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The study of applying ANP model to assess dispatching rules for wafer fabrication

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Abstract

Wafer fabrication is a capital-intensive high-tech sector with highly complex manufacturing processes. Therefore, most of the fabs resort to production dispatching as a means to enhancing production efficiency. The commonly seen methods of production dispatching at the present time are devised to meet single performance indicators. Few methods take into account multiple, or even conflicting performance indicators. Therefore, different production control managers adopt different criteria. Also, as performance indicators change with the variances of production lines and actual demands, it is necessary to clarify the rules of varying dispatching methods and their impacts on all the production performance indicators so that it is possible to explore an architecture for multiple-rule or multiple-target production dispatching in order to meet dynamic performance targets. This paper uses analytical network process (ANP) method to construct a dispatching model based on the characteristics of all the production facilities on-site (such as the utilization of bottleneck machines), in order to explore the relationship among various performance indicators and correlation between performance indicators and the dispatching rules. The aim of this paper is to analyze the production dispatching issues of wafer fabs in an effective and systematic approach, so as to provide an on-site dispatching analysis model that takes into consideration production characteristics and indicator adjustments. This paper finds that the most optimal dispatching method for ANP dispatch model is EDD dispatching method, followed by LS dispatching method. FIFO dispatching method yields the worst performance. The ANP dispatching assess model proposed in this paper can surely serves as an analytical architecture for decision makes to evaluate production dispatching models of multiple production indicators in the future.

Keywords: Wafer fabrication; Dispatching rules; Analytical network process

1. Introduction

The wafer fabrication industry has a highly demanding, complex and yet highly repetitive manufacturing process. There are characteristics such as re-entrance and long production cycles, making it very difficult to arrange production and dispatching schedules. Missing the deadlines or suffering from an overly high inventory of work-in-process is not unusual. For the wafer fabrication industry, the advantages lie in flexible productions and reliable high yields. In order to maintain these two core competencies, it is necessary to constantly improve the manufacturing processes in order to upgrade production performances. There are many disruptions in the production systems, such as equipment breakdowns, urgent orders taking priority, shortage of materials, rework of wafers, and improper operations of operators. Any of these factors may directly or indirectly affect production performances. Therefore, in the face of market competition, all the wafer fabrication plants spare no efforts in the considerations and

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evaluations of various kinds of control policies, in order to gain insights into the variances caused by production factors (characteristics) to production systems. The purpose is to construct a reliable and stable production environment where the volatility of production performances is immune to impacts due to various scenarios. The impacts of production characteristics aside, the changes of all kinds of production performance indicators are often highly complex. Koriyama, Yazaki, Kato, and Kisakibaru (1995) believes that total throughputs, yields, production cycles, quantities of work-in-process are all issues that production control managers are concerned about in the process of wafer fabrications. However, there may exist correlation among these performance indicators.

All the dispatching rules applied in wafer fabrication have different assumptions regarding the environments and performance indicators chosen. There is no single dispatching rule that is superior in every aspect (Chang, Sueyoshi, & Sullivan, 1996). Therefore, managers usually have to measure all the pros and cons and strike a balance in their planning of the systems. Besides, different production control managers adopt different dispatching rules. Therefore, it is an issue that requires across-the-board considerations to incorporate different production performance indicators and perspectives from production control managers into the choice of dispatching rule. It is a critical issue for the wafer fabrication industry amid fierce market competition. In order to solve this problem, this research paper centers its focus on the interdependencies of performance indicators so as to screen out the appropriate combination of production performance indicators and to identify potential factors that may affect production performances. This paper applies multi-principle planning concept (Wein, 1988) and analytic network process (ANP) to examine all the characteristics of the production sites (such as bottleneck equipment utilization rates), in order to explore the relationship among performance indicators and the correlation between performance indicators and dispatching rules. This paper aims to provide a dynamic valuation model that considers a set of production characteristics and performance indicators. This paper presents the whole picture of all the productions issues and the synergies of various dispatching rules via expert questionnaires. With an evaluation model that factors into these performance indicators and production factors that impact performances, production controllers will be able to effectively adjust on-site dispatching methods.

2. Literature review

2.1. Principles

The timing and performance presentations of various dispatching rules differ due to their different concerns over performance indicators. In other words, under different production modes and different assumptions, different dispatching rules emerge. Therefore, the choice of dispatching rules is a result of analysis of pros and cons (Pierreval & Mebarki, 1997). Blackstone, Phillips, and Hogg (1982) divides traditional dispatching rules into four categories: (1) process time (e.g. shortest processing time, shortest remaining process time, shortest processing time plus setup time, etc.); (2) due date (e.g. earliest due date, critical ratio, minimum slack time, etc.); (3) part characteristics (e.g. random, FIFO, etc.); (4) hybrid of the previous two or three.

Conway (1965) finds that among the 16 dispatching rules, SRPT and FRO are able to minimize work-in-process, while LS yields the best performance as far as all the delivery effectiveness criteria is concerned. Hershaner and Ebert (1975) finds that among the 13 dispatching rules, SRPT yields the shortest Mean Flow Time and LS is the best option for securing delivery. French (1982) finds that for certainty scheduling of a single machine for multi-tasks, EDD is able to minimize Maximum Tardiness. Wein (1988) denotes that M1–M2 a better dispatching rule to improve performance of bottleneck equipment; whereas FIFO yields better performance for non-bottleneck equipment. Chang et al. (1996) states that as far as the reductions of Mean Tardiness and Tardy Jobs are concerned, EDD and LS generate better results. Wang (2003) realizes that with high equipment utilization rates, EDD is able to effectively reduce variance of tardiness. With a single bottleneck machine, FIFO is able to reduce variance of flow time. Lu, Ramaswamy, and Kumar (1994) studies the fluctuation smoothing policy for mean cycle time (FSMCT) and fluctuation smoothing policy for variance of cycle time (FSVCT). They point out that under these two methods, the shorter production cycles get, the more are they able to meet customer requirements. Their study finds that FSMCT is able to effectively reduce the average waiting time; while FSVCT is very effective in reducing cycle time standard deviations. Li, Tang, and Collins (1996) proposes the minimum inventory variability schedule (MIVS) to shorten production cycles with the reduction of total inventories. Also, it is possible to reduce the variances in the system by leveraging on the positive correlation of arrival rates and utilization rates of all the machines within the system. Experiments prove that it is very effective in the reduction of average cycle times and variances. Chen, Chen, Tai, and Tyan (2004) proposes the dynamic state-dependent dispatching (DSDD), with key considerations placed on the status of production systems. This method seeks out bottleneck machines within the system at different times, and uses three different dispatching rules based on the loading of the waiting lies in front of the bottleneck machines. Experiments prove that dynamic dispatching rules are significantly effective in improving production cycles of the production system, as well as in reducing the average work-in-process and standard deviations.

2.2. Production performance indicator

Production performance indicators express the operational status of the production system in a quantitative