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# Analytic network process (ANP) approach for product mix planning in semiconductor fabricator

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**Abstract**

This paper proposes an application of the analytic network process (ANP) for the selection of product mix for efficient manufacturing in a semiconductor fabricator. In order to evaluate different product mixes, a hierarchical network model based on various factors and the interactions of factors is presented. By incorporating experts' opinion, a priority index can be calculated for each product mix studied, and a performance ranking of product mixes can be generated. The results provide guidance to a fab regarding strategies for accepting orders to maximize the manufacturing efficiency in considering the aspects of product, equipment efficiency and finance. The model can be easily understood and followed by administrators to determine the most efficient product mix for a fab.


*Keywords:* Analytic network process; Efficiency; Production performance; Product mix; Semiconductor fabricator

## 1. Introduction

Global competitiveness has become the biggest concern of semiconductor industry. How to increase the overall profit and the return on investment of a company is therefore very essential. The purpose of this paper is aimed at the strategic planning level and attempts to present an effective approach for product mix evaluation that allows for the consideration of various factors and important interactions among factors. The product mix selected can best represent a near-optimal utilization to the factory resources and a highest possible profit attained, and it can be a reference for production planning and order acceptance.

Wafer fabs involve the most complex manufacturing system in the manufacturing world. Its manufacturing process is of high complexity, with several hundreds of processing steps on a single wafer and a flow time of usually more than 1 month. Different product mix only complicates the already-complex system. Depending on the types of products, the process plan of a product can range from very identical to being extremely distinctive, and the requirement of setups may also be different. The greater the difference, the more diverse the loading demand and batch difficulty on the factory. The actual throughput and cycle time under a given product mix thus depend on how badly the fab is bottlenecked, whether the bottleneck is shifted, and how many

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machine setups are needed because of product type conversions.

Many metrics can be applied for evaluating factory productivity. Leachman and Hodges (1996) evaluated semiconductor wafer fabrication plants around the world to quantify manufacturing performance and to establish comparative benchmarks in manufacturing technology, factory operations, organization, and management. The major technical metrics they used to measure manufacturing performance are cycle time per wafer layer, line yield, die yield, stepper productivity, direct labor productivity, total labor productivity and on-time delivery. Although their study provided a comprehensive performance evaluation and identified those practices that underlie top performance, there was no attempt to correlate the interactions of the metrics. There are at least three aspects that are necessary for measuring the overall effectiveness of a factory: production, utilization of assets, and costs (SEMI, 2002). SEMI provided a guideline for definition and calculation of overall factory efficiency (OFE) and other associated factory-level productivity metrics. The document focused on evaluating production; however, utilization of assets and costs were outside of its scope.

Organizing available data and providing a singular metric to compare performances is not an easy task. Chung et al. (2002), however, adopted a good nonlinear programming method called Data Envelopment Analysis (DEA) to deal with multiple inputs and outputs. Without pre-assigning weights, DEA can be used to measure multiple inputs and outputs for product mixes in a semiconductor fabricator, and an efficiency score for producing each product mix relative to other mixes can be obtained. The major advantage of DEA, without pre-assigning weights to any performance measure, can also be its drawback. Managers often have their own opinion on what performance measures are more important than others. In that case, analytic hierarchy process (AHP) and/or analytic network process (ANP) can be a good alternative in evaluating production performance under different product mixes.

While AHP has been a popular research and application tool for multi-attribute decision-making, the ANP technique so far has had only a few applications in literature. A matrix manipulation approach, developed by Saaty and Takizawa (1986), is applied to solve a network, which is very similar to a hierarchy but has dependence among criteria and dependence among alternatives with respect to each criterion. Lee and Kim (2000) used the above-cited ANP approach within a zero-one goal-programming (ZOGP) model to suggest an information system project selection methodology, which can reflect interdependencies among evaluation criteria and candidate projects. Karsak et al. (2002) dealt with product planning in quality function deployment by also using a combined ANP and goal programming approach. Chung et al. (2004) adopted Saaty's matrix manipulation concept and suggested a simplified ANP approach to analyze multiple process inputs and outputs, and with experts' opinion on their priority of importance, to obtain optimal product mixes for semiconductor production. Sarkis (2002) presented a systemic ANP model to evaluate environmental practices and programs in analyzing various projects, technological or business decision alternatives. Momoh and Zhu (1998) proposed an application of AHP and ANP to enhance the selection of generating power units for appropriate price allocation in a competitive power industry. Meade and Sarkis (1999) suggested a decision methodology that applied ANP to evaluate alternatives (e.g. projects) and to help organizations become more agile, with a specific objective of improving the manufacturing business processes. Meade and Presley (2002) used ANP to support the selection of projects in a research and development (R&D) environment.

Suwignjo et al. (2000) and Bititci et al. (2001) constructed an innovative framework and supporting system to let organizations incorporate and map performance measures in a hierarchical way. The quantitative model for performance measurement system (QMPMS) relies on AHP to quantify both tangible and intangible factors for performance. Bititci et al. further applied the QMPMS for manufacturing strategy evaluation and management in a dynamic environment. Sarkis (2002) revisited the above works and applied ANP to the QMPMS process. Through