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An Implementation of Using Throughput Dollar-Day in IC Design Industry Outsourcing Management~ a Case Study

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Abstract

Due to the fabless characteristic of the IC design industry, all the production and manufacturing procedures of the entire product have been outsourced to outsourcing foundries/fabs, therefore subcontractor's performance will also affect the competitiveness of IC design companies. Managers need a simple and reliable method of supplier performance ratings for production decisions reference. The purpose of this study is to apply the Theory of Constraints (TOC) which proposed sub-system performance indicators throughput dollar-day (TDD) for using in subcontractor performance indicators rating and study the feasibility of using TDD as a performance indicators for IC design industry outsource management. The TDD is easier than the current measure of outsourcing can be clearly demonstrated both advantage and disadvantage of outsourcing factory. Finally, this study provides a convenience and reliability of performance measurement indicators, so that manager can do good work for subcontractor's performance measurement and support manager to do outsourcing decisions, and strengthen company competitive advantage.

Keywords: Theory of Constraints, Throughput Dollar-Day, Performance Indicators

1. Introduction

The IC design industry is a highly competitive industry, and companies of the industry continue to face business challenges. According to the study, the 2010 global IC industry market size was 220 billion USD including the output value of IC design industry of 52.2 billion USD, which accounts for about 23% of the total value of the global IC industry. Taiwan's semiconductor industry plays an absolutely vital role on the world stage, and its IC design industry has been vigorously developing in recent years with the output value second only to that of the United States in the world. In 2012, the total turnover of Taiwan's IC design industry is expected to grow by 13.1%. At present, there are about more than 300 IC design companies in Taiwan (IEK, 2012). With the fierce competition in the market, IC design companies must spare no effort to meet the needs of customers to maintain competitiveness. IC design factories all pay special attention to product delivery, quality, cost, and other competitive factors to create the maximum corporate operating performance. Due to the fabless characteristic of the IC design industry, all the production and manufacturing procedures of the entire product have been outsourced to outsourcing foundries/fabs.

Therefore, in addition to the product competitiveness of the IC design company, the business performance of the outsourcing foundries manufacturing IC is one of the factors affecting the competitiveness of IC design companies. If the outsourcing foundry orders are not appropriately allocated, it may result in high production costs and low product yield or low (throughput) TH. Therefore, in supply chain management, how to identify the outsourcing foundries with excellent performance by objective appraisal is considerably important. outsourcing foundries with excellent performance can meet the requirements of the company in terms of conditions include price, quality, delivery time and delivery quantity and thus allow the company to accurately and rapidly meet the customer needs to keep competitive advantages. Therefore, for the effective management of the entire supply chain, supplier management should be done properly and the supplier performance appraisal has become one of the important jobs of supply chain management. Managers need an easy-to-use and reliable supplier performance appraisal method to help make the right outsourcing decisions.

The case company evaluates the wafer foundry performance by the performance monthly appraisal conducted by the quality assurance department. The production management, quality assurance and produce engineering departments form the appraisal team to conduct the foundry performance seasonal appraisal. Although the two appraisals have developed various appraisal criteria and demerit of scores for objective-failing items, the current performance appraisal method has not taken into consideration delivery delay time and sum and the appraisal scores may suffer bias due to personal subjective factors. In addition, the current appraisal method cannot clearly find out the level of impact of foundry delivery delay on the case company. Moreover, the current appraisal process takes time and energy as the current seasonal appraisal requires the summary of relevant data after the completion of the individual

appraisal by members of the appraisal team. Specifically, This study aims to apply the subsystem performance evaluation indicator of Throughput Dollar-Day (TDD) of the Theory of Constraints (TOC) in the outsourcing foundry performance appraisal to explore the feasibility of applying TDD as the outsourcing management performance indicator of IC design companies, and whether TDD can more explicitly display the advantages and disadvantages of the outsourcing foundry than other current outsourcing measurement indicators. Finally, it is expected to provide managers with a set of performance measurement indicators of convenience and reliability to allow them to measure the performance and help them in making outsourcing decisions for the strengthening the competitive advantages of the enterprises. This study explores the measurement of the foundry performance by N Company without touching on the backend packaging and testing process.

2. Literature Review

This section aims to review the literature, methods and theories relating to the research topic. First, we explores the literature relating to outsourcing, then the literature relating to supplier performance appraisal indicators, and finally the TOC performance assessment indicators.

2.1 Definition of Outsourcing

Competitive advantage refers to the effective use of resources to get higher performance than competitors. The resources of the enterprises are the basis of competitive advantage. in order to achieve certain goals, enterprises want to access to resources from the outside once they find their own scale is not sufficient or for strategic considerations, expecting to get a competitive advantage in the market. Tsai and Wang (2005) pointed out that the strategic outsourcing is to outsource some repetitive non-core or core business processes to suppliers to reduce the costs while improving service quality. Strategic outsourcing is considered an effective means of improving the core competency of enterprises by effectively reducing the cost of the product, and the introduction and use of external resources.

