Service Time Performance Analysis of Improved Automated Restaurant by Layout Reconfiguration and Conveyor System

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Abstract. Achieving effective service time in restaurants hinges on implementing and integrating innovation in design and technology. A combination of restaurant layout configuration and conveyor belt system integration is proposed to enhance the turnaround service time performance. Emphasis on the layout reconfiguration with optimized dining capacity and conveyor system for semi-automated function are applied to existing restaurants by heuristic method. Then operation is simulated by agent-based approach in Anylogic simulator. Results yielded an improved in the total turnaround service time by 2.75% to 5%, which correspond to an approximate 78% reduction on a food-to-table service time. The enhanced performance shows the effectiveness of reconfigured layout to service more customers without compromising delivery time. While conveyor belt mechanism provides the greatest food delivery time and manpower reduction, with a considerable payback period of 6 months. The findings and modelling will aid the implementation of semi-automated restaurant as a stepping stone to one fully automated.

1. Background
Restaurants have been an integral part of society for many centuries, with their history dating all the way back to the eighteenth century in Paris when they were in the form of taverns, inns, traiteurs, cook shops, and boarding houses [1]. Fast forward to present day society, restaurants have become a saturated profit-based & market-driven by the forces of urbanization, globalisation and digitalization. The restaurant industry of today, like any other service industry, relies heavily on customer satisfaction to determine its success and any feedback is immediately amplified and spread to thousands if not tens of thousands in seconds, highlighting the need and importance of keeping customers happy [2,3].

Based on the research done by previous researchers, one of the major factors affecting customer satisfaction in restaurants is service time. [4,5,6]. Therefore, it can be inferred that even after flourishing for centuries, the service time component still remains to be an issue for the restaurant industry of today. The service time component in a restaurant can be broken down into various individual components; these include the time to be seated, time for order to be taken and also time for food and drinks to be delivered. In order to improve the service time in restaurants, layout reconfiguration of the restaurant as well as the implementation of semi-automation features such as conveyor systems may be applied to help increase the efficiency of service.
Several previous researches that featured different restaurant layout reconfiguration models were studied. Among the notable models is the theoretical Takashi model or the queuing theory which applied two-dimensional cellular automata and multi-agent simulation to aim for reducing number of waiting customers and average number of seat sharing ratio among customers. The 4-seated tables in the restaurant were reduced and 1-seated tables were increased to improve seating efficiency since the probability of customers coming alone is higher than that of them coming in a group. The research succeeded in reducing the average number of waiting customers by 72.91% [7]. Next, the empirical Nobutada model which aimed to decrease the required moving distance of kitchen staff members by adjusting number of cooking machines in the restaurant’s kitchen and arranging closer to each other and succeeded with a reduction of 9.30% [8]. Besides, the empirical Takeshi model which aimed to shorten cooking time using the similar approach, which was also used in the Nobutada model, accomplished a reduction of 8.80% [9].

On the other hand, with the rise of the 4th industrial revolution, automation has been slowly but surely creeping into many industries. Some of the earlier incorporation of automation into the restaurant industry started off by implementing automated food ordering systems, using software systems that allowed customers to browse the menu and order via their own mobile phones [10]. Subsequently, these systems were upgraded by integrating built in touch panels at every table and by using more advanced technology such as wireless mesh networking technology in order to smoothen communication between stations [11]. In accordance with the continued advancement of technology, automation in restaurants gradually broke free from the ordering process limitations and moved into the actual serving and billing process by combining robots and high-level programming to successfully step into the era of full automation [12].

2. Methodology

There will be two selected cases of different restaurants with their layouts featured for improvements in this research. The methodology for the two cases will be focused on layout reconfiguration and implementation of automation technologies respectively. The research of case 1 is divided into two aspects: the restaurant layout reconfiguration based off of researched algorithms and then the simulation in AnyLogic. As for case 2, the two aspects are implementation of conveyor system based off of actual data collected through survey and then simulation using AnyLogic as well.

