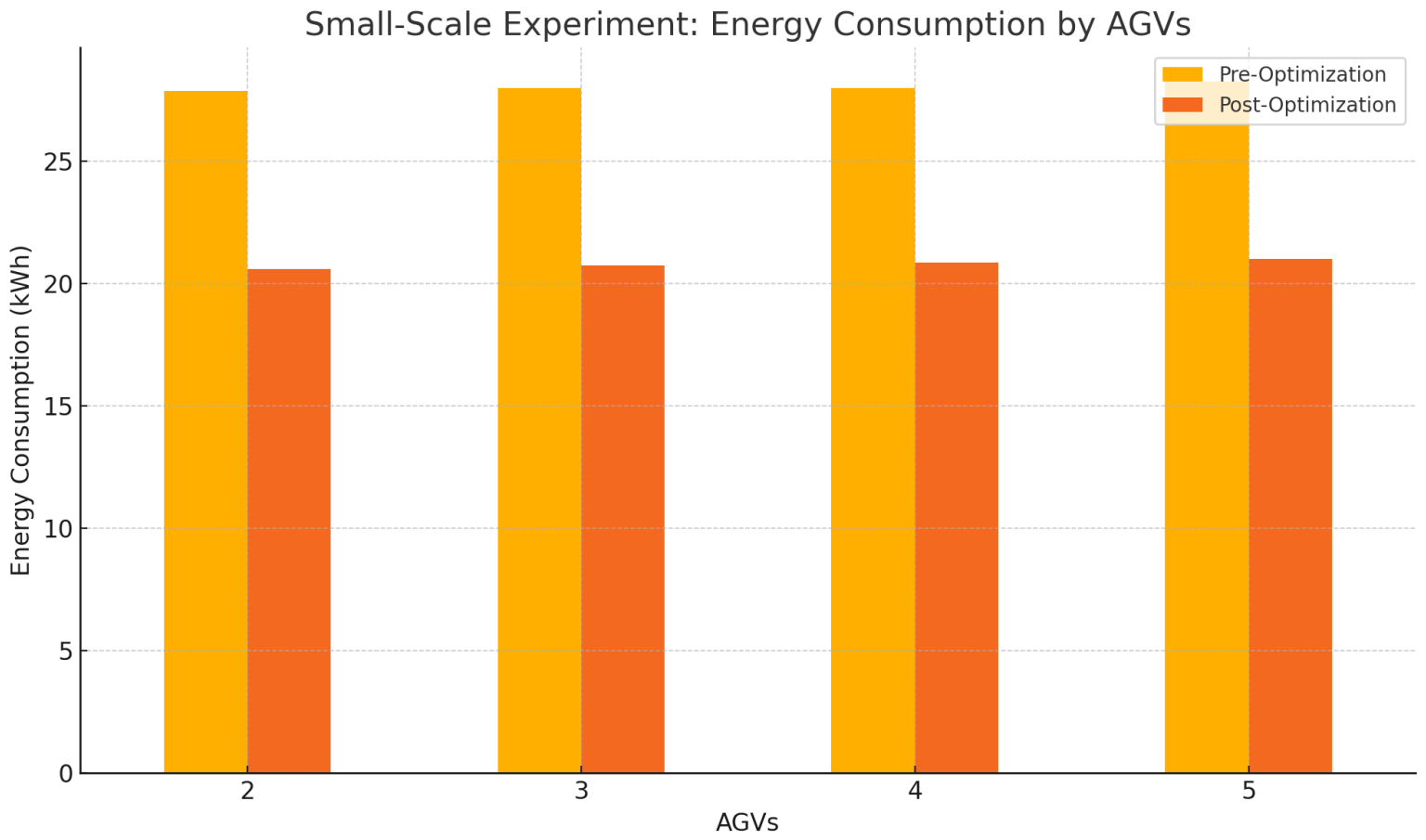


VNS Algorithm Process



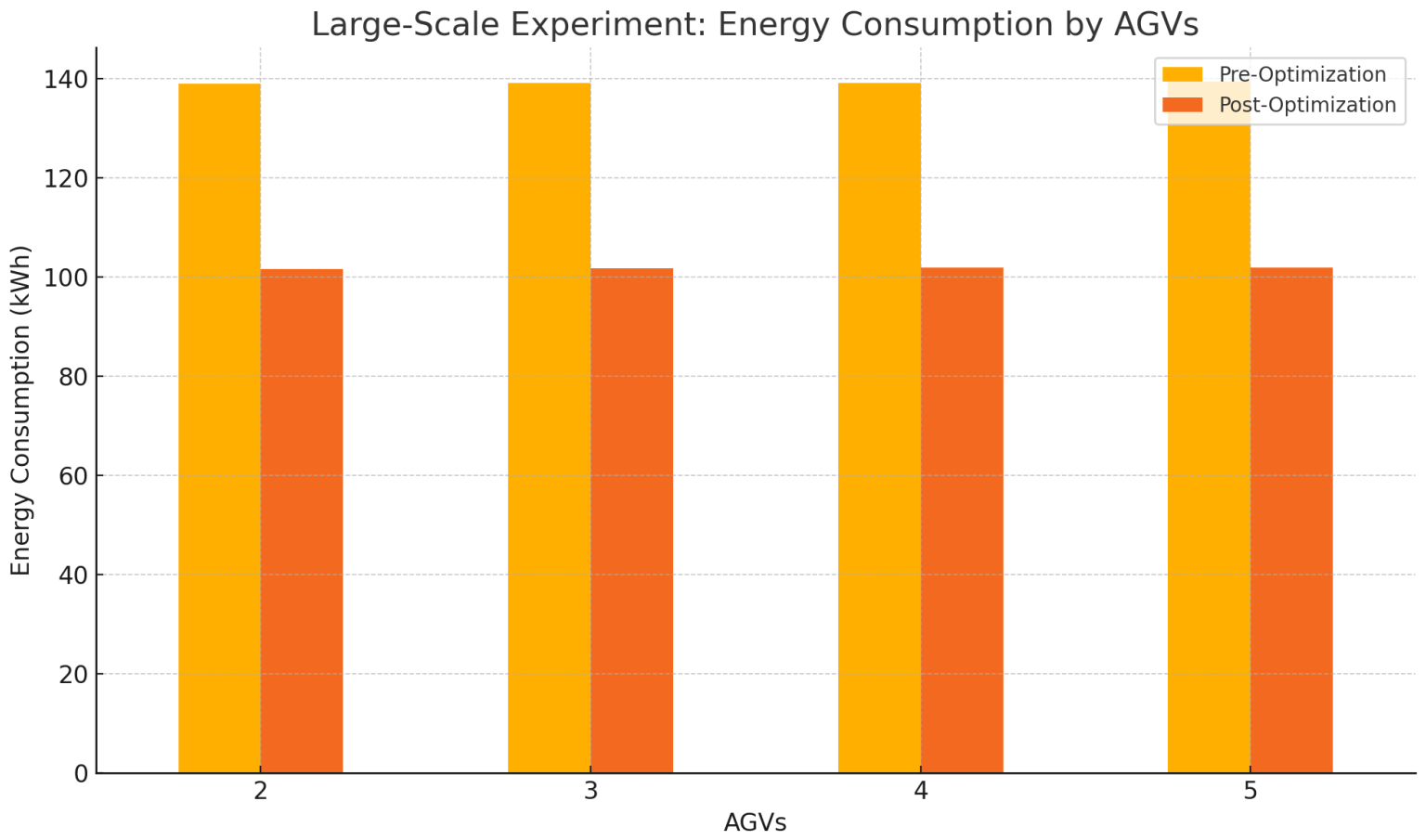
Small-Scale Experiment

2 AGVs,
Pre 27.85 kWh,
Post 20.57 kWh,
Reduction 26%



Large-Scale Experiment

2 AGVs,
Pre 139 kWh,
Post 101.7 kWh,
Reduction 27%



