Utilizing Grey Relational Analysis Method to Investigate the Evaluation of the Equipment Suppliers

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摘要

本研究以晶圓測試廠為研究對象，運用灰色關聯分析方法來建構設備機台供應商評選，其以提供測試業者一種客觀評選方式，讓購買設備決策者有一應變之道，以避免購滿不良之設備機台而造成生產效率惡化之影響。

Key Words: Grey Relational Analysis、Evaluation of the Equipment Supplier、IC Test.

Abstract

This investigation aims to analyze wafer test factories using the method of grey relational analysis to build an equipment supplier selection model, thus providing an objective evaluation method for the wafer test industry, giving the decision maker a way to deal with unexpected events, and avoiding the adverse effects imposed on the production in case of inferior machines purchased.

1. Semiconductor Foundries and IC Packaging and Test

According to the information on the website of Hsinchu Cooperate Manager Association, wafer foundry in the Semiconductor Industry refers to the Integrated Circuit (IC) wafer manufacturing company. manufacturing companies do not design their own IC.

Instead, they convert customers' product design to multiple layers of masks through the mask-manufacturing companies and the mask design is in turn converted to dies on silicon-based wafer using the manufacturing flow of the IC wafer. Nowadays, the service range of the foundries has been expanded to include almost all of the manufacturing jobs such as design support, mask making, wafer manufacturing, IC test and packaging, and problem analysis of products.

The semiconductor manufacturing can be divided into three phases:

1. Wafer-manufacturing: Focuses mainly on the manufacturing of the silicon-based wafer.
2. Front-end manufacturing (wafer processing): Focuses mainly on converting the silicon-based wafers into wafers of different functions according to the customers' requests.
3. Backend manufacturing (IC packaging and test): Focuses mainly on die sawing, IC packaging and final testing of the wafers manufactured in the front-end, and product shipment to the customers.

The supplier evaluation researchers such as Chen (2003), You (2004), Wang (2004), Liao (2004), Lai (2004) and Chuang (2005), evaluated the suppliers using the Delphi method, Fuzzy Theory and AHP. As to the wafer test industry, there are only a few suppliers capable to providing the relevant equipments for wafer testing. Hence, it is more appropriate to use the properties of Grey Relational Analysis to conduct the analysis based on the small samples and multi-factors.

This investigation emphasizes on the evaluation and selection of the equipment suppliers of the more expensive machines, such as the testing machines, auto probing machines and handlers, used in the wafer test factories.

2. The Relational Theory of Supplier Evaluation

According to the contents of the referenced literatures, the primary methods used in constructing a method to evaluate suppliers are Delphi method, the Fuzzy Theory and AHP.

As for the Delphi method, Wang (2004) combined the Delphi method and AHP to investigate the evaluation of the suppliers of the nutritious lunch at primary and secondary schools in Taipei. Based on the results of the surveys completed by four types of relevant people of interest in regards of the nutritious lunch in schools, Wang attempted to build a "Model for Evaluating the Suppliers of the Nutritious Lunch in Schools" suitable for use in all meal suppliers.

With respect to AHP, Liao (2004) used the contrasting property of AHP to organize the overall comments of the supplier evaluation, derive appropriate relative weights, and investigate the important items to be possessed by a suitable supplier. Effectively integrating suppliers into the value chains of products based on the supplier selection survey conducted by the experts and professionals of the aerospace industry is a key to raise the competitiveness of the companies.

Lai (2004) understands, based on the information collected and using AHP and the Fuzzy Theory, how big companies include the requirement of environment protection in the supply chain management and other green supply chains in the recent years, and further compares the methods of the green supplier selection adopted by enterprises.

As for other supplier evaluation methods, Chuang (2005) used survey investigation to study the impact of information process theory of the cross organization IT system on the supplier performances; You (2005) used regression analysis model to investigate the supplier-partner relationship and the impact of the electronic system on the supplier performances; Chen (2003) used the overall quality and cost to analyze the model for evaluating the supplier performances.

3. Grey System Theory Introduction

Professor Deng proposed the Grey System Theory in 1982. Deng (1982), under the circumstance of undefined model and incomplete information, performed relevant Relational Analysis and Model construction of the system.

3.1 Grey Relational Analysis

This is a measuring method for analyzing the correlation extent between the discrete sequences in the Grey System Theory. The traditional statistical regression is a mathematical method to process the correlation between variables. There are a few restrictions described below:

1. There exists a "mutual-affecting" correlation between the variables.
2. Large number of data is required.
3. Data distribution must be a typical type: For example, the normal distribution.
4. The variable factors must not be too many.

Hence, in some situations, it is not very easy to derive an answer. However, the Grey Relational Analysis can be conducted with few data and many factors, thus compensating the disadvantages of the statistical regression, according to Chang (2000).