2.1. Conceptual framework

Ideal Table Mix is a technique used to calculate the optimal mix of tables with different seating sizes in an assigned dining area. From the original research that has proposed this technique, several layout rearrangement methods were compared and the Ideal Table Mix was proven to be superior to the other proposed methods in terms of customers lost daily and generated restaurant revenue. The technique utilises restaurant parameters like seating areas in a dining area, probability weightage of different number of customer parties and tables’ seating sizes to calculate the optimum amount of tables in an assigned area [13].

For the introduction of automation, a simple conveyor system that connects the kitchen to all tables is proposed. This improvement was proposed because one of the leading causes of delay in service time is attributed to server movement [8]. By substituting the manual service for kitchen to table orders with an automated food delivery conveyor system, the service time can be greatly reduced.

2.2. Simulation in AnyLogic

Both the original and reconfigured layout floor plan of MODU automated restaurant were imported into AnyLogic and necessary blocks and components were drawn on the floor plans and model spaces of the software to simulate restaurant operations on them. The customers, waiters and food were assigned as three different agents and the Markov chain of blocks that simulate the actions of them in the simulation model will be elaborated.
In both of the layouts, the customers will enter the restaurant, queue up at the order counter to check the menu or order for food, then they will move to the seats in the different dining areas, one where the waiters will serve the food and one where food are delivered through conveyor belts. Then, the customers will wait for waiters to approach them for ordering or fulfilling extra needs. After consuming their food in the restaurant for a specific time, they will leave the restaurant. The chain of blocks responsible for simulating the customers’ actions is shown in figure 1.

**Figure 1.** The Markov chain of blocks for different agents’ actions.

The waiters however, will wait in the kitchen area until a customer sits down and need them to take their orders or have their food available to be delivered by the waiters. The waiters will return to the kitchen if there are no available works in the dining area. The chain of blocks that simulates the actions of the waiters is also shown in figure 1.

Lastly, the chain of blocks that simulates the food’s actions is responsible for distributing the food into two routes, one which makes the food to be sent to customers through the conveyor and one which makes the waiters deliver them. This particular chain of blocks is shown in figure 1 as well.

Both of the simulations of the original and reconfigured layout of MODU restaurant have the similar blocks as discussed with some tweaks in their properties to ensure a well-controlled comparison.

3. Results

The operation of two different cases of selected restaurant layouts were simulated in AnyLogic and the results will be discussed below.

**Figure 2.** Situations in original and reconfigured MODU restaurant layout during lunch hours.
3.1. CASE 1: Conveyor system with reconfiguration of layout

The simulation of the MODU restaurant’s operation was run for 10 hours with a customer arrival rate ranging from 45 per hour for the peak lunch hours, 10 per hour for the less busy hours, 45 per hour for the peak dinner hours and 35 per hour for the less-busy dinner hours. After the simulation was run, the movement and egress of the agents on the layout was observed. Figure 2 shows the situation in the restaurant with both the original and reconfigured layouts during peak lunch hour from 12pm to 2pm.

Several time-measuring blocks were also placed in specific position in the Markov chain to measure different times in the model during simulation and to generate time-distribution graphs for easier results comparison of the original and reconfigured layouts. The resulting time distribution graphs that show the total time the customers spent in the restaurant for both layouts are shown in figure 3.

![Ratio of customer frequency](Original layout) ![Ratio of customer frequency](Reconfigured layout)

Figure 3. Comparison of histogram of total time customers spent in restaurant of both layouts.

Lastly, the simulated resulting times waited by the customers before their food arrive after their orders were taken for both the conveyor-delivering area and waiter-serving area for both layouts are shown in table 1.

| Time distribution criteria                      | Original layout’s time | Reconfigured layout’s time |
|------------------------------------------------|------------------------|---------------------------|
| Time waiting for food in conveyor-delivering area | 5 m 9 s                | 5 m 12 s                  |
| Time waiting for food in waiter-serving area     | 5 m 44 s               | 5 m 40 s                  |

3.2. CASE 2: Conveyor system implementation without layout reconfiguration

The simulation for Sushi Jiro, Midvalley Megamall was carried out twice, the first time to simulated normal operating conditions while the second simulation incorporated a food delivery conveyor system that connected the kitchen to all tables in the restaurant. The conveyor was designed above the existing sushi belt and had a width of 30cm while operating at a speed of 0.8m/s. The restaurant layout with the conveyor system can be seen below in figure 4.

