Forecasting and evaluating the tourist hotel industry performance in Taiwan based on Grey theory

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ABSTRACT *Although Grey theory is extensively adopted to construct the forecasting models for evaluating organisational performance, it is rarely used in the hotel industry. This study draws on the GM(1,1) model to accurately predict the coming year's output value and on Grey relational analysis to select the best-performing hotels in Taiwan. Measures of hotel performance — including profit before tax, ROI before tax, revenue per employee, REVPAR, revenue per square meter, and occupancy rate — were collected from the Tourism Bureau in Taiwan. These data contain the performance of 56 international tourist hotels in 2002 and industry data from 1992 to 2005. Results in this study indicate that four-point GM(1,1) is the best model for predicting output value in the future. In addition, this investigation reveals the various competitive advantages and strategies in these top hotels, such as their appropriate site, higher price, and higher occupancy rate.*

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INTRODUCTION

The World Tourism Organization reports that tourism has become a major source of foreign exchange in many countries. International tourism has grown rapidly in recent decades and ranks second only to oil in world trade (Chu, 2004). The output value ratio of the service and manufacturing industry in Taiwan was 1.34 in 1991 and increased to 2.23 in 2003. According to the Tourism Bureau's report, the greatest number of the people visited Taiwan in 2002, when the growth rate was 4.18 per cent. In recent years, the three main purposes of visitors to Taiwan have been sightseeing (34.54 per cent), business (27.92 per cent), and visiting relatives (11.07 per cent). The number of sightseeing visitors increased by 3.8 per cent and number of visitors for other purposes decreased slightly (Taiwan Tourism Bureau, 2004). The average visitor's daily expenditure

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in Taiwan is about US$210, and most of this — about 45 per cent — is the hotel cost. Thus, the hotel industry is an important part of the hospitality industry, and will become more significant in the coming decade.

The hotel industry in Taiwan is reputedly one of the most competitive sectors in the country. The number of international tourist hotels in Taiwan has doubled in the past 24 years. According to Go *et al.* (1994), this intense competition has resulted from long-term over-building and the resultant excess capacity. This study aims to accurately predict the future of this industry and find the better performing company. Recent research concerning the tourism industry includes a study predicting the tourism demand (Chu, 2004), a study measuring changes in hotel managerial efficiency (Hwang and Chang, 2003), a proposal for a contingency approach for evaluating hotel performance and competitive advantage (Phillips, 1999), and miscellaneous studies (Au and Tse, 1995; Phillips *et al.*, 1999).

To our knowledge, no study has evaluated the hotel industry simultaneously from the macro and the micro perspectives. From the macro perspective, Hsu (2003) compared the Grey model with other prediction models, revealing that the Grey model is more accurate than the time series and exponential smoothing approaches. Phillips (1999) and Hwang and Chang (2003) discuss hotel performance at the micro point. No study, however, integrates these two points. The phenomenon of industry development and company competition is an ongoing concern in hospitality industry research. This study explores the implications of this phenomenon by drawing from two complementary streams of research: operating revenue as a predictor of industry development and operating efficiency as an evaluative indicator of company performance.

This study attempts the following: first, use GM(1,1) to predict the coming years output value of the hotel industry in Taiwan exactly; secondly, evaluate the performance of the tourist hotel in this area by performing Grey relational analysis; and thirdly, induce the strategy of these outstanding hotels and give the suggestion in this industry.

HOTEL INDUSTRY IN TAIWAN AND HOTEL PERFORMANCE TEST

The international tourist hotel industry in Taiwan has been expanding since 1970, when the total number of guest rooms was 2,163, and there were 14 international tourist hotels. Through more than 30 years of development, up to the end of 2003, there are now 59 international tourist hotels in Taiwan, and the number of guest rooms is 212,390 (Taiwan Tourism Bureau, 2003). Although international tourist hotels need to pass the strict review processes of the Tourism Bureau, they are different in age, area, scale, and strategy.

The hotels in Taiwan can be classified into four groups according to standards of accommodation: international tourist hotel, ordinary tourist hotel, ordinary hotel, and pension. Data in Table 1 indicate that the international tourist hotel is required to conform to the strictest rules and is superior to other three classifications of hotels in Taiwan as these hotels attract more foreign tourists than others. International tourist hotels and ordinary tourist hotels are the most popular ones in Taiwan's tourism industry.

Performance measurement is an essential managerial activity and of priority concern among hotel general managers (Phillips, 1999). The hotel industry has particular features associated with provision of hotel product, and, therefore, the measures used to assess hotel performance should reflect the specific activities and products and services offered (Harris and Mongiello, 2001). Traditional financial performance measures, such as return on investment (ROI), are important measures of managerial performance. Overemphasis on ROI can, however, produce myopic behaviour (Phillips, 1999). Performance in this study is based on 56 Taiwanese tourist

Table 1: The difference of the four classifications hotel in Taiwan

Hotel classifications	*International tourist hotel*	*Ordinary tourist hotel*	*Ordinary hotel*	*Pension*
Rooms number	80(in city) 40(others)	50(in city) 40(others)	Between 6 and 50	Less than 5
The measure of area (meter^2)	Single room: 13 Double room: 19 Suite: 32	Single room: 10 Double room: 15 Suite: 25	Single room: 9 Double room: 13 Suite: 22	Less then 150 (all of the floor)
Grading	5 or 4 stars	4 or 3 stars	3 stars or less	
Supervisor institution	Tourism Bureau	Tourism Bureau	Municipality	Municipality
Number of hotel 2004	57	26	2,619	576

Source: Taiwan Tourism Bureau (2004).

hotels focusing on financial and non-financial indicators.

Hotel operators and investors adopt a number of industry statistics as benchmarks when assessing operations and when forecasting development and generating plans. The most commonly used statistics are occupancy and Revenue per Available Room (REVPAR) (Enz *et al.*, 2001). Berger (1997) used returns, operating margins, and REVPAR to evaluate hotel performance. Hotel occupancy rates are usually used as an important indicator in hotel performance-related research (Jeffrey and Barden, 2000; Enz *et al.*, 2001; Marris, 1992). These studies described above confirmed the effective performance evaluation of these indictors (occupancy, REVPAR, returns, operating margins). The REVPAR statistic is calculated by dividing revenue by the number of rooms available. Occupancy is estimated by dividing the number of rooms sold by the number of rooms available and multiplying by 100. Hotel occupancy rates are the most frequently maintained and closely monitored records kept by hotels (Marris, 1992). Additionally, efficiency of human resource management (Alleyne *et al.*, 2006), space and room management (Orkin, 2003) are also significant hotel services. These factors (employees, space, and hotel rooms) influence hotel customer perceptions directly. Consequently, efficiencies of employees, space, and rooms in this study are measured using revenue per employee, revenue per square meter (m^2), and REVPAR. This study selected the following six critical indicators of hotels' operational outcomes to evaluate hotel performance: profit rate; ROI; revenue per employee; revenue per square meter (m^2); REVPAR; and occupancy rate (%).