As for the use of Grey Relational Analysis, Chen (2007) used Grey Relational Analysis to investigate the reuse of historical sites and buildings, providing an important reference for the managing bureaus in the operation and management of the reuse of historical sites and buildings. Cheng (2005), based on the partial Grey Correlation Analysis of the Grey Relational Analysis method and the GM(0, N) model of the Grey prediction method, reconstructed a more objective evaluation standard which acted as a basis for the property insurance field to draft the annual revenue goal and evaluate the performance of each operating department.

Yu (2005) used Grey Relational Analysis to calculate the appropriate trading in the future of stock exchanges, and then reused grey clustering to convert index clustering into trading information. Liao (2003) used the sound source tracking system built using four sets of piezoelectricity to retrieve signals and derive the sound source signals in 16 directions based on the correlation extent of the Grey Theory.

To the wafer test industry, there are only a few suppliers capable to providing the relevant equipments for wafer testing. Hence, it is more appropriate to use the properties of Grey Relational Analysis to conduct the analysis based on small samples and multi-factors.

3.1.1 Grey Relational Analysis Model of the Supplier Evaluation

"Grey Relational Analysis" makes use of discrete measuring method to measure the distance so as to investigate the correlation extent between two sequences according to Deng (1982). It possesses advantages such as simple calculation method, reasonable amount of samples, data not necessarily complied with normal distribution, conclusions not conflicting with the qualitative analysis, and etc, according to Weiche Chang (2000). Hence, it is more appropriate to use Grey Relational Analysis in processing the correlation extent difference between uncertain data and incomplete factors. The Grey Relational Analysis Model of supplier evaluation in this investigation mainly includes the following steps:

(1). Judge whether the original data of the equipment supplier evaluation satisfy the comparability property; use the data in Grey Relational Analysis if satisfied.

In the Grey Relational space $\{P(X); \Gamma\}$, there exists a sequence

$$\chi_i(\chi_i(1), \chi_i(2), \ldots, \chi_i(k)) \in X \qquad (1)$$

where $i=0, 1, 2, \ldots, m$ (number of equipment suppliers), $k=1, 2, 3, \ldots, n \in N$ (evaluating factor), that i

$\chi_0 =（\chi_0(1)，\chi_0(2)，\ldots，\chi_0(k)）$

$\chi_1 =（\chi_1(1)，\chi_1(2)，\ldots，\chi_1(k)）$

$\chi_2 =（\chi_2(1)，\chi_2(2)，\ldots，\chi_2(k)）$

$\vdots = \vdots$

$$\chi_m =（\chi_m(1)，\chi_m(2)，\ldots，\chi_m(k)） \qquad (2)$$

(2). Derivation of the Grey Correlation Coefficients

The Grey Correlation Coefficients of the partial Grey Correlation Extent $\gamma(x_i(k), x_j(k))$ is defined below:

Partial: When there is only one reference sequence $x_0(k)$ and other sequences are relative sequences, then the Grey Correlation Coefficient is defined as:

$$\gamma(x_i(k), x_j(k)) = \frac{\Delta \min. + \varsigma \Delta \max.}{\Delta_{oi}(k) + \varsigma \max.} \qquad (3)$$

$\Delta_{oi} = \|x_0(k) - x_i(k)\|$: x_0 & x_i : The absolute value of the k^{th} difference between x_0 and x_i.

$$\Delta \min. = \overset{\min.\min}{\forall j \in i \forall k} \|x_0(k) - x_j(k)\|$$

$$\Delta \max. = \overset{\max.\max}{\forall j \in i \forall k} \|x_0(k) - x_j(k)\|$$

(3). Derivation of the Grey Correlation Extent

As the importance of each factor is different to the system, the above equation is extended based on the actual situation of unequal factor weights after obtaining the Grey Correlation Coefficients and the correlation extent is redefined as:

$$\gamma(\chi_i, \chi_j) = \sum_{k=1}^{n} \beta_k \gamma(\chi_i(k), \chi_j(k)) \qquad (4)$$

where βk refers to the normalized weight of factor k, decided by the user but $\sum_{k=1}^{n} \beta_k$ =1 must be satisfied.

When the weights are equal, then

$$\gamma(x_i, x_j) = \frac{1}{n} \sum_{k=1}^{n} \gamma(x_i(k), x_j(k)) \qquad (5)$$

(4) Arrange the Grey Correlation Sequence in order

According to the definition of Grey Relational Theory, the traditional correlation extent represents the correlation between two sequences and is a qualitative analysis. Hence the most important information is the size sorting of the individual correlation values. The data values obtained from the Grey Correlation of the m^{th} relative sequence and the reference sequence x_0 are sorted in order, forming a relationship of difference sizes called Grey Correlation Sequence:

$$\gamma(x_0, x_i) \geq \gamma(x_0, x_j) \qquad (6)$$

where the respective correlation extent of x_i and x_0 is greater than the correlation extent of x_j and x_0, and are represented using $x_i \succ x_j$. It is also called the Grey Correlation Sequence of x_i and x_j.