The common definition of outsourcing is as follows: Loh and Venkatraman (1992) defined outsourcing as the external suppliers providing the required tangible and intangible products or services in whole or in part. Kotabe (1990) proposed that outsourcing is the activities of providing finished and semi-finished products to transnational corporations by independent suppliers around the world. Lei and Hitt (1995) defined outsourcing as depending on external resources to manufacture the product, or to engage in value enhancing activities. Sharpe (1997) indicated that outsourcing is to delegate parts or complete functions outside the core competency selected by the organization to external suppliers while the enterprise needs only to perform the most expertise and most valuable activities of the value chain. Arnold (2000) summarized the ideas of scholars, and arguing outsourcing is the acronym of Outside Resource Using. Therefore, outsourcing should be explained in three parts:

1. Outside means the value creating activities are not inside the company, but from the outside.

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2. The external perspective is considered at the strategic level and is mainly resource-based. The company is regarded as the combination of resources and knowledge. If the company cannot get resources from the environment, it is bound to not be able to survive in the competition.

3. External resources are used to enhance the company's competitiveness, and supply chain management is to use the developed resources to achieve the purposes of the company.

Labbs (1993) defined outsourcing as: the required but not core capabilities for business operation are provided by external service providers according to contract to maintain business operations. Minoli (1995) defined outsourcing as: if the external organization can do the job of the organization more efficiently and cheaper, the job should be done by the external organization. If the organization can do the job better, the job should be self-done.

2.2 Supplier performance appraisal indicators

The selection of supplier is based on the supplier performance, and a number of literature has explored the supplier performance appraisal. According to Liu and Hai (2005), in the supplier appraisal procedure, supplier appraisal indicators should be selected to facilitate the measurement of the supplier performance. In the first study to explicitly define supplier appraisal indicators, Dickson (1996) proposed 23 appraisal supplier indicators. In the study on the purchase decision of single supplier or multiple suppliers, Swift (1995) selected 21 appraisal indicators. Cheng and Chen (2008) applied BSC (Balanced Score Card) theoretical basis in the construction of the multiple measurement constructs. By literature review and analysis, a number of important outsourcing appraisal indicators are identified. Coupled with the hierarchical analysis method and the questionnaire survey results, the weights of the successful outsourcing appraisal indicators of the electronic industry are measured and understood to construct an outsourcing appraisal indicator model suitable for the electronics manufacturing industry.

Torng *et al*., (2009) explored the supplier performance assessment indicators to select 32 relevant performance indicators by literature review and selection by experts in the fields of IC design industry and total quality management. Afterwards, the 32 indicators are extracted into 19 performance indicators for statistical analysis by the factorial analysis method. First, by using the hierarchical analysis method, the weights of various performance indicators can be obtained. By using the grey relational analysis (GRA), the problem of the different measurement units and vectors in between performance appraisal indicators can be solved to provide a supplier performance evaluation model. With four major attributes including quality, delivery, price and service, Pi (2005) set a range of allowable differences. Then, according to the performance of the suppliers in the allowable difference range, appropriate relative scores are granted. The relative importance of the four major attributes is computed by using the hierarchical analysis method with appropriate weights before using TOPSIS method for ranking to establish the supplier assessment selection model. However, as far as the practical applications are concerned, the company should consider carefully about the most important

factor in the evaluation of the suppliers to compare the relative importance to get the actually objective quantitative analysis indicators.

Chen (2004) explored the application of Total Involved Quality Cost Analysis in supplier performance evaluation. The study proposes the planning and establishment of a supplier performance evaluation system of total quality cost and preset cost matrix structure as well as target management. The study explores the interactive relationships in between members of the supply chain "supplier -manufacturer-customer", and integrates the results of various material use stages: incoming, internal customers, external customers, and the seriousness levels of quality events: returns, picking, reprocessing, end-of-life, downing, and customer complaints.

2.3 Theory of Constraints (TOC) performance appraisal indicators

Theory of Constraints (Huang, 2007; Huang *et al*., 2008; Huang *et al*., 2011) was first proposed by Israeli physicist Dr. Goldratt in late 1970s. He advocated that any organization in the development process has the factors that have hindered its development, and thus, the enterprise should be regarded as a system while management behavior should be considered in accordance with the overall system benefits. In the system, partial benefit optimization does not equal the overall optimization. The overall performance is not derived from the strongest sector, but is limited by the weakest part. TOC proposes the output management concept and three performance measurement indicators: (1) Throughput (TH); (2) Inventory (I); (3) Operating Expense (OE) defined as follows:

TH: the rate of making money through sales by the organization. TH = sales volume - cost of materials.
I: the monetary investment of the organization to purchase raw materials.
OE: the investment of the organization to convert I into TH.