METHODOLOGY

The Grey system theory

Grey system theory is an effective mathematical means of resolving problems containing uncertainty and indetermination. Since its inception 20 years ago (Deng, 1982), Grey theory has advanced in many disciplines (Hsiao and Tsai, 2004) and in research areas such as forecasting of the passengers on international air transportation (Xu and Wen, 1997), the number of engineering officers on a Taiwanese ship (Lin and Wang, 2000), and the curve of stock market (Lin *et al.*, 2001). The Grey system prediction theory uses very few data (four or more) to create the model and the calculation is relatively simple. The Grey model (GM) (1,1), that is, a single variable first-order Grey model, is the most important prediction model. A condition to establish a GM(1,1) is that the data should be taken at equal intervals (Zhang *et al.*, 2003). Grey systems modelling is carried out mainly through the generation of Grey numbers or functions of series operators to find the hidden patterns.

Base on filtering, refinement, extension, and analogy of a small amount of Grey information, human understandings about a system of interest are deepened (Lin and Liu, 1999).

The Grey System theory treats each random process as a Grey process internally, and requires only four or more data to get precise forecasting result (Deng, 1986). The Grey System theory can be applied to solve several different problems, including: (a) Grey generating, (b) Grey relational analysis, (c) Grey forecasting, (d) Grey decision making, and (e) Grey cluster and statistic. This study uses Grey relational analysis and Grey forecasting to analyse hotels' actual data. The following section briefly specifies the theoretical background for these two techniques.

Construction of GM(1,1) model

Assume that $X^{(0)}$ represents the primitive series of the system to be handled, and is expressed in the following form.

$$X^{(0)} = (x^{(0)}(1), x^{(0)}(2), \ldots, x^{(0)}(n)) \tag{1}$$

Let $X^{(1)}$ be the first-order accumulated generating series of $X^{(0)}$, which can be obtained with the following first-order accumulated generating operation (AGO).

$$\begin{aligned} X^{(1)} &= (x^{(1)}(1), x^{(1)}(2), \ldots, x^{(1)}(n)) \\ &= \left(\sum_{k=1}^{1} x^{(0)}(k), \sum_{k=1}^{2} x^{(0)}(k), \ldots\ldots, \sum_{k=1}^{n} x^{(0)}(k) \right) \end{aligned} \tag{2}$$

By series $X^{(1)}$, a first-order differential equation for the GM(1,1) model is formed as

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = b \tag{3}$$

where t can be considered as a time variable, and a and b are two unknown parameters to be determined. Based on the Ordinary Least Square (OLS) method, the values of a and b can be obtained with equation (4).

$$\hat{a} = \begin{bmatrix} a \\ b \end{bmatrix} = (B^{T}B)^{-1}B^{T}Y_N \tag{4}$$

where the matrices B and Y_N are defined as

$$B = \begin{bmatrix} -\frac{1}{2}[x^{(1)}(1) + x^{(1)}(2)] & 1 \\ -\frac{1}{2}[x^{(1)}(2) + x^{(1)}(3)] & 1 \\ \vdots & \vdots \\ -\frac{1}{2}[x^{(1)}(n-1) + x^{(1)}(n)] & 1 \end{bmatrix} \tag{5}$$

$$Y_N = \begin{bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ \vdots \\ x^{(0)}(n) \end{bmatrix} \tag{6}$$

After the constants a and b are obtained, the GM(1,1) prediction model base on $X^{(1)}$ can be constructed as equation (7).

$$\hat{x}^{(1)}(k+1) = \left(x^{(0)}(1) - \frac{b}{a} \right) e^{-ak} + \frac{b}{a} \tag{7}$$

If the data predicted in the original space are required, they can be obtained by using one order inverse accumulated generating operation (IAGO), and the sequence is reduced to:

$$\hat{x}^{(0)}(k) = \left(\hat{x}^{(0)}(1) - \frac{b}{a} \right) e^{-a(k-1)}(1 - e^{a}) \tag{8}$$

To measure the efficiency of the new forecasting model, two tests, shown in Table 2, are used: residual error test and post-error test. In the residual error test, the predicted result is better with a smaller indicator, $e(k)$, value. In the post-error test, the pairs of forecasting indicators P and C characterise four grades of forecasting accuracy as shown in Table 2 (Deng, 1986). A lower post-error ratio C implies a better model. The post-error ratio indicates the change rate of the forecasting error. The probability of small error, P, is another indicator of forecasting accuracy (Deng, 1986). P is commonly required to be larger than 0.95. The first three grades of post-error test *good*, *qualified*, and *just the mark* are equivalent to the first grade, *useful*, in the residual error test.

Table 2: The grades of forecasting accuracy

Residual error test		*Post-error test*		
Grade	*e(k)*[1]	*Grade*	P^2	C^3
Useful	$1-e(k)$ $\geqslant 90\%$	Good	>0.95	<0.35
		Qualified	>0.8	<0.5
		Just the mark	>0.7	<0.65
Useless	$1-e(k)$ $<90\%$	Unqualified	$\leqslant 0.7$	$\geqslant 0.65$

[1] $e(k)=|x^{(0)}(k)-\hat{x}^{(0)}(k)/x^{(0)}(k)|\times 100\%$.
[2] $P=\text{Prob.}\{|q(k)|<0.6745S_1\}$.
[3] $C=S_2/S_1$.

Grey relational analysis

Grey relational analysis can be performed when system factors have an uncertain relationship, or when a factor's effect upon the system's main behaviour is unclear. It measures changes in relations between two systems or between two elements that occur in a system over time. The analysis method is based on the degree of similarity or difference between development trends among these elements. It analyses and decides the degree of influence between factors, and measures the contribution of the factors to the principal behaviour. It also compares the geometrical relations within dispersed data. Grey relational analysis needs only a small amount of data and is simple to calculate (Deng, 1982, 1986). The method has been applied in many fields, such as evaluating performance of airlines (Feng and Wang, 2000), evaluating the importance of various service quality factors (Chen and Ting, 2002), and colour planning in product design (Hsiao and Tsai, 2004).

