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FROM DISRUPTION TO PROFITABILITY: A SIMULATION STUDY ON HIGH-RUNNER FOCUSED FLEXIBILITY IN ENHANCING RESILIENCE IN DUAL-FAB SYSTEMS

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ABSTRACT

This study investigates which product segments benefit most from dual-fab flexibility in semiconductor manufacturing. Dual-fab flexibility refers to the strategic capability of producing the same product at multiple geographically dispersed fabrication facilities. The focus is on selective flexibility, defined as the targeted allocation of flexibility to specific product segments, such as high-runners (HR: high-volume, frequently ordered products) and low-runners (LR: low-volume, infrequently ordered products). A discrete-event simulation model evaluates four flexibility scenarios under demand uncertainty. Results indicate that prioritizing flexibility for HR products leads to approximately a 7% improvement in cumulative profit values after five years of simulation compared to baseline scenarios. Simulations under 80% forecast accuracy further validate the model's practical relevance. The findings highlight the value of strategic, demand-driven flexibility in enhancing semiconductor supply chain resilience and provide a foundation for future research on incorporating stochastic demand, dynamic lead times, and advanced forecasting techniques.

1 INTRODUCTION

The semiconductor industry's complexity and capacity constraints necessitate manufacturing flexibility—the ability to adapt production across facilities or products—which has been widely adopted to enhance responsiveness (Kumar and Sosic 2021). Additionally, Herding and Mönch (2024) show that borderless fab flexibility can improve profits by up to 23% through better load balancing and shorter queues. However, flexibility is often applied uniformly, without considering differences in product demand. This study investigates how selectively assigning flexibility to high-runner (HR) products versus low-runner (LR) products affects system performance. Definitions for HR and LR products align with industrial classifications where HRs typically require consistent replenishment, while LRs are produced infrequently with lower demand regularity.

2 METHODOLOGY

This study employs Discrete-Event Simulation (DES) in AnyLogic simulation software (2023) and the simulation model includes six products: two HRs and four LRs. HR demand is set 20 times higher than LR demand, and both have a 20-week processing time. Production occurs in two identical fabs (Fab 1 and Fab 2), but initially only Fab 1 is active. With flexibility, products can be produced in both fabs, using Little's Law under capacity limits; flexible products move to Fab 2 if Fab 1 is full, while non-flexible products remain in Fab 1, risking delays. Orders waiting over 120 weeks are removed; unmatched products in the DC after 157 weeks are scrapped and the simulation runs for 260 weeks. Four scenarios are tested: No Flexibility, Flexibility for LRs only, Full Flexibility, and Flexibility for HRs only.

3 RESULTS AND DISCUSSION

In the first scenario without flexibility, disruptions led to queue buildup and major profit lossesdue to high penalties and lost orders after week 251. Flexibility for low-runners had little impact, while full flexibility helped but added costs. The best outcome came from focusing on high-runner products, boosting cumulative profits by ~7% and confirming the value of targeted flexibility during disruptions.

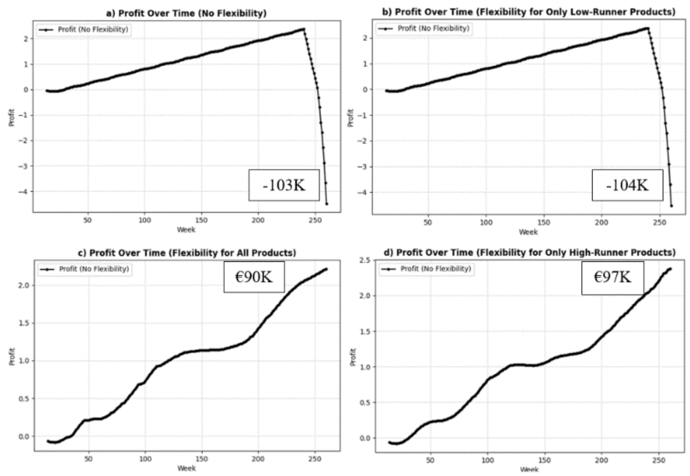

Figure 1: Simulation results with cumulative profit values for each scenario shown in boxes.

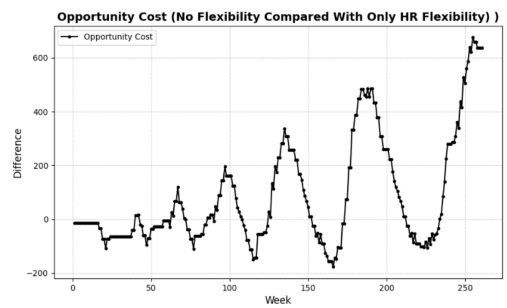

Figure 2: Simulation results of "no flexibility" and "HR flexibility" under 80% forecast accuracy.

Under 80% forecast accuracy, strategic flexibility leads to growing profit advantages over time, as increased capacity better meets cyclical demand, which highlights its increasing value under realistic conditions. As shown in Figure 2, the 20-week production lead time leads to significant differences between the flexibility and no-flexibility scenarios. Values below zero indicate that flexibility is more costly, while values above zero suggest that the lack of flexibility is more expensive. Flexibility proves beneficial in managing demand uncertainties, especially in cases with 80% forecast accuracy by preventing queue congestion, reducing high penalty costs, and ultimately supporting a more profitable management strategy.

4 CONCLUSION

The study shows that selective flexibility, especially for high-runner (HR) products, improves capacity utilization, reduces penalty costs, and increases profitability—outperforming other configurations by up to 10%. Under 80% forecast accuracy, the profit gap between flexible and inflexible systems widens over time, reinforcing the value of strategic flexibility under realistic demand conditions. These findings highlight the importance of targeted flexibility in building resilient and efficient supply chains.

REFERENCES

Fransoo, M. 2020. "Supply Chain Transparency and Resilience During the COVID-19 Pandemic." Journal of Global Operations 5(2):121–135.

Hartwick, A., A. Ismail, B. K. ValladãoNovais, M. Zeeshan, and H. Ehm. 2023. "System Dynamics Simulation of External Supply Chain Disruptions on a Simplified Semiconductor Supply Chain." Winter Simulation Conference Proceedings 2023.

Tukamuhabwa, B. 2015. "Planning for Supply Chain Resilience." Journal of Supply Chain Management 51(2):73–94.

Kumar, S., and G. Sosic. 2021. "Building Resilient Supply Chains in Uncertain Times: A Comparative Study of EU and ASEAN Approaches." *Asia Europe Journal* 20:457–475.

Herding, M., and L. Mönch. 2024. "Herding in the Consumption and Purchase of Digital Goods and Moderators of the Herding Bias." *Journal of the Academy of Marketing Science* (Forthcoming).