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Binomial Real Option Pricing for Restaurant Menu Analysis

By Chih-Yun Yang[1] and Te-Yi Chang[1]

Abstract

Numerous researchers have proposed methods to improve the profitability of restaurant menus. The profit-analysis techniques that have been proposed generally assess menu items according to popularity as against comparative contribution margin or a similar scheme that theoretically allows managers to apply a portfolio adjustment approach or simply to replace items that are low in profitability. However, none of the analytical models discussed in the literature consider the element of time, which is an essential consideration in planning for menu item replacement. This study uses a real option pricing model to construct time-axis profiles of menu items and to analyze their potential profitability given varying time constraints. The analysis applies a binomial real option pricing model, as applied to actual data, and a real option pricing model was used to compare the advantages and benefits of different menu items. A comparison of the binomial model's results with those of other menu analysis models found that the time-based model was more effective in determining how to construct a menu portfolio.

Keywords

food and food service, asset pricing, pricing, operations management

Proper menu pricing is critical to a restaurant's success. To assist restaurateurs in maximizing menu profitability, various menu analysis methods have been proposed over the years. The most commonly studied model is the Matrix Menu Analysis Model (MMAM), which was first proposed by Miller, Kasavana and Smith, and Pavesic in the 1980s (see, e.g., Pavesic 1985). With MMAM, restaurant managers can use a spreadsheet to quickly determine the relative profitability status of each menu item. Because of its simplicity, the MMAM is available as a module in many POS systems. However, one strong perception of MMAM is that it provides insufficient information for restaurant managers. To address this issue, scholars have presented different analytical techniques, such as goal value analysis (Hayes and Huffmann 1985), micro-marketing mix model (Atkinson and Jones 1994), the graphical economic approach (Beran 1995), and data envelopment analysis (Taylor, Reynolds, and Brown 2009).

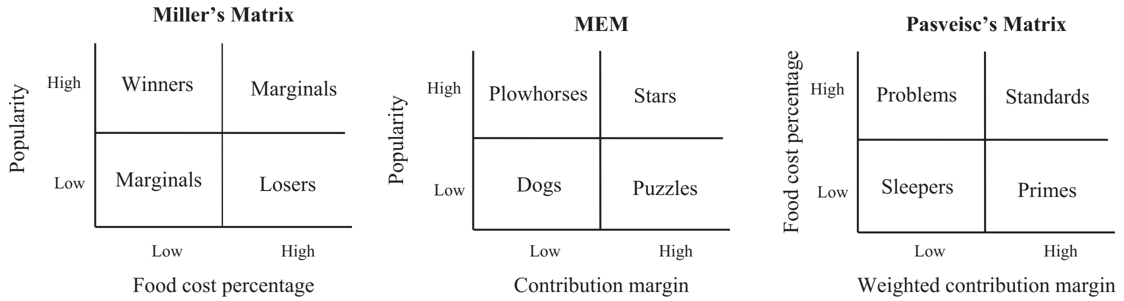
What these models have in common is that they are all relatively static analytical techniques that employ timeline cross-sectional analysis and therefore do not consider the time factor. Given the nature of the restaurant business, we propose that the risk of information volatility associated with time factors must also be considered to evaluate the profitability of menu items. Therefore, menu-analysis techniques should be based on timelines with longitudinal sections. From a financial capital budgeting perspective, setting menu item prices for future cash inflows can be considered an "investment." A meal that is popular with customers and has good financial performance is equivalent to a successful investment project. With a view of menu items as investment projects, restaurant managers must make trade-offs between menu items and content and between project evaluation accuracy and potential time volatility. Since these decisions are no different from those in other investment analysis, this research analyzes each menu item as an individual investment. The primary factor when evaluating such investments is the uncertainty of future menu sales. The real option pricing method allows us to evaluate future sales uncertainty.

