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Simulation Based Analysis of Hierarchical Timed Colored Petri Nets Model of the Restaurant Food Serving Process

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ABSTRACT

The major goal of establishing a restaurant is improved earnings making which can be jeopardized by customers' withdrawals due to lengthy ready lines. The above scenario was studied in this paper using simulation-based analysis of a Hierarchical Timed Coloured Petri Nets (HTCPN) model, which abstracted the serving operation of a renowned restaurant in the Ibadan metropolis. The restaurant was characterized by two or more servers that serially served each Customer from the multiple available servers at the four serving points. One hundred simulation runs were carried out on the HTCPN model using CPN Tools to determine the four (4) parameters,Customers' Average Flow Time (CAFT),Customers' Average Waiting Time (CAWT),Servers' Average Utilization Rate (SAUR) andCustomers' Average Queue Length (CAQL) required in serving 567, 1100, 1103, 770 and 829 customers from Monday to Friday, respectively. The model was validated by carrying out a statistical analysis t-Test between the simulated and the actual customers' flow time andservers' utilization rate at a 5% significant level. The validation results showed no significant differences between the simulated and the actual customers' average flow time andservers' utilization rate at a 5% significance level. Hence, the model can represent the restaurant under consideration.

Keywords*:* Hierarchical Timed Coloured Petri Nets, Restaurant Processes, Simulation-Based Analysis, Queuing Problem

1. INTRODUCTION

It is of great pertinence for the management of the restaurant industry to take customer satisfaction profoundly to avoid the withdrawal of Customer, which can consequently lead to the closure of the such business (es). Customer satisfaction contributes immensely to the success of every business organization, majorly restaurant industries [1]. The restaurant is a food serving outlet that provides food and drinks to Customer in exchange for money and therefore needs to pay cognizance attention to problems that could hinder customer satisfaction and changes the motive for starting such business Agnes et al. [2]. The success of every business organization, especially a restaurant, can be traced to good service quality and Customer's satisfaction [3]

Customer dissatisfaction can result from long waiting line / queue, a general phenomenon that occurs in every area of life. It can also be referred to as a waiting line, which can be encountered on a daily basis at petrol stations, banks, supermarkets, restaurants, telecommunications, transportation (especially roads), and so on [4],{5]. Queue occurred when customers have to wait for service, which could make them move to competitors' doors. For instance, when there is a higher demand with fewer attendants, the waiting line will be prolonged, and Customer may be frustrated to leave. A long queue may also be connected to slow service, especially when servers do not attend to customers on time. In [6], they opined that waiting in line To improve a system like a restaurant, one must understand how it works. Each modeled system can be simulated through experimentation to provide solutions to its future problems [7],[8]. Simulations, can be done under different configurations, are essential for understanding multiple scenarios of the modeled systems. Simulation of any system first requires the development of a model that represents the key characteristics and behaviour of the system. Then, the modeled system can be simulated by experimenting with it to provide a solution to its imminent problems. Simulation is essential for understanding several scenarios in modeled systems. It can also be used to examine the conduct of operation of a system, whether existing or proposed system, which is usually done under different configurations of interest and proposed periods of real-time. Various systems such as restaurant industries, transport companies, banking sectors, telecommunication companies, health clinics, logistics, and airports can be modeled and simulated [9]. Simulation surpasses all other approaches for evaluating modeling scenarios and is thereby given more priority over others [5].

However, to address the problem of Customer long waiting times and queue lengths in restaurants, most existing works are limited to the modelling of restaurant Food Serving Processes (FSPs) where each Customer in a queue is singlehandedly and completely served by a server from the multiple available servers. Thus, most existing models could not be used to study and improve restaurant FSP where each Customer in a queue is entirely served by two or more servers (a scenario where the first server starts the service for a customer and the second server ends it for the same Customer). To bridge the gap as mentioned above, [10] developed a model for restaurant FSP where each Customer in the queue is serially and ultimately served by two or more servers using HTCPN.