Dr. Goldratt proposed the concept of TH, stressing that the effective value can only be produced after selling the product and that is thus the TH, otherwise, it is only I. Specifically, the enterprise should spare no efforts to increase TH, reduce I and OE to enhance the operating performance. Dr. Goldratt argued that the major purposes of performance evaluation are: (1) to drive all supply chain members to do the things best for the protection of TH; (2) To allow the supply chain members to know the place of improvement. Dr. Goldratt argued that good performance evaluation should ensure that the right things can be done well, such as the reliable delivery, and it should avoid doing well the wrong things such as I. Therefore, in the measurement of the subsystem performance, it should be focused on the evaluation of the places that have not been properly done. TOC proposes the new performance measurement indicator of output, TDD, which is defined as: the loss of output caused by delay and failure of delivery. TDD = the total sum of all orders (order output sum × days of delay), low TDD represents that the delivery is right and timely. TDD can be represented by the following equation:

TH: organizations make money through sales rate. TH = sales - cost of materials.
I: organizations must purchase in order to sell the money invested in raw materials.
OE: organization so I converted to TH must invest money.

$$TDD = \sum_{i=1}^{n} T_i \times Di = \sum_{i=1}^{n} P_i \times N_i \times Di$$

T_i = the loss of output of ith work order = $P_i \times N_i$
P_i = product price of ith work order; N_i = the quantity of delays of ith work order.
D_i = delay time of ith work order.

TDD indicator is mainly to evaluate the reliability, namely, it is to evaluate the results of poorly done things that should have been properly conducted. Therefore, the importance of failure to fulfill the commitment of the customer should be taken into consideration. Huang *et al*. (2011) pointed out in their study that conventional production planning often uses delivery time and cycle as two major measurement benchmarks. The maximum delay in delivery time and average production procedural time are most commonly used as the performance measurement indicators of order delivery and production cycle.

However, from the TH point of view, to factories, they are not the best performance measurement indicators. From the viewpoint of the delivery performance, the delay in delivery of the orders of different values should have different levels of impact on the company. For example, the impact of the delay in the delivery of the order valued at $100,000 should be different from that of the order valued at $100. In addition, in the case of the order of the same value, the delay in delivery by 1 day is different from the delay of 1 month in delivery in terms of level of impact. Therefore, using the maximum delay in delivery time to measure the factory delivery time performance will overlook the significance of the order value and delay time. TOC argues that the value of the order and delay length should be taken into consideration at the same time in the case of any order delay. Therefore, TOC proposes the TDD as the delivery time performance measurement indicator. TDD represents the multiplication of the total sales volume of all the delayed orders by the relative delivery time. Such an indicator can reflect the overall delivery time performance. Greater TDD indicator represents poorer performance, and TDD is expected to be 0.

3. Case study

3.1 Case company's current performance appraisal indicators

The case company is a specialized wafer design company (Fabless) with image display as the core technology to develop the diversified production lines for the applications in panel display and multimedia systems. Its outsourcing foundries are mainly distributed in Taiwan, China, and Singapore etc. All the production procedures of the case company include the first stage wafer manufacturing and the late stage packaging test. All of the procedures are outsourced. The regular outsourcing management is in the charge of three departments including production

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management, quality assurance and product engineering for regular management and outsourcing foundry performance appraisal.

The outsourcing foundry performance appraisal is elaborated as follows: as for the foundry performance appraisal model, there are the monthly appraisal and seasonal appraisal. First, in terms of the monthly appraisal, it is mainly conducted by the quality assurance department and the major performance appraisal indicators include wafer incoming inspection defect rate (30%). Quality abnormality cases reported by downstream outsourcing factories(30%); the abnormal case processing efficiency (20%); the level of coordination between quality reports and relevant quality engineering (20%). The monthly appraisal of the outsourcing foundry is conducted in the first week of the month. The current means of monthly appraisal is that the quality assurance/control personnel collects the production indicator information of the previous month and makes statistics of the abnormal cases of various outsourcing foundries as well as information regarding processing timeliness and engineering coordination. Afterwards, the monthly appraisal is conducted according to the collected information and the appraisal results are summarized for the reference of the managers. The appraisal criteria are as shown in the following Table 1:

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Table 1: Foundry monthly appraisal items and grading criteria

Item	Grading Criteria	
Wafer incoming inspection defect rate (30%)	<100dppm	30
	100~500dppm	27
	500~1,000dppm	24
	1,000~1,500dppm	21
	1,500~2,000dppm	18
	2,000dppm~3,000dppm	15
	>3,000dppm	0
Quality abnormal cases reported by downstream outsourcing factories (30%)	By the number of quality abnormal cases reported by downstream outsourcing factories or company N, each established abnormality case results in a demerit of 3% of the score.	
The abnormal case processing efficiency (20%)	When an abnormal case occurs, the outsourcing manufacturer is required within four working days to submit emergency measures and improvement measures to company N. If the outsourcing manufacturer fails to come up with effective emergency measures and improvement measures within four days due to production problems, each abnormal case can result in a demerit of 5% of the score. In the case of two days overdue in providing improvement and countermeasures, another 1% demerit of the score ensues.	
Coordination between quality reports and relevant quality engineering (20%)	Outsourcing manufacturers are required to provide the correct statements to company N in weekly/monthly reports. The outsourcing manufacturers fail to provide the correct statements as required: (1) each statement inconsistent with time requirement can result in a demerit of 2% of the score; (2) each statement inconsistent in accuracy can result in a demerit of 2% of the score.	
	With the process quality operations or quality analysis requirements, the outsourcing manufacturers should within required working days to come up with relevant measures, projects or countermeasures to company N. If the outsourcing manufacturers fail to come up with relevant information, projects or countermeasures, each case can result in a demerit of 2% of the score.	