A "real option" is an application of the financial option concept to real capital. Real options were first developed by Myers (1977), who argued that cash flow from an investment arises from the use of currently owned assets with the right to future investment opportunity. Option theory can

[1]National Kaohsiung Hospitality College, Kaohsiung, Taiwan, Province of China

Corresponding Author:
Chih-Yun Yang, National Kaohsiung University of Hospitality and Tourism, Department of Hospitality Marketing and Event Management, No1 Sung-Ho Rd.,Hsiao-Kang Destric, Kaohsiung, 802, Taiwan
Email: chihyun@mail.nkuht.edu.tw

Exhibit 1:
Three matrices models



Source: Hayes and Huffmann (1985).

therefore be applied to assess the value of investment projects, such as restaurant menu items. By applying the binomial model to real option evaluation, managers can estimate the intrinsic profit of each menu item at a future point in time and develop their menus accordingly. Before we examine the binomial option pricing model, let us review menu matrix analysis routines. Then we use the binomial option pricing method to analyze actual 2008 POS data for the sample restaurant's entrée menu and to compare the result using MMAM analysis.

Development and Imperfection of Matrix Menu Analysis Model

The earliest menu analysis technique that applied the matrix categorization concepts was developed by Miller (1980). Miller proposed that menu items could be categorized on a matrix according to the percentage of ingredient cost and the item's proportion of total sale. Kasavana and Smith (1982) took this a step further with a menu engineering model (MEM) that modified Miller's percentage of cost construct to marginal contribution (sales minus costs). Kasavana and Smith further defined the percentage of sales construct as the index of product popularity. Bayou and Bennett (1992) proposed that MEM can be considered a system for categorizing the sales and marginal benefits of menu items as well as a tool for analyzing the marginal benefits of menu sales price and cost and differences in total revenue. Pavesic (1983) modified MEM by using weighted contribution margins and percentage of food ingredient costs for his menu item matrix. Although the constructs are different, the matrix analysis models developed by Miller, Kasavana and Smith, and Pavesic used similar methods of categorizing menu items, as shown in Exhibit 1.

Although they are easy to use, these matrix models use overly simplified categorizations that yield imperfections in their analytical results, thereby limiting their use by managers for actual decision making. For instance, Beran (1995) argued that using average value for menu item sorting and categorization was inappropriate if the purpose of menu engineering was to maximize profits. Pavesic attempted to address the core problem of menu engineering that attempts to maximize the marginal contributions of menu items. If the total marginal contribution is no higher than the original meal after menu item modification, the Miller model and MEM reveal no effects. Pavesic's model still has weaknesses common to all three MMAMs, because it uses average values and indexes. Items are either higher or lower than average, for instance, and each menu item is therefore tightly linked to the location of the four quadrants. If any menu item in the matrix is moved, all other menu items must be recalibrated (Hayes and Huffmann 1985; Atkinson and Jones 1994). If a poorly performing menu item is replaced with a different item, the original sort changes, and items that have performed well may be deemed underperforming. As in the following, managers would be thrown into an endless loop of trying to improve the menu content (Bayou and Bennett 1992).

Another notable issue is that MMAM did not include costs other than direct materials. LeBruto, Quain, and Ashley (1995) included labor as the third construct and changed the original two-dimensional MEM model into a three-dimensional model that provided a more detailed categorization system (eight categories rather than four). Cohen, Ghiselli, and Schwartz (2006) proposed a multidimensional model that included five variables: food cost, price, labor cost, popularity, and marginal contribution, but the sorting of advantages and disadvantages still resemble that of other MMAMs. In addition, items with high marginal contribution were usually served with high-priced meals, and the menu items' food costs also constituted a higher percentage of total materials cost, which is why high-priced meals with high marginal contribution would also reduce the quantity of restaurant products and services that customers require (Coltman and Jagels 2001).

Finally, as we hinted above, MMAM and other menu analysis models do not provide managers with sufficient information for timing the removal and replacement of menu items. The current menu analysis models discussed above and data analysis could only be obtained when restaurants have a sufficiently long operating history (sales percentage of each menu item). Sales percentage data may differ, for instance, between months or between seasons. A sales fluctuation caused by time effects may cause an inappropriate reclassification of items from an unfavorable segment to a favorable one. This error may cause restaurant managers to incorrectly decide to replace high-value items. This matter of time is the reason that we propose the real option analysis model.