The Grey System relational analysis can be summarised thus:

Step 1: Take a reference series

The original data can further be transformed into a suitable type by dividing with the initial value, minimum value, maximum value or mean value of the original data to form a reference series X_0.

$$X_0=(x_0(1),x_0(2),\ldots,x_0(n)) \quad (9)$$

Step 2: Decide the series to be compared

The entries to be compared with X_0 are denominated as X_i, which are taken in the same form as X_0.

$$X_i=(x_i(1),x_i(2),\ldots,x_i(n)) \quad 1\leqslant i\leqslant m \quad (10)$$

Step 3: Compute the distance between the compared series and the reference series

The kth entry of the distance series is

$$\Delta_i K=|X_0(k)-X_i(k)| \quad 1\leqslant i\leqslant m \quad (11)$$

Step 4: Find the maximum and minimum values of the entries in the distance series

$$\max_{j\in I}\max_k |x_0(k)-x_j(k)| \text{ and } \min_{j\in I}\min_k |x_0(k)-x_j(k)| \quad (12)$$

Step 5: Compute the Grey relation coefficient $\xi_i(k)$

The relational coefficient $\xi_i(k)$ between the reference series X_0 and the compared series X_i at the kth entry can be calculated by the following equation.

$$\xi_i(k)=\frac{\min_{j\in I}\min_k |x_0(k)-x_j(k)|+\zeta\max_{j\in I}\max_k |x_0(k)-x_j(k)|}{|x_0(k)-x_j(k)|+\zeta\max_{j\in I}\max_k |x_0(k)-x_j(k)|} \quad (13)$$

where $\zeta\in[0,1]$ is the identification coefficient, which is usually taken as 0.5.

Step 6: Calculate the Grey relational grade

The Grey relational grade between X_0 and X_i is defined as the average of the Grey relational coefficients, which gives

$$r_i = \frac{1}{n}\sum_{k=1}^{n} \xi_i(k) \quad 1 \leqslant i \leqslant m \tag{14}$$

Arranging the Grey relational grades for all hotels in size, the relative performance of each hotel can be compared.

FINDING AND DISCUSSIONS

To analyse the tourist hotel industry, two first-order Grey models with one variable (time), GM(1,1), compared with time series regression were first generated to forecast market growth. Grey relational analysis was applied to evaluate international tourist hotel performance. Tourist hotel industrial output values (14 years) and performance data for 56 international tourist hotels over one year are collected from Taiwan's Tourism Bureau between 1992 and 2005. Procedures and analytical results are listed in following sections.

The Grey forecasting of output value for Taiwan's hotel industry

This study contains three models for forecasting Taiwan hotel industry output value for the coming year, and the results of the three compared models displayed in Table 3 were forecasted using the data from year 1992 to 2005. The

Table 3: The forecasting results and accuracy for three GM(1,1) models

Year	*Actual output value (NT$)*	*GM model 1*		*GM model 2*		*Regression model 3*	
		Total		*4-point*		*Time series*	
		Forecasted output value	*Residual error %*	*Forecasted output value*	*Residual error %*	*Forecasted output value*	*Residual error %*
1992	21,465,831,998						
1993	22,234,633,523	27,140,759,132	22.07	22,303,251,745	0.42	25,678,402,798	15.49
1994	25,750,153,632	27,881,043,038	8.28	25,522,235,777	1.38	26,698,452,031	3.68
1995	29,184,689,732	28,641,518,724	1.86	29,205,809,381	0.42	27,718,501,263	5.02
1996	31,053,639,916	29,422,736,937	5.25	33,421,025,848	1.78	28,738,550,496	7.46
1997	33,641,675,517	30,225,263,444	10.16	34,305,310,531	0.30	29,758,599,728	11.54
1998	33,642,930,221	31,049,679,443	7.71	36,022,076,727	0.29	30,778,648,960	8.51
1999	34,108,824,585	31,896,581,988	6.49	35,414,710,424	0.00	31,798,698,193	6.77
2000	34,137,942,567	32,766,584,414	4.02	34,268,598,742	0.33	32,818,747,425	3.86
2001	34,167,060,549	33,660,316,788	1.48	34,460,034,448	1.54	33,838,796,658	0.96
2002	33,689,914,911	34,578,426,361	2.64	34,196,217,859	4.60	34,858,845,890	3.47
2003	30,994,491,154	35,521,578,039	14.61	33,553,714,009	0.37	35,878,895,122	15.76
2004	35,051,785,075	36,490,454,864	4.10	29,931,108,225	—	36,898,944,355	5.27
2005	38,917,856,693	37,485,758,507	3.68	34,677,915,626	—	37,918,993,587	2.57
2006	(Forecast)	38,508,209,780		43,621,068,618		38,939,042,820	

The grades of forecasting accuracy

	GM model 1		*GM model 2*		*Time series model 3*	
Average residual error	Useful	7.10%	Useful	1.04%	Residual error	6.95%
Accuracy rate		92.90%		98.96%	Accuracy rate	93.05%
C	Just the mark	0.52	Good	0.29	R^2	0.72
P		0.85		0.97	$\bar{R}^2$	0.70

first GM(1,1) model and the third model (time series regression) inputs 14 years of data totally for conducting the analysis, while the second GM(1,1) model inputs every four years of data each time in turn. Previous four years of data forecast the output value of the next year in the second model (model 2), such as the output value of 2006 is forecasted by the data from year 2002 to 2005 and the output value of 2005 is forecasted by the data from year 2001 to 2004. The forecasting accuracy of the two GM(1,1) models was examined by taking the residual error and post-error methods according to Deng (1982). All of these three models forecast that the output value of the coming years will increase in 2006.

Using the least-squares method, the parameters of model 1(total) are obtained as $\hat{a}_1 = (-0.1348, 17{,}939{,}616{,}445)$, and the forecasting function expressed as

$$\hat{x}^{(1)}(k+1) = \left(21465831998 - \frac{17939616445}{-0.1348}\right) \times \exp(0.1348k) + \frac{17939616445}{-0.1348} \quad (15)$$

The forecasts were estimated through the first-order Accumulated Generating Operation. The same procedure was adapted for model 2. The obtained parameters of model 2 are $\hat{a}_2 = (-0.1130, 25{,}548{,}562{,}861)$. To select a proper model for getting accurate prediction results, the prediction results for three prediction models were compared with actual values in Figure 1 and Table 3. The results show that the four-point GM(1,1) model is the nearest curve in Figure 1 and has the lowest average residual in Table 3. Additionally, the four-point GM(1,1) model has better *P* and *C* indices, because its index *C* is lower and index *P* is higher than the total GM(1,1) models. Thus, four-point GM(1,1) is suggested to be used as the prediction model. As a result, the output value of the tourist hotel industry in 2006 will be near NT$ 43,621m and also will be higher in the following year (2007). The study infers that the tourist hotel market in Taiwan is saturated and will enlarge in the next one or two years if other factors remains in the same situation.

