Department of Industrial Engineering

School of Engineering & Applied Sciences

Industrial Engineering Major

IE 420 - System Engineering Practicum

Lab Report 4 - Original Pancake House renovation plans

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Executive summary

The Original Pancake House in Williamsville, NY is a very well-known and popular restaurant. They are currently experiencing issues with customers balking upon seeing the length of the queue and simply not having enough room to meet their demand. Too much business is never a bad problem to have, but it is a problem nonetheless. The goal of this project is to analyze their current system with the help of ARENA simulation software and recommend some potential solutions to them.

The current system consists of 25 four person tables with enough room for a queue of 14 people. Any customers who arrive when the waiting area is full will balk because no one wants to wait outside in Buffalo in the midst of winter. The plan to solve the problem is to expand the restaurant to add more tables as well as more space for a larger queue. The main requirement is to be able to afford to repay their loan amount within 2 years.

With the combination of ARENA and an Economic Analysis, it was determined that the best option for the Pancake House would be to expand to 55 total tables and a queue capacity of 20 customers. This added square footage of 360 sq. ft. will yield the greatest profit when paired with an 18-month loan of $140,000. This would be a major expansion for the Pancake House and may even draw in new customers with the added space.

1. Problem statement

Original Pancake House is a domestic chain of restaurants specializing in providing breakfast items such as sweet pancakes and hearty scrambled eggs. One of its restaurants located along Main Street, Buffalo sees a high demand for their services. However, it is unable to keep up with the customer's demand due to high waiting times resulting in a high proportion of customers balking. The focus of this report is the reduction in the number of customers balking and to improve the customer's dining experience by reducing overall waiting time to get a table.

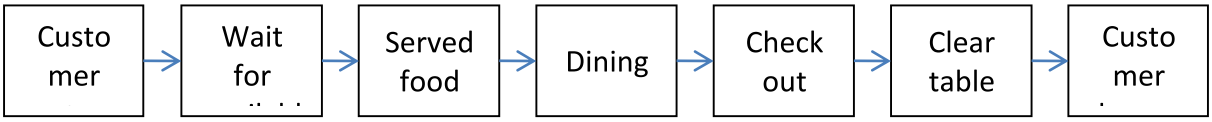

Figure 1.1: Process flow of Original Pancake House

Figure 1.1 illustrates the current process of the restaurant. First, customers enter the restaurant's waiting area which has a limited capacity. If there are too many customers waiting, they would have to wait outside the restaurant, providing the impression of a long queue which induces customers to balk. Customers wait for available tables to sit a number of customers in a group. Once a group of customers are seated, they would be served food. After consuming food, the group would proceed to check out before leaving the restaurant and the table will be cleared for the next group of customers.

2. Background

Original Pancake House will be renovating their premises which include upgrades to the kitchen, dining area, and the waiting area. Currently, the dining area has the capacity to house 100 customers while the waiting area has the capacity for 14 waiting customers.

A queuing-based optimization model can be developed to capture the demand with respect to the congestion on a simulation system to come up with a cost effective solution that balances the quality of service while maximizing profits (Hwang, Gao and Jang, 2010). To do so, data on the waiting time, service rate, and utilization rate would be collected to develop the M/M/s queuing model (Mishra, Chauhan and Chandra, 2013).

The two potential options to implement are to increase the seating capacity of the dining area, which is more expensive but would be able to allow the restaurant to cater to more customers and/or to increase the capacity of the waiting area, which is less expensive but does not effectively solve the problem directly.

3. Methodology

In evaluating possible expansion opportunities for Pancake House, the following assumptions are made:

- The fixed cost of a kitchen upgrade is $40,000. This cost is only implemented if the restaurant decides to expand.
- 10 square feet are required for both single customer queue place and a single customer seat, purchased at a rate of $80 per square foot expansion.
- A loan must be taken out to pay for the renovation. This loan will have an interest rate of 8% compounded annually.