Because we cannot see the future, real option analysis is an iterative process. Menu item alternatives are derived by a series of decisions, and the current decision only provides opportunities at the next decision level. For each menu item, this study viewed the next opportunity level as a "call option," and the next level of menu item sales is assumed to be better than the previous one. This "bull market" expectation for menu items is consistent with the expectations for value menu items. Menu planning analysis using a timeline vertical section by real option not only provides managers with valuable information for actual menu items but it can also predict changes in the analytical results.

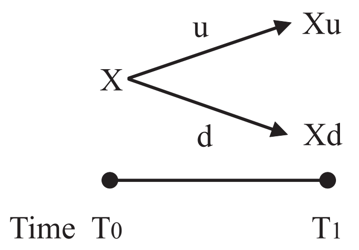
Applying and Implementing the Binomial Real Option Pricing Concept

The real option concept was derived from the continuous option pricing theory developed by Black and Scholes (1973). Application of this model proved difficult until Cox, Ross, and Rubinstein (1979) developed an option pricing theory that used a simpler binomial distribution in discrete time rather than the continuous option approach.

The binomial lattice option pricing model developed by Cox, Ross, and Rubinstein (1979) is a simple and flexible option pricing method. The advantage of this model is the easier application of mathematical formulas in actual cases and the clearer expression of its financial implications in comparison with the Black-Scholes pricing model. What Cox, Ross, and Rubinstein determined is that as the time-steps approach zero and the number of steps approach infinity, the results stemming from a binomial lattice approximate those obtained by the Black-Scholes pricing model (Mun 2002).

Binomial pricing theory is structured according to risk neutral pricing theory, which transfers each period's cash flow from risk aversion to cash flow under risk neutrality. It then obtains the present value with the discounted risk-free rate. This method can include the future uncertainty of investment plans, and it uses open market information rather than subjective judgments, as occurs with other models, making its assessment results more subjective and rational. Without derivation of difficult mathematical theory, certain hypothesis constraints can be eliminated. This study applied the binomial option pricing model developed by Cox et al. (1979) to derive the one-period call option value of real option.

Exhibit 2:
Changes of menu entrée future sales



If menu item cash inflow from sales is X, two changes may occur in the future: sales may increase X_u or decrease X_d. The value u is the increased multiplier of X to be future X_u, and its occurrence probability is P. The value d is the multiple of X used to determine future decrease in sales X_d, and its occurrence probability is $(1 - P)$. The changes in menu item sales for one time-step period are illustrated in the lattice in Exhibit 2.

When the potential profitability of a menu item is viewed as a call option, the call option values of this menu item change to C_u and C_d, which are corresponding future variations of X_u and X_d. That is, the future alternative value of menu items change according to the changes in the sales performance of menu items. Thus, C_u and C_d present the possible call option price under the status of X_{uu} and X_{dd}. The analysis extends from one time-step period to another time-step, and the option value of each period continues moving backward to the previous period and accumulating discount to C. This procedure is illustrated on the lattice in Exhibit 3.

Call options assume that investors get loan amount B, with risk-free interest r, to make one-item meals n times. It also assumes the return of total principal and interest with the same cash flow and total selling price if future sales increase, given loan amount B with interest r. After building this investment portfolio at period T_0, the compensation for call option and investment portfolios should be equivalent regardless of the rise or fall in menu item sales at T_1 period if the market has no risk-free arbitrage opportunities. The derivation entrée's call option value is shown in Exhibit 4.

