

MODEL FOR THROUGHPUT PERFORMANCE MEASURES AND
MONITORING SYSTEM IN SEMICONDUCTOR INDUSTRY

NG POH LAY

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Universiti Teknologi Malaysia

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ABSTRACT

Manufacturing Science has been a proven discipline to further enhance traditional manufacturing practices where manufacturing performance can be quantify, measure and improve. Factory Physics is one of the approaches in manufacturing sciences. Through the application on Factory Physics principles, manufacturing performance gap can be systematically identify for throughput maximization. Managing manufacturing throughput is always a challenge as most of the manufacturing shop floor information available are either qualitative or quantitative but in piece mail which practically make us almost impossible to directly use the information for systematic scientific analysis. This is mainly driven by the dynamic of operation behaviors primary influence by manufacturing variability. Variability in manufacturing is unavoidable and sometime just simply unpredictable. It consists of the varies in people skills, process requirement, equipment performance and products. Buffering the shop floor with excessive work in progress (WIP) is the most common undocumented tribal knowledge to overcome throughput uncertainty. As a result some people even describe that running manufacturing is an art. Four fundamental models for throughput performance measures and monitoring system for a semiconductor assembly plant being developed and introduced. Overall manufacturing system performance expected to be further enhanced and a common ground for continual improvement to be established through this systematic modeling approach with the application of the basic concept of Factory Physics Principles. Based on initial mid range financial analysis over seven months, there is a potential opportunity for USD48000/week incremental Gross Margin through additional 20% of quality throughput couple with 30% Cycle time improvement.

ABSTRAK

Sains pembuatan terbukti berkesan untuk menilai dan meningkatkan proses pembuatan traditional. 'Factory Physics' merupakan salah sebuah unsur sains pembuatan. Dengan mengamalkan prinsip 'Factory Physics', jurang pelaksanaan pembuatan dapat dikesan dengan sistematik untuk meningkatkan pengeluaran. Pengurusan pengeluaran adalah cabaran yang amat besar bagi sesebuah kilang kerana informasi yang biasanya diperolehi adalah terhad dan tidak mencukupi untuk analisis yang sistematik. Ini disebabkan oleh perwatakan operator dan pembuatan yang berubah-ubah. Variasi pada proses pembuatan ini susah dielakan mahupun diramalkan. Variasi ini merangkumi kemahiran pekerja, keperluan proses, prestasi mesin dan produk. Penimbal kepada kerja dalam proses (WIP) yang tinggi adalah cara yang umum digunakan untuk mengurangkan variasi dalam pengeluaran. Disebabkan inilah, pengurusan pembuatan adalah suatu seni. Intregrasi untuk menilai dan memantau prestasi pengeluaran diperkenalkan dan dibina. Penilaian dan penganalisan keadaan sekeliling, penimbangan kapasiti sediaada dan pengendalian kerja dalam proses (WIP) dalam lingkungan masa akan dibincangkan. Keseluruhan prestasi sistem pembuatan dijangkakan akan meningkat melalui kaedah sistematik yang dicadangkan dengan menamalkam prinsip 'Factory Physics'. Berdasarkan penilaian kewangan dalam tujuh bulan terkini, terdapat peluang peningkatan sebanyak USD48000/minggu pendapatan kasar daripada peningkatan kualiti pengeluaran 20% dan pembetulan masa pemprosesan sebanyak 30%.

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CHAPTER 1

INTRODUCTION

1.1. Background of the Project

In today's ever competitive marketplace, where the level of semiconductor manufacturing capability among competitors are rapidly raising. It is expected to deliver a higher quality output, low cost product at right time and quantity to achieve competitive advantage.