2. REVIEW OF RELATED WORKS OF LITERATURE

[11] developed a model for health center patient care flow processes using Timed Coloured Petri Nets. The developed model was simulated using CPN tools, while its validation was done by comparing the simulated and actual number of patients of the health center under study. The results revealed that thirty-four (34) (seven inpatients and twenty-seven outpatients), fifty-three (53) (nine inpatients and forty-four outpatients), forty-two (42) (eight inpatients and thirty-four outpatients), and forty-five (45) (nine inpatients and thirty-six outpatients) were regular visitors to the health center. The average number of patients entering the health center during the first, second, third, and fourth working days under consideration varies considerably. queue is an important activity of our daily routine, especially during lunchtime at restaurant(s).

Reference [13] developed a restaurant process model to analyze process alternatives. The model represented an abstraction of a business process. The process alternatives with the application of the two best practices (specialist-generalist trade-off and flexible assignment policy) for improvement of the process were modeled and evaluated. The simulation was used to measure performance indicators. This simulation model was represented as a CPN. They found alternatives with the lowest average throughput time, which improved the initial process.

[12] Examining the queuing system in Blue Meadows restaurant to determine its operating features and improve customers' satisfaction during waiting time with the adoption of queuing theory. Data were collected from a fast-food restaurant at the University of Benin called Blue Meadows, which has only two servers. The arrival rate (λ) at Blue Meadows restaurant was about 40 customers per hour, while the service rate was about twenty-two (22) customers per hour for each server. The average number of customers in the system in an hour window was forty (40), with a utilization rate of 0.909. It was discovered from the model that most customers will have to wait in the queue to be served. This resulted from the high value generated for utilization rate, that is, 0.909 which showed the probability of the servers being busy at 90.9%.

3 RESEARCH METHODOLOGY

In this paper, a novelty approach to serving Customer (s) serially and consecutively was explored during the food serving process in restaurants that considered four serving points using Hierarchical Timed Coloured Petri Nets was adopted.

Simulation Analysis of the Developed HTCPN Model for Restaurant Food Serving Process

Figure 1 displays the Simulation of the environment page (main page) of the developed HTCPN model [10] for the Restaurant Food Serving Process (FSP) at a renowned Restaurant in the Ibadan Oyo State of Nigeria, while the Simulation of the four sub-pages (modules) which consist of Simulation of the four (4) serving points: serving point1, serving point2, serving point3 and serving point 4 are shown in Figures. 2, 3, 4, and 5. The main page (Environment) of the model provides an overview of the entire restaurant food serving operation, including the four sub-pages which model how customers arrive at each serving point in the restaurant. In this paper, the developed HTCPN model in [10] was implemented and simulated within the CPN Tools environment.

