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IMPROVING PLAN STABILITY IN SEMICONDUCTOR MASTER PLANNING THROUGH STOCHASTIC OPTIMIZATION AND SIMULATION

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ABSTRACT

This research investigates how stochastic optimization and simulation can reduce plan nervousness in semiconductor supply chain master planning. Due to both demand and supply uncertainty, plans must be periodically optimized. Traditional linear programming models often yield unstable plans due to their sensitivity to input changes. We propose a two-stage stochastic programming model to improve plan stability and an aggregated simulation framework to evaluate the performance of generated plans. The two-stage stochastic programming model incorporates demand uncertainty through scenario-based optimization. The simulation framework is used to assess key performance indicators such as on-time delivery and inventory position under rolling horizon conditions. Using real-world data from NXP Semiconductors, we demonstrate that two-stage stochastic programming improves plan stability compared to linear programming, while maintaining comparable on-time delivery and inventory performance. These findings suggest that stochastic optimization and simulation can enhance the robustness of semiconductor supply chain planning.

1 INTRODUCTION

Semiconductor supply chains are characterized by long lead times, high capital intensity, and volatile demand. Master planning in this context is critical to align wafer starts in the front-end with customer demand in the back-end. Traditionally, deterministic linear programming (LP) is used to generate these plans. However, LP's reliance on extreme point solutions makes it highly sensitive to small changes in input parameters, resulting in frequent and significant plan revisions, commonly referred to as plan nervousness.

Plan nervousness undermines operational stability, increases coordination costs, and reduces trust in planning systems. This research explores whether stochastic optimization and simulation can mitigate this issue. Specifically, we investigate two complementary approaches: (1) a two-stage stochastic programming (2SP) model for wafer planning, and (2) an aggregated simulation framework to evaluate the performance of plans generated under uncertainty (Rosman et al. 2024).

2 METHOD

2.1 Stochastic Optimization

The 2SP model is designed to generate more robust wafer plans by incorporating demand uncertainty directly into the optimization process. Demand distributions are fitted to historical data using a Markov Chain for demand arrivals and a Gamma distribution for demand sizes, maintaining demand patterns. These distributions are used to generate multiple demand scenarios, each with an associated probability.

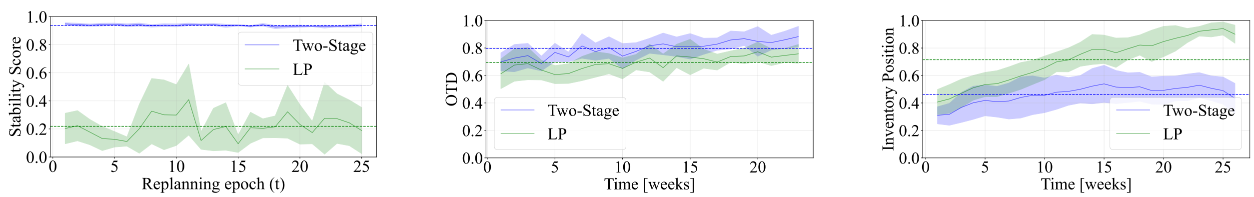
The model is implemented in a rolling horizon setting, where plans are re-optimized weekly as new demand information becomes available. A modified Kabak-Ornek stability metric is used to quantify plan changes over time, penalizing changes in earlier planning periods more heavily (Kabak and Ornek 2009). This allows us to evaluate the stability of plans generated by 2SP compared to LP.

2.1.1 Simulation Framework

To evaluate the performance of plans generated by LP and 2SP, we develop an aggregated discrete-event simulation model of the front-end supply chain, based on the method proposed by Rosman et al. (2024), which uses existing master data structures to minimize data maintenance and computational complexity. The simulation is implemented in a rolling horizon setting and is used to assess key performance indicators, plan stability, on-time delivery (OTD), and inventory position (IP). It enables a fair comparison between LP and 2SP by simulating how each planning method performs under stochastic demand over time.

3 APPLICATION

Results from simulation experiments using real-world data from NXP Semiconductors are shown in Figure 1, where 1 demand scenario is provided to LP and 5 to 2SP. It is evident that the 2SP model significantly improves plan stability compared to LP. While both models achieve similar OTD performance, 2SP results in lower IP. The stability metric confirms that 2SP produces fewer and smaller plan changes. The simulation framework reveals that 2SP better anticipates demand variability due to its scenario-based formulation. LP, by contrast, tends to overreact to demand changes, leading to higher inventory levels and more volatile plans. These findings highlight the value of incorporating demand uncertainty into the planning model and demonstrate the utility of simulation for evaluating planning performance under realistic conditions.



(a) Planning stability over time. (b) Average OTD over time. (c) Average IP over time.

Figure 1: Plan stability, OTD, and IP including 95% confidence intervals over time for LP and 2SP.

4 CONCLUSIONS

This research demonstrates that combining stochastic optimization with simulation can effectively reduce plan nervousness in semiconductor supply chains. The 2SP model offers a more stable alternative to LP, while the simulation framework provides a robust means of evaluating planning performance under uncertainty. While both approaches are practical for industrial deployment, 2SP involves higher computational costs.

Future work will focus on extending the models to incorporate supply-side uncertainty, such as yield and cycle time variability. Additionally, we aim to optimize the number and probability distribution of scenarios in the 2SP model and explore other stochastic optimization methods such as chance-constrained programming and robust optimization.

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