The Grey relational analysis of performance for Taiwan's international tourist hotel industry

Following the prior discussion of the effective hotel performance indicators, the study evaluated data using the six parameters: (a) profit rate before tax; (b) ROI before tax; (c) revenue per employee; (d) revenue per square meter (m^2); (e) REVPAR; and (f) occupancy rate (%) for the 56 international tourist hotels listed in Table 4. The secondary data collected in this study were calculated by means of the Grey relational analysis to evaluate the performance of each hotel.

After transforming the negative data in Table 4 (eg profit rate and ROI) into positive type by adding the absolute value of the minimum in the same column, the reference series can be determined. The reference series, X_0 in this study is the series whose elements have the maximum value for each indicator. $X_0 = (134.75, 108.33, 2{,}786{,}266, 173{,}285, 1{,}618{,}379, 82.83)$. The Grey relational grade $r(X_0, X_i)$ for each hotel's operational data series, X_i, with respect to the reference series, X_0, was computed in Table 5. Table 5 lists these hotels in descending order of Grey relational grade. This study further explores and analyses the characteristics of the top, the middle and bottom performing hotels using the other data in Table 5.

From the data of these hotels in Table 5, the following section describes three major phenomena. First, from the level of average room price and occupancy rate, these 56 hotels can be divided into three groups as shown in Figure 2 from the different hotel marketing strategies. Previous studies have shown that an occupancy rate of about 66 per cent is the break-even point for hotel operation (Crossley and Jamieson, 1997). Figure 2 clearly shows that the 15 international tourist hotels of the lower performance have suffered from surplus room availability and that their occupancy rates are almost below 57 per cent.

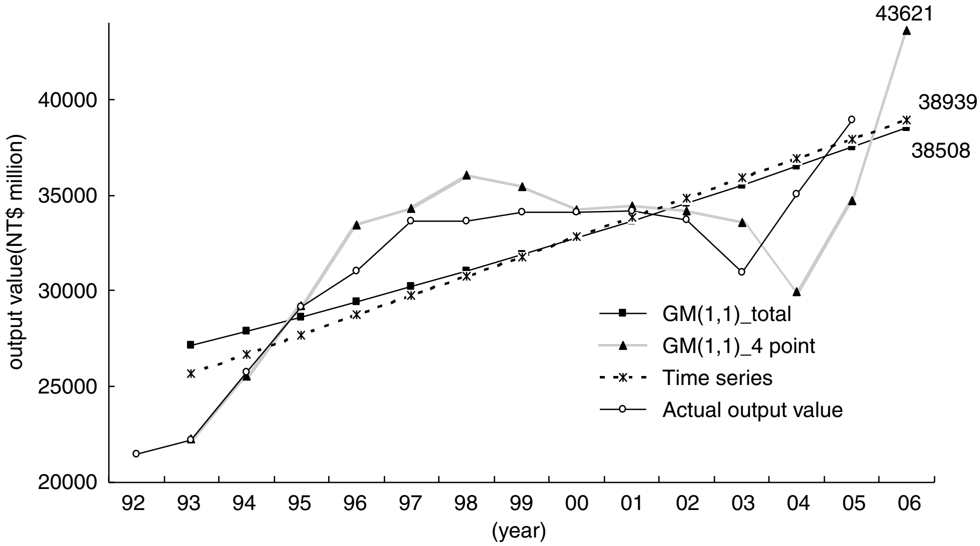

Figure 1 Total output value of Taiwan tourist hotel industry from 1992 to 2006
Note: R1–R15 shows the hotels whose Grey Relational grades ranked from the first to the 15th in Table 5

Table 4: The evaluated values with six indicators for 56 international tourist hotels in 2002

No	*Hotel name*	*Profit rate before tax (%)*	*ROI before tax (%)*	*Revenue per employee*	*Revenue per m²*	*REVPAR*	*Occupancy rate %*
TH1	The Grand Hotel	−2.70	−0.65	1,468,811	46,030	926,521	71.33
TH2	The Ambassador Hotel	10.34	0.92	1,867,363	132,729	740,379	63.88
TH3	Mandarina Crown Hotel	−39.83	−3.73	1,614,199	114,324	533,676	68.55
TH4	Imperial Hotel Taipei	−33.92	−5.59	1,366,775	35,025	590,926	67.59
TH5	Gloria Prince Hotel	−44.05	−8.64	1,614,727	96,575	581,432	65.64
TH6	Emperor Hotel	−4.46	−1.94	750,834	43,432	391,172	53.13
TH7	Hotel Riverview Taipei	6.68	2.26	1,383,452	38,124	400,214	71.63
TH8	Caesar Park Taipei	21.60	83.58	1,415,886	82,144	791,457	74.59
TH9	Golden China Hotel	23.07	6.66	1,478,823	56,812	604,716	74.03
TH10	Brother Hotel	−9.92	−10.68	1,310,726	144,881	678,674	68.91
TH11	Santos Hotel	22.24	8.61	1,268,112	32,440	598,553	70.32
TH12	The Landis Ritz Hotel	8.48	3.19	1,425,582	137,542	854,444	64.48
TH13	United Hotel	6.17	1.57	1,371,349	83,149	532,986	60.18
TH14	Sheraton Taipei Hotel	6.34	4.92	883,481	51,877	47,7927	66.94
TH15	Taipei Fortuna Hotel	−5.19	−0.86	996,973	41,154	384,279	60.96
TH16	Holiday Inn Asiaworld Taipei	−42.59	−3.10	1,565,549	54,943	301,417	40.95
TH17	Hotel Royal Taipei	24.52	6.05	1,623,418	81,575	968,034	76.81
TH18	Howard Plaza Hotel	20.04	4.60	1,821,664	167,834	954,690	75.24
TH19	Rebar Crowne Plaza Taipei	−11.41	−12.52	1,174,909	120,792	725,184	66.02
TH20	Grand Hyatt Taipei	12.27	9.74	2,664,812	152,205	1,266,043	76.43
TH21	Grand Formosa Regent Taipei	39.60	22.82	2,786,266	129,577	1,273,482	82.83
TH22	The Sherwood Hotel Taipei	32.75	7.23	1,919,538	164,763	1,305,486	77.86