Evaluation of possible expansion scenarios requires an experimental design to apply to an Arena model, which will be further described in Section 4. Two independent variables were used:

1. Total number of tables in the restaurant, with four treatment levels
2. Total queue capacity in restaurant, with two treatment levels

Combinations of these independent variables result in eight possible scenarios. Table 3.1 outlines the scenarios, with the index used for each.

Total Tables	**Queue Capacity**	
	14	**20**
25	A1	A2
35	B1	B2
45	C1	C2
55	D1	D2

Table 3.1: Scenario index

The current state of the restaurant is denoted by Scenario A1, with 25 tables and a queue capacity of 15. To assess these scenarios, weekly customers served was used as the dependent variable. Customers served is simply the difference between arrivals and balks over a week's time. For each scenario, four replications were completed in Arena to allow for more accurate comparison.

After outputs were obtained from Arena, a selection of statistical tests were applied to evaluate differences resulting from altering the independent variables. First, two-factor analysis of variance (ANOVA) was completed. Then, paired t-tests were completed for a selection of scenario combinations. The paired t-test is useful here, as Arena uses the same random number seeds for each replication of different scenarios. Directly comparing results from the same random number seed allows for greater accuracy. The results are further discussed in Section 5.

After statistical evaluation, an economic analysis was completed to determine the most cost-effective option for the restaurant. This includes loan calculations and long-term value of each scenario, and can be found in Section 6.

4. System Modeling

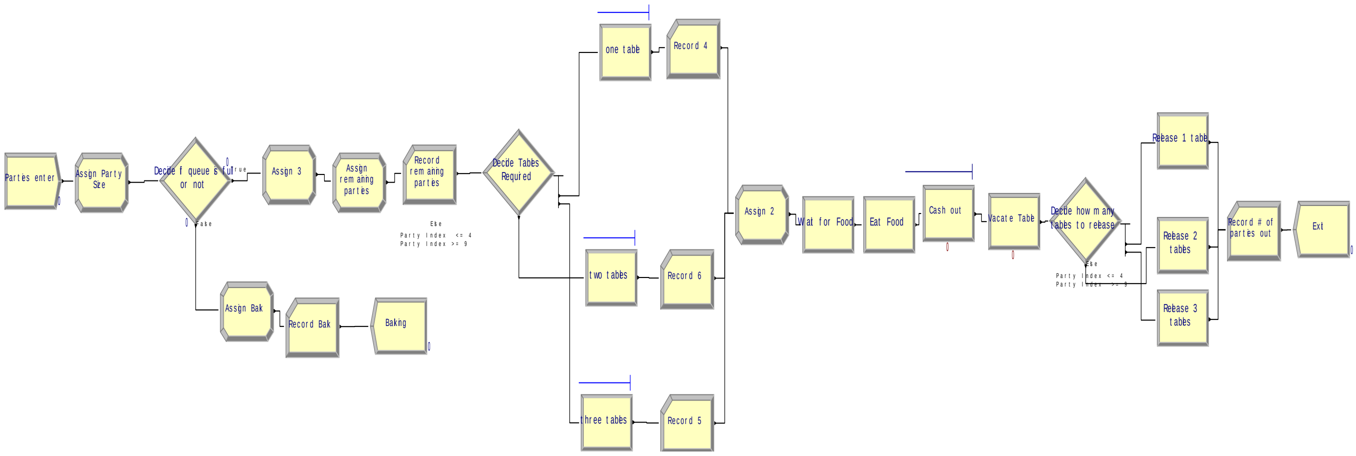

Figure 4.1: Simulation model of The Original Pancake House

Arena software is used to simulate advanced systems, so that the real scenario can be analyzed. To create an accurate model, the model must run for validation. In order to represent the real scenario, the parameters run for a replication length of seven days. This allows each replication to model a full workweek. In the Arena model shown in Figure 4.1, the current system of The Pancake House is described.

