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Article

Improving Queuing System with Limited Resources Using TRIZ and Arena Simulation

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Abstract: A university canteen is a queueing system characterised by non-stationary time of arrival with limited resources where the arrival rate is time dependent and has different pattern of arrival for different time interval. This means at certain time of the day, the arrival rate is much higher than other time and for a university canteen, the arrival rate of customer during the lunchtime is much higher and the food (resources) is limited. Non-stationary time dependent queueing system is not easily modelled mathematically hence such queueing systems are modelled using simulation tools such as ARENA. In order to model a non-stationary time dependent queueing system with limited resources and solve queueing problems using ARENA, researchers have to depend on their knowledge and experience in identifying the appropriate and relevant parameters for the system and make modifications to these parameters of the system to solve queueing problems by means of trial and error. Hence, this research work explores the potentials of applying a systematic problem solving tool, TRIZ to help users to make better decisions in deriving solutions to improve a non-stationary time dependent queueing system with limited resources. A case study was carried out to minimize the waiting time of the customers at the cafeteria of the Faculty of Engineering, Universiti Putra Malaysia (UPM), which has queueing problems for years during lunchtime. TRIZ was applied in this case study and the results showed that TRIZ can assist researchers to derive a solution model that lead to shorter waiting time without incurring additional cost and resources.

Keywords: Queuing problem; TRIZ; Arena software; average waiting time

1. Introduction

Queueing problems can lead to serious drawbacks since waiting in a queue will cost time for the customers. Customers who cannot afford to wait will leave the queue and cause losses to the service provider. Queues may occur at a bank or a supermarket where people are waiting for services. There are also queues for public transport where people are waiting for a train or a bus. The most common queueing problem is queueing up for food, which usually occurs at a restaurant. According to Malaysia Food Barometer (MFB), 64.1% of Malaysian population are eating outside rather than having their meals at home [1]. This habit of eating outside means Malaysians will be more likely to encounter waiting queues, which currently are a common sight in restaurants especially during lunchtime. The waiting time during these periods is usually longer than other operation hours.

As an effort to reduce this waiting time, researchers used simulation method to aid them in visualizing and understanding the situation. A simulation model implicates a model that has been adapted to be analysed with the use of simulation [2]. In this research work, a simulation model was applied to solve the queueing problem instead of using queueing theory. The simulation model was

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derived using Arena, a commercial simulation tool which is well established in various applications for simulation modelling [3]. Arena is using a graphical modelling method to define the simulation model by creating, manipulating and linking a number of available basic building blocks [4]. In applying Arena to solve queueing problems, there are six key model elements needed, namely, Model Entities, Model Activities, Model Resources, Exogenous Event, Endogenous Event and Queue [5]. Based on these key model elements, the model for the university canteen was developed and the Arena parameters were obtained via on-site observations and data collections.

Based on past research works, there are several positive opinions and outcomes on using simulation approaches to solve a queueing system problem. The performance criterion of a restaurant can easily be measured through simulation and it helps to understand the situation better as well as to simulate any improvement decision [5]. A simulation model can mirror the actual operation of the restaurant/cafeteria. It can be flexibly adapted to deal with complex service and arrival patterns but a simulation model is still considered to be a simplification of the real-life system [6]. Adding complexity is possible in a simulation to allow the simulation model to mirror the actual operation of the restaurant/cafeteria [7]. The Arena software provides users a friendly interface to model events or activities and others in a system. The statistical reports that can be obtained from Arena after each run are useful and contain valuable information [8]. In a case study to find the reasonable shoreline length of a fishing port, it is reported that with the aid of computer simulation, the approach was able to deal with random service problems and demonstrated good results [9]. The analysis and simulation of factory layouts using Arena have enabled researchers to see the individual movements from one machine to another machine [10].

From these past research work, it can be implied that simulation modelling can be used to solve queueing system problems and provides good results. The simulation modelling of queueing system using Arena has been applied in literature to give clear view on the actual real-life scenario on the operation of restaurants and to improve their services. The application of simulation models using Arena allows restaurants to be modelled based on their current scenarios and users can then modify their restaurant based on trial and error basis to remove bottlenecks, number of service counters, layout design and others to improve the performance of their restaurants' services. Although the application of simulation models using Arena have been successful based on trial and error basis, the trial and error basis can take significant amount of time and effort to come up with a good solution. In addition to that, the time and effort to find a solution to improve a queueing system will substantially increase when the complexity of the system get higher or if the system is huge with many resources, activities and events and the chances of success in finding a good solution will plunge. Therefore, there is a need for a systematic approach that can assist a user in using simulation modelling method such as Arena to find a good solution to improve a queueing system. One of the established tools that have been applied by many enterprises to solve design and manufacturing problems systematically and were proven to be successful is TRIZ [11,12]. In this research work, we explored the application of one the classical TRIZ tool known as the engineering contradiction instead of using the trial and error basis to help users to improve the service performance of a cafeteria located in UPM campus, which frequently experienced long queues particularly during lunchtime.

2. TRIZ

TRIZ has been applied to help engineers in solving engineering problems for many years and has been used to solve many issues faced by enterprises [12-14]. The application of TRIZ has also been extended into other areas including computer science [15,16], social sciences [17], energy efficiency [18], and manufacturing [14,19,20]. With TRIZ, many leading multi-national and innovative companies are able to record tremendous growth and achievements to enhance their global competitiveness [21,22].

TRIZ or the theory of inventive problem solving was derived by Genrich Altshuller [23] based on his study on patent documents since 1940s. The applications of TRIZ were used by many leading enterprises such as Ford, General Motors, Intel, and Xerox to increase their competitiveness [22].

TRIZ is a systematic problem solving method that helps engineers to define and solve technical problems. Figure 1 shows a general model of TRIZ problem solving process. In TRIZ, a specific problem is transformed into TRIZ generic problem and then to TRIZ generic solution before a user translates the TRIZ generic solution to produce specific solution for the specific problem [24].