Table 4: *Continued*

No	*Hotel name*	*Profit rate before tax (%)*	*ROI before tax (%)*	*Revenue per employee*	*Revenue per m²*	*REVPAR*	*Occupancy rate %*
TH23	Far Eastern Plaza Hotel (Taipei)	−4.61	−10.01	2,035,291	173,285	1,618,379	81.65
TH24	The Westin Taipei	−5.42	−7.32	1,929,272	108,242	1,465,956	75.40
TH25	Hotel Kingdom	−5.33	−2.66	704,309	43,845	235,958	47.80
TH26	Hotel Holiday Garden Kaohsiung	−12.48	−1.20	938,643	44,011	268,287	51.32
TH27	The Ambassador Hotel Kaohsiung	−12.18	0.67	1,423,930	80,133	326,994	53.85
TH28	Linden Hotel Kaohsiung	1.92	1.92	1,220,028	68,198	500,219	66.32
TH29	Grand Hi-Lai Hotel	−10.51	−1.29	1,308,765	55,582	659,997	61.51
TH30	Howard Plaza Hotel Kaohsiung	−1.15	−0.43	1,538,999	32,869	667,831	76.00
TH31	The Splendor, Kaohsiung	−33.48	−4.18	1,369,308	34,549	393,987	46.90
TH32	Park Hotel	−25.98	−1.92	743,963	11,317	57,691	14.40
TH33	Hotel National	−33.94	−3.85	1,226,099	37,003	212,828	45.83
TH34	Plaza International Hotel	−17.60	−7.08	1,035,551	33,919	254,556	46.20
TH35	Evergreen Laurel Hotel (Taichung)	4.73	0.84	2,106,695	44,305	638,685	68.10
TH36	Howard Prince Hotel Taichung	1.09	0.60	1,537,409	42,269	670,568	63.76
TH37	The Splendor, Taichung	−95.15	−9.16	1,487,552	45,276	710,325	67.78
TH38	Astar Hotel	−52.71	−15.07	591,505	361	88,407	10.63
TH39	Marshal Hotel	−0.93	−0.63	923,503	52,735	240,591	53.31
TH40	Chinatrust Hotel Hualien	1.89	0.69	1,616,352	108,507	355,656	69.45
TH41	Parkview Hotel	5.73	2.13	1,381,718	83,415	669,285	67.24
TH42	Hotel Landis China Yangmingshan	−27.06	−1.84	757,649	48,363	462,742	36.00
TH43	Grand Hotel Kaohsiung	−35.85	−21.04	1,016,521	46,740	356,067	56.08
TH44	Caesar Park Hotel Kenting	9.26	3.68	1,976,416	108,517	798,281	66.67
TH45	Hotel Royal Chihpen Spa	18.78	7.42	1,312,612	124,361	1,021,637	65.74
TH46	Grand Formosa Hotel, Taroko	−15.79	−4.45	2,009,518	63,310	670,268	57.92
TH47	Howard Beach Resort Kenting	9.96	2.97	2,158,167	34,752	854,306	77.34
TH48	The Hibiscus Resort	−56.22	−7.91	882,212	47,852	352,609	45.22
TH49	Taoyuan Holiday Hotel	−1.68	−0.65	990,507	23,105	193,140	37.70
TH50	Taoyuan Plaza Hotel	−41.93	−24.75	825,249	44,806	84,412	27.09
TH51	Hotel Tainan	−0.73	−0.40	1,418,378	118,945	401,504	49.95
TH52	Ta Shee Resort Hotel	0.99	0.16	1,409,410	54,646	593,171	59.66
TH53	Hotel Royal Hsinchu	6.98	2.19	1,451,367	35,038	812,082	63.54
TH54	The Ambassador Hotel Hsinchu	4.70	0.81	2,110,220	83,899	876,390	68.72
TH55	Formosan Naruwan Hotel	−69.98	−6.27	976,712	34,074	431,050	41.78
TH56	Tayih Landis Tainan	−4.36	−4.34	1,361,873	41,936	578,498	55.82

Room price is another significant index for differentiating between hotels with better and worse performance (see Figure 2). Different room prices of tourist hotels may reveal their various competitive strategies. According to the general strategy of Porter (1985), cost leadership, differentiation, and focus are three effectiveness strategies used to derive competitive advantage. A cost leadership strategy is implemented effectively when a company designs,

Table 5: The Grey relational grades and characteristics of 56 hotels

Rank	*No*	*Hotel name*	*Grey relational grade*	*Site*	*Average room price*	*No. of rooms*	*No. of employees*	*Guest type FIT %*	*Foreign guests %*
1	TH21	Grand Formosa Regent Taipei	0.8062	Taipei	4,446	569	799	67.2	87.6
2	TH23	Far Eastern Plaza Hotel (Taipei)	0.7654	Taipei	5,431	422	776	70.0	82.0
3	TH22	The Sherwood Hotel Taipei	0.7439	Taipei	4,598	349	492	100.0	86.1
4	TH20	Grand Hyatt Taipei	0.7369	Taipei	4,628	873	957	74.0	83.2
5	TH8	Caesar Park Taipei	0.6849	Taipei	2,930	388	522	58.9	87.6
6	TH18	Howard Plaza Hotel	0.6847	Taipei	3,476	606	989	88.2	84.9
7	TH24	The Westin Taipei	0.6421	Taipei	5,327	288	568	48.6	84.0
8	TH17	Hotel Royal Taipei	0.6145	Taipei	3,470	203	273	100.0	86.0
9	TH45	Hotel Royal Chihpen Spa	0.5980	Scenic Area	4,281	183	240	82.8	10.6
10	TH47	Howard Beach Resort Kenting	0.5946	Scenic Area	3,026	405	278	58.2	0.8
11	TH2	The Ambassador Hotel	0.5904	Taipei	3,213	432	480	36.2	92.3
12	TH44	Caesar Park Hotel Kenting	0.5857	Scenic Area	3,347	250	154	73.2	4.5
13	TH12	The Landis Ritz Hotel	0.5846	Taipei	3,631	209	312	100.0	82.1
14	TH54	The Ambassador Hotel Hsinchu	0.5812	TauHsiuMaio	3,494	254	329	90.5	56.9
15	TH9	Golden China Hotel	0.5712	Taipei	2,244	215	184	42.0	85.9
16	TH10	Brother Hotel	0.5652	Taipei	2,698	250	490	81.2	87.6
17	TH35	Evergreen Laurel Hotel (Taichung)	0.5531	Taichung	2,570	354	273	83.3	52.4
18	TH40	Chinatrust Hotel Hualien	0.5497	Hualien	1,639	221	108	64.5	32.1
19	TH11	Santos Hotel	0.5474	Taipei	2,332	287	233	13.6	91.9
20	TH1	The Grand Hotel	0.5411	Taipei	2,948	405	764	49.3	73.9
21	TH30	Howard Plaza Hotel Kaohsiung	0.5404	Kaohsiung	2,297	238	273	54.8	51.1
22	TH41	Parkview Hotel	0.5401	Hualien	2,727	343	293	52.0	24.1
23	TH19	Rebar Crowne Plaza Taipei	0.5338	Taipei	3,049	228	324	91.2	87.1
24	TH53	Hotel Royal Hsinchu	0.5254	TauHsiuMaio	3,333	198	226	97.8	76.3
25	TH3	Mandarina Crown Hotel	0.5251	Taipei	3,765	323	470	92.1	85.0
26	TH7	Hotel Riverview Taipei	0.5245	Taipei	1,531	201	129	11.2	92.1
27	TH13	United Hotel	0.5210	Taipei	2,426	243	170	38.7	68.4
28	TH36	Howard Prince Hotel Taichung	0.5170	Taichung	2,659	155	177	78.7	51.6
29	TH28	Linden Hotel Kaohsiung	0.5163	Kaohsiung	1,996	311	325	80.0	33.4
30	TH46	Grand Formosa Hotel, Taroko	0.5162	Scenic Area	3,438	224	123	56.1	3.8
31	TH51	Hotel Tainan	0.5156	Others	2,202	152	191	92.1	33.1