The first module is the create module, which will set the arrival rate of customers. In this module, customers arrive based on a schedule. This schedule contains different distributions of inter-arrival times based on the time and day including zero arrivals during the closed hours. After that, entities are assigned for a party size based on the probability of each party size arriving. This assignment is used throughout the model to determine the number of tables required.

Then, a decide module is added to determine whether customers are willing to stay in the system or leave the system based on the queue capacity. If the queue reaches maximum queue capacity, the entities will exit the system and the number of leaving are recorded. If the queue is not full, the parties continue to the queue and the number of staying are recorded.

The model will decide the number of tables for the needs of each party. If the party is of 4 or less, one table is required. For parties with 5 to 8 customers, two tables are needed. For 9 or more than 9 customers, three tables are necessary. There are currently twenty-five tables in the restaurant. This number is displayed on the resource spreadsheet of the model as the capacity for the tables.

When tables are available, the party will seize the required number of tables and will be removed from the queue. Another party with same size or smaller size is allowed to add to the queue. The party will be delayed 20 to 30 minutes while waiting for their food. It will take on average 60 minutes for the party to eat and then 5 minutes to be cashed out at one of the two cash-out stations. The capacity for the cash-out stations is made in the resource spreadsheet similar to the tables.
A delay is added for the time for parties to vacate the table. This delay takes on average 5 minutes. Based on size, the parties go through another decide module, which divides the parties. Tables are released based on the number of tables the party had originally seized.

Finally, parties leave the restaurant and the number of customers' leaving are recorded. After the party leaves, the tables are needed to be clean and setup for the next party. This process will takes 5 minutes on average and is modeled as a failure function. When this process complete, the table will be available for next party.

5. Simulation Results

As previously described, simulations were run for each of the eight scenarios, with four replications each. Figure 5.1 illustrates average results for weekly customers served.

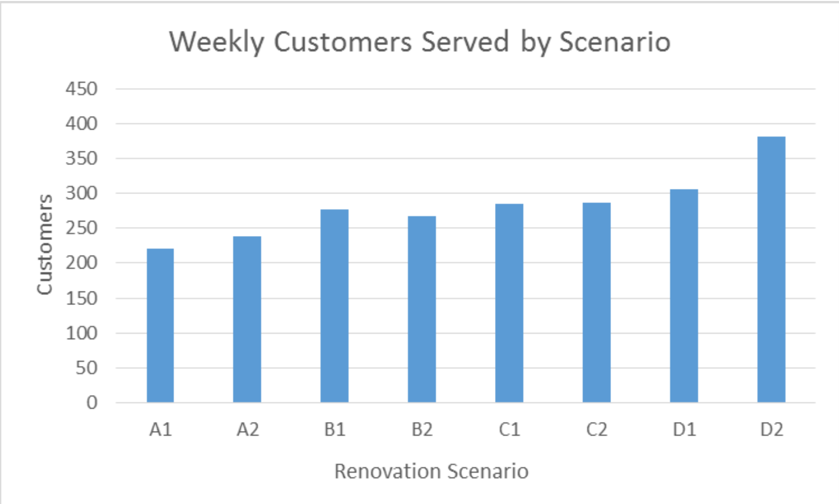

Figure 5.1: Weekly customers served by scenario

From the figure, it can be observed that the maximum customers are able to be served in Scenario D2, with 55 total tables and a queue capacity of 20. The lowest number of customers are served in Scenario A1, which is the current state of 25 total tables and a queue capacity of 14. Each of the other six renovation scenarios fall between A1 and D2 in terms of customer throughput.

From this output data, statistical tests were applied to determine if there was a difference in means in customer throughput between scenarios. First, two-factor ANOVA was completed. This allows for simultaneous computation of the main effects of both independent variables, as well as interaction between them at an alpha level of 0.05. The results of the test are outlined as follows:

Null Hypothesis: Factors have equal means

Alternate Hypothesis: Factors have different means

Source of Variation	**P-value**
Total Tables	0.084
Queue Capacity	0.348
Interaction	0.919

Table 5.1: P-values of variation source

Because each P-value is greater than the recommended alpha level of 0.05, we fail to reject the null hypothesis, and can conclude that there is no difference in means of customers served for all factors combined. However, because the P-value for total tables is relatively low, further inspection is needed.