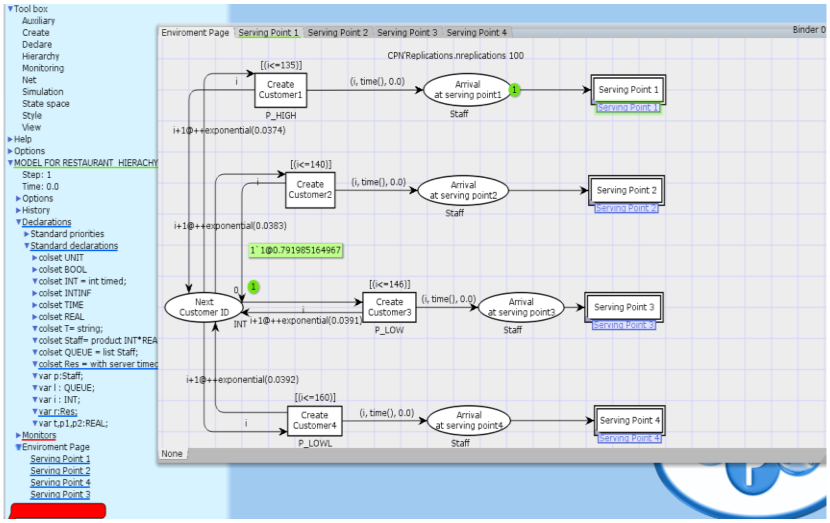

Figure 1: Simulation of the environment page

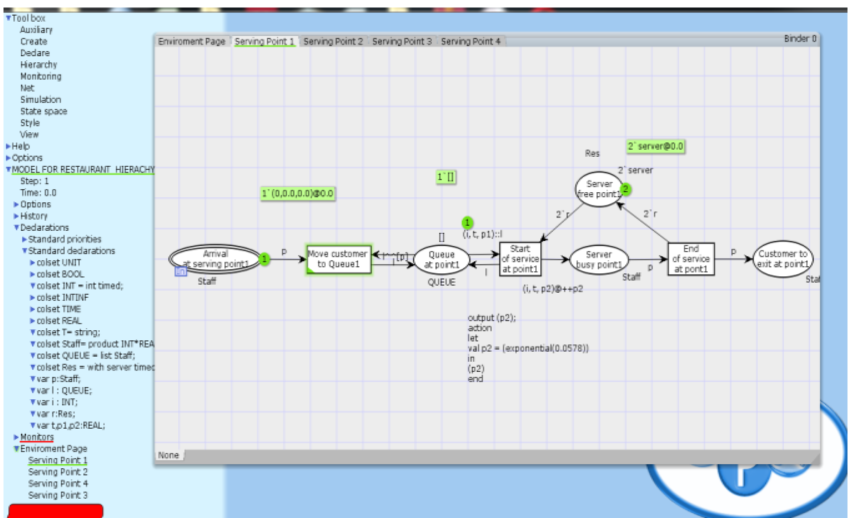

Figure 2: Simulation of serving point 1

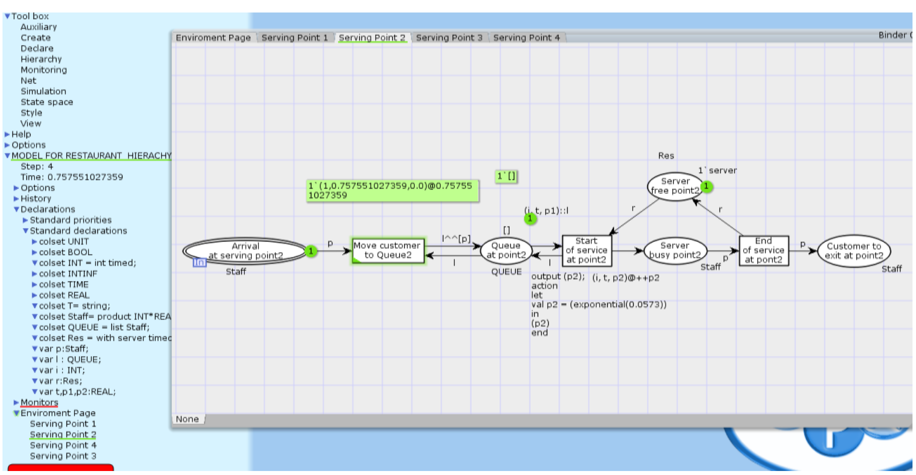

Figure 3: Simulation of serving point 2

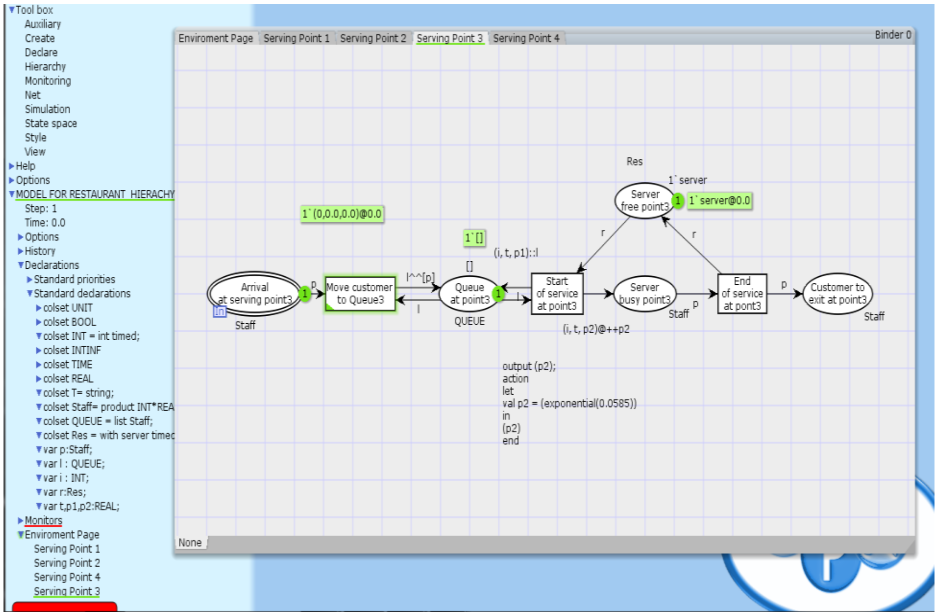

Figure 4: Simulation of serving point 3

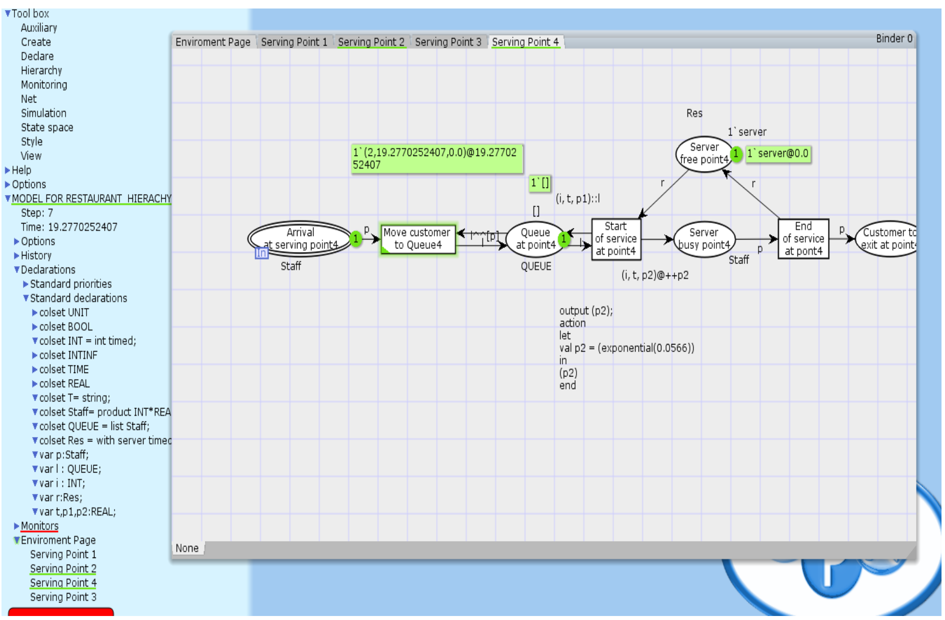

Figure 5: Simulation of serving point 4

4 SIMULATION RESULT OF THE DEVELOPED HTCPNS MODEL

Results generated during Simulation of the developed HTCPNs model are as shown in Tables 3 to 7, which include the four (4) performance metrics: average flow time, average waiting time, average utilization rate, and average queue length at each serving points for a week (Monday to Friday). Table 3 shows the simulated values at the serving point 1 for the four (4) performance metrics in the consideration of the five scenarios 0%, 25%, 50%, 75%, and 100% increase in a number of customers to take care of possible future scenarios.

Table 1: Simulation Result of Five (5) Scenarios for Serving Points 1 to 4 **Serving Points 1 to 4**