We can summarize the relationships in Exhibit 4 as follows:

$$Cu = nuX - (1+r)B \,, \tag{1}$$

Exhibit 3:
Relationship of menu entrée option value vs. changes in future sales

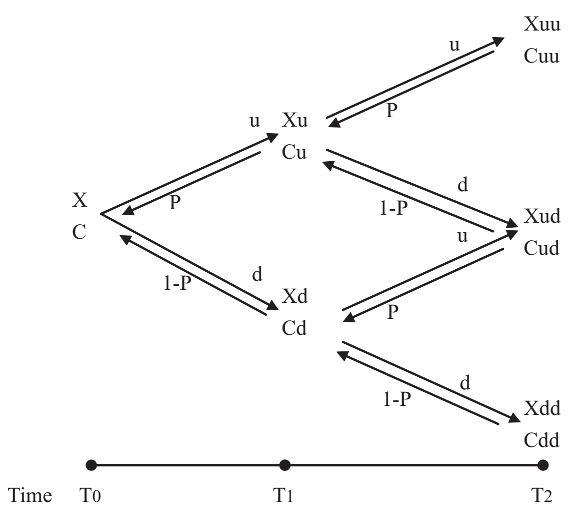
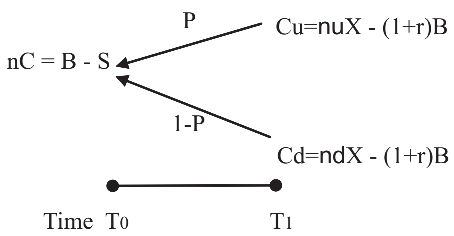


Exhibit 4:
Derivation of menu entrée's call option value



$$Cd = ndX - (1+r)B\,. \tag{2}$$

Combining equations (1) and (2) and solving for n and B, we get:

$$\text{N} = \frac{Cu - Cd}{(u-d)X},\ \text{B} = \frac{dCu - uCd}{(u-d)(1+r)}\,. \tag{3}$$

Without arbitrage opportunities, the price should be the same for the call option value after spending B money to make n meals as it is to replicate this relationship through a portfolio of call options. Therefore,

$$C = nX - B$$

assuming $(1+r)$ as R.

Substituting B and n from equation (3) into the formula, $C = nX - B$, we get

$$\begin{aligned} \text{C} &= \frac{Cu - Cd}{(u+d)X} \cdot X - \frac{dCu - uCd}{(u-d)(1+r)} \\ &= \frac{\dfrac{(1+r)-d}{u-d}Cu + \dfrac{u-(1+r)}{u-d}Cd}{(1+r)}\,. \end{aligned} \tag{4}$$

Let $P = \dfrac{(1+r)-d}{u-d}$.

We can then simplify equation (4) as follows:

$$\text{C} = \frac{P \times Cu + (1-P)Cd}{1+r}\,. \tag{5}$$

The formula shown in equation (5) represents the real call option value of a menu item. As for the determination of rise margin u and fall margin d at each period, the real call option pricing model P is viewed as call option rise probability under the risk-neutral assumption. Call option value is calculated by the possible future value C_u and C_d and multiplied by the risk-neutral probability and finally discounted to present value with risk-free interest. Cox, Ross, and Rubinstein (1979) demonstrated in their study that the binomial pricing model could operate as follows under the assumption of risk-neutrality.

We can model this situation using the following parameters:

$$u > r > d > 0 \quad u = 1/d$$

u = increased multiplier at each period
d = decreased multiplier at each period
σ = underlying asset volatility
Δt = time unit
r = risk-free interest

Increased multiplier at each period, $u = e^{\sigma\sqrt{\Delta t}}$

Decreased multiplier at each period, $d = e^{-\sigma\sqrt{\Delta t}}$

Risk-neutral probability, $P = \dfrac{e^{r\Delta t} - d}{u-d}$

Data Collection and Data Verification

Let us demonstrate how this works in practice. This study used POS system data for all entrées sold in 2008 at a popular restaurant in Kaohsiung, Taiwan. The sales data included five dishes: Chicken Cordon Bleu, Sirloin Steak, Long Island Roast Duckling, Lamb Steak, and Pork Steak. The time-step unit was one week for each item.