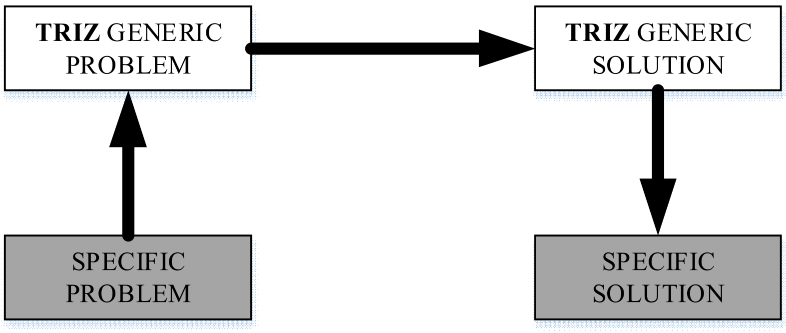

Figure 1. General model of TRIZ application

One of the major key discoveries of TRIZ is the 40 inventive principles, which are derived from thousands of patents starting from 1946 to 1985 [21,22,24]. This is the basic concept of TRIZ that have been widely applied to generate ideas to solve many engineering problems. There are three categories of contradiction in TRIZ namely administrative contradiction, technical contradiction, and physical contradiction [14,22,24]. Administrative contradiction are contradiction that normally develops from management problems and the solutions to such contradiction are not clear [14]. However, administrative contradiction can be transformed into engineering contradiction to be resolved more easily [14]. Physical contradiction is applied for problems with a single antonymous parameter, which creates a contradiction in the same parameter with two different values such as short and long for the length parameter. This contradiction can be solved using Separation strategies, Satisfaction and Bypass [14] of TRIZ. Meanwhile, the engineering contradiction is a tool that is derived based on the notion that there will be technical contradictions that need to be resolved in order to solve any inventive problem i.e. improving a parameter will cause one or more other parameters to worsen.

Inventive problems are problems that involve a parameter or feature of a system where when it is improved due to an action taken or a design change, another parameter or feature of the system will get worsen. Hence, the engineering contradiction tool (also known as engineering contradiction matrix) developed by Altshuller has listed 39 improving parameters or features and 39 worsening parameters or features. Each corresponding improving and worsening parameter will have a list of recommended inventive principles that may provide an idea to solve the problem [12].

There are 40 inventive principles in total. A good definition of contradiction and by identifying the root cause of the problem will be essential for an effective TRIZ application. After modelling the problem and identifying the root cause of the problem, there are several steps need to be followed before the application of the contradiction matrix and the inventive principles [12]. In order for the user to solve a problem, the user need to identify a parameter that he wants to improve to solve the problem and due to that improvement, another parameter will become worsen. Based on the identified improving and worsening parameters, the engineering contradiction matrix will provide a list of recommended inventive principles (out of the 40 inventive principles mentioned earlier) that maybe be able to solve that particular problem [25].

In applying TRIZ engineering contradiction to solve an identified problem, not all the recommended inventive principles must be used to solve the problem. Sometimes none of the recommended inventive principles can be applied to solve the problem, In fact, quite a few of the identified improving and worsening parameter has no recommended inventive principles (there are quite a number of blanks in the contradiction matrix). However, these inventive principles provide good ideas or hints to the user to think of solutions for an identified problem.

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In addition to that, it is advised that the user should identify a single parameter to improve and a single parameter that will become worsen to enable the list of inventive principles recommended will not be too many. Therefore, it is important to model the system by defining the problem and break down the system into components. Then, the user should investigate and explore to determine the root cause of the problem before trying to solve the problem.

3. Problem Definition

This section elaborates the background of the problem and describes the observations being conducted to identify the actual scenario of the cafeteria.

3.1. Introduction

It was observed that the waiting time was long at the cafeteria of Faculty of Engineering, UPM, Serdang. Based on the current situation, customers can come from any direction to enter the system. In other words, there is no proper queue or line to enter the system. This situation caused hassles at the cafeteria, as customers will dash or swarm around the front counter of the cafeteria to pick their meals. A study was conducted during lunch hour, which was from 12.00pm to 1.00pm because it was the peak hour and thus maximum queueing time at the cafeteria consistently occurred during this period. It is important to find out how long a customer had to wait in a queue before they are served and how the waiting time can be reduced without deploying extra working staff. A long waiting time may cause the cafeteria to lose customers since customers tend to leave the queue if they have to wait for a long time to get their lunch.

Hence, the development of a simulation model for the cafeteria would help to evaluate possible improvement on the current situation. By performing the simulation, the average waiting time for each customer would be figured out. This case study is important, as it is able to bring benefits to both customers and the cafeteria itself. For instance, if customers know the average waiting time, they can estimate how much time they need to spend if they want to dine at this cafeteria. It helps customers to make decision and provide more efficient time management. Eventually, this might help to reduce the possibilities of balking customers and company would not suffer losses. Nevertheless, the management of the cafeteria is not keen on incurring additional cost such as using automation and on increasing the number of workers. Thus, the objective of this research is to investigate and minimize the waiting time at the cafeteria of Faculty of Engineering, UPM, Serdang, Selangor, Malaysia, without incurring additional cost by using the TRIZ and Arena software.

3.2. System description based on observation

Observation was done at the cafeteria to identify the actual scenario of the cafeteria in order to enable the modelling of the cafeteria system to be made as accurate as possible. In this research, the observation was done during lunch hour from 12.00pm to 1.00pm. The arrival time of customers was recorded by using a stopwatch. The purpose of the observation was to collect data to be entered into the model.

The observation conducted was also to determine the layout of the cafeteria. Figure 2 illustrates the layout of the cafeteria while Figure 3 shows the flowchart of the process of current queueing system. From Figure 2, it can be seen that the cafeteria has a counter that can accommodate variety of dishes. Other than that, it is observed that only one staff is working at the front counter at a time and he acts both as a waiter and a cashier.

According to Figure 2, it is shown that customers arriving at the same time at the counter. If the customers want to purchase food from the cafeteria, they have to request for the rice from the working staff. Then, customer will choose and pick the first dish from all of the dishes that were served in the front counter. After that, the customers have to decide whether they want to pick the next dish or not. If yes, customer will take another dish. Otherwise, they will proceed to pay counter and finally leave the system.