Regarding the appraisal score, the case company also develops different grades. As for the outsourcing foundries of poor appraisal scores, for examples, the outsourcing foundries of level D or E in appraisal, they will be required to improve and hold weekly or biweekly review meetings to enhance the situations. If necessary, responsive measures should be taken to

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reduce the quantity or suspend the outsourcing relationship. The appraisal grades are as classified as shown in below Table 2.

Table 2: Outsourcing foundry performance appraisal grades

Grade	Score	Comment
A	Ranking≧91	Excellent
B	80≦Ranking≦90	Very good
C	70≦Ranking≦79	Good
D	60≦Ranking≦69	Fair
E	Ranking≦59	Poor

Second, the case company conducts the seasonal appraisal of the outsourcing foundries mainly by three departments including production management, quality assurance, and product engineering. The appraisal items include the research and development technological services, production quality and reliability, capacity and delivery, and customer service. Compared with the monthly appraisal, the appraisal items are more extensive. Therefore, the results of the seasonal appraisal are more concerned by the managers and the foundries. The seasonal appraisal's major performance appraisal indicators include technicality (20%); design and IP services (10%); quality and reliability (50%); capacity and delivery (15%); customer service (5%). The product engineering department is responsible for the appraisal of the technicality, and design and IP services. The quality assurance department is responsible for the appraisal of the quality and reliability. The department of the production management is responsible for the appraisal of the capacity and delivery, and the customer service. Finally, the quality assurance department is responsible for the summary of the all the appraisal information of various departments and the proposition of the seasonal appraisal information to managers and various foundries for reference. Quarterly Business Review (QBR) meeting is conducted every season with the major foundries to review the overall production performance and continuous improvement plans. The appraisal standards are as shown in Table 3:

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Table 3: Foundry's seasonal appraisal items and grading criteria

Category	Items	Max. Score
Technology (20%)	Technical support and provision	10
	Yield improvement	5
	Yield stability	5
Design and IP Service (10%)	The accuracy of the technical documentation	5
	The availability of the technical documentation	5
Quality and reliability (50%)	Failure Analysis (FA) support	5
	Return Material Authorization (RMA)	5
	Outgoing quality	10
	Quality problem solving timeliness	10
	Continuous improvement plan	10
	Important process parameter C_{pk} level	10
Capacity and Due-Date (15%)	Capacity support	5
	Cycle time	3
	Timely delivery rate	3
	Emergence delivery support	4
Customer service (5%)	Customer satisfaction	5

Regarding the case company's current outsourcing foundry performance appraisal indicators and appraisal means, this study has identified the following problems:

(1) Current monthly appraisal is conducted by the quality management department only and the appraisal items only focuses on quality-related items. Therefore, it uses the appraisal achievements of a single department for the appraisal of the performance of the outsourcing foundries. It can easily mislead the decision makers to make inappropriate decisions as the impact of the increase or decrease in TH on company benefits have not been considered.

(2) Although the case company's seasonal appraisal is jointly implemented by three departments including production management, quality assurance, and product engineering, there are no explicitly defined appraisal rules. If the outsourcing foundry performance is evaluated by different personnel, the appraisal scores can be easily affected by personal subjective factors.

(3) The current monthly/seasonal appraisal of the case company have not taken into consideration of the delay in delivery time factor and the value of the order, and thus it is unable to highlight the damage of the delay in delivery of some key orders to the company.

(4) As for the current monthly/seasonal appraisal means, its weight distribution is formulated jointly by the related departments and the weight distribution's appropriateness is debatable.

(5) Regarding the current monthly/seasonal appraisal. Relevant departments collect the production information of the outsourcing foundry in advance for analysis and summary. Therefore, it costs time and energy to do the appraisal. As appraisal work takes time and energy, at present, the case company only conducts the regular appraisal of major foundries and is not able to assess all the foundries.

3.2 Design of the TDD performance appraisal indicator

TDD indicator defined by Dr. Goldratt refers to the total sum of the TH loss caused by delay in order. Hence, it considers the value of the order and the days of delay (Huang, 2007).

$$\text{TDD} = \sum_{i=1}^{n} T_i \times D_i = \sum_{i=1}^{n} P_i \times N_i \times D_i$$

T_i = output loss of the ith lot of production.
D_i = days of delay of the ith lot of production.
P_i = the value of the ith lot of production, in this study, we use the wafer priority to represent the value of the order.
N_i = quantity of delayed products of ith lot of production.