Exhibit 5:
Entrée Annual Sales, Average, Actual Standard Deviation, and Simulation Standard Deviation (2008)

Menu Entrée	Entrée Annual Sales	Weekly Average Sales	Standard Deviation of Actual Sales	Standard Deviation of Normalized
Sirloin Steak	4,881	94	9.0207	8.5422
Long island Roast Duckling	4,190	81	5.9123	6.0774
Lamb Steak	4,228	81	5.9328	5.8434
Chicken Cordon Bleu	4,454	86	6.3056	6.4224
Pork Steak	3,656	70	5.7036	5.9329

Using the Cox, Ross, and Rubinstein model that we discussed above, we calculated the standard deviation of actual number of sales and average sales for the five entrées. We assumed that sales data for each menu item were subject to a normal distribution, so a computer program was used to perform a volatility simulation by the bootstrap method for each menu item for twenty years (twenty steps) to obtain the standard deviation of sales after the simulation. Exhibit 5 shows annual sales, weekly average sales, standard deviation of actual sales, and normalized standard deviation thus obtained.

To review, the following are the binomial model parameters we used in this paper.

- X means sale of each entrée in the binomial lattice model.
- V means the share of fixed cost for each menu entrée.
- C means the real option value for each menu entrée.
- σ means the volatility based on sales data for the previous year (fifty-two weeks) from the POS system's data for the sample restaurant and using bootstrap to simulate standard deviation of each entrée under normal conditions.
- Sample restaurant data. In this study, each time-step unit represented one week, so $\Delta t = 1$.
- Risk-free rate based on the twenty-year U.S. bond yield as of November 24, 2008, $r = 4.01\%$, which is the yield on a 20-year U.S. government bond as of November 24, 2008. This is the closest possible approximation to a risk-free investment.

- Increased multiplier $u = e^{\sigma\sqrt{\Delta t}}$.
- Decreased multiplier $d = e^{-\sigma\sqrt{\Delta t}}$.
- Risk-neutral probability $P = \dfrac{e^{r\Delta t} - d}{u - d}$.

The biggest advantage of using the real option model for menu engineering is its inclusion of fixed costs as a consideration in decision making. This study assumes that the minimum objective of any restaurant is to break even, so the principle of fixed cost sharing should be applied to each menu item, in this case applying an average fixed cost to each menu item. Using the sample restaurant as example, the total monthly fixed cost is approximately US$8,850 (including salaries, rent, and the like). Only considering the five entrées, the weekly average cost is $442.50. This amount of $442.50 is an important decision-making condition for each item in this menu, because this study adopted an abandonment option strategy to examine the correlations between the weekly profit margin of each item and weekly share costs. In short, an item should be dropped if its weekly profit margin is lower than $442.50.

Data Analysis

Exhibit 6 gives the parameters for each of the five entrées, including volatility, time-step, increased multiplier, decreased multiplier, and risk-neutral probability, which are entered into a spreadsheet for calculation.

The initial cash inflow of the items, shown in Exhibit 7, also uses 2008 data, and this initial sales net cash inflow for each entrée is used as the marginal profit of each entrée multiplied by the average weekly sales number of the POS data for 2008. The amount after multiplication is the standard net cash inflow for each product at the beginning of the first node on binomial lattices.

Exhibit 8 shows how this analysis works for Sirloin Steak, based on the increase multiplier, decrease multiplier, and initial net sales cash inflow. The binomial tree model in Exhibit 8 starts with the $559.30 initial net cash flow, as shown in Exhibit 7. Given that the increase multiplier of Sirloin Steak's sales is 1.0891 and the decrease multiplier of Sirloin Steak's sales is 0.0981 (as shown in Exhibit 6), the lattices of Sirloin Steak's sales cash flow can be constructed. Exhibit 8 then shows the value from each time-step (node), which represents the net sales cash inflow for each future time-step (node).