Table 1: Monday	**Increase in % of Customer**	**Flow Time (Second)**	**Waiting Time (Seconds)**	**Utilization Rate (%)**	**Queue length (Customers)**	**Number of Customers**	**Number of Servers**
Serving Point 1	0%	46.78	29.30	65	**17**	135	2
	25%	87.40	69.93	80	39	169	2
	50%	46.07	128.47	89	56	203	2
	75%	397.33	379.61	98	81	236	2
	100%	650.19	632.61	99	155	270	2
	0%	23.41	2.15	59	**2**	135	3
Serving Point 2	0%	50.35	32.78	64	**17**	140	2
	25%	93.31	75.83	80	18	175	2
	50%	206.52	188.97	93	31	210	2
	75%	432.18	405.59	98	56	245	2
	100%	703.54	686.00	99	109	280	2
	0%	19.93	2.28	60	**0**	140	3
Serving Point 3	0%	50.27	33.10	66	**25**	146	2
	25%	85.05	68.00	80	23	183	2
	50%	212.62	195.37	93	31	219	2
	75%	446.75	429.63	98	52	256	2
	100%	740.91	723.53	99	140	292	2
	0%	10.45	2.22	58	**0**	146	3
Serving Point 4	0.00%	59.25	41.32	69	**23**	146	2
	25.00%	104.85	87.04	84	21	183	2
	50.00%	244.98	227.31	94	31	219	2
	75.00%	503.63	485.82	99	48	256	2
	100.0%	798.61	780.72	99	143	292	2
	0.00%	20.29	2.50	59	**0**	146	3

