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Expanding Operations in Fast-Food Industry under Uncertain Market Conditions

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***Abstract*—In the last two years global economic crisis has devastated almost all business sectors. However, the fast food sector is a one of the industries that has managed to be saved from the crisis. The industry is experiencing phenomenal growth that has been stimulated by the consecutive increases of consumer consumption and capital investment in many countries. Investments into the sector create ever growing furious competition expanding in the global markets.**

In this study, a simulation optimization spreadsheet model was proposed for the decision of expanding operations in the fast-food industry. The model was presented via a hypothetical illustrative example and was aimed to determine optimum number of stores and their locations considering uncertain market conditions. The problem was solved by the use of "RISKOptimizer" optimization software, which has been recently introduced and is a simultaneous application of the Monte Carlo simulation and genetic algorithm.

***Index Terms*—Decision Making, Fast-Food Industry, Simulation Optimization, Uncertainty.**

I. Introduction

Recent global economical crisis, originated in USA, has had a crippling effect on almost all financial sectors in many countries. Surprisingly, the fast food industry has not been adversely affected; on the contrary, it has shown signs of growing faster, creating more fierce competition. The main reason may be precautious spending of the food dollars on cheaper fast food than on expensive luxury restaurants, fueled by the attractive prices offered by the advertisement campaigns of the fast food companies.

For instance, China, which is the fifth largest fast food consuming nation in the world, has been experiencing phenomenal growth in the fast food industry; with the compounded annual growth rates of the market crossing 25%. Moreover, with the fast emerging middle class population and surging disposable income, it is expected that the industry will continue to grow at a pace in coming years [2]. In UK, the number of outlets selling food on-the-go has surged during the recession. Among the UK's biggest fast-food chains, Subway grew its number of restaurants by 25.9 per cent to 734 in 2009, Domino's increased its outlets by 19.8 per cent to 260, and Eat expanded its estate by 17.8 per cent to 86, according to the Local Data Company's survey of 705 town centers. In the 10 biggest cities, fast-food outlets soared by 8.2 per cent to 1,456 premises, with London, Edinburgh and Glasgow leading the way [16]. In US, the fast food industry has reported significant growth despite being severely affected by the economic turmoil. According to "US Fast Food Market Outlook 2010", fast food is an important segment of the restaurant industry and growth of this segment is outpacing the growth of overall restaurant industry [30].

According to PricewaterhouseCoopers, fast food is proving to be recession-proof in emerging markets. Because the fast-food sector works from a franchise model, expansion into emerging markets has been rapid and comparatively low-risk in financial terms. In spite of economic recession, firms like Subway, McDonalds, KFC and Domino's Pizza have opened new stores in the emerging markets in the recent times [14]. Subsequently, many food companies are trying to increase their profits by pushing into new markets in the global scale.

Fast food restaurant site selection problem have been analyzed in several studies. In Melaniphy's study [17], principles of fast food restaurant site selection were emphasized. In the study, geography, sales size and trends, market size, type of location, accessibility, topography, visibility, adjacent uses, competition and demographics were considered location criteria. Timor and Sipahi [22] surveyed fast food restaurant site selection criteria and they analyzed their relative weights using Analytic Hierarchy Process method. According to their study, cost, location, visibility, traffic pattern, competition, areas' future and physical characteristics were found the most important factors. In another study, Lorentz [13] analyzed the location decision criteria and their relative weights in the context of food manufacturing internationalization into emerging markets. The study demonstrated that economic activity potential, consumption potential, available acquisition targets, adequate supply of raw materials, competitive situation, favorable level of input costs, and supply chain management readiness are the most important factors in the location decision. In their study, Hurvitz et al. [23] examined potential associations between demographic factors, a novel transportation variable and fast-food restaurant density in King County at the census tract level. Their study demonstrated that fast food restaurant density was significantly associated in regression models with low median household income and high arterial road density.

Differing from previous studies, the purpose of this study is to propose an alternative spreadsheet optimization model for the problem of expanding operations in multiple locations in the fast-food industry. The model aims to determine the optimum number of new stores in various locations considering uncertainty in the market conditions. The model

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was presented and solved by "RISKOptimizer" optimization tool, which successfully combines genetic algorithm with Monte Carlo simulation.

II. Simulation Optimization Applications in Service Sector

The simulation optimization can be defined as the process of finding the best input variables among all possibilities without explicitly evaluating each of the possibilities [33]. Overview of methodologies and applications was conducted by Carson and Maria [33] and Azadivar [11].