The figures in Exhibit 8 do not account for average fixed costs, so we show the results of deducting $442.50 from each week's call option value, as adjusted by its

Exhibit 6:
Binominal Parameter Value of Entrée

Entrée/Parameter	Σ	Δt	*u*	*d*	*P*
Sirloin Steak	8.5422	1	1.0891	0.9181	0.7181
Long Island Roast Duckling	5.7774	1	1.0594	0.9438	0.8401
Lamb Steak	5.8434	1	1.0601	0.9432	0.8358
Chicken Cordon Bleu	6.4224	1	1.0663	0.9378	0.8024
Pork Steak	5.9329	1	1.0611	0.9423	0.8301

Exhibit 7:
Initial Cash Inflow Standard of Menu Entrée (Unit: U.S. dollars)

Menu Item	Profit Margin	Average Weekly Sales	Initial Sales Net Cash Inflow
Sirloin Steak	5.95	94	559.3
Long Island Roast Duckling	8.32	81	673.92
Lamb Steak	4.69	81	380.17
Chicken Cordon Bleu	7.75	86	666.5
Pork Steak	7.36	70	515.2

risk-neutral probability. The highlighted nodes in Exhibit 9 show the result of the rule that items are removed if their anticipated cash flow is less than zero (and the lattice shows negative numbers as zero). In Exhibit 9, the risk-neutral probability of Sirloin Steak is 0.7181 (again, shown in Exhibit 6). The call option value, then, is the discounted present value from the end node of the lattices back through each previous node as modified by the risk-neutral probability and finally risk-free interest rate. The \$442.50 fixed cost will be deducted from the present value of each node and will accumulate to the first node on the top of lattices. As this exhibit shows, the value of each time-step (node) represents the net sales cash inflow accumulated from each future time-step (node). Although we calculated all fifty-two time steps (and although the derivation can be extended infinitely), we show only ten weeks (ten nodes) for the sake of space.

At this point in the analysis, the restaurant manager must determine the overall direction of economic forces. In the case of the steak, this entrée will provide strong cash flow if the economy (and, thus, sales) continues upward, or even holds steady. However, the implicit profit of Sirloin Steak is zero at the node of the seventh week if sales remain depressed. So a restaurant manager could expect the Sirloin Steak to confer value for seven weeks even during slow economic times. Exhibits 10 through 13 show this forward-looking analysis for the other four entrées. The binomial tree diagram shows that each menu item has its own implicit profit, as well as its own call option value structure.

Results and Discussions

The analyses of menu items in this study using binomial model revealed the following main differences between real option analysis and MMAM.

1. The real option model considers sales uncertainty as a value creation opportunity and provides a scientific method for evaluating the future profit of a menu item.

All the MMAM analytical tools show that the lamb is a weak entrée, but the real option model offers direction on when to feature it and when to remove it. Kasavana and Smith's model would term the lamb steak an underperforming item and would recommend removal. Even with its initial cash inflow value, \$380.17, it does not cover its share of fixed costs. According to the MMAM category and individual item cash inflow, lamb steak is a failed menu item. From the real option perspective, though, lamb steak has possible future net present value (Exhibit 11) under the circumstances of economic growth. Lamb steak hence has the implicit profit of \$60.63 according to real option pricing. Although its financial contribution is lower than that of other items, this menu item still has sufficient value for inclusion in the menu from an options perspective. Meanwhile, this item may also maintain the loyalty of customers who enjoy lamb.

2. Real option analysis can sort menu items according to the two constructs of implicit profit and existence period.

The static menu analysis tools are unable to analyze the actual values of menu items and instead categorize them by rank order. Therefore, they are not able to order the menu items by their potential values. For instance, from the data, Long Island Roast Duckling and Pork Steak will be categorized as "puzzles" by Kasavana and Smith, items that have a high marginal contribution but low sales. However, the call option approach shows a substantial difference between the duckling and pork steak. The duckling has double the implicit profit of pork steak