Table 2: Tuesday Simulation Result of Five (5) Scenarios for

	Increase in % of Customer	**Flow Time (Seconds)**	**Waiting Time (Seconds)**	**Utilization Rate (%)**	**Queue length (Customers)**	**Number of Customers**	**Number of Servers**
Serving Point 1	0.00%	52.28	37.81	70	**21**	184	2
	25.00%	116.06	101.68	89	28	230	2
	50.00%	288.58	274.26	97	57	276	2
	75.00%	569.35	554.97	99	83	322	2
	100.00%	871.86	857.56	99	159	368	2
	0.00%	16.75	2.36	63	**1**	184	3
Serving Point 2	0.00%	44.39	30.90	68	**22**	280	2
	25.00%	101.51	88.03	85	26	350	2
	50.00%	390.30	295.81	96	31	420	2
	75.00%	671.89	568.44	99	59	490	2
	100.00%	1145.06	1130.58	100	83	560	2
	0.00%	15.56	2.01	61	**0**	280	3
Serving Point 3	0.00%	47.49	34.22	66	**29**	310	2
	25.00%	107.73	94.46	87	31	388	2
	50.00%	339.79	321.19	97	40	456	2
	75.00%	767.03	753.79	99	56	543	2
	100.00%	1236.46	1223.16	100	102	620	2
	0.00%	15.53	2.08	60	**0**	310	3
Serving Point 4	0.00%	44.02	32.73	65	**30**	326	2
	25.00%	92.13	78.97	85	36	408	2
	50.00%	303.50	290.30	97	51	489	2
	75.00%	787.86	774.60	99	70	571	2
	100.00%	1285.16	1271.96	100	119	652	2
	0.00%	17.56	1.85	60	**5**	326	3

Table 3: Wednesday Simulation Result of Five (5) Scenarios for Serving Points 1 to 4

	Increase in % of Customer	**Flow Time (Seconds)**	**Waiting Time (Seconds)**	**Utilization Rate (%)**	**Queue length (Customers)**	**Number of Customers**	**Number of Servers**
Serving Point 1	0.00%	67.69	53.57	67	**10**	199	2
	25.00%	182.56	170.28	94	12	249	2
	50.00%	442.26	428.98	99	32	299	2
	75.00%	732.61	719.80	100	54	348	2
	100.0%	1110.21	1058.32	100	79	398	2
	0.00%	16.02	2.94	62	**0**	199	3
Serving Point 2	0.00%	57.08	43.88	75	**10**	210	2
	2500%	141.03	127.89	93	8	263	2
	50.00%	391.21	377.95	99	28	315	2
	75.00%	706.75	693.61	99	52	368	2
	100.00%	1020.11	1007.01	100	76	420	2
	0.00%	16.03	2.85	65	**0**	210	3
Serving Point 3	0.00%	130.41	114.45	87	**20**	300	2
	25.00%	447.35	424.24	98	28	375	2
	50.00%	927.72	913.07	99	60	450	2
	75.00%	1467.10	1452.10	100	97	525	2
	100.00%	2028.04	2012.92	100	132	600	2
	0.00%	19.19	4.04	69	**0**	300	3
Serving Point 4	0.00%	39.38	26.93	68	**20**	394	2
	25.00%	94.74	82.21	85	22	493	2
	50.00%	314.33	301.88	97	23	591	2
	75.00%	772.85	760.38	100	60	690	2
	100.%	1368.80	1356.43	100	109	788	2
	0.00%	14.31	1.81	58	**0**	394	3

Table 4: Thursday Simulation Result of Five (5) Scenarios for Serving Points1 to 4

