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DYNAMIC MULTIPLE-LOAD MOBILE TRANSPORT OPERATION IN SEMICONDUCTOR FAB

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ABSTRACT

In semiconductor fabs, the efficiency of automated material handling systems is critical for maintaining productivity. While single-load mobile transport systems are the conventional choice, multiple-load mobile transport systems have gained attention for their potential to enhance transportation efficiency. However, existing research primarily focuses on the analytical aspects of multiple-load mobile transport systems, leaving a gap in the exploration of advanced operational policies. This study addresses this gap by utilizing an adaptive large neighborhood search algorithm to optimize job assignment and scheduling in dynamic environments. Our approach is validated through simulation experiments using a hypothetical semiconductor fab layout, comparing the proposed policy against various policies. The results demonstrate that our policy significantly reduces average delivery time, showcasing its superiority in dynamic operation. The findings provided valuable insights into how the proposed algorithm can be applied to real-world scenarios, laying the groundwork for future application and testing in an actual semiconductor fab.

1 INTRODUCTION

Automated material handling systems (AMHSs) are used in semiconductor fabs, manufacturing lines, and automated warehouses to transport products or components. Typically, single-load mobile transport (SLMT) systems are employed, where one vehicle handles only one load at a time. Due to increasing demand and limited resources in the semiconductor industry, multiple-load mobile transports (MLMTs) are gaining prominence. MLMT systems enable a single vehicle to transport two or more loads simultaneously, potentially outperforming SLMTs by handling more jobs with the same number of vehicles.

Most existing studies focus on the analytical aspects of MLMT systems rather than practical operational policies (Nayyar and Khator 1993; Yan et al. 2020). This paper addresses the dynamic operation of MLMTs by making optimal decisions at each job request and operating vehicles according to the solution until the next decision point. We employ the adaptive large neighborhood search (ALNS) algorithm, a method proven to be effective for combinatorial optimization problems. To demonstrate the efficiency of the proposed algorithm, we conduct simulation-based experiments and analyze why it can effectively operate MLMTs through comparisons with various policies.

2 ALNS FOR MLMT OPERATION

In this study, we modify the ALNS algorithm proposed by Ropke and Pisinger (2006) to solve job assignment and scheduling problems for MLMTs. The key differences from previous research are that each vehicle has a different initial location, and vehicles may already have loads onboard at the time of decision-making. Since the loads onboard a vehicle cannot be handled through the typical job removal and insertion heuristics, an additional step is introduced before each iteration begins. This step involves randomly shuffling the order of unloading loads onboard within the schedule of each vehicle. The constraints to consider when determining a vehicle's schedule include the precedence relationship between pickup and delivery location and the vehicle's capacity. Considering these constraints, swapping the unloading locations of loads onboard in the schedule does not affect the feasibility of the solution.

3 EXPERIMENT

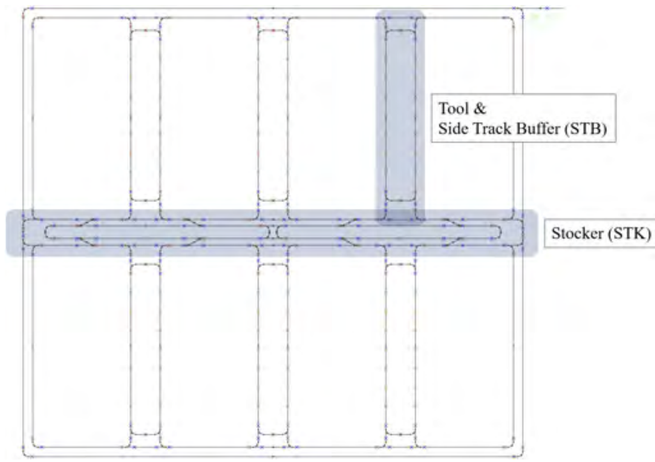

Figure 1: Layout for experiments.

To evaluate the effectiveness of the proposed policy for optimizing MLMT operations, we conducted a series of simulation experiments using the AutoMod^{TM} simulation tool within a hypothetical semiconductor fab layout as shown in Figure 1. This layout, while not directly representing a real-world system, serves as a valid proxy to test and compare different operational policies. The simulated fab includes 50 vehicles, each with a capacity of 2. We tested the proposed policy against 6 conventional rule-based heuristic policies, varying the load factor from 20 to 50 in increments of 10, where a load factor of 10 corresponds to approximately 16,000 jobs per day. In each simulation test, we set the warm-up period as 1 hour and evaluate the 1-day performance of policies.

Table 1: Average delivery time (sec) according to load factor and operational policy.

Load factor	Proposed	AA	NN	LA	LN	CA	CN
20	35.53	40.61	40.63	36.87	36.87	48.70	49.21
30	37.44	44.50	44.42	40.21	40.21	59.35	59.67
40	39.89	49.17	48.92	48.72	47.95	85.53	83.47
50	42.68	54.92	54.93	106.18	104.97	105.69	104.46

The average delivery time results of the proposed policy and policies for comparison are as Table 1. The results demonstrate that the proposed policy performs better than other policies for comparison in all load factor cases. Unlike other rule-based heuristics, the proposed policy considers all vehicles and jobs in each job assignment and scheduling decision, and it allows the re-assignment of jobs to different vehicles as time and environment change. This approach enables a more effective dynamic operation of the MLMT system.

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