With the performance appraisal of foundry as an example, the performance indicator is TDD, and the way of appraisal is to make statistics of total loss of delivery failure caused by the delay in delivery of the wafer to provide a reference to the managers in making decisions. Meanwhile, the appraisal results are provided to the foundry regularly to continuously enhance TH. The method is to make statistics of the sum of the delivery delays or reduction of output quantities of the wafer foundry in each month. The foundry performance score table designed in this study is as shown in Table 4.

Table 4: Foundry performance score table

Fab	Part No.	Lot no.	Priority	WS date	WO date	CT	CT Target	CT GAP	WS Q'ty(pcs)	WO Q'ty(pcs)	TDD

Related fields are described as follows:

Item	Description
Fab	Foundry
Part No.	Product Model
Lot No.	Product Lot No.
Priority	The wafer is generally divided into the Normal, Hot Run (HR), Super Hot Run (SHR) levels. As the foundry prices are involved with the confidentiality of the case companies, this study uses the different weights to represent Priority for the distinction of the value of batches of cargo of different levels: Normal is 1; Hot Run is 1.5; and Super-Hot Run is 2.
WS date	the starting time of wafer production
WO date	the ending time of wafer production
CT	Cycle time = [WO date – WS date]
CT Target	Fab produces the target value of the production time required by the product according to product process, photo layer, and grading or not.
CT GAP	[CT – CT Target]
WS Q'ty (pcs)	the starting quantity of wafer production
WO Q'ty (pcs)	the ending quantity of wafer production
TDD	The total sum of TH loss caused by order delay

As the outsourcing quantity varies from each wafer fab, for the sake of fairness, we add in the TDD calculation equation the release proportion factor of *Ra* to more objectively conduct the appraisal of the performance of the fabs. Therefore, the TDD equation is modified as shown below:

$$\text{TDD} = \sum_{i=1}^{n} T_i \times D_i = (\sum_{i=1}^{n} P_i \times N_i \times D_i)/Ra$$

Ra = pieces of wafers outsourced to the fab under assessment in the month ÷ the total pieces of wafer outsourced to all the fabs under assessment in the month.
T_i = the amount of the output loss of *i*th lot of production.
D_i = the days of delay in output of *i*th lot of production.
P_i = the value of *i*th lot of production, in this study, we use the wafer priority to represent the value of the lot of the production.
N_i = quantity of delayed products of *i*th lot of production.

3.3 Elaborations of the scenarios of TDD performance indicator

If two orders of wafer are manufactured in Fab A in January, the fab performance score table is as shown in Table 5:

Table 5: Foundry performance score table of Fab A

Fab	Part no.	Lot no.	Priority	WS date	WO date	CT	CT Target	CT gap	WS Q'ty(pcs)	WO Q'ty(pcs)	TDD
A	N88	A12345	1	1/27	3/27	58	56	2	25	25	50
A	N67	A12789	2	1/29	2/27	29	29	0	25	20	290

(1) If an order A12345 is manufactured in Fab A, and the lot priority is Normal, CT target is 56 days, the 1/27 wafer start is 25pcs, and the 3/27 wafer out is 25pcs, therefore, the CT can be computed as 58 days, exceeding the target by 2 days (58 - 56), as a result, the TDD value is: TDD = (58-56) ×25×1 =50.

(2) If an order A 12789 is manufactured in Fab A, and the lot priority is Super Hot Run (SHR), CT target is 29 days, the 1/29 wafer start is 25pcs, and the 2/27 wafer out is 20pcs, therefore, the CT can be computed as 29 days, and the delivery time is in line with the target value. However, the output quantity is reduced by 5pcs due to abnormality in process, and thus the TDD value should be calculated. As the shortage can only be made up for by reinvestment of raw materials. Hence, the TDD is computed by the following equation: CT Target ×pieces of shortage × P_i. TDD = 29×5×2 =290.

If the quantity of wafer outsourced to Fab A in January is 2,000pcs, and the total quantity of wafer outsourced to all fabs under appraisal is 10,000pcs, then *Ra* =2,000/10,000 =0.2; ΣTDD = (50+290)/0.2 = 1,700.

3.4 The application of TDD performance indicator in the outsourcing appraisal of the case company

With the wafer fab performance monthly appraisal during the continuous three months of 2010/01 ~03 and the seasonal appraisal of 2010/Q1 as examples, this study compares TDD and current performance appraisal indicators. First, as for the wafer fab performance monthly appraisal of the case company conducted by the quality assurance department, the appraisal scores of the fab during the period of 2010/01 ~03 are as shown in Table 6:

Table 6: The current performance indicators' monthly appraisal results

Items	Jan-10			Feb-10			Mar-10		
	Fab A	Fab B	Fab C	Fab A	Fab B	Fab C	Fab A	Fab B	Fab C
Wafer incoming inspection defect rate (30%)	21	24	24	24	24	24	24	24	27
Quality abnormality cases reported by downstream outsourcing factories (30%)	21	24	27	27	27	21	27	27	27
The abnormal case processing efficiency (20%)	14	15	15	15	15	14	14	15	14
Coordination between quality reports and relevant quality engineering (20%)	16	16	18	16	18	16	16	18	18
Total Score	72	79	84	82	84	75	81	84	86
Ranking	3	2	1	2	1	3	3	2	1
Grade	C	C	B	B	B	C	B	B	B