Table 5: *Continued*

Rank	*No*	*Hotel name*	*Grey relational grade*	*Site*	*Average room price*	*No. of rooms*	*No. of employees*	*Guest type FIT %*	*Foreign guests %*
32	TH14	Sheraton Taipei Hotel	0.5090	Taipei	1,956	686	978	73.7	88.6
33	TH52	Ta Shee Resort Hotel	0.5061	TauHsiuMaio	2,724	208	252	76.8	78.1
34	TH5	Gloria Prince Hotel	0.5058	Taipei	2,427	220	211	58.9	87.6
35	TH29	Grand Hi-Lai Hotel	0.4984	Kaohsiung	2,331	436	742	68.0	53.6
36	TH27	The Ambassador Hotel Kaohsiung	0.4869	Kaohsiung	2,071	457	337	55.4	53.6
37	TH56	Tayih Landis Tainan	0.4869	Others	2,839	306	369	53.6	34.0
38	TH4	Imperial Hotel Taipei	0.4847	Taipei	2,824	336	280	59.6	92.1
39	TH15	Taipei Fortuna Hotel	0.4793	Taipei	1,727	304	226	65.7	87.7
40	TH37	The Splendor, Taichung	0.4713	Taichung	2,651	205	412	76.5	36.8
41	TH39	Marshal Hotel	0.4693	Hualien	1,324	289	193	30.3	25.0
42	TH6	Emperor Hotel	0.4631	Taipei	1,997	97	65	100.0	95.3
43	TH26	Hotel Holiday Garden Kaohsiung	0.4546	Kaohsiung	1,437	274	140	34.9	46.8
44	TH25	Hotel hKingdom	0.4498	Kaohsiung	1,371	302	273	48.4	57.9
45	TH31	The Splendor, Kaohsiung	0.4458	Kaohsiung	2,302	592	543	78.6	31.1
46	TH16	Holiday Inn Asiaworld Taipei	0.4448	Taipei	2,011	755	474	44.1	90.2
47	TH43	Grand Hotel Kaohsiung	0.4430	Scenic Area	1,756	107	164	59.4	59.5
48	TH49	Taoyuan Holiday Hotel	0.4425	TauHsiuMaio	1,404	390	143	4.9	37.4
49	TH34	Plaza International Hotel	0.4407	Taichung	1,496	226	161	44.1	54.9
50	TH33	Hotel National	0.4358	Taichung	1,737	404	252	50.8	47.0
51	TH42	Hotel Landis China Yangmingshan	0.4314	Scenic Area	5,917	50	57	71.8	2.3
52	TH48	The Hibiscus Resort	0.4216	Scenic Area	2,136	201	135	63.2	0.0
53	TH55	Formosan Naruwan Hotel	0.4138	Others	2,826	276	246	48.0	2.3
54	TH50	Taoyuan Plaza Hotel	0.3959	TauHsiuMaio	866	277	40	39.0	21.3
55	TH32	Park Hotel	0.3945	Taichung	1,089	124	40	44.3	7.9
56	TH38	Astar Hotel	0.3682	Hualien	2,293	168	26	64.7	19.6

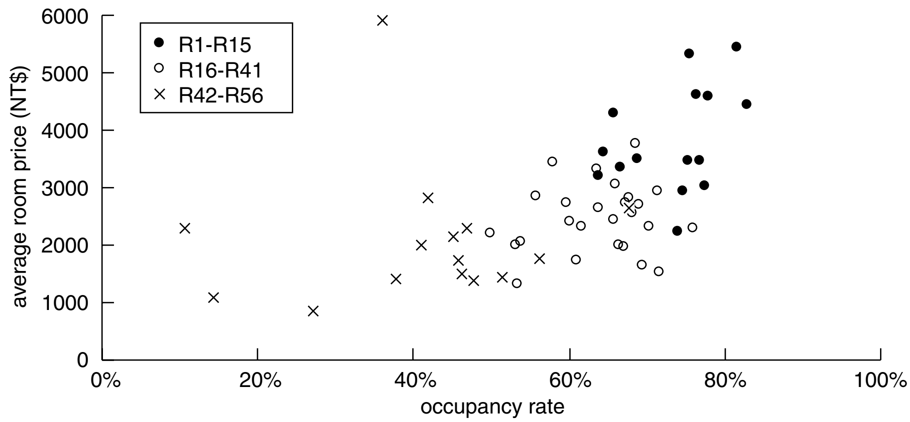

Figure 2 Average room price and occupancy rate of the 56 hotels

produces, and markets a product more efficiently than its competitors. A differentiation strategy is implemented effectively when a business provides unique or superior value to customers via product quality, features, or after-sale support. Focus strategies grow market share by operating in niche markets or markets not attractive to, or overlooked by, larger competitors. Since the top 15 hotels obviously have higher room price than other hotels, this investigation concludes that the successful strategy of international tourist hotels is not a cost leadership strategy but rather a differentiation or focus strategy.

Secondly, another indicator for differentiating between hotels with better and worse performance is hotel site. Over 73 per cent of the top 15 hotels in Taiwan are located in Taipei city — the capital of the Republic of China (see Table 5), not only because Taipei is the political and economic centre of Taiwan but also because of the surrounding natural scenery. Numerous international activities, meetings, conferences, and exhibitions are held in Taipei city, and Taipei is located close to the scenic area of Yangmingshan national park. Regarding other areas, the famous scenic areas of the south (Kenting national park) and east (Taitung and Hualien) coasts of Taiwan are attractive to tourists and beneficial to tourist hotels located in those areas. The results of the Grey relational analysis in Table 5 reveal that 20 per cent of the top 15 hotels in Taiwan are located in scenic areas.