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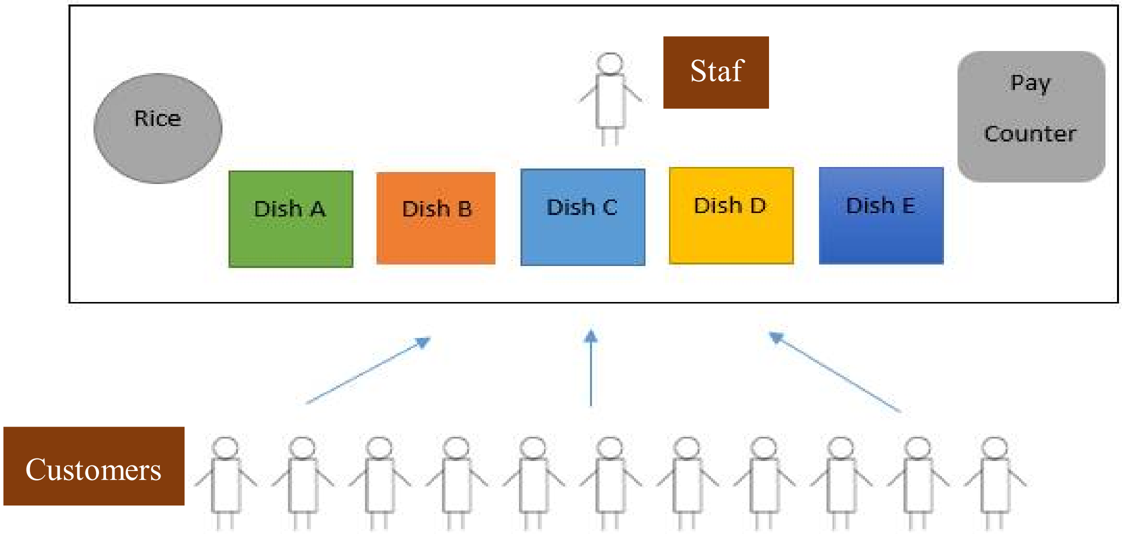

Figure 1. Layout of the cafeteria.

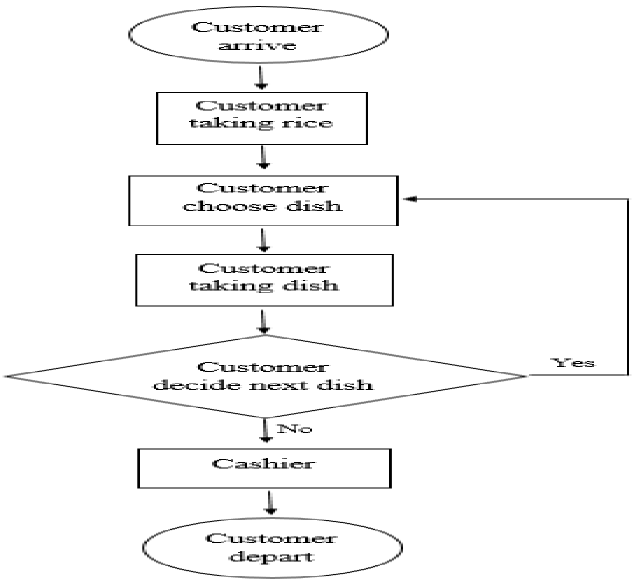

Figure 2. Flowchart of the current queuing system at the cafeteria.

The time between arrivals of the customers and time taken for each customers being served by the staff were observed. The time was recorded in minutes and the average value obtained from that one-hour observation was inserted into the software as the input. The time to serve customer caused delay to the process and thus queue was forming up during this stage. In this case study, each customer was served by a staff at two different processes. The first process was to serve the customer with rice when the customer requested for it and the second process was to collect payments for the food when the customer wanted to pay.

The data of the one-hour observation was recorded and is shown in Table 1. According to the data collected, the average time between arrivals is 2 minutes. This average arrival time was set in the Arena software as an input. In addition to that, the maximum arrival was set to infinity, 10 replications, 60 of replication length and the base time unit in minutes were set.

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Table 1. Collected data during one-hour observation.

Customer i^{th}	Customer arrival time (min)	Time between arrival (min)	Service time for rice (min)	Service time at cashier (min)
1	12.00pm	-	0.25	0.25
2	12.03pm	3	0.25	0.25
3	12.04pm	1	0.5	1.0
4	12.05pm	1	1.0	1.0
5	12.08pm	3	0.5	0.25
6	12.09pm	1	0.5	0.5
7	12.11pm	2	0.5	0.5
8	12.14pm	3	0.25	0.25
9	12.17pm	3	0.25	0.25
10	12.18pm	1	1.0	0.5
11	12.21pm	3	0.5	0.25
12	12.22pm	1	0.5	0.5
13	12.28pm	6	0.25	0.25
14	12.31pm	3	0.5	0.5
15	12.35pm	4	0.25	0.25
16	12.37pm	2	1.0	0.5
17	12.38pm	1	1.0	1.0
18	12.39pm	1	1.0	1.0
19	12.42pm	3	0.25	0.25
20	12.46pm	2	0.5	0.5
21	12.48pm	2	0.5	0.5
22	12.50pm	2	0.5	0.5
23	12.52pm	2	0.5	0.5
24	12.53pm	1	1.0	1.0
25	12.54pm	1	1.0	1.0
26	12.57pm	3	0.25	0.25
27	12.59pm	2	0.5	1.0
28	1.00pm	1	1.0	1.0
	Total	58	16	15.5
	Average	2.07	0.57	0.55

4. Arena Model of the Current Queueing System

The Arena model of the current queueing system at the cafeteria is as shown in Figure 4. A customer who arrives and wants to have lunch has to request for the rice first. The customer has to request for the rice from the staff before he decides on the first dish that he wants to choose. Then, the customers will proceed to take the first dish and then decide on whether to choose the next dish and so on or going straight to the pay counter before leaving the queue.

In this model, the probability of arrival of any server or choosing a dish (Decide module) was set as 20% since there were five dishes (servers) available. The processing time given was based on

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Triangular (TRIA) (0.25, 0.5, 1) distribution. There were four assumptions that were made in this model which are:

i. Only five dishes available at the cafeteria at a time.
ii. Customers can take as many dishes as they want as long as they do not leave the system.
iii. After requested for rice from the staff, customers cannot exit the system without picking at least one dish before paying for the food.
iv. Customers enter the system individually, not in groups.