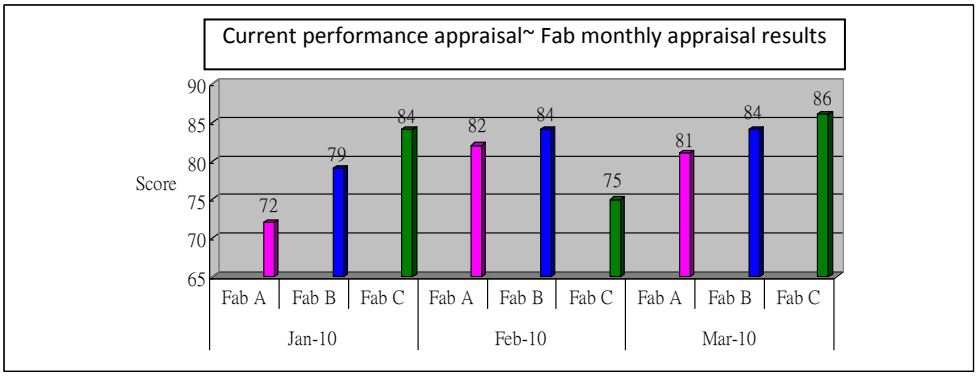

Figure 1: Current performance appraisal~ Fab monthly appraisal results

According to the 2010/01 ~03 monthly appraisal scores of the fabs as shown in Figure 1, unless the outsourcing fabs have some major abnormal cases, the gap between appraisal scores is not considerable and the performance of the fabs cannot be easily distinguished. Second, as for the seasonal appraisal of the performance of the fabs of the case company, it is mainly conducted by three departments including the production management, quality assurance, and product engineering according to their individually defined performance indicators. It can be learnt from the appraisal scores of 2010/Q1, the performance of Fab B is best followed by Fab A, and Fab C is the poorest. The seasonal appraisal results are as shown in Table 7:

Table 7: the current performance indicators' seasonal appraisal results

2010/Q1					
Category	**Items**	**Max. Score**	**Fab A**	**Fab B**	**Fab C**
Technicality (20%)	Technical support and provision	10	7	8	8
	Yield improvement	5	4.5	4.7	4.5
	Yield stability	5	3.5	2	3.5
Design and IP service (10%)	The accuracy of the technical documentation	5	4	4	4
	The availability of the technical documentation	5	4	4.5	4
Quality and reliability (50%)	Failure Analysis (FA) support	5	4	5	4
	Return Material Authorization (RMA)	5	5	3.5	4
	Outgoing quality	10	8	8	7
	Quality problem solving timeliness	10	6.5	7	6
	Continuous improvement plan	10	7.5	7.5	7
	Important process parameter C_{pk} level	10	8	8	8
Capacity and delivery (15%)	Capacity support	5	4.5	4.6	3
	Cycle time	3	2.8	2.7	2.6
	Timely delivery rate	3	2.8	2.75	2.8
	Emergence delivery support	4	3.8	3.85	3.7
Customer service (5%)	Customer satisfaction	5	4.2	4.6	4.5
		Score	80.1	80.7	76.6
		Ranking	2	1	3

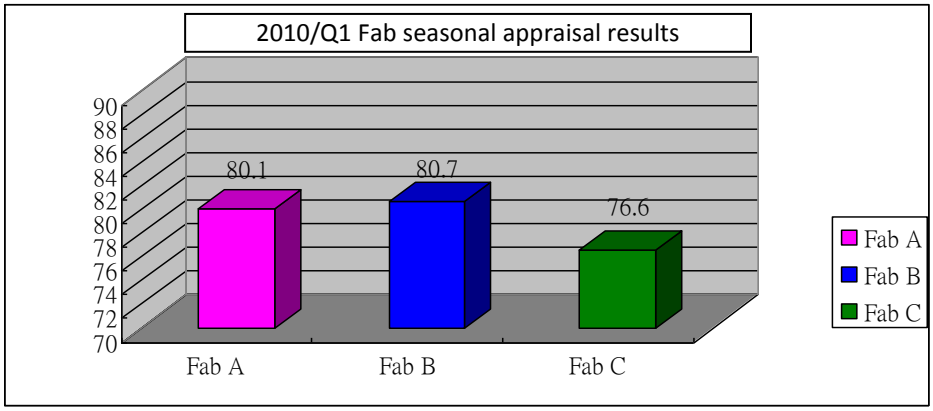

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Figure 2: Traditional performance appraisal~ 2010/Q1 Fab seasonal appraisal results