Finally, more than 82 per cent of guests are foreigners for all the top 15 hotels except Hotel Royal Chihpen Spa, Howard Beach Resort Kenting, Caesar Park Hotel Kenting, and The Ambassador Hotel Hsinchu. The top 15 hotels can be divided into two categories by their ratio of foreign guests, namely the hotels located in Taipei, which have a higher ratio of foreign guests (more than 82 per cent), and those located in scenic areas of Taiwan, which have a lower ratio of foreign guests (lower than 11 per cent). This phenomenon demonstrates that domestic consumers appear to be the main target market for hotels in scenic areas. Other indicators between the better and worse performing hotels, including number of rooms, number of employees, and guest type are not different considerably.

CONCLUSIONS

This study analysed the development and performance of the tourist hotel industry in Taiwan using Grey system theory. In this approach, the first two GM(1,1) models and a time-series regression were utilised to identify a trend for future market capacity in the tourist hotel industry in a macro view. Then, from a micro perspective, hotel performance was compared via Grey relational analysis calculated from six annual indicators to assess which hotels performed best, which reveals the most appropriate strategy for their business. As Phillips (1999) proposed, competitive advantage can be achieved when inputs, processes, outputs, markets, and environmental characteristics are congruent with business objectives.

According to the application of Grey System theory, we concluded that the four-point GM(1,1) model is superior as it satisfies the requirement that rapid changes in industry should be forecasted using recent data. The result of the four-point GM(1,1) forecasting model is consistent with those of other models, indicating that the tourist hotel market is changeable and will expand somewhat in the future. Moreover, Grey relational analysis was applied to evaluate and compare the performance of almost all tourist hotels in Taiwan and to identify the general strategies used by the hotels with superior performance. Grey relational analytical results demonstrate that the characteristics of the best performing tourist hotels in Taiwan are high average room price, high occupancy rate, and a location at a special site (near the capital or a national park). This study presents three discussion points and suggestions for survival and competition in this industry based on analytical results.

First, high average room price in hotels with superior performance confirmed that the hotels adopted differentiation or focus strategies. Average room price (US$ 126) of the top ten best performing hotels is almost double than that (US$ 65) of the ten worst performing hotels. In addition to the average room price, differentiation or focus strategy is also evident in the locations of these hotels. The hotel site is extremely important simply because of access to different consumers and due to variable demands. The best performing tourist hotels in Taiwan are primarily located at two sites, namely big cities such as Taipei and at scenic areas such as Kenting national park. The rates for foreign guests at the top ten tourist hotels exceeded 80 per cent for hotels located in urban areas, and were <11 per cent for those located in scenic areas. The significantly different rates for foreign guests between big cities and scenic areas reveal that location is an extremely important factor for segmenting the sources of tourist hotel customers.

Differentiation strategy hotels always have higher room costs than those using a cost leadership strategy, and also have competitive advantage that is not easily imitated. Examples of hotels using a differentiation strategy are the Grand Formosa Regent Taipei and the TAI PAN Residence & Club, which is an all-butler hotel that combines traditional Chinese design with contemporary levels of comfort. Good customer relationship management, service quality, and promotion maintain high and stable occupancy rates; examples include the Total Customer Experience (TCE) offered at the Grand Formosa Regent Taipei, and the art collection exhibited and wireless internet access offered at The Sherwood Taipei. A good hotel location can attract considerable tourists. The Caesar Park Taipei is ideally located in the centre of the Taipei business district, whereas the Grand Hyatt Taipei is near the Taipei World Trade Center and the Taipei 101 building. The Hotel Royal Chihpen Spa and the Howard Beach Resort Kenting are located in famous scenic areas in southern Taiwan.

Secondly, control of the hotel occupancy rate is critical in this industry because one characteristic of hotel service is that it cannot be kept in stock (Parasuraman *et al.*, 1985); consequently, hotels should promote their products at the appropriate time to increase the occupancy rate. This view is confirmed in this study as the tourist hotels with positive ROI and strong profit rate before taxes all have occupancy rates exceeding 60 per cent. Not completely conforming to the law of demand (Tables 4 and 5), hotels that apply a lower than average room price do not have high occupancy rates (eg Marshal Hotel and Park Hotel). Conversely, hotels that apply higher average room prices also have high occupancy rates (eg Far Eastern Plaza Hotel Taipei, and Hotel Royal Chihpen

Spa). Price is not the only factor that influences hotel occupancy rates, variables related to customer demand, such as comfort or convenience, may be important factors influencing occupancy rates at hotels. Therefore, hotels must identify the main demand of their guests.

Thirdly, while various organisational strategies have been identified over the years, Porter's generic strategies remain the most commonly supported and identified in strategic management literature (Allen *et al.*, 2006). Porter (1980) argued that a firm must choose between generic strategies to achieve profitability to avoid being 'stuck in the middle'. In this highly competitive tourist hotel industry, development and manipulation of unique hotel resources is essential. A resource-based view of a firm focuses on exploitation of resources to acquire a sustainable competitive advantage that results in superior performance (Wernerfelt, 1984, Peteraf, 1993). Given a firm's overall resource portfolio, only those resources that are intangible offer sustainable economic benefit (Galbreath, 2005). Hotel resources such as employees, location, and management efficiency can be evaluated using Grey relational analysis. Investigation results provide insight into the competitive conditions of the Taiwanese tourist hotel industry. Industry practitioners should attempt to generate unique company resources to achieve competitive advantage.

Additionally, performance measurement in this study utilised financial and non-financial indicators, a methodology similar to the balanced scorecard model (BSC), which is effective in evaluating and improving organisational performance (Kaplan and Norton, 1992). The four BSC dimensions are customer, internal business processes, innovation and learning, and financial perspectives. Hotel occupancy reflects customer loyalty and preference. Both REVPAR and revenue per square meter reveal the efficiency of internal business processes. Revenue per employee is similar to the innovation and learning dimension in BSC. These three dimensions can be used to further improve the last dimension, financial outcomes. This analytical result confirms that the direction in this study is appropriate for measuring and comparing tourist hotel performance.

This study has several limitations. First, although study indicators in Grey relational analysis are important and similar to those in the BSC model, indicator selection is limited by the ability to acquire secondary data, which influences overall evaluations of performance. Secondly, this study does not consider the importance of government policy, which can impact future development of the tourist industry; nor does this study consider the different weights of these indicators when evaluating hotel performance, which have an influence on the estimated performance result.