In line with the above expectation, apply sciences into manufacturing and integrating right level of performance measures into execution strategy is essential. Traditional manufacturing system approaches which solving single phase problems without integrating and clear understanding on basic manufacturing behaviors with interdependencies no longer adequate today. This is mainly due to the increased of manufacturing variability and the complexities of product technology requirements which are always in a flux. Variability namely from difference in people skills, multiple product flows in same value stream, high volatile on demand ordering rate, complexity in frequent equipment conversion to maximize install capacity, dependency on equipment processing time against product types, product quality compliances and more. Anyway, variability can never be eliminated from system but

it can always minimize to certain controllable level for a more predictable performance and delivery.

Factory Physics principles will be applied in this study to ensure manufacturing variability are well understood before setting up a more practical and sustainable throughput performance measures, analysis and monitoring system. Area of improvement can then be identify, measure, improve and sustain systematically at all stages of assembly process for next level of operational excellence.

1.2. Objective and Scope of Project

The objectives of this project are to develop and define a systematic and scientific way in managing and sustaining performance measures and monitoring system which encompass Capacity Planning, Work In Progress (WIP) and Cycle Time management in a semiconductor assembly operation which ultimately further enhance assembly line throughput performance.

Four fundamental performance measures models will be develop at different levels of aggregation planning stage to integrate information and data. These models will be use as basis to perform productivity analysis and proactive performance monitoring. They are:

- i. Machine Throughput Model
- ii. Factory Capacity Model
- iii. Loading-Output-WIP Model
- iv. Cycle Time–Lot Size Model

Throughout this exercise, overall throughput performance expected to increase not less than 20% couple with 30% cycle time improvement within 7 months. This will then yield total incremental Gross Margin of USD 48000/week based on current financial assumptions.

The scope of this project is to further enhance throughput improvement on assemble the unit of integrated circuit chip in a semiconductor industry from silicon wafer to a complete unit.

Plant throughput is a bottom-line delivery as results from integrated productivity performance measures for a product specific capacity and flow cross process operations. Figure 1.2 illustrated the ideal production system where the capacity measures comprehend the build-in concept of Theory of Constraint (E M. Goldratt and J.Cox, 1984). Individual operation capacity measures are express as in UPH_1 , UPH_2 and UPH_3 as stated in Figure 1.1 An overall system flow measure is referring to actual output or throughput. It is the minimum measures of UPH_x

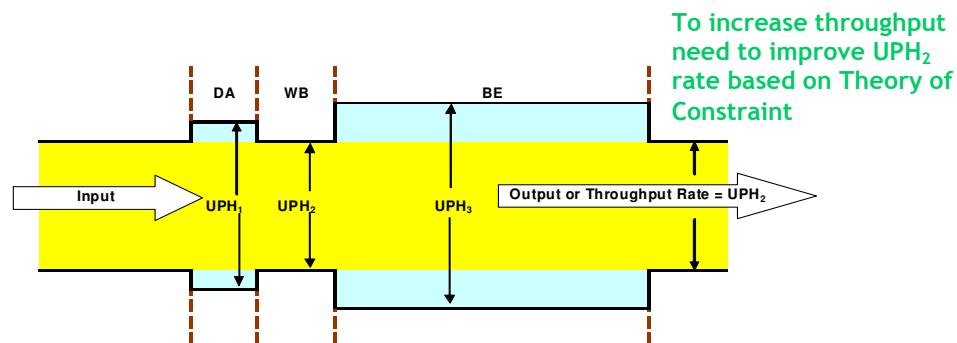


Figure 1.1: Ideal Production System

There are three key fundamental parameters for throughput enhancement. They are:

- i. Capacity Planning
- ii. Work In Progress (WIP) Management
- iii. Cycle Time Management

1.2.1 Capacity Planning

Capacity planning scope encompasses the definition and itemization of standard measures of individual equipment performance parameters such as unit per hour and overall equipment efficiency at product and individual process level. Line capacity can then be define with the integration of both. Proper application on Line Balancing technique (MCS Media, 2003) and the application on Theory of Constraint (E M. Goldratt and J.Cox, 1984) are key. Regular capacity monitoring and reconciliation for the needs of additional capacity by investing in equipment capital for mid-long range planning are essential to ensure ramp capability are always in place to support business continuity.