In the recent years there is a growing interest in the use of simulation optimization models in the service sector. For instance, in their study, Hutchison and Hill [10] investigated ways to reduce the cost and magnitude of air traffic delays. They used the SIMMOD air traffic simulation to model the problem in order to determine a set of control measures that achieve the best system performance. The model was a constrained stochastic optimization problem with nonlinear objective function and nonlinear stochastic constraints. They used the simultaneous perturbation stochastic approximation algorithm. In another study, Su and Yao [26] conducted a field study in a Shanghai public hospital to investigate the hospital's registration process and collected the data to determine the elapsed time between the inter-arrival time and every procedure's service time. By using MedModel software, they set up a simulation model based on the realistic workflow and the operational data. The optimized registration process was able to shorten the average cycle time from 17.24 minutes to 3.15 minutes. Gosavi, Ozkaya and Kahraman [1] developed a model-free simulation-based optimization model to solve seat-allocation problem arising in airlines. Their model was designed to accommodate a number of realistic assumptions for real-world airline systems. Dzeng and Lee [27] proposed a model searching the optimal development schedule of resort projects by integrating simulation and a polyploidy genetic algorithm. The model prioritized the value that each amenity brought to the project, and constructed the development schedule based on net present values. In their study, Dittman and Hesford [9] combined optimization with Monte Carlo simulation to model an investment decision by means of a case study of a hotel considering converting a portion of its inventory to allergy-friendly rooms. Klassen, and Yoogalingam [19] used a simulation optimization approach to determine optimal rules for a stochastic appointment scheduling problem in an outpatient health care service. Their model allowed for the consideration of more variables and factors than did prior studies.

RISKOptimizer is one of the commercially available tools for modeling and solving simulation-based optimization problems. It uses a proprietary set of genetic algorithms to search for optimum solutions to a problem, along with probability distributions and simulation to handle the uncertainty in the model [25]. While the optimization is in progress, it runs a Monte Carlo simulation for each trial solution and finds the combination of decision variables that provide the best simulation results. In the last ten years, RiskOptimizer has been used in several studies especially in finance and manufacturing. Table 1 summarizes remarkable studies that RiskOptimizer was utilized.

TABLE 1 Literature of RiskOptimizer Studies

Ref. #	Journal/Publication Name	Year	Author(s)	Problem Definition
[29]	J of Revenue and Pricing Man.	2009	S. Kumar; T. Ressler; M. Ahrens	Selection of an optimal product configuration for a new business venture
[12]	Expert Systems with Appl.	2009	F. C. Yuan	Application of real options to value expansion investment
[6]	J of Business Case Studies	2008	D. F. Togo	Risk Analysis for capital budgeting
[15]	Omega	2008	J. Sounderpandian, S. Prasad, M. Madan	Optimizing order quantity when raw material suppliers of a global supply chain are situated in developing countries
[9]	Cornell Hotel and Restaurant Administration Quarterly	2007	D. A. Dittman; J. W. Hesford	Simulation optimization for investment decision for a hotel considering the converting a portion of its inventory to
[18]	Ecology Letters	2007	J. C. Svenning; F. Skov	Estimating migration rate probability distribution functions
[21]	Journal of Applied Statistics	2007	M. Evans; R. E. Johnston	Optimizing production scheduling model
[8]	Journal of Engineering Design	2006	D. Lacey; C. Steele	Augmenting design of experiments for optimization and robustification
[3]	Omega	2005	C. Chandra, M. Everson, J. Grabisa	Determining the overall business value of flexible manufacturing systems
[20]	Probl. and Perspectives in Man.	2004	M. A. G. Dias; M. A. Rivera	Modeling of dynamic hedging
[7]	Information and Software Tech.	2004	D. Greer, G. Ruhe	Software release planning
[4]	J of the Operational Res. Society	2003	C. Hope	What strategy should a football (soccer, in American parlance)club adopt when deciding whether to sack its manager
[24]	Social Science & Medicine	2003	P. Sendi, M. J. Al	Cost–effectiveness analysis under uncertainty
[28]	Logistics Information Man.	2001	R. L. Nersesian; M.D. Troutt; G. J. Weinroth	Maximizing quality performance in terms of a cost-benefit analysis
[31]	Western Agricultural Economics Association Annual Meeting	2000	W. A. Wilson; B. L. Dahl; D. D. Johnson	Evaluating cost/risk tradeoffs of three alternative procurement strategies