Based on the Arena model shown in Figure 4, it can be observed that a user will have difficulty of trying to improve the system using trial and error approach even though the system is just a simple cafeteria with a single server. This difficulty is partly because of the possible involvement of multiple servers, constraints and other factors particularly for new users or users that have little of experience and knowledge in improving a queueing system. This task of improving a queueing system increases significantly, when the system become more complex and large such as a shopping mall.

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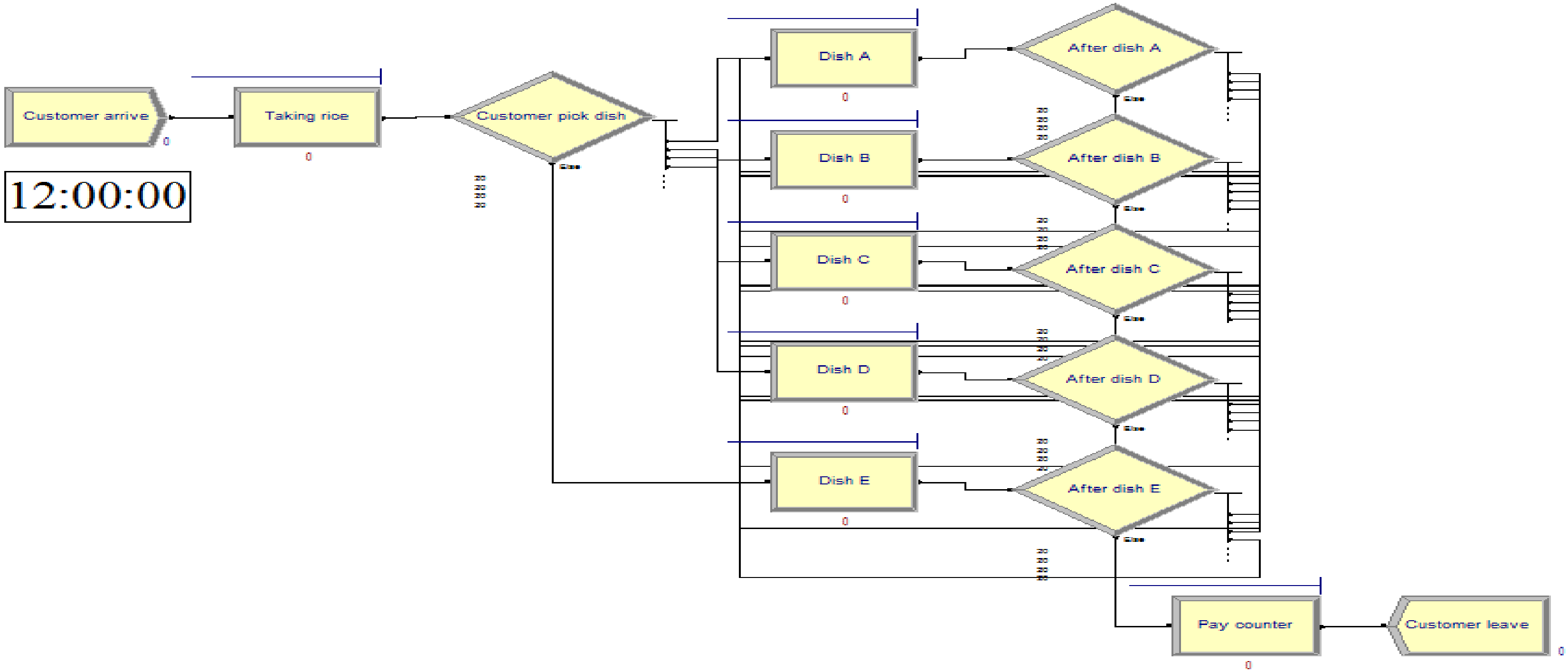


Figure 4. Arena model of current queueing system in the cafeteria at UPM.

5. Using TRIZ to Improve a Queueing System

One of the classical TRIZ tools, the engineering contradiction was applied to improve this queueing problem found at the cafeteria in UPM. The component modelling done by Arena shown in Figure 4 can be used to represent the cafeteria system and the components inside the system as step towards determining the root cause of the long queue in the cafeteria during lunchtime. The cafeteria system can then be modelled functionally as shown in Figure 5 to identify the queueing problems of the cafeteria system based on the observations conducted and the interaction links between components. Based on the observations, the cashier/waiter has an insufficient rate of serving rice to the customer and also insufficient rate of collecting payment from the customer due to high arrival rate of customers. The observation also noted that the rate customer taking dishes is at normal rate and is not causing significant delays.

Based on the functional model developed for the cafeteria, a root cause and effect analysis can be carried out to determine the actual cause of the queueing problem and this is shown in Figure 6. Therefore, it is obvious that from the observations, the lone waiter/cashier will be struggling to serve rice to the customer and to collect payment at the same time during lunch time when the arrival rate of customers is high.

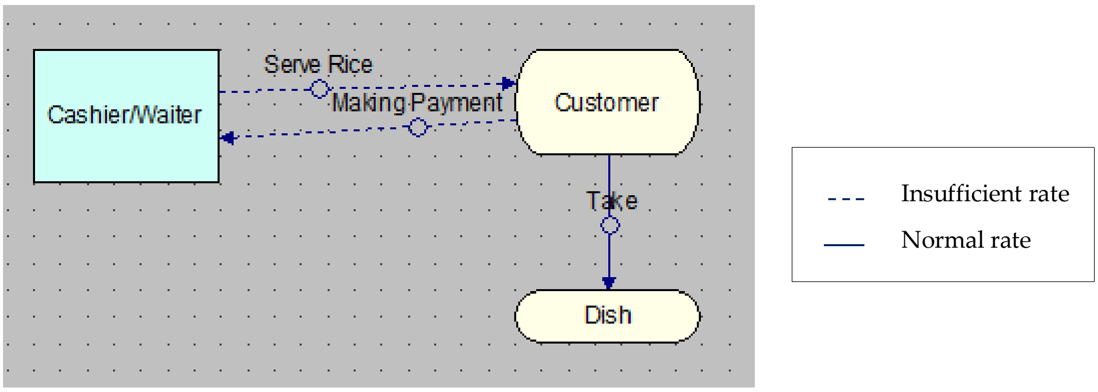


Figure 5. Functional model of current queueing system in the cafeteria at UPM.