1.2.2 Work In Progress (WIP) Management

Work In Progress (WIP) Management scope encompasses the definition of individual process work in progress triggering limits includes constant work in progress (CONWIP) and work in progress (WIP) staging arrangement which align to predefined push and pull strategies. The dependencies on die loading process will

also be discussed as it impact overall Assembly plant inventory level at given time. The daily WIP level monitoring process by operation and inventory turns developed to serve as an actual real time performance feedback mechanism to always keep WIP in manageable level whenever variability exists in any point of the flow.

1.2.3 Cycle Time Management

Cycle Time Management scope encompasses the applications of Factory Physics Principles namely Little's Law (Factory Physics, 2006). Lot level cycle time tracking automation, aging lot movement aligning to equipment conversion strategy, Lot on-hold disposition business process and individual lot level queue time analysis for continual improvement to be established.

The propose approaches of redefine, define, develop, monitor and sustaining the integrated performance measure are basis for reinforcing continual improvement as the process cycle continues. Shop floor raw performance data or information will be channel up systematically as it is basis for value added analysis, process improvement and streamlining. Silo or single phase performance measures without bottom-line value stream integration can be easily avoided.

Quality and Safety compliance measures assume as built in process which is given from the study. Also, this performance measurement system excluded external customer and supplier business process and delivery cycle time.

Conducting the study in Assembly operation consider good representative for the plant performance as Assembly Operation usually covers more than 80% of plant capital and resources investment for a standard semiconductor Assembly-Test plant

in Asia. Test operation which conducting the functional and structural test on assembled chip is out of scope from this study.

1.3. Problem Identifications

Initial findings were done through observation and interview. Summary of qualitative challenges listed in Table 1.1 below. Improvement focus on capacity, work in progress and cycle time are essential to ramp the factory to next level of excellent with the same available resources.

Table 1.1: Summary of Preliminary Findings

Process Failure Mode	Caused of Failure	Effects
Capacity Process		
Frequent change in incoming product mix (package; body size; device)	Maximize Loading	Fire fight to meet commit output timely as capacity limitation is not being consider upfront in input process
Differrent cut off for different product	To meet various or non standard customer requiriment	Capacity gaps between plan vs actual due to different available day in specific calendar work week
Unpredictable expedite lot list	Would like to support urgent customer demand	Impact conversion schedule; jerk the flow in pipeline; impact throughout and cycle time
Work In Progress Management Process		
Late in die delivery	None linear die supply	Waste capacity
Not able to meet required FIFO target	No auto FIFO lot triggering system. Lack of visibility in lot movement via automated system due to multiple operation are represent in single operation code in system	High cycle time; too resouce intensive to track every lot movement manually and accurately
High work in progress in pipeline but all are not align to custmer product line item requiriment	Conversion based on WIP	High queue time as work in progress stage more than capacity; additional conversion caused low output; high consumption on techical resources
Cycle Time Process		
Ageing lot in onhold location	Not clear on material disposition plan; whether it is equipment related or incoming customer related issues	Impact cycle time
No clear visibility on the chain effects to line execution and performacne; Not able to drive to true capability	Lack of capacity, target and actual performance sharing periodically as well as resource capability alignment to the right level of people.	Not able to decide and plan right strategy on equipment conversion (Output or WIP) ahead of time. Reactive execution prolong cycle time.
No direct cycle time and on schedule delivery measure which align to actual mfg process flow	Lack of target and measurement sharing with right level of people	Not able to monitor and predict Cycle Time & On schedule Delivery effectively

Preliminary problem statement identified based on preliminary findings stated in Table 1.3. Preliminary problem containment includes:

- i. Capacity
 - a. Develop capacity model which optimized between input or loading and shiftily capacity to minimize potential variability downstream.
 - b. Update actual performance capability at all time to manage potential product schedule or delivery skew. Right level of equipment dedication strategy may apply to minimize the impact upstream.
 - c. Synchronized production cutoff timing cross process operations and customers.