Exhibit 8:
Binomial lattices diagram of Sirloin Steak sales net cash inflow

										1205.7
									1107.1	
								1016.5		1016.4
							933.4		933.3	
						857.0		856.9		856.8
UpState	1.0891				786.9		786.8		786.7	
DownState	0.9181			722.5		722.4		722.4		722.3
			663.4		663.3		663.3		663.2	
		609.1		609.1		609.0		609.0		608.9
	559.3		559.2		559.2		559.1		559.1	
		513.5		513.4		513.4		513.3		513.3
			471.4		471.4		471.3		471.3	
				432.8		432.8		432.7		432.7
					397.4		397.3		397.3	
						364.8		364.8		364.8
							335.0		334.9	
								307.5		307.5
									282.3	
										259.2

Exhibit 9:
Call option value binomial lattices diagram of Sirloin Steak

										763.24
									682.57	
Risk Free	0.04							609.16		573.93
							542.40		508.60	
						481.71		449.28		414.34
Discount Rate	0.96				426.58		395.47		361.94	
Week Cost	442.5			376.55		346.69		314.50		279.81
			331.18		302.51		271.61		238.30	
		290.11		262.60		232.92		200.89		166.40
	232.97		226.67		198.20		167.40		134.08	
		194.47		167.29		137.87		105.83		70.79
			140.05		112.30		82.22		48.88	
P	0.7181			90.53		63.09		33.75		0.00
1-P	0.2819				47.92		23.30		0.00	
						16.09		0.00		0.00
							0.00		0.00	
								0.00		0.00
									0.00	
										0.00

with real option pricing (Exhibits 10 and 13), and the existence period of duckling (the length of time one could expect a profit) is three weeks longer than pork steak assuming economic recession.

This matter of existence period is a useful gauge. Based on the implicit profit from the first node of every lattice and the existence period for each menu entrée, we can set up a table for the five entrées such as the one found in Exhibit 14, which is rendered graphically in Exhibit 15.

The summary graph in Exhibit 15 shows that Roast Duckling is potentially the most profitable entrée, nosing out Chicken Cordon Bleu, which was considered an all-star item by MEM. Its existence period is shorter than that of Long Island Duckling during economic recession.

Exhibit 10:

Call option value binomial lattices diagram of Long Island Roast Duckling

										690.29
									644.73	
Risk Free	0.04							601.98		566.68
							561.86		527.95	
						524.23		491.65		456.56
Discount Rate	0.96				488.92		457.63		423.92	
Week Cost	442.5			455.81		425.75		393.36		358.45
			424.77		395.89		364.77		331.23	
		395.66		367.92		338.02		305.80		271.06
	342.73		341.73		313.00		282.04		248.66	
		317.21		289.61		259.86		227.79		193.19
			267.75		239.16		208.34		175.10	
P	0.8401			219.85		190.23		158.29		123.83
1-P	0.1599				173.38		142.68		109.56	
						128.22		96.37		62.03
							84.34		51.18	
								42.21		6.98
									5.64	
										0.00

Exhibit 11:

Call option value binomial lattices diagram for New Zealand Lamb Steak

										200.33
									181.44	
Risk Free	0.04							163.89		129.45
							147.61		114.51	
						132.54		100.71		66.38
Discount Rate	0.96				118.63		88.11		54.96	
Week Cost	442.5			105.85		76.75		45.47		10.26
			94.16		66.58		37.59		8.25	
		83.50		57.55		31.05		6.63		0.00
	60.63		49.59		25.63		5.33		0.00	
		42.61		21.14		4.28		0.00		0.00
			17.43		3.44		0.00		0.00	
P	0.8358			2.76		0.00		0.00		0.00
1-P	0.1642				0.00		0.00		0.00	
						0.00		0.00		0.00
							0.00		0.00	
								0.00		0.00
									0.00	
										0.00

3. Real option analysis is able to provide managers with dynamic menu management decisions.

The real option analysis model enables managers to extend existing data for predictions about menu sales. For example, the model clearly reveals the potential profit fluctuations of each item in the binomial tree graphic, and it simulates possible routes to the future sales. During recession, managers can project the exit time for each item, and they can control material preparation and storage as well as track the dynamic value of each item by actual sales performance and actual sales time. In addition, managers have better control of materials costs and can increase the margin profit of menu items in order to extend their lifetimes during