III. Problem Definition

The hypothetical problem presented is based on Ragsdale [5]. Suppose that the franchisee of an international fast-food company is planning to expand its operations to more outlets in the nation for the coming year. The company operates three different types of stores as lunch counters, eat-in stores and stand alone stores. It has identified several locations for each type of new stores. There are two categories of costs associated with the new stores; setup cost and annual operation and maintenance cost. The company has made three operating cost versus annual return on investment estimates for each of the prospective site; a minimum possible value, a most likely value, and a maximum value. For each type of store, cost and return on investment estimates in dollars and full-time employees needed for alternative sites are given in Tables 2 through 4. The company wants to keep the total setup cost under $4,000,000 and the annual operating cost under $1,000,000. It aims to open minimum two and maximum twenty outlets for each type of stores. Also it does not want to open more than three stores in the same location. Even though the company does not have any limits or constraint on the number of employees, it is preferable to employ about minimum of 250 employees in total. The objective of the problem is to determine the number of stores to be opened in each site to maximize the total revenue of the new stores due to limited setup and operating budget.

TABLE 2. DATA FOR LUNCH COUNTER STORE ALTERNATIVES

	Alternative Sites			
Lunch Counter	**A**	**B**	**C**	**D**
Employees Needed	9	12	10	14
Annual Op. Cost (Worst)	$80,000	$85,000	$70,000	$95,000
Annual Op. Cost (Most Likely)	$60,000	$75,000	$60,000	$80,000
Annual Op. Cost (Best)	$50,000	$60,000	$50,500	$65,000
Costs	$150,000	$180,000	$160,000	$200,000
Annual Return (Worst)	$60,000	$75,000	$60,000	$90,000
Annual Return (Most Likely)	$85,000	$100,000	$90,000	$110,000
Annual Return (Best)	$100,000	$115,000	$135,000	$144,000

TABLE 3 DATA FOR EAT-IN STORE ALTERNATIVES

	Alternative Sites					
Eat-In Stores	**E**	**F**	**G**	**H**	**I**	**J**
Employees Needed	12	7	4	10	15	12
Annual Operating Cost (Worst)	$80,000	$70,000	$55,000	$75,000	$90,000	$65,000
Annual Operating Cost (Most Likely)	$65,000	$60,000	$45,000	$60,000	$75,000	$55,000
Annual Operating Cost (Best)	$55,000	$45,000	$38,000	$52,000	$65,000	$42,000
Costs	$275,000	$200,000	$150,000	$250,000	$300,000	$260,000
Annual Return (Worst)	$95,000	$75,000	$80,000	$90,000	$100,000	$90,000
Annual Return (Most Likely)	$125,000	$95,000	$100,000	$120,000	$150,000	$125,000
Annual Return (Best)	$145,000	$130,000	$120,000	$140,000	$164,000	$150,000

TABLE 4 DATA FOR STAND ALONE STORE ALTERNATIVES

	Alternative Sites				
Stand Alone Stores	**K**	**L**	**M**	**N**	**O**
Employees Needed	35	32	37	40	34
Annual Operating Cost (Worst)	$90,000	$75,000	$95,000	$100,000	$98,000
Annual Operating Cost (Most Likely)	$80,000	$70,000	$80,000	$85,000	$75,000
Annual Operating Cost (Best)	$65,000	$53,000	$72,000	$80,000	$64,000
Costs	$450,000	$420,000	$480,000	$480,000	$425,000
Annual Return (Worst)	$150,000	$110,000	$155,000	$150,000	$120,000
Annual Return (Most Likely)	$175,000	$150,000	$180,000	$200,000	$150,000
Annual Return (Best)	$195,000	$175,000	$190,000	$220,000	$178,000

IV. METHOD AND FINDINGS

When the annual operating cost and expected annual return on investment value for each new store are deterministic, a solution may be obtained by the use of integer linear programming. However, in this problem, annual operating cost and annual return values are probabilistic.

For modeling and solving the problem as a linear model, the annual operating costs and annual returns of each alternative site must be deterministic values. In the Table 5, for calculating the expected values of annual operating costs and annual returns, worst values, most likely values and best values were weighted by 25%, 50% and 25% respectively. Considering the Table 5, the integer linear programming model of the problem can be expressed as follows:

$$\text{Maximize} \sum_{c=1}^{4} R_c x_c + \sum_{e=1}^{6} R_e y_e + \sum_{s=1}^{5} R_s z_s \quad (1)$$