- ii. Work In Progress Management
 - a. Optimize equipment conversion through input scheduling and batching strategy from upstream.
 - b. Automated lot aging reporting. This can be done by creating unique operation code for all process operations in current production system.
 - c. Leverage on expeditor to expedite lot movement based on FIFO to avoid lot aging.
 - d. Define maximum work in progress triggering limit for each operation correlate to throughput and cycle time target.

- iii. Cycle Time Management
 - a. Automated lot cycle time reporting. This can be done by creating unique operation code for all process operations in current production system.
 - b. Set business process to clear lot on hold triggering limit. Define specific timeline for disposition with clear ownership.

- c. Detail out lot movement cross process operations through automated production lot movement report. Valuable information such as lot processing time and queue time are good to identify problem for continual improvement and analysis.

There are many disciplines under manufacturing sciences which is applicable to further enhance throughput performance. Factory Physics (Factory Physics, 2006) is one of the approaches chosen to drive manufacturing throughput in this project.

The application of Factory Physics Principles (Factory Physics, 2006) describes the fundamental operation behavior of operations such as work in progress, capacity and cycle time relationships. This is important principle which should eventually help to better understand and quantify performance measures systematically.

Figure 1.2 summarized few key component and approaches for operation control under manufacturing sciences. Factory physics is one of it and we will discuss more on this section throughout this project.



Figure 1.2: Manufacturing Sciences and Components

1.4. Significance

Throughput performance is most significant productivity measures compare to others in the entire assembly plant as it has the highest potential in financial improvement measures as it link directly to bottom line manufacturing unit cost estimation which consist in all 5 cost models in predefined cost structure as stated below

- i. Depreciation
- ii. Fix Overhead
- iii. Variable Overhead
- iv. Direct Labor (DL) / Indirect Labor (IDL)
- v. Direct Materials

1.5. Thesis Structure

This thesis consists of total six chapters. Chapter 1 begins with the introduction and background of the project. Objectives and scope are based on limited time and resources throughout this project study. Significances of this project are based on the current environmental scan and preliminary findings based on existing system limitations. This project was then structured to align to the predefined objectives.

Chapter 2 focuses on literature review summarized from total four related literatures and manufacturing sciences related theoretical principles. This was the basis for this project write up.

Chapter 3 elaborates on model development principles, concept and methodology. Critical approaches in applying sciences into manufacturing for a more systematic performance measures and monitoring system will be discussed in details. These models cover critical value chain from financial modeling to shop floor execution modeling.

Chapter 4 discuss on project implementation and results. There are 2 phases of implementation. Phase 1 discusses on introducing of the models developed for performance measures tracking and Phase 2 discusses on the monitoring systems for sustaining purposes.

Chapter 5 reviews on the overall achievement based on results from pilot run. Some critical appraisal and future researches are also suggested.

Chapter 6 summarized and concluded all the learning and results throughout the projects.

1.6. Resume

In summary, the project focus on developing models for systematic performance measures and monitoring system for throughput enhancement were discusses through the application of manufacturing sciences. Approaches and methodology are aligned based on predefined objectives and scopes with relevant literature review as well as preliminary findings. Thesis structure at the end of this chapter also provided a good overview for this entire project write-up. Next chapter will be discuss on details literatures for more in dept understanding.

CHAPTER 6

CONCLUSION

In summary this project meets the initial objective and expected results by applying Factory Physics Principles, Theory of Constraint and Pull and Push System. The approach of using Factory Physics as fundamental to define performance measures analysis and monitoring system proven effective but it might not the only way to applying sciences into manufacturing. Other approaches are encouraged to explore. The weight age on criticalness of one performance measures might change from time to time whenever there is a change in company business acumen and strategies. Therefore, it always recommended to revisit whenever needed. Change management need to apply to ensure smooth implementation for a sustainable, repeatable and reproduce-able continual improvements.

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