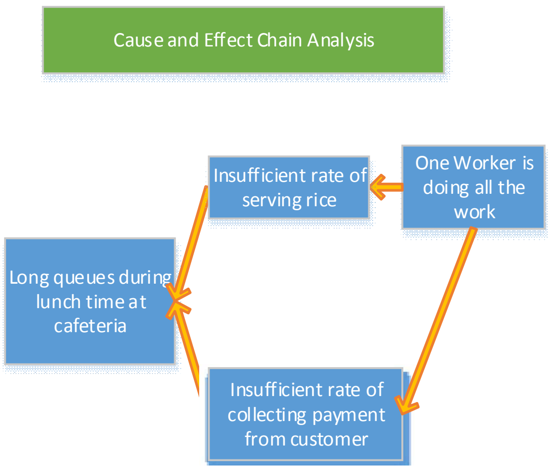
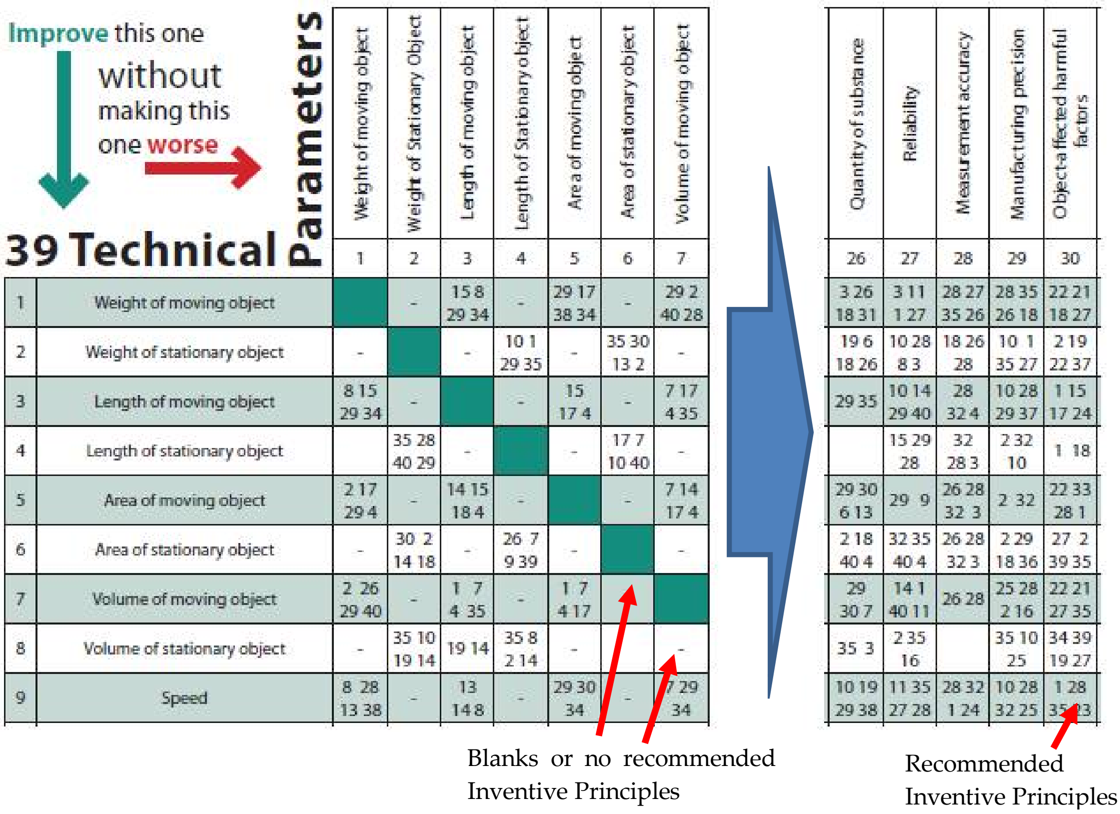


Figure 6. Root cause and effect of the queueing problem in the cafeteria at UPM during lunchtime.

This finding corresponds to the results of the Arena model demonstrated in simulation of the scenario at the cafeteria during lunchtime. However, since the owner of cafeteria does not wish to hire additional staff to solve this queueing problem, another inventive solution needs to be figured out to solve or ease the queueing problem at the cafeteria. In view of this, the knowledge and experience of the user are needed to solve this queueing problem at the cafeteria and the user usually applies trial and error approach to solve this problem. In this research work, TRIZ contradiction matrix will be applied to solve this queueing problem.

In applying TRIZ engineering contradiction matrix, the improving feature or parameters in this queueing problem is to speed up the service provided of the lone waiter/cashier to reduce the queueing problem in the cafeteria during lunchtime. However, increasing the speed of the services will definitely help in reducing the queue during the lunch time but the waiter/cashier who is serving the rice to the customer as well as collecting payment from the customer will most likely to be working under duress. The best matching improving parameter from the engineering contradiction matrix for improving the speed of service would be improving parameter number 9, speed. The worsening parameter will be the worker is working under duress and the best matching worsening parameter for working under duress will be worsening parameter number 30, object affected harmful factors. Figure 7 illustrates the part of contradiction matrix that indicates the inventive principles recommended based on the matching improving and worsening parameter. Table 2 summarises the information on the engineering contradiction, improving and worsening parameters as well as the recommended TRIZ inventive principles.



		1 Weight of moving object	2 Weight of Stationary Object	3 Length of moving object	4 Length of Stationary object	5 Area of moving object	6 Area of stationary object	7 Volume of moving object	26 Quantity of substance	27 Reliability	28 Measurement accuracy	29 Manufacturing precision	30 Object-affected harmful factors
1	Weight of moving object		-	15 8 29 34	-	29 17 38 34	-	29 2 40 28	3 26 18 31	3 11 1 27	28 27 35 26	28 35 26 18	22 21 18 27
2	Weight of stationary object	-		-	10 1 29 35	-	35 30 13 2	-	19 6 18 26	10 28 8 3	18 26 28	10 1 35 27	2 19 22 37
3	Length of moving object	8 15 29 34	-		-	15 17 4	-	7 17 4 35	29 35	10 14 29 40	28 32 4	10 28 29 37	1 15 17 24
4	Length of stationary object		35 28 40 29	-		-	17 7 10 40	-		15 29 28	32 28 3	2 32 10	1 18
5	Area of moving object	2 17 29 4	-	14 15 18 4	-		-	7 14 17 4	29 30 6 13	29 9	26 28 32 3	2 32	22 33 28 1
6	Area of stationary object	-	30 2 14 18	-	26 7 9 39	-		-	2 18 40 4	32 35 40 4	26 28 32 3	2 29 18 36	27 2 39 35
7	Volume of moving object	2 26 29 40	-	1 7 4 35	-	1 7 4 17			29 30 7	14 1 40 11	26 28	25 28 2 16	22 21 27 35
8	Volume of stationary object	-	35 10 19 14	19 14	35 8 2 14	-		-	35 3	2 35 16		35 10 25	34 39 19 27
9	Speed	8 28 13 38	-	13 14 8	-	29 30 34	-	7 29 34	10 19 29 38	11 35 27 28	28 32 1 24	10 28 32 25	1 28 35 23