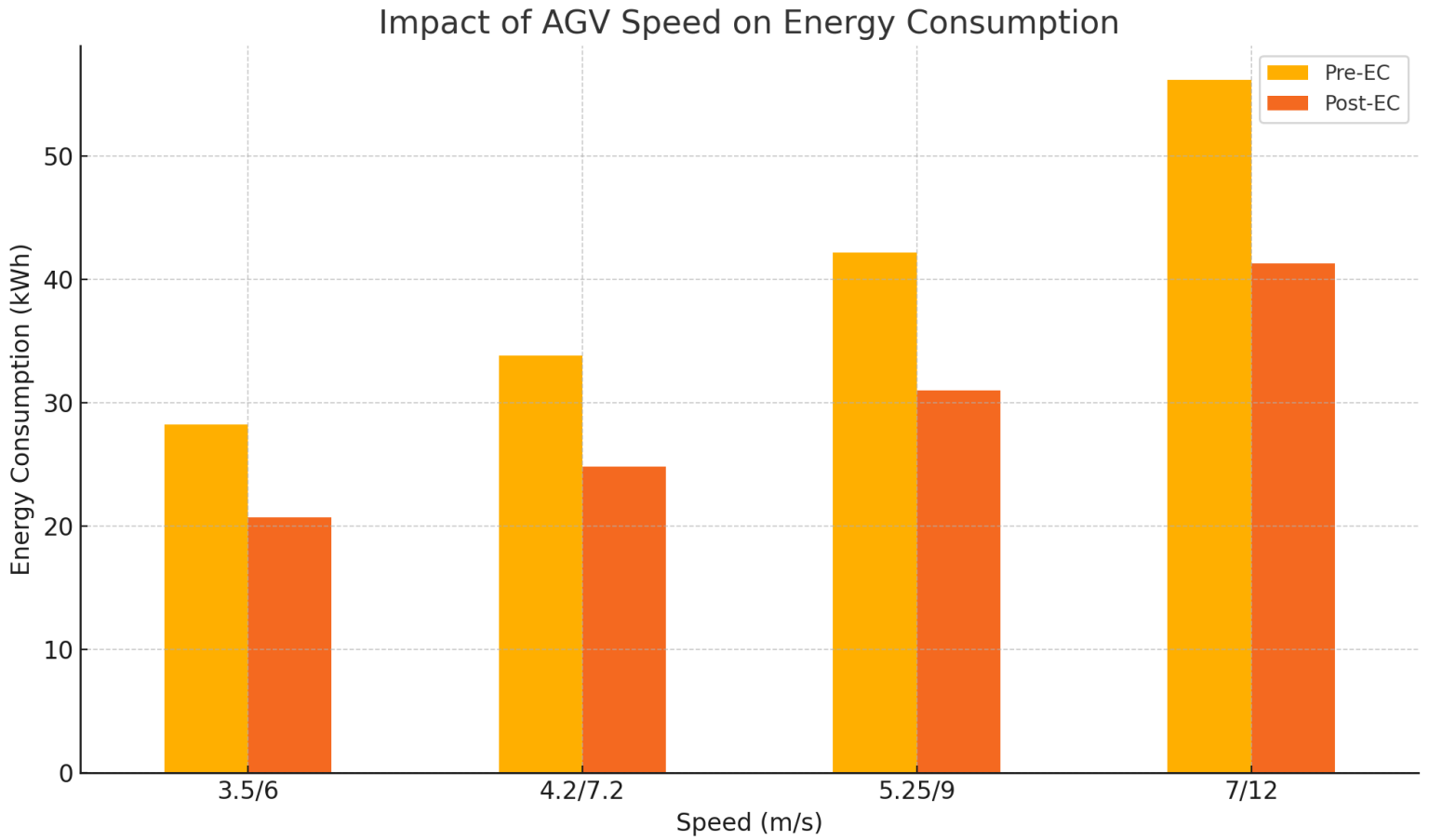
Comparison: VNS vs GA

- VNS: +13% BETTER EC, ~30% FASTER

- MORE STABLE CONVERGENCE

Impact of AGV Speed

Speed 3.5→7m/s,
EC ↑ Up to +99%,
VNS Efficient ~26% savings

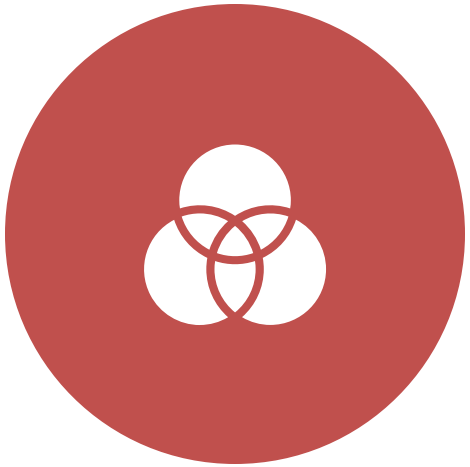


Practical Implications

- VNS IMPROVES ENERGY & TIME

- WORKS AT DIFFERENT TERMINAL SCALES

Conclusion



- NEW MODEL: CONSIDERS ENERGY STATES

- VNS: EFFICIENT, STABLE, SCALABLE

Future Work

- Real-time scheduling
- Congestion/recharge integration
- Hybrid models

Thank you!

Contact

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