Exhibit 12:
Call option value binomial lattices diagram of Chicken Cordon Bleu

										745.22
									689.36	
Risk Free	0.04							637.32		602.09
							588.85		555.01	
						543.71		511.22		476.21
Discount Rate	0.96				501.69		470.48		436.85	
Week Cost	442.5			462.58		432.61		400.31		365.49
			426.19		397.40		366.38		332.93	
		392.34		364.69		334.89		302.76		268.12
	335.79		334.31		305.68		274.82		241.54	
		306.10		278.60		248.95		216.98		182.48
			253.50		225.02		194.29		161.16	
P	0.8024			202.90		173.39		141.52		107.17
1-P	0.1976				154.17		123.59		90.46	
						107.35		75.79		40.93
							63.11		31.58	
								24.36		0.00
									0.00	
										0.00

Exhibit 13:
Call option value binomial lattices diagram of Pork Steak

										436.08
									403.25	
Risk Free	0.04							372.60		337.80
							343.98		310.55	
						317.28		285.15		250.51
Discount Rate	0.96				292.36		261.50		228.21	
Week Cost	442.5			269.13		239.47		207.49		172.99
			247.47		218.97		188.24		155.09	
		227.29		199.91		170.38		138.51		104.14
	188.96		182.19		153.83		123.23		90.14	
		165.75		138.53		109.20		77.55		42.99
			124.42		96.40		66.38		34.31	
P	0.8301			84.78		56.55		27.39		0.00
1-P	0.1699				47.99		21.86		0.00	
						17.45		0.00		0.00
							0.00		0.00	
								0.00		0.00
									0.00	
										0.00

recession. The real option model enables a dynamic style of managing restaurant menu items.

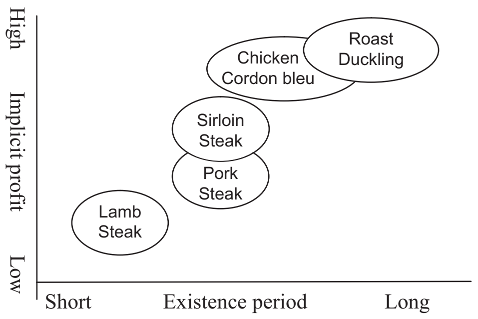
Conclusion

In closing, we must stress that this study only considered sales data for five main entrées from the menu of a single restaurant. There is no reason to believe that this analysis would not apply to other restaurants, or to other menu categories, such as appetizers, soups, desserts, and drinks. We do not suggest disregarding menu-engineering methods, but instead that managers combine the real option analysis model with other models such as MMAM in actual practice. Managers are able to use MMAM for initial analysis and categorization of menu items. Real option can then be used to further define the implicit profit of each menu item and to precisely distinguish the sorting of items in each category and their true values in order to enhance restaurant operational efficiency and gain the biggest profit.

Exhibit 14:
The Implicit Profit and Existence Period of Each Entrée

Item/Construct	Implicit Profit	Existence Period
Sirloin Steak	232.97	5 week (node)
Long Island Roast Duckling	342.73	8 week (node)
Lamb Steak	60.63	3 week (node)
Chicken Cordon Bleu	335.79	7 week (node)
Pork Steak	188.96	5 week (node)

Exhibit 15.
Entrée sorting by implicit profit and existence period (summarizing Exhibit 9 to Exhibit 13)



Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Bios

Chih-Yun Yang, PhD, is an Associate professor in the department of hospitality marketing and event management at National Kaohsiung University of Hospitality and Tourism (chihyun@mail.nkuht.edu.tw) where **Te-Yi Chang**, PhD, is an Associate Professor of Graduate Institute of Travel Management, National Kaohsiung University of Hospitality and Tourism, Taiwan.