Figure 7. Part of the engineering contradiction matrix indicating the recommended inventive principles 1, 28, 35, 23 based on improving parameters of speed versus worsening parameters of object affected harmful factors.

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Table 2. Tabulated information about the engineering contradiction, improving and worsening parameters as well as the recommended TRIZ inventive principles.

	Description
Engineering Contradiction	If the waiter/cashier is to improve his speed in providing services, then there will not be a long queue of customers waiting but the waiter/cashier will be working under duress.
Improving Feature No. 9	Speed (speed of services by the waiter/cashier)
Worsening Feature No.30	Object affected harmful factors (working under duress)
Recommended TRIZ Inventive principles obtained from Engineering Contradiction Matrix	#1 Segmentation #28 Mechanics Substitution #35 Parameter Changes #23 Feedback

6. Potential solution for solving the queueing problem at the cafeteria in UPM based on the recommended TRIZ inventive principles

The first recommended inventive principle is inventive principle number 1, which is segmentation. In the current layout of the cafeteria, the lone worker has to perform two tasks, which is to become a waiter that serve rice to arriving customers as well as to collect payment from the customers after the customers have selected their dishes. Segmentation principle is a principle that hint at a solution based on dividing or breaking down a task into separate tasks. This inventive principle immediately provide an idea that the worker may only need to collect payment from the customers as this is most important task for any business. The task of serving of rice can be allocated to the customers themselves as the customers are already choosing and taking up the dishes on their own. This means the tasks of serving rice will be a self-service task. With this task is transferred to the customer as a self-service task, the lone worker can focus to be cashier and can speed up the overall rate of service and reduce the problem of long queueing time.

The second recommended inventive principle is mechanics substitution, which implicates a kind of replacement for the current system to solve a particular problem. This inventive principle hinted at a solution that replace the currently manual service to an automated one. This means the serving of rice or the payment collection can be done by an automated system but since the management of the cafeteria prefers not to incur additional cost, hence this solution will not be explored.

The third recommended inventive principle is parameter changes. This inventive principle is suggesting a solution to change certain parameters of the system to solve a particular problem. Parameter change principle for the queueing problem in the cafeteria problem means identifying the parameters in the cafeteria that can be changed to solve the queueing problem. With the current layout of the cafeteria, the arrangement of dishes from A to E allows a large number of customers to simultaneously choose and take their dish after requesting for rice and then queue at the cashier point, This will cause long queues at the point of serving rice and the cashier point. If only one worker is serving the rice and collecting the payment then the worker will highly likely to focus on the serving of rice to enable the customers to enter the system but then queue at the cashier point will be very long as the worker is mostly pre-occupied at the point where the rice is served. With the self-service introduced for serving of rice, the lone worker can focus on collecting payment to reduce the queue at the cashier point but the arrangement of the dishes that allows the customers to choose and take their dishes simultaneously may still overwhelm the rate of payment collection. Hence, parameter changes suggest a change in the layout of the cafeteria to allow the customer to prolong their rate of taking up the dishes in order to balance the rate of payment collection.

Based on the parameter changes inventive principle, the layout of the cafeteria was modified to allow a single line queue to access the dishes in order to only allow every customer to choose and take their dish one at time and therefore balancing the rate of taking dishes with the payment collection. After modification, customer can only enter the cafeteria from one designated specified entrance as shown in Figure 8. In this way, customers are single-lined and to queue from a rice serving point. The customers are self-served based on First in First out (FIFO) rule.

The last recommended inventive principle is feedback. Based on this principle, the hinted solution should involve some kind feedback that can be incorporated into the cafeteria to solve the queueing problem. A potential solution from this inventive principle is that the cashier point can have a bell or ringing system to indicate that there are customers waiting to pay for their food while the worker is focused on serving the rice to the customer. This feedback system via a ringing system can slightly improve the rate of collecting payment for service but with the adoption of the first inventive principle (introduction of self-service in rice serving), this ringing system seems to be unnecessary. Nevertheless, the ringing system can still be introduced at rice serving point to inform the worker when there is a need to replenish rice, which may run out during peak demand. Such feedback system will improve the rate of service significantly.

The inventive principle feedback also provides an idea of creating a list of menu (menu-of-the day) to provide feedback to the customer about the dishes that will be served in the cafeteria to prevent unnecessary queueing by customers that are not interested with the dishes served, which may cause delay in serving genuine interested customers.

Figure 8 shows the modified layout of the cafeteria and Figure 9 shows the flowchart of the process of the proposed queueing system at the cafeteria. In this modified cafeteria layout, customers are able to see the menu list earlier before entering the queue. In the menu list, all of the dishes of the day are displayed so that customer can make decision faster and easier. If customer was not interested in the menu on that day, they can leave the queue straight away.

Based on Figure 8, customers arrive at the cafeteria in a line or a queue. The customers will take up rice via self-service and the lone worker plays the role of the cashier at the pay counter. Then, customer will decide whether to pick the first dish or go to the next dish. If yes, customer will take the dish or else customers have to decide whether to pick the next dish. The process is the same until the last dish. After the customers are done picking the dishes, they proceed to pay at the counter and finally leave the system.