While the effects of all independent variables may not be significantly different, a paired t-test can be used to evaluate individual pairs of scenarios separately. As previously stated, the paired t-test is useful here, as Arena uses the same random number seeds for each replication of different scenarios. With an alpha level of 0.05, the relevant results of paired-tests are outlined as follows:

Null Hypothesis: Factors have equal means

Alternate Hypothesis: Factors have different means

Scenario Comparison	**P-value**
A1, D2	0.030
A2, D2	0.033
C2, D2	0.041

Table 5.2: P-values of scenario comparison

This table shows a selection of three comparisons in which the null hypothesis is rejected. It should be noted that this table only shows three of the 28 possible comparisons. In general, Scenario D2 generated the most significant differences of all eight scenarios. Because A1 represents the current state of the restaurant without renovation, the comparison of A1 to D2 is particularly important. It shows a statistically significant increase in customer throughput gained from restaurant renovation.

6. Economic Analysis

Upon gaining results through experimentation, economic analysis was applied to determine the most beneficial renovation plan for the restaurant. Although some scenarios were shown to have negligible differences in customer throughput, the economics for each will still be evaluated for the restaurant. Figure 6.1 shows the monthly profit predicted for each of the eight renovation scenarios, using a profit of $6 per meal.

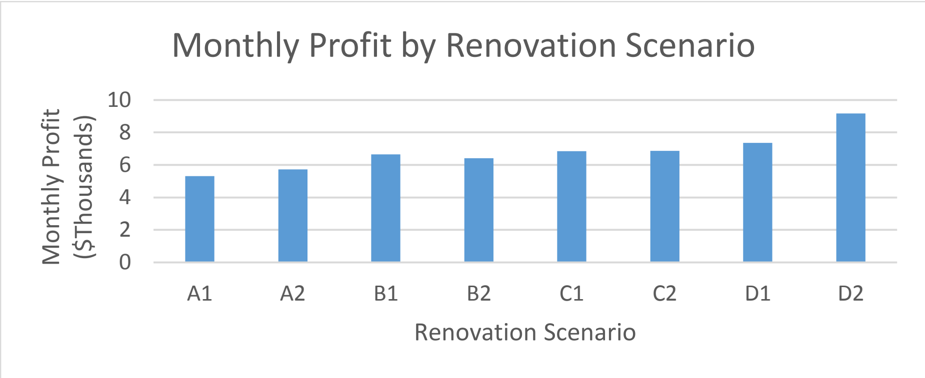

Figure 6.1: Monthly profits by renovation scenario

It can be observed that Scenario D2 has the highest monthly profit at $9168. However, the costs of renovation must be taken into account. The $40,000 kitchen renovation cost is required for all renovations. Additionally, one square foot of expansion costs $80. Using these expense figures, the total capital cost of each scenario is outlined in Table 6.1.

Renovation Scenario	Total Capital Needed ($)
A1	0.00
A2	44,800.00
B1	72,000.00
B2	76,800.00
C1	104,000.00
C2	108,800.00
D1	136,000.00
D2	140,000.00

Table 6.1: Total capital needed by renovation scenario

To cover the cost of renovation, the restaurant will have to apply for a business loan. Interest rates for business of this size are typically around 8% (Bender, 2014), and thus will be used in payment calculations. Furthermore, the Pancake House requires that the loan be repaid in no more than two years. Three different business loans will be considered: 24-month, 18-month, and 12-month. For each of these, monthly payments will be calculated with the equation:

$$Monthly\ Payment = \frac{r * PV}{1-(1+r)^{-n}}$$

Where:

r = rate per period

PV = present value

n = number of periods

Monthly payments for each scenario can be found in Table 6.2. Red values denote payments that are greater than the corresponding scenario's monthly profit, and cannot be made.