4. The Evaluation Results of the Equipment Supplier of Wafer Test Factories

4.1 The analysis of the results of Grey Relational Analysis Model

(1) The evaluation analysis of the Wafer Test Equipment Suppliers. Table 1 contains the basic information of the wafer test equipment suppliers,

including the weights of measuring factors and its normalized values. The analysis steps and results are outlined below:

Table 1 The original data of the test equipment supplier of Company A (Data Source: Data provided by company A)

Measuring Factor	Weight Setting	T1 Supplier	T2 Supplier	T3 Supplier
Acquiring Cost	0.4	2	1	2
Moving Condition	0.1	2	1	3
Engineering Service	0.1	3	1	2
Space Requirement	0.1	3	1	2
Factory Service Cost	0.1	3	1	1
Production Flexibility	0.1	3	1	2
Production Standard	0.1	2	1	3

1. The part where the Grey Relational Analysis is used on Evaluation and Selection of Wafer Test Machine:

(1) The original data already satisfy the comparability, and the original data are used for Grey Relational Analysis.

Reference sequence：

(3.0000, 3.0000, 3.0000, 3.0000, 3.0000, 3.0000, 3.0000).

Relative sequence：

(2.0000, 2.0000, 3.0000, 3.0000, 3.0000, 3.0000, 2.0000), (1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000, 1.0000), (2.0000, 3.0000, 2.0000, 2.0000, 1.0000, 2.0000, 3.0000).

(2) Use the equation of △oi(k)=|x0(k)-xi(k)| to solve for the difference in the sequence size, the results are obtained below.

△o 1 = (1.0000, 1.0000, 0.0000, 0.0000, 0.0000, 0.0000, 1.0000).

△o 2 = (2.0000, 2.0000, 2.0000, 2.0000, 2.0000, 2.0000, 2.0000).

△o 3 = (1.0000, 0.0000, 1.0000, 1.0000, 2.0000, 1.0000, 0.0000).

(3) Use the equation to solve for the absolute maximum and minimum.

Maximum difference: 2.0000.

Minimum difference: 0.0000.

(4) Calculate the Grey Correlation Coefficients: Use the equation and the results are obtained below:

r(x 0(1) ,x 1(1)) = 0.5000, r(x 0(2) ,x 1(2)) = 0.5000, r(x 0(3) ,x 1(3)) = 1.0000, r(x 0(4) ,x 1(4)) = 1.0000, r(x 0(5) ,x 1(5)) = 1.0000, r(x 0(6) ,x 1(6)) = 1.0000, r(x 0(7) ,x 1(7)) = 0.5000, r(x 0(1) ,x 2(1)) = 0.3333, r(x 0(2) ,x 2(2)) = 0.3333, r(x 0(3) ,x 2(3)) = 0.3333, r(x 0(4) ,x 2(4)) = 0.3333, r(x 0(5) ,x 2(5)) = 0.3333. r(x 0(6) ,x 2(6)) = 0.3333, r(x 0(7) ,x 2(7)) = 0.3333. r(x 0(1) ,x 3(1)) = 0.5000, r(x 0(2) ,x 3(2)) = 1.0000. r(x 0(3) ,x 3(3)) = 0.5000, r(x 0(4) ,x 3(4)) = 0.5000. r(x 0(5) ,x 3(5)) = 0.3333, r(x 0(6) ,x 3(6)) = 0.5000, r(x 0(7) ,x 3(7)) = 1.0000.

(5) Calculate the Grey Correlation Extent: Weights are used as a reference standard: Unequal weights -- Statistics method --β(k).

Weights of each individual factor:

β=(0.4000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000, 0.1000).

Obtain:

r(x 0 ,x 1)=0.7000, r(x 0 ,x 2)=0.3333, r(x 0 ,x 3)=0.5833.

(6) Sort the Grey Correlation Sequence: Sort in a decreasing order.

r(x 0, x 1) = 0.7000 (T1 Supplier) > r(x 0, x 3) = 0.5833 (T3 Supplier) > r(x 0, x 2) = 0.3333 (T2 Supplier).

Table 2 is the summary of the results of the Grey Relational Analysis conducted on the evaluation and selection of the test equipment suppliers. Table 3 and 4 are the respective summaries of the evaluation and selection of the equipment suppliers of wafer auto probing machine and wafer handler. In table 2, supplier T1 is the best supplier of the wafer test machines, supplier T3 is ranked second and the poorest is supplier T2.