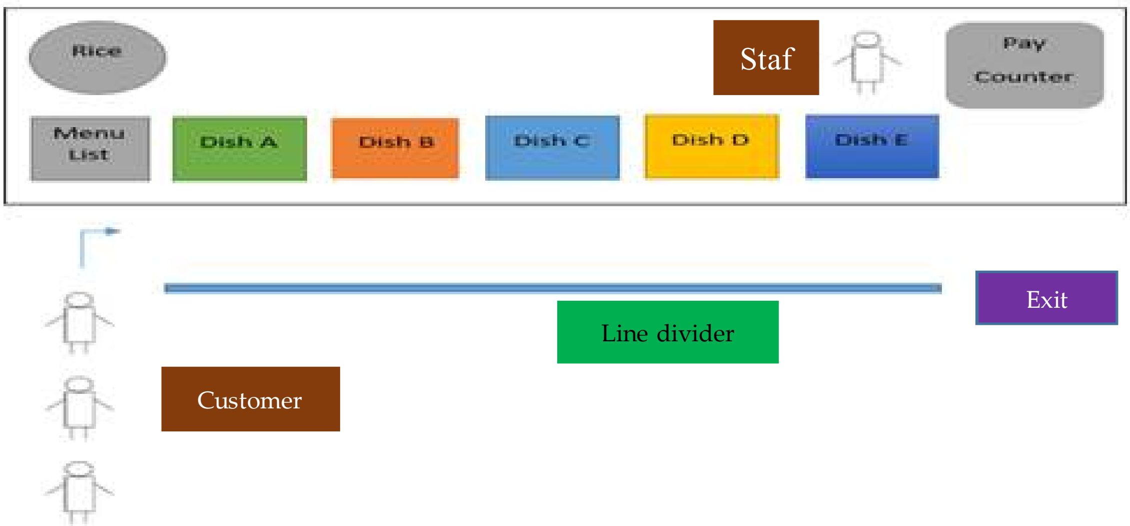

Figure 8. Modified layout of the cafeteria.

With the layout design and the processes of food serving at the cafeteria based on TRIZ engineering contradiction tool, the user can apply their modification to the cafeteria model using Arena and re-simulate the proposed cafeteria model to determine whether there were improvements in the queueing problem faced by the cafeteria.

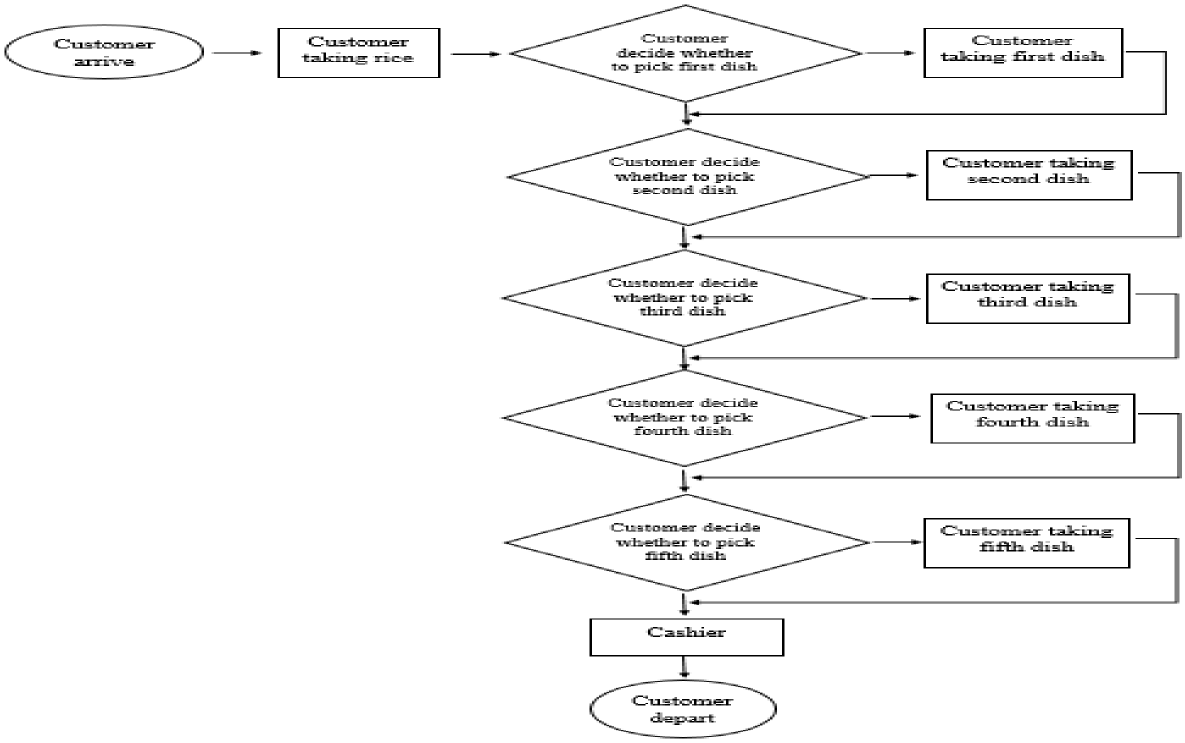

Figure 9. Flowchart of the proposed queueing system at the cafeteria.

The Arena model of the proposed queueing system for a cafeteria in UPM is as shown in Figure 10. In this model, the probability is considered as 50% for each dish because there is a Decide module before every single dish. Customer had to make decision before every dish and they might skip the dish if they want to. In other words, the probability is 50% of whether customer will pick the dish or go to the next dish. The processing time is based on Triangular TRIA (0.25, 0.5, 1) distribution. The number of staff and timeframe was set the same as the current queueing system.

There were five assumptions that were made in this proposed model. Assumptions number i, ii and iv were the same as in the current queueing system of the cafeteria. Assumption iii was modified such that customers would take up race via self-service. The new additional assumption was: there was no U-turn for customers who change their mind on choosing the dishes or in short, the customer is not expected to change their mind in choosing their dishes. Once customer passed a dish, they could not go back to the previous dishes.