	Increase in % of Customer	**Flow Time (Seconds)**	**Waiting Time (Seconds)**	**Utilization Rate (%)**	**Queue length (Customers)**	**Number of Customers**	**Number of Servers**
ServingPoint 1	0.00%	37.00	20.81	70	**20**	170	2
	25.00%	58.14	41.91	71	23	213	2
	50.00%	115.14	97.79	84	46	255	2
	75.00%	244.83	228.39	95	60	298	2
	100.00%	464.38	474.94	99	81	340	2
	0.00%	17.86	1.62	56	**0**	170	3
ServingPoint 2	0.00%	37.73	21.54	67	**18**	180	2
	25.00%	54.10	37.59	69	22	225	2
	50.00%	91.14	74.93	82	35	270	2
	75.00%	176.09	160.10	93	52	315	2
	100.00%	437.64	421.53	98	67	360	2
	0.00%	17.43	1.31	55	**0**	180	3
ServingPoint 3	0.00%	31.35	15.32	88	**21**	210	2
	25.00%	40.48	29..37	60	28	263	2
	50.00%	59.20	43.26	71	40	315	2
	75.00%	99.44	83.47	83	55	368	2
	100.00%	168.49	152.52	91	89	240	2
	0.00%	17.04	1.13	48	**0**	210	3
ServingPoint 4	0.00%	31.21	15.15	89	**19**	210	2
	25.00%	42.50	26.33	60	21	263	2
	50.00%	60.26	44.16	71	42	315	2
	75.00%	99.57	83.42	83	60	368	2
	100.00%	199.51	183.48	92	78	420	2
	0.00%	17.05	1.15	47	**0**	210	3

Table 5: Friday Simulation Result of Five (5) Scenarios for Serving Points1 to 4

	Increase in % of Customer	Flow Time (Seconds)	Waiting Time (Seconds)	Utilization Rate (%)	Queue length (Customers)	Number of Customers	Number of Servers
Serving Point 1	0.00%	108.98	87.13	80	**20**	160	2
	25.00%	288.20	268.12	94	42	200	2
	50.00%	540.88	521.00	99	46	240	2
	75.00%	975.20	955.15	100	70	280	2
	100.00%	1307.03	1287.15	100	101	320	2
	0.00%	24.47	4.51	70	**1**	160	3
Serving Point 2	0.00%	141.55	122.43	84	**27**	199	2
	25.00%	356.99	337.82	97	28	249	2
	50.00%	760.88	741.62	99	43	299	2
	75.00%	1223.71	1204.62	100	63	348	2
	100.00%	1665.20	1646.14	100	99	398	2
	0.00%	23.68	4.51	65	**0**	199	3
	0.00%	172.34	154.89	86	**28**	230	2
Serving Point 3	25.00%	421.07	401.75	97	31	288	2
	50.00%	920.85	901.58	99	59	345	2
	75.00%	1472.83	1453.48	100	86	403	2
	100.00%	2016.93	1979.57	100	122	460	2
	0.00%	24.15	4.72	60	**0**	230	3
Serving Point 4	0.00%	135.01	115.13	84	**23**	240	2
	25.00%	364.08	342.23	96	27	300	2
	50.00%	965.54	945.43	99	46	360	2
	75.00%	1451.02	1431.11	100	87	420	2
	100.00%	2042.74	2022.74	100	119	480	2
	0.00%	24.85	4.88	67	**0**	240	3

From the simulation result, it was discovered that by an increasing the number of servers from two to three, customers' average flow time and average waiting time decreases, reducing servers' utilization rate and customers' average queue length drastically. Thus, customers' satisfaction with the restaurant food serving process can be improved if the management can increase the number of servers at each serving point. It was also discovered from the result of Simulation on Friday that all the performance measures considered were on the high side, which can be explained from a business point of view by the type of food served on Friday (Fried rice/ Jollof rice with chicken). Customers' patronage was also noticed to be on the high side on Wednesday and Friday, which consequently increased servers' workload (Servers' utilization rate). It was discovered that as the utilization rate was less than 1(100%), the queue was reduced to the minimal, but as the utilization rate tended towards 1(100%), the queue began to increase. So, it can be deduced that queues can build up if servers are highly utilized, which will lead to low productivity and can be connected to queues experienced on the days of the week, and this can also account for the long waiting time of customers in the system (average flow time).

From the simulation result, it was discovered that queue length increases based on the increase in servers' utilization rate, which is in support of [5] which states that the higher the servers' utilization rate, the higher the customers' queue length.