Table 2: Evaluation Results of Wafer Test Equipment Suppliers

Test Machine Suppliers	T1 Supplier	T2 Supplier	T3 Supplier
Grey Correlation Extent Value	0.7000	0.3333	0.5833
Ranking	1	3	2

In table 3, supplier P2 is the best supplier of the wafer test machines, supplier P1 is ranked second and the poorest is supplier P3.

Table 3: Evaluation Results of Wafer Auto Probing Machine Suppliers

Test Machine Suppliers	P1 Supplier	P2 Supplier	P3 Supplier
Grey Correlation Extent Value	0.8000	0.9000	0.5333
Ranking	2	1	3

In table 4, supplier H2 is the best supplier of the wafer handlers, supplier H3 and H4 are the next and the poorest is supplier H1.

Table 4: Evaluation Results of Wafer Handler Suppliers

Test Machine Suppliers	H1 Supplier	H2 Supplier	H3 Supplier	H4 Supplier
Grey Correlation Extent Value	0.5600	0.6587	0.6286	0.6800
Ranking	4	1	3	2

5. Conclusion and Recommendations

Due to rapid changes in the environment of the wafer test industry and fast strengthening of the enterprise competitiveness, companies, on the operation and management level, will face great challenges in purchasing equipments. As the quality of the equipments purchased will have great impacts on the production ability of the wafer test industry. Hence, building an effective equipment supplier evaluation system is the most widely discussed issue in the industry.

The main purpose of the Grey Relational Analysis Model of the supplier evaluation proposed in this investigation is to build an objective evaluation system capable of processing small amount of samples. The model can be used by the company owners and managers for equipment purchase decisions and, at the same time, is relatively effective compared to other evaluation models of test equipments. Finally, this investigation recommends the future researchers to combine the methods of AHP and Grey Relational Analysis and use in weight analysis and evaluation analysis. In terms of the industry research, this investigation only focuses on the analysis and research of the wafer test industry. It is recommended that the researchers extend the concept to other different industries in the future.

Reference

[1] http://www.cpmah.org.tw/2002/home/c91a041 /www/half.htm.

[2] C. C. Chen, "utilizing the overall quality and cost to analyze the performance evaluation model of suppliers," **Unpublished Ph.D paper of the Graduate School of the Industrial Engineering**

Department of Chungyuan University, 2003.

[3] H. C. You, "supplier-partner relationship and the impact of the electronic system on the supplier performances – based on the example of one LCD display manufacturing company," **Unpublished master's paper of the MBA school of Yuan Ze University**, 2004.

[4] F. C. Wang, "construction of the evaluation model of the nutritious lunch suppliers – based on the example of companies certified by HACCP in Taipei," **Unpublished master's paper of the MBA school of the National Taipei University**, 2004.

[5] C. C. Liao, "investigation of the supplier selection evaluation model for the manufacturing industry of small production quantity but various kinds of products – based on the example of one aerospace industrial company, " **Unpublished master's paper of the industrial management graduate school of I-Shou University**, 2004.

[6] Y. F. Lai, "evaluation of the green supply chains within the green suppliers – based on an example of a PCB supplier," **Unpublished master's paper of the resources engineering graduate school of the National Cheng Kung University**, 2004.

[7] M. L. Chuang, "study of the impact of the cross organization IT system on the supplier performances based on information process theory," **Unpublished master's paper of the IT management graduate school of the National Central University**, 2005.

[8] J. L. Deng, "Introduction to Grey Systems Theory, " **The Journal of Grey Systems**, 1982; Vol. 1, No. 1, pp.1-24,1982.

[9] W. C. Chang , Principle and Application of Grey Forecast. In: Chwa Taiwan Inc 2003.

[10] L. C. Chen, "study of the reuse of the historical sites and buildings based on Grey Relational Analysis," **Unpublished master's paper of the Civil Engineering Graduate School of the National Central University**, 2007.

[11] S. M. Cheng, "study of an operation performance evaluation model for property insurance companies – Grey Theory Applications," **Unpublished master's paper of the insurance graduate school of Chaoyang University of Technology**, 2005.

[12] P. T. Yu, "Trading strategies of the future of stock exchanges in Taiwan based on Grey Theory," **Unpublished master's paper of the Graduate School of the Department of Computer Science and Information Engineering of the National Taiwan University of Science and Technology**, 2005.

[13] T. W. Liao, "GA-PID fuzzy controller applied to the tracking and design of the grey signal Sources," **Unpublished master's paper of the Graduate School of the Department of Electrical Engineering of Dayeh University**, 2003.