Finally, in future research, the scope of indicators should be expanded by collecting primary and secondary data simultaneously to evaluate the tourist hotel performance. Secondly, future studies can further explore the industry by comparing hotels in different regions or countries, or by comparing different methods such as Data Envelopment Analysis (DEA) to gain an insight into the different characteristics and strategies of the tourist hotel industry.

References

Allen, R. S., Helms, M. M., Takeda, M. B., White, C. S. and White, C. (2006) 'A Comparison of Competitive Strategies in Japan and the United States', *S.A.M. Advanced Management Journal*, **71**, 1, 24–35.

Alleyne, P., Doherty, I. and Greenidge, D. (2006) 'Approaches to HRM in the Barbados Hotel Industry', *International Journal of Contemporary Hospitality Management*, **18**, 2, 94–109.

Au, A. K. M. and Tse, A. C. B. (1995) 'The Effect of Marketing Orientation on Company Performance in the Service Sector: A comparative study of the hotel industry in Hong Kong and New Zealand', *Journal of International Consumer Marketing*, **8**, 2, 77–87.

Berger, J. (1997) 'Applying Performance Tests in Hotel Management Agreements', *Cornell Hotel and Restaurant Administration Quarterly*, **38**, 2, 25–30.

Chen, C. N. and Ting, S. C. (2002) 'A Study Using the Grey System Theory to Evaluate the Importance ofVarious Service Quality Factors', *The International Journal of Quality & Reliability Management*, **19**, 6, 838–861.

Chu, F. L. (2004) 'Forecasting Tourism Demand: A cubic polynomial approach', *Tourism Management*, **25**, 2, 209–218.

Crossley, J. C. and Jamieson, L. M. (1997) 'Introduction to Commercial and Entrepreneurial Recreation', Sagamore, Champaign, IL.

Deng, J. L. (1982) 'Control Problems of Grey System', *System and Control Letters*, **1**, 5, 288–294.

Deng, J. L. (1986) 'Grey Forecasting and Decision', Huazhong University of Science and Technology Press, Wuhan, pp. 97–134.

Enz, C. A., Canina, L. and Walsh, K. (2001) 'Hotel-Industry Averages: An inaccurate tool for measuring performance', *Cornell Hotel and Restaurant Administration Quarterly*, **42**, 6, 22–32.

Feng, C. M. and Wang, R. T. (2000) 'Performance Evaluation for Airlines Including the Consideration of Financial Ratios', *Journal of Air Transport Management*, **6**, 3, 133–142.

Galbreath, J. (2005) 'Which Resources Matter the Most to Firm Success? An Exploratory Study of Resource-Based Theory', *Technovation*, **25**, 9, 979–987.

Go, F., Pine, R. and Yu, R. (1994) 'Hong Kong: Sustaining competitive advantage in Asia's hotel industry', *Cornell Hotel and Restaurant Administration Quarterly*, **35**, 5, 50–61.

Harris, P. J. and Mongiello, M. (2001) 'Key Performance Indicators in European Hotel Properties: General managers' choices and company profiles', *International Journal of Contemporary Hospitality Management*, **13**, 3, 120–128.

Hsiao, S. W. and Tsai, H. C. (2004) 'Use of Grey System Theory in Product-Color Planning', *Color Research and Application*, **29**, 3, 222–231.

Hsu, L. C. (2003) 'Applying the Grey Prediction Model to the Global Integrated Circuit Industry', *Technological Forecasting & Social Change*, **70**, 6, 563–574.

Hwang, S. N. and Chang, T. Y. (2003) 'Using Data Envelopment Analysis to Measurement Hotel Managerial Efficiency Change in Taiwan', *Tourism Management*, **24**, 357–369.

Jeffrey, D. and Barden, R. R. D. (2000) 'Monitoring Hotel Performance Using Occupancy Time-Series Analysis: The concept of occupancy performance space', *The International Journal of Tourism Research*, **2**, 6, 383.

Kaplan, R. S. and Norton, D. P. (1992) 'The Balanced Scorecard: Measures that drive performance', *Harvard Business Review*, **70**, 1, 71–79.

Lin, C. B., Su, S. F. and Hsu, Y. T. (2001) 'High-Precision Forecast Using Grey Models', *International Journal of Systems Science*, **32**, 5, 609–619.

Lin, C. T. and Wang, S. M. (2000) 'Engineering Officers of National Vessels in Taiwan', *International Journal of Information and Management Sciences*, **11**, 4, 13–30.

Lin, Y. and Liu, S. (1999) 'Several Programming Models with Unascertained Parameters and their Applications', *Journal of Multicriteria Decision Analysis*, **8**, 4, 206–220.

Marris, T. (1992) 'Research Needs of Small Tourism Enterprises', in Pearce, D. G. and Butler, R. W. (eds), 'Tourism Research: Critiques and challenges', Routledge, London, pp. 345–353.

Orkin, E. (2003) 'The Emerging Role of Function Space Optimisation in Hotel Revenue Management', *Journal of Revenue and Pricing Management*, **2**, 2, 172–174.

Parasuraman, A., Zeithaml, V. A. and Berry, L. L. (1985) 'Conceptual Model of Service Quality and Its Implications for Future Research', *Journal of Marketing*, **49**, 4, 41–50.

Peteraf, M. (1993) 'The Cornerstones of Competitive Advantage: A resource-based view', *Strategic Management Journal*, **14**, 3, 179–191.

Phillips, P. A. (1999) 'Hotel Performance and Competitive Advantage: A contingency approach', *International Journal of Contemporary Hospitality Management*, **11**, 7, 359–365.

Phillips, P., Davies, F. and Moutinho, L. (1999) 'The Interactive Effects of Strategic Planning on Hotel Performance: A neural network analysis', *Management Decision*, **37**, 3, 279–290.

Porter, M. E. (1980) 'Competitive Strategy: Techniques for analyzing industries and competitors', The Free Press, New York.

Porter, M. (1985) 'Competitive Advantage', Free Press, New York.

Taiwan Tourism Bureau. (1990–2004) 'The Operating Report of International Tourist Hotels in Taiwan', Republic of China Press, Taipei.

Wernerfelt, B. (1984) 'A Resource-Based View of the Firm', *Strategic Management Journal*, **5**, 2, 171–180.

Xu, Q.Y. and Wen, Y. H. (1997) 'The Application of Grey Model on the Forecast of Passenger of International Air Transportation', *Transportation and Planning Journal*, **26**, 3, 525–555.

Zhang, H., Li, Z. and Chen, Z. (2003) 'Application of Grey Modeling Method to Fitting and Forecastingwear Trend of Marine Diesel Engines', *Tribology International*, **36**, 10, 753–756.