Renovation Scenario	2-Year Monthly Payments ($)	1.5-Year Monthly Payments ($)	1-Year Monthly Payments ($)
A1	0.00	0.00	0.00
A2	2026.18	2649.00	3897.08
B1	3256.36	4258.10	6263.17
B2	3473.46	4541.97	6680.71
C1	4703.64	6150.59	9046.80
C2	4920.73	6436.46	9469.34
D1	6150.91	8043.08	11,830.43
D2	6368.00	8326.95	12,247.97

Table 6.2: Monthly payments by renovation scenario

To determine the long-term impact of the scenario, expected profits were projected over a 10-year period. Payment periods and infeasible loans were taken into account in the calculations. Figure 6.2 summarizes the 10-year profitability of each scenario for a given loan. A loan column is missing for a scenario if the payments for the original loan were unable to be paid, as these are infeasible options.

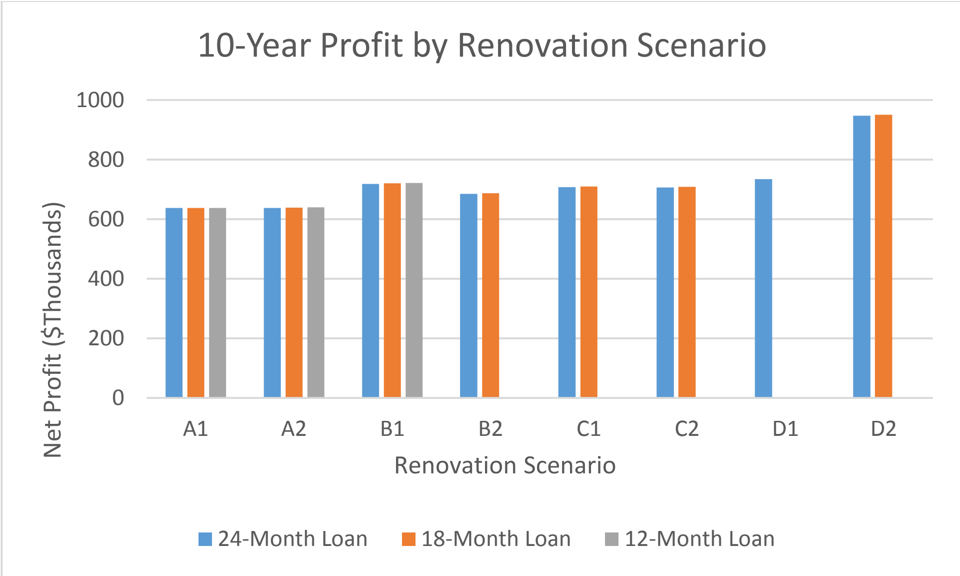

Figure 6.2: 10-year profit by renovation scenario

7. Conclusions

The Original Pancake House is a very successful restaurant in Williamsville, NY and they want to keep growing. This goal of this project was to analyze their current system and determine the best potential option to stop customers from balking and increase service time. The only major requirement the Pancake House had was the ability to repay the loan within 2 years.

ARENA software was used to simulate the current system and determine the most optimal amount of tables and queue capacity to maximize customer throughput. Pairing the ARENA results with an Economic analysis revealed that the most cost-effective approach would be to expand to 55 total tables for seating and a queue capacity of 20 customers. This increases the Pancake House square footage by 360 sq. ft. and will cost them $140,000. Although, that may seem like a big investment, this loan can be paid off in 18 short months while still remaining profitable. Not only will this expansion increase the Pancake House's profitability, but customer satisfaction will be on the rise as well. Having more tables, as well as, a larger queue will allow customers to be seated quicker and give them more space in the waiting area.

8. References

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