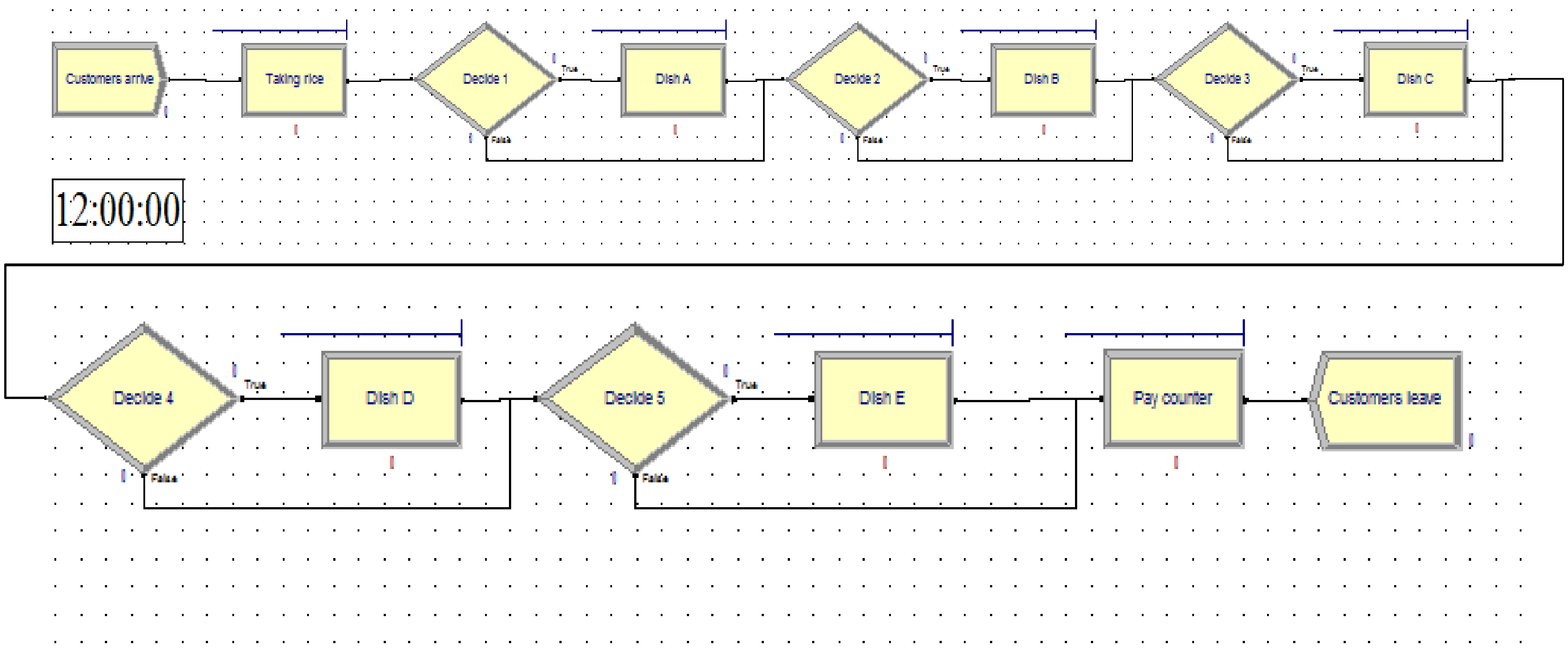

Figure 10. Arena model of the proposed queueing system.

4. Discussion

Table 3 shows the summary of the results obtained from the model simulations. According to the table, number of customer entering the system was 32 for both models. This figure was not much different from the observation, which was 28 customers within 1 hour period. For current queueing system, the average waiting time for customer is 5.2557 minutes; the minimum waiting time is 3.8826 minutes while the maximum waiting time is 7.0082 minutes. For the proposed model, the average waiting time for customer is 3.6521 minutes. The minimum of the waiting time is 2.8473 minutes while the maximum waiting time is 4.9456 minutes.

Table 3. Summary of results of the waiting time for both models.

	Current situation simulation model	Proposed solution simulation model	Improvement
Number of customer entering the system	32	32	-
Average waiting time for customer (min)	5.2557	3.6521	30.51%
Minimum waiting time for customer (min)	3.8826	2.8473	26.67%
Maximum waiting time for customer (min)	7.0082	4.9456	29.43%

The results show that there were significant improvement in terms of average waiting time, minimum waiting time and maximum waiting time in the proposed model compared to the current queueing model. The average waiting time, minimum waiting time and the maximum waiting time were improved in the range of 26% to 31% in the proposed model. Hence, the proposed model has potential to be used as service improvement method of the cafeteria.

It is observed that the improvement was achieved without deploying extra working staff or resources, which could incur extra cost. The modification on the layout alone and the introduction of the self-service in serving rice are able to minimize the waiting time of the customers. In addition to that, a list of menu was proposed to be put up in front of the counter before customers enter the queueing system to reduce the potential of balking customer. By showing the menu-of-the-day, customer can make early decision whether to purchase food from the cafeteria or simply leave from the venue. Hence, the application of TRIZ and Arena can be used to help a cafeteria to reduce its queueing problem significantly and this will contribute to the increase of profits and satisfaction of the customers.

5. Conclusion and Research Contributions

A long waiting time (due to long queues) problem in the cafeteria was investigated and modelled using Arena simulation with the intention of using TRIZ engineering contradiction tool to derive solutions to the problem instead of using trial and errors approach. The root cause for the long waiting time in a cafeteria indicated that the lone worker was unable to cope with the tasks of serving rice and collecting payments at lunchtime where customers arrive in high rate. TRIZ engineering contradiction tool was applied to find the solutions to improve the queueing problem at the cafeteria. The potential solutions derived from the recommended inventive principles of TRIZ was then applied to modify the layout of the cafeteria, convert the rice serving task to self-service and to create menu-of-the-day that will provide feedback to the customers to prevent unnecessary queueing.

The proposed system was then modelled and tested on the Arena simulation. The results showed that the proposed model based on TRIZ solutions produced promising results with no significant impact on the cost because the number of the resources was kept the same as the current situation. Based on the results, it is proven that the objective of this research was successfully achieved. The results show that the proposed solution model has a shorter waiting time compared to the current model.

This research showed that TRIZ could be applied with Arena simulation to contribute to the betterment of the cafeteria management in terms of its minimising the waiting time of the customers to be served. With the minimising of the waiting time for customers, the cafeteria management is able to increase their Quality of Service (QoS) by optimising the layout and workforce to cater customers better and faster. In addition to that, the lone worker of the cafeteria can also work more efficiently in a less duress environment and can focus the key task of collecting payments.

The reduction of waiting time at the cafeteria can significantly affect the overall level of satisfaction of the customers. By reducing the waiting time, it will help the company to attract more customers to the cafeteria and company should be able to increase their profits.

Supplementary Materials:

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