Subject to:

$$\sum_{c=1}^{4} O_c x_c + \sum_{e=1}^{6} O_e y_e + \sum_{s=1}^{5} O_s z_s \leq 1{,}000{,}000$$

$$\sum_{c=1}^{4} S_c x_c + \sum_{e=1}^{6} S_e y_e + \sum_{s=1}^{5} S_s z_s \leq 4{,}000{,}000$$

$$2 \leq \sum_{c=1}^{4} x_c \leq 20$$

$$2 \leq \sum_{y=1}^{6} y_e \leq 20$$

$$2 \leq \sum_{s=1}^{5} z_s \leq 20$$

$0 \leq x_c \leq 3$ for $c = 1,2,...4$
$0 \leq y_e \leq 3$ for $e = 1,2,...6$
$0 \leq z_s \leq 3$ for $s = 1,2,...5$

x_c = integer for $c = 1,2,...4$
y_e = integer for $e = 1,2,...6$
z_s = integer for $s = 1,2,...5$

R_c, R_e, R_s = Annual returns of lunch counter, eat-in stores and stand alone stores respectively

O_c, O_e, O_s = Operating costs of lunch counter, eat-in stores and stand alone stores respectively

S_c, S_e, S_s = Setup costs of lunch counter, eat-in stores and stand alone stores respectively

x_c, y_e, z_s = Number of lunch counter stores, eat-in stores and stand alone stores respectively to be opened in the corresponding alternative site

The problem was solved by Microsoft Excel Solver, which is a powerful spreadsheet tool for solving linear and some nonlinear models. The optimum solution was presented in the Table 5. In the Table 5, number of stores to be opened in alternative sites for each type of operation was defined as decision variable of the problem. Total labor, total operating cost, total setup cost and total annual return were calculated in the range I1:I4. The formulas of the integer linear spreadsheet model were presented in the Table 6. Inspecting the Table 5, it can be seen that the total revenue was found as $1,930,000. Number of lunch counter stores, eat-in stores and stand alone stores were found as 3, 11, and 2 respectively. The total number of employees is 269, which is exceeding 250.

TABLE 5 INTEGER LINEAR SPREADSHEET MODEL OF THE PROBLEM

	A	B	C	D	E	F	G	H	I	J	K
1								Total Labor	269		
2	Lunch Counter	A	B	C	D			Total Operating Cost	995,125	<=	$1,000,000
3	Labor	9	12	10	14			Total Setup Cost	3,965,000	<=	$4,000,000
4	Annual Operating Cost	$62,500	$73,750	$60,125	$80,000			Total Annual Return	1,930,000		
5	Setup Cost	$150,000	$180,000	$160,000	$200,000						
6	Annual Return	$82,500	$97,500	$93,750	$113,500						
7	Number of Stores	0	0	3	0	3	Total Number of Stores				
8											
9	Eat-In Stores	E	F	G	H	I	J				
10	Labor	17	12	10	15	20	16				
11	Annual Operating Cost	$66,250	$58,750	$45,750	$61,750	$76,250	$54,250				
12	Setup Cost	$275,000	$200,000	$150,000	$250,000	$300,000	$260,000				
13	Annual Return	$122,500	$98,750	$100,000	$117,500	$141,000	$122,500				
14	Number of Stores	0	1	3	1	3	3	11	Total Number of Stores		
15											
16	Stand Alone Stores	K	L	M	N	O					
17	Labor	35	32	37	40	34					
18	Annual Operating Cost	$78,750	$67,000	$81,750	$87,500	$78,000					
19	Setup Cost	$450,000	$420,000	$480,000	$480,000	$425,000					
20	Annual Return	$173,750	$146,250	$176,250	$192,500	$149,500					
21	Number of Stores	0	0	0	1	1	2	Total Number of Stores			
22											

TABLE 6 FORMULAS OF THE INTEGER LINEAR SPREADSHEET MODEL

CELL	FORMULA
B4	=80000*0,25+60000*0,50+50000*0,25
F7	=SUM(B7:E7)
H14	=SUM(B14:G14)
G21	=SUM(B21:F21)
I1	= SUMPRODUCT($B$7:$E$7,B3:E3) +SUMPRODUCT ($B$14:$G$14,B10:G10)+ SUMPRODUCT ($B$21:$F$21,B17:F17)
I2	= SUMPRODUCT ($B$7:$E$7,B4:E4)+SUMPRODUCT ($B$14:$G$14,B11:G11)+ SUMPRODUCT ($B$21:$F$21,B18:F18)
I3	= SUMPRODUCT ($B$7:$E$7,B5:E5)+SUMPRODUCT ($B$14:$G$14,B12:G12)+ SUMPRODUCT ($B$21:$F$21,B19:F19)
I4	= SUMPRODUCT ($B$7:$E$7,B6:E6)+SUMPRODUCT ($B$14:$G$14,B13:G13)+ SUMPRODUCT ($B$21:$F$21,B20:F20)

Even though the problem can be modeled as an integer linear model by the use of expected values of operating costs and annual returns, it would be more realistic to consider the probability distribution of operating costs and annual returns.

