Estimate and Evaluate the Number of Vehicles for Automated Material Handling System

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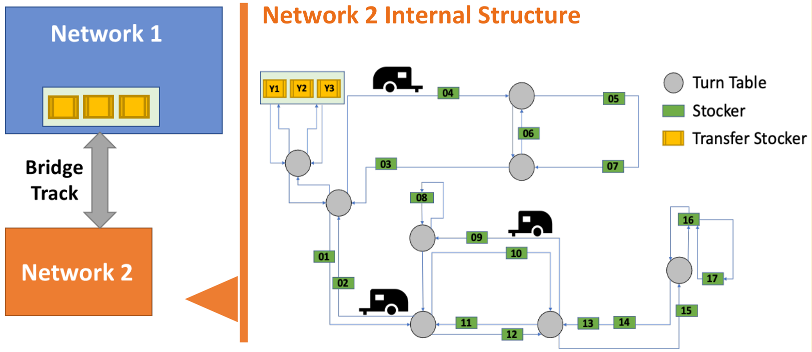
Introduction

We present a multi-phase approach to estimate and evaluate the requirement of the number of vehicles for an automated material handling system (AMHS) in a semiconductor manufacturing environment, where the monorail network is fixed and unidirectional, and with a certain number of workstations as demand nodes. The proposed approach deploys a mathematical model to obtain the most optimistic estimation. We subsequently experiment on balancing of the network flow and conducting cost analysis to recommend the practical estimation and the corresponding system performance. This approach provides a less complex method for manufacturers to evaluate the utilization of transportation resource of AMHS.



Study Subject: AMHS (Automated Material Handling System)

System Components:

- Network Structure: Two incompatible networks, connected by a bridge track and some transfer stockers.
- Arcs: fixed unidirectional monorails.
- Demand Nodes: 51 stockers in network 1; 20 stockers in network 2. Each stocker is associated with a workstation and represents a certain amount of demand within a certain time period.

Challenges:

- Supply of the vehicles is limited.
- Adding a new vehicle is costly.
- Vehicle idle time is not identified.

Objectives:

- Find the optimal number of vehicles that meets the system demand at the same time dose not excess the budget.
- Identify the flow unbalance.

Approach

PHASE I Mathematical Model → **PHASE II** Identify Flow Unbalance → **PHASE III** Flow Balancing and Performance → **PHASE IV** Cost Analysis and Optimal Number

PHASE I Mathematical Model

1 Calculate the net flow of stocker i, denoted by $NF(i)$: $NF(i) = \sum_k v_{ki} - \sum_j v_{ij}$

where v_{ij} is the number of loaded vehicle trips that must be sent from stock i to stock j.

2 Linear programing formulation:

Minimize	$\sum_i \sum_j t_{ij} x_{ij}$	(1)	Minimize the total travel time of empty vehicles.
Subject to	$\sum_j x_{ij} = a_i,\ \forall i$	(2)	# of empty vehicles in = # of loaded vehicles out.
	$-\sum_k x_{ki} = b_i,\ \forall i$	(3)	# of empty vehicles out = # of loaded vehicles in.

$$a_i = \begin{cases} NF(i), & if\ NF(i) \geq 0 \\ 0, & otherwise \end{cases} \qquad b_i = \begin{cases} NF(i), & if\ NF(i) < 0 \\ 0, & otherwise \end{cases}$$

x_{ij} : Decision variable, the number of empty vehicles sent from stocker i to stocker j.
t_{ij} : The shortest on-track time from stocker i to stocker j.

3 Calculate the lower bound and upper bound of the number of vehicles, N:

$$H_{LB} = \sum_i \sum_j t_{ij} u_{ij} + \sum_i \sum_j t_{ij} x_{ij} \qquad H_{UB} = \sum_i \sum_j t_{ij} w_{ij} + \sum_i \sum_j t_{ij} x_{ij}$$

t_{ij}: Total time needed from stocker i to stocker j, including load and unload time.
H_{LB}: Lower bound of total vehicle travel time, $u_{ij} = ROUND(v_{ij})$.
H_{UB}: Upper bound of total vehicle travel time, $w_{ij} = ROUNDUP(v_{ij})$.
h: Available hours per vehicle per shift.

$$N \in \left[\left\lceil \frac{H_{LB}}{h} \right\rceil, \left\lceil \frac{H_{UB}}{h} \right\rceil\right]$$

	N_LB	N_UB
Network 1	40	52
Network 2	17	18
Total	57	70

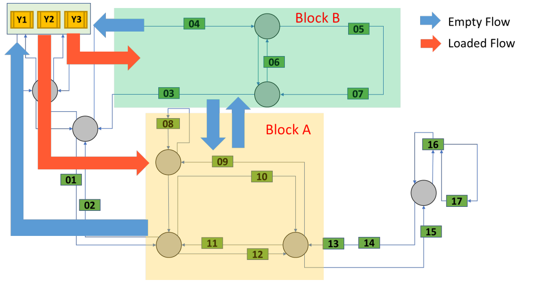
Overall Output of Phase I

- Number of empty vehicles assigned between each pair of stockers
- Total empty travel time
- Daily availability per vehicle
- Daily total loaded travel time
- Lower bound and upper bound of the number of vehicles needed
- Vehicle utilization

PHASE II Identify Flow Unbalance

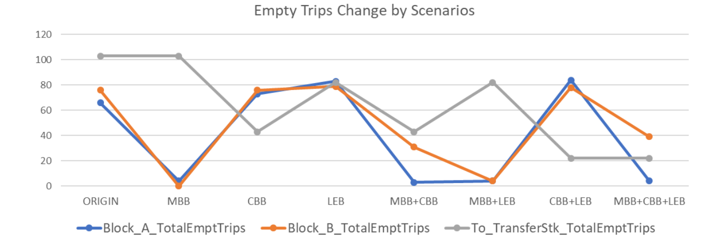
3 types of unbalance

- Flow unbalance within the network
- Flow unbalance crossing network 1 and network 2
- Flow unbalance entering and leaving the system



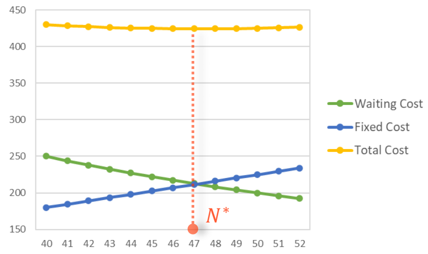
PHASE III Flow Balancing and Performance

Test flow balancing under 7 scenarios and choose the one that has ideal performance.



PHASE IV Cost Analysis and Optimal Number

- As add more vehicles in the system, the waiting cost of lots to be shipped decreases while the fixed cost grows.
- The optimal number of vehicles leads to the minimum total cost.



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