Similar to the layout reconfiguration simulation, time measuring blocks were used to measure the time starting from the moment the food is prepared and released from the kitchen to the moment it reaches the customers table. The resulting comparison between frequency-time graphs for original operating conditions and with food delivery conveyor system can be seen in figure 5 below.
Figure 4. Simulated conditions for layout with conveyor system (bottom) of Sushi Jiro, Malaysia

Figure 5. Comparison of service time between original operating conditions and with addition of food delivery conveyor system.

The total dining time of customers in the restaurant was also measured in the simulation using time measuring blocks and the results were similarly compared between the original model with the model that had the additional food delivery conveyor system. The comparison between the two frequency-time graphs can be seen in figure 6 below.

Figure 6. Comparison of total dining time between original operating conditions and with addition of food delivery conveyor system.

From the graphs shown in figure 5 and figure 6, it can clearly be seen that the addition of the food delivery conveyor system greatly reduces the service time for kitchen to table process. The service time is reduced from an average of 207.3 seconds to 42.57 seconds and shows a reduction of almost...
78%. The average total dining time of customers has also been reduced from 38.3 minutes to 36.3
minutes which translates into an overall average reduction of 5%.

Therefore, based on the results obtained from this simulation, it can be observed that the
implementation of the food delivery conveyor system does indeed manage to achieve the objective of
this research. Not only does this modification reduce the service time, it manages to do so by a great
degree, largely improving the efficiency of service in a restaurant and showcasing the potential of
automation.

4. Discussion

4.1 Improvement on Service Time

From case 1 which is based on layout reconfiguration, improvements can be seen from both the
average total dwell time of customers in the restaurant and the time customers spent waiting for food
in the waiter-serving area. The amounts of reductions achieved are 2.75% and 1.17% respectively.

For case 2 which focused on implementation of the conveyor system, it can be seen that the
improvement in service time obtained is significant as it is a 78% reduction when compared to the
original. However, this degree of improvement is directly related to the limitations in the original
layout of the site which contributes greatly to the delay in service time. Therefore, the same
improvement when implemented in different settings might not bring about as great a degree of
improvement as can be seen from the results of this study.

4.2 Justification of the distribution

For case 1, from the graph shown in figure 3 which was generated from the simulation of the
reconfigured layout, what could be observed is its uneven distribution. This can be justified by the
varying arrival rate of customers throughout the 10-hours simulation which was set according to a
schedule. With the number of waiters remaining same throughout the simulation, the serving time
fluctuates to the varying arrival rate.

For case 2, based on the graphs generated through simulation, it can be seen that for the original
operating conditions, the distribution of service time for kitchen to table process is concentrated to be
within 100 seconds especially at the start of the simulation. However, as the simulation continues, the
tasks the servers have to perform start to pile up and the delay gradually starts to lengthen, ultimately
increasing to above 8 minutes. After implementation of the conveyor system, as the conveyor is able
to deliver multiple orders at the same time, the service time is limited to be within 1 minute which
represents the furthest distance the conveyor has to deliver. For the total dining time of the customers,
the distribution is normal for both with and without implementation of conveyor system.

4.3 Payback period

Cost analysis was only carried out during case 2 and therefore only results of case 2 will be shown. By
estimating the cost of the conveyor system to be at RM1000 per metre and the wage of servers to be at
RM 10 per hour working 12 hour shifts daily, the cost of implementing the conveyor system which
spans 45 metres can be recouped in half a year by reducing the number of servers from 3 to 1.

5. Conclusion

From case 1 which focused on layout reconfiguration, the average total time the customers had to
spent in the restaurant was reduced by 2.75% and the time customers had to wait before their food
arrives after their orders were taken in the waiter-serving area was reduced by 1.17%. From case 2
which focused on implementation of automation, the average total dining time had been reduced by
5% while the service time for kitchen order to be served was reduced by a large margin of 78%. In
conclusion, it can be seen from the results of the simulations that while both re-configuration of
restaurant layouts and incorporation of semi-automation technology in the form of conveyor systems
did both achieve reduction of service time in the restaurants, it is apparent that the usage of semi-
automation technology is more efficient as it brings about greater impact while taking less effort to implement.

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