However, the spreadsheet model would be non-deterministic. For modeling uncertainty and solving the problem, @RISK 5.0 and RiskOptimizer 5.0, powerful Microsoft Excel spreadsheet tools by Palisade Corporation were combined. The RiskOptimizer spreadsheet model of the problem was presented in the Table 7.

TABLE 7 RISKOPTIMIZER SPREADSHEET MODEL OF THE PROBLEM

	A	B	C	D	E	F	G	H	I	J	K
1								Total Labor	278		
2	Lunch Counter	A	B	C	D			Total Operating Cost	$881,667	<=	$1,000,000
3	Labor	9	12	10	14			Total Setup Cost	$3,970,000	<=	$4,000,000
4	Annual Operating Cost	$63,333	$73,333	$60,167	$80,000			Total Annual Return	$1,720,000		
5	Setup Cost	$150,000	$180,000	$160,000	$200,000						
6	Annual Return	$81,667	$96,667	$95,000	$114,667						
7	Number of Stores	3	0	0	0	3	Total Number of Stores				
8											
9	Eat-In Stores	E	F	G	H	I	J				
10	Labor	17	12	10	15	20	16				
11	Annual Operating Cost	$66,667	$58,333	$46,000	$62,333	$76,667	$54,000				
12	Setup Cost	$275,000	$200,000	$150,000	$250,000	$300,000	$260,000				
13	Annual Return	$121,667	$100,000	$100,000	$116,667	$138,000	$121,667				
14	Number of Stores	0	2	1	0	0	3	6	Total Number of Stores		
15											
16	Stand Alone Stores	K	L	M	N	O					
17	Labor	35	32	37	40	34					
18	Annual Operating Cost	$78,333	$66,000	$82,333	$88,333	$79,000					
19	Setup Cost	$450,000	$420,000	$480,000	$480,000	$425,000					
20	Annual Return	$173,333	$145,000	$175,000	$190,000	$149,333					
21	Number of Stores	3	2	0	0	0	5	Total Number of Stores			

Mean (Best Simulation) = 1720930.6850

TABLE 8 RISKOPTIMIZER MODEL SETTINGS

RISKOptimizer Model			
Optimization Goal	Maximum	**Constraints**	**Type**
Cell to Optimize	=I4	2 <= F7 <= 20	Hard
Statistic to Optimize	Mean	2 <= H14 <= 20	Hard
Adjustable Cell Ranges:		2 <= G21 <= 20	Hard
0 <= B7:E7 <= 3	Integer	0 <= I2 <= 1000000	Hard
0 <= B14:G14 <= 3	Integer	0 <= I3 <= 4000000	Hard
0 <= B21:F21 <= 3	Integer		

At the RiskOptimizer model, number of iterations and total simulation number were set as 1000. It means that during the optimization process 1000 trials were made. Furthermore, since all constraints were defined as hard (Table 8), only trials that satisfy all constraints and optimality conditions were taken into account during the simulation. The summary of optimization results were presented in the Table 9. The optimal value of total annual revenue was found as $1,720,931. Optimum solution was evaluated at 438th simulation. For lunch counter stores, opening three stores in the site A was found optimal. For eat-in stores, opening two stores in the site F, one store in the site G, and three eat-in stores in the site J was found as the best solution. Also opening three stand-alone stores in the site K and two stand-alone stores in the site L was optimal. As can be seen in Table 7, all constraints and optimality conditions were satisfied.

TABLE 9 RISKOPTIMIZER MODEL RESULTS

Total Simulations	1000
Number of Iterations	1000
Valid Simulations	542
Best Value Found	$1,720,931
Best Simulation Number	438

V. CONCLUSION

Admittedly, the unfavorable economic conditions are the major driver in business decisions in many industries such as fast-food business. For the companies projecting to expand their operations to more outlets, it is definitely essential to be concerned with the uncertain market conditions while making the best decisions. The expected changes in operating costs and annual return in investments should be scrutinized. When problem data is deterministic, this type of decision problems can be modeled and solved easily by the use of linear integer programming. However, when the problem cannot be solved by linear models due to uncertain factors or stochastic variables, the RISKOptimizer spreadsheet tool can provide accurate solutions by using probability distribution functions and combining the Monte Carlo simulation with genetic algorithm-based optimization.

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