5. VALIDATION OF THE DEVELOPED HTCPNS MODEL

Validation of the developed HTCPN model is to check the correctness and credibility of the model developed. Thus, the developed HTCPN model was validated to check whether it represents the system under consideration by comparing the output of the simulated Restaurant food serving process (that is, increase in the number of customer arrival at each serving point and servers utilization rate) with the absolute values of the actual system (from input data gotten from direct observation at the system)

Simulated and the actual customers' average flow time and servers' utilization rate were used for statistical analysis using Statistical Package for Social Sciences software (SPSS) version 20.0. Table 8 shows that statistically, there were no significant differences between the simulated and the real average values at 5% significance difference level. Figure 6 displays the validation result of the developed HTCPN model. Hence, the developed HTCPN model of the restaurant food serving process is valid and accurately represents the restaurant under consideration.

Table 8: Statistical Analysis summary of the Validation Results of the Developed Model

Variable	t-value	p-value	Remark
Pair 1 Simulation_flow_time - Real_flow_time	-1.438	0.224	the p-value is discovered to be greater than 0.05, which implies that there is no significant difference between the real data and simulated data (customers' flow time) at a 5% significant level
Pair 2 Simulation_utilization_rate - Real_utilization_rate	-2.449	0.07	the p-value is greater than 0.05, which implies that there is no significant difference between the real data and the simulated data (servers' utilization rate) at a 5% significant level

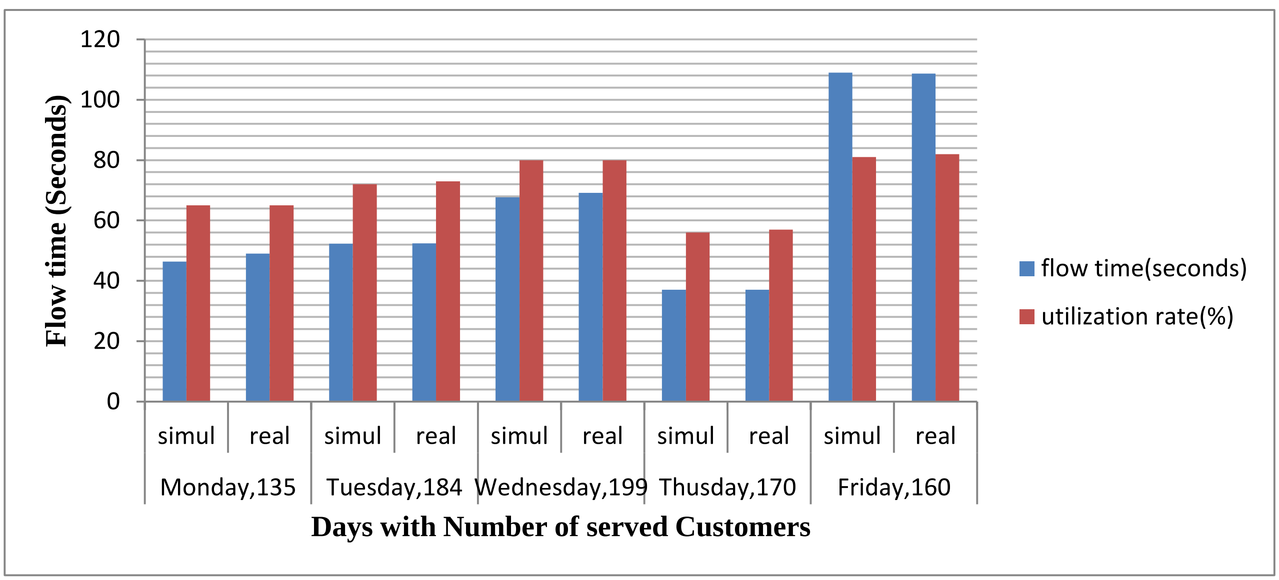

Figure 6: Validation Results of the Developed HTCPN Model

*NOTE
simul = Simulation value
real = Real value

6.CONCLUSION

The developed HTCPNs simulation model revealed a valid representation of the system (restaurant food serving process) under consideration. The analysis of the HTCPNs simulation reports shows that some serving points experienced queues (waiting lines) in the process of attending to customers throughout the week. The queue was due to an increase in the servers' utilization rate because utilization rate represents the average proportion of time in which the servers are occupied. As the utilization rate tends to 100%, servers' capability to attend to customers reduces and, consequently queue build up.

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