According to the appraisal scores of 2010/Q1 as shown in Figure 2, Fab A and Fab B are roughly the same in terms of score, and the appraisal has taken 3 people to work in 9 working days. However, the performance of the outsourcing fabs can hardly be determined according to the appraisal scores. Finally, this study uses the TDD indicator to conduct the appraisal of the performance of the case company by the following steps: (1) to collect the relevant production information of three major fabs during the period of 2010/01~2010/03; (2) to input the relevant production information into the fab performance score table; (3) to make statistics of the lots of failure in delivery of the required amounts caused by delay or reduction in output of the wafer fabs; (4) to calculate the TDD values of various lots and add up the total TDD value; (5) to conduct the fab performance appraisal according to the TDD indicator. This study collected the production information of three fabs of the case company in 2010/Q1, and obtained a total of about 5,800 samples of production lot information. We computed in accordance with the above steps the TDD performance appraisal results of the fabs in 2010/Q1 as shown in Table 8:

Table 8: 2010/Q1 TDD performance appraisal results

Quarterly	**2010/Q1**		
Fab	Fab A	Fab B	Fab C
Original TDD	20942.4	47866.6	50138
Throughput	22898	67683	48861
Weight *Ra*	0.16421	0.48538	0.3504
Total TDD	127,533	98,615.8	143,086
Ranking	2	1	3

The ranking of the fabs as assessed by TDD is: No. 1 is Fab B; No. 2 is Fab A; No. 3 is Fab C. As the seasonal appraisal results have shown that the appraisal ranking is the same with that obtained by using the traditional performance indicators. However, the performance gap between various fabs cannot be determined by the traditional performance indicators. For example, the scores of Fab A and Fab B are different only by 0.6 points (Fab A: 80.1; Fab B: 80.7) and the gap of the delivery time appraisal score is only about 0.05 points (Fab A: 2.8; Fab B: 2.75). However, by TDD indicator, the gap in the performance of the two fabs can clearly be identified (Fab A's TDD: 127,533; Fab B's TDD: 98,615.8). Hence, the change in TDD value is greater to allow the managers to identify the differences more easily and continuously require the fab of poorer appraisal performance to improve. Moreover, by comparing the TDD indicator and the current traditional monthly appraisal indicators, we first computed the single month TDD value of various fabs during 2010/01~2010/03 as shown in Table 9:

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Table 9: 2010/01~03 TDD performance's monthly appraisal results

Month	Jan-10			Feb-10			Mar-10		
Fab	Fab A	Fab B	Fab C	Fab A	Fab B	Fab C	Fab A	Fab B	Fab C
Original TDD	12963.7	19986.7	13424.1	7115.2	11750.1	9994.34	863.57	16129.8	26719.5
Throughput	10817	22639	14485	9431	24464	17540	2650	20580	16836
Weight (*Ra*)	0.22563	0.47223	0.30214	0.18336	0.47563	0.34101	0.06614	0.51365	0.42021
Total TDD	57,455.1	42,324.5	44,429.7	38,805	24,704.3	29,307.8	13,056.5	31,402.1	63,586.6
Ranking	3	1	2	3	1	2	1	2	3

The summary of the appraisal results by using the current monthly appraisal indicators are as shown in Table 10:

Table 10: 2010/01~03 current performance monthly appraisal results

Item	Jan-10			Feb-10			Mar-10		
	Fab A	Fab B	Fab C	Fab A	Fab B	Fab C	Fab A	Fab B	Fab C
The current performance indicators' monthly appraisal results	72	79	84	82	84	75	81	84	86
Ranking	3	2	1	2	1	3	3	2	1

It can be found by comparing the TDD indicator and the current traditional monthly appraisal indicators: since the current monthly appraisal is conducted only by the quality management department and the appraisal items focus only on the quality-related items without considering the impact of TH, the appraisal results will be greatly different from those obtained by using TDD performance indicator. As we can find that appraisal score gap is not great in the case of using current traditional monthly appraisal indicators in Mar-10, and the No. 1 is: Fab C. However, if compared to the appraisal results obtained by using the TDD indicator, the results are: No. 1 is: Fab A; and Fab C is No. 3. The appraisal results have suggested that partial optimization is not necessarily the optimization as a whole. According to the analysis results of the case company, we can draw the following conclusions:

(1) The current monthly appraisal indicators focus only on the appraisal of the quality-related indicators of the outsourcing fabs without considering the impact of the performance indicators other than quality on the company benefits. Hence, the appraisal results cannot actually reflect the true performance of the outsourcing fabs.

(2) The current monthly/seasonal appraisal method has not considered the time factor of delay in delivery and value of the order, and thus is unable to highlight the damage of delay in the delivery of some important lots to the company.

(3) The current monthly/seasonal appraisal takes time and energy to collect relevant production information for analysis and summary. Therefore, the current appraisal method is not convenient to assessors.

(4) In the case of the current monthly appraisal performance indicators, unless some major abnormalities occur in the outsourcing fabs, the gap in between scores is not sufficiently great to distinguish the true performance differences in between outsourcing fabs.

(5) The appraisal method using the TDD appraisal performance indicator has taken the time factor of delay in delivery and value of order into consideration, and thus the change in TDD value is big enough to allow the managers to identify the gap in performance of various fabs. The outsourcer company can regularly review the lots of relatively higher TDD value and require the wafer fab to continuously improve TH. The wafer fab can clearly understand the lots of products that the customer is concerned about and how the production line should be improved to benefit both parties.

(6) When the TDD appraisal performance indicator is used, it needs only to obtain the information relating to the foundry performance score table from the ERP system of the fab or the case company to rapidly sum up the performance of various outsourcing fabs. Hence, the proposed method is convenient and reliable.

4. Conclusions

This study applied the subsystem performance appraisal indicator TDD of the TOC theory in the outsourcing manufacturer performance appraisal. It was found that TDD is better than current outsourcing measurement indicators in terms of displaying the advantages and disadvantages of the outsourcing fabs. By using the TDD indicator, it can guide the case company and outsourcing fab to allow them to know how to improve and obtain the optimal TH. Moreover, the application of the TDD indicator in the case company is more convenient and objective to the assessor. To the managers, TDD indicator is a set of performance measurement indicators of convenience and reliability that allow the managers to do the performance measurement work and help them in outsourcing decision making to strengthen the competitive advantages of the enterprises.

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References

Anrold, U., (2000), "New dimensions of outsourcing: a combination of transaction cost economics and the core competencies concept," European Journal of Purchasing & Supply Management, Vol. 6, No. 1, pp.23-29.

Chen, C.C., (2004), "A Study of supplier performance rating using total-involved-quality-costs analysis," Journal of the Chinese Institute of Industrial Engineers, Vol. 21, No. 3, pp. 272-281.

Cheng, C.S. and Chen, K.I., (2008), "The Study of Outsourcing Evaluation Indictors for Electronic Manufacturing Industry," Journal of Quality, Vol. 15, No. 1, pp.23-37.

Dickson, G.W., (1996), "An analysis of vendor selection systems and decisions," Journal of Purchasing, Vol. 2**,** No**.** 1, pp. 5-17.

Huang, Y.H., (2007), "Research on using TDD as the subcontractor performance index-A case of memory manufacturing company," Master thesis, Department of Industrial Engineering and Management, National Chiao-Tung University, Hsin-Chu, Taiwan.

Huang, C.Y., C.P. Chen, R.K. Li and C.H. Tsai, (2008), "Applying Theory of Constraint on Logistic Management in Large Scale Construction Sites~ A Case Study of Steel Bar in TFT-LCD Factory Build-Up," The Asian Journal On Quality, Vol. 9, No. 1, pp.68-93.

Huang, C.L., H.G. Chang, R.K. Li and C.H. Tsai, (2011), "Using game and statistical analysis to confirm Goldratt's logical analysis of poor delivery in a multi-project environment," South African Journal of Industrial Engineering, Vol. 22, No. 2, pp.133-150.

IEK, (2012), "2012 Taiwan IC Industry Yearbook," Industrial Economics & Knowledge Center, Taiwan.

Kotabe, M., (1990), "The Relationship between Offshore Sourcing and Innovativeness of U.S. Multinational Firms: An Empirical Investigation," Journal of International Business Studies, Vol. 21, No. 4, pp. 623-638.

Labbs, J.J., (1993), "Successful outsourcing depends on critical factors," Personnel Journal, Vol. 72, pp.51-60

Lei, D., and M. Hitt, (1995), "Strategic Restructuring and Outsourcing: The Effect of Merger and Acquisitions and LBOs on Building Firm Skills and Capabilities," Journal of Management, Vol. 21, No. 5, pp. 835-859.

Liu, F.H., and Hai, H.L. (2005), "The voting analytic hierarchy process method for selecting supplier," International Journal of Production Economics, Vol. 97, No. 3, pp.308-317.

Loh, L., and Venkatraman, N., (1992), "Determinants of Information Technology Outsourcing: A Cross-sectional Analysis," Journal of Management Information Systems, Vol. 9, No. 1, pp. 7-24.

Minoli, D., (1995), "Analyzing outsourcing: reengineering information and communication systems," McGraw-Hill, Inc. New York, NY, USA.

Pi, W.N., (2005), "Supplier Evaluation Using AHP and TOPSIS," Journal of Science and Engineering Technology, Vol. 1, No. 1, pp.75-83.

Sharpe, M., (1997), "Outsourcing, organizational competitiveness and work," Journal of Labor Research, Vol. 18, No. 4, pp.535-549.

Swift, C.O. (1995), "Preferences for single sourcing and supplier selection criteria," Journal of

Business Research, Vol. 32, No. 2, pp.105-111.

Torng, C.C., C.C. Tseng, P.H. Lee, and S.C. Chang, (2009), "Constructing Supplier Performance Evaluation Model on IC Design Industry in Taiwan and Empirical Study," Journal of Technology Management, Vol. 14, No. 2, pp.1-26.

Tsai, F.L. and Wang, F.S., (2005), "Reflection and Prospection for the Changing of Work under Strategic Global Outsourcing," Asia-Pacific Economic and Management Review, Vol. 8, No. 2, pp.61-76.