Development of a Model for an Inbound Call Centre Using Hierarchical Timed Coloured Petri Nets

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Authors' contributions

This work was carried out in collaboration among all authors. Author AOA established a research gap, spelt out a detailed methodology for model development and wrote the first draft of the manuscript. Authors RAG and OTA carried out data acquisition, model simulation and validation. Author AOG managed the literature searches. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

Inbound call centres are centralized offices which are operated by modern organizations to administer incoming product supports or information inquiries from consumers. In this paper, a model for an inbound call centre, which is characterized by agent utilization and call abandon rates, was developed using Hierarchical Timed Coloured Petri Nets (HTCPN). The inbound call section of *SN* Nigeria Ltd., Lagos, Nigeria, was used as a case study in developing the HTCPN model. Data were collected and analyzed statistically using ARENA simulation software to determine the model parameters. These parameters were used as inputs in developing the HTCPN model which consists of *Call Arrival, Hang up Processes, Sales Processes, Customercare* and *Enterprise Process* modules. The model was simulated using Colour Petri Nets tools and validated by carrying out a statistical analysis (t-Test) between the simulated and the real number of abandon calls and agents utilization rates at 5% significance level. The simulation results of the developed HTCPN model revealed that increase in number of agents utilized resulted into decrease in abandon calls from 71, 7 and 108 to 35, 4 and 102 in customer care, enterprise and sales departments, respectively. Correspondingly, increase in number of utilized agents led to reduction in agents'

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utilization rates from 96, 50 and 96% to 84, 40 and 92% for customer care, enterprise and sales departments, respectively. The result of the validation showed that there were no significant differences between the simulated and the real number of abandoned calls and agents utilization rates.

1. INTRODUCTION

Call Centres are locations where calls are placed, or received, in high volume for the purpose of sales, marketing, customer service, telemarketing, technical support or other specialized business activity [1]. Call centres have become an integral part of doing business as many companies use call centres for customer interactions such as selling products and services, providing product support, and resolving billing issues [2]. The three main components of any call centre are the customers (or calls), the technologies employed, and the customer service representatives. Customers are typically grouped according to the flow direction of the call as either inbound call (or incoming call) or outbound call (or outgoing call).Call centres are categorized accordingly based on the calls they process, namely inbound call centres, outbound call centres, or mixed call centres. Inbound calls are those initiated by customers to the centre. Call centres are used by many firms that operate in very different sectors, such as mail-order catalogue organizations, telemarketing companies, computer product help desks, banks, hotels and any large enterprises that use telephone as a medium of attending to customer services and products. Call centers and their contemporary successors, contact centers, have become a preferred and prevalent means for companies to communicate with their customers. Most organizations with customer contact—private companies, as well as government and emergency services—have reengineered their infrastructure to include from one to many call centers, either internally managed or outsourced. For many companies, such as airlines, hotels, retail banks, and credit card companies, call centers provide a primary link between customer and service provider. The call center industry is thus vast and rapidly expanding, in terms of both workforce and economic scope [3]. Using stochastic models to plan call center operations, schedule call center staff efficiently, and analyze projected performance is not a new phenomenon, dating back to Erlang's work in the early twentieth century. However, several factors have recently conspired to increase demand for call center simulation analysis. These include Increasing complexity in call traffic, coupled with the almost ubiquitous use of Skill-Based Routing; Rapid change in operations due to increased merger and acquisition activity, business volatility, outsourcing options, and multiple customer channels (inbound phone, outbound phone, email, web, chat) to support; Cheaper, faster desktop computing, combined with specialized call center simulation applications that are now commercially available [4].

Furthermore, [3] stated that several complexities are encountered in modern call centres, which are mainly due to the insufficient number of call agents, resulting in long waiting time of customer's call. It is therefore imperative to improve the performance of call-centre business processes using powerful decision-making tools to visualize, simulate and analyze the processes. The best available tools today to perform these functions are simulation tools [5]. The use of computer simulation to help in effective decision making has become a common practice in solving sensitive problems [6]. This is because of its ability to dynamically analyze situations and present to the stakeholders a more realistic view of the system [7]. Fishwick [8] defined simulation as the imitation of the operation of a real-world process or system over a period by experimenting with a model. A model is a description or a representation of the operations of a real system either mathematically or symbolically. Petri Nets is a graphical and mathematical tool for describing and studying systems that are characterized as being concurrent, synchronous, asynchronous, distributed, parallel, deterministic, non-deterministic and/or stochastic [9]. Coloured Petri Nets (CPN) is an example of high-level Petri Nets which combines the strength of Petri Nets with the strength of functional programming language Standard ML [10,4,11]. The executable nature of CPN, Timed CPN (TCPN) and Hirarchical Timed CPN (HTCPN) models makes them a right candidate for studying varying call centre systems.

More so, the continued growth in the economic importance and complexity of call centres prompted increasingly deep investigation of their operations by a growing body of researchers [12]. Developed a simulation model, for a simple call centre logic flow, which consists of the processing of phone calls at an inbound call centre for a major retailer of home electronics products. To limit the scope of this model, the details and complexities of actual call-centre operations were ignored. However, [4] extended the simulation model developed by White and Ingalls [12] with significant improvement. Also, Takakuwa and Okada [13] modelled and simulated an inbound call centre of a city-gas company to examine the proper target of the service level procedures by finding the optimal number of agents, considering their skills and the scheduling of the agents to meet the frequency of customer calls. In addition, several studies focused on various issues concerned with call centres through modelling. Performance was measured within the call centre at the service level, which was defined as the percentage of customers served within some fixed time period, known as the service level target. Similarly, both inbound and outbound calls were treated and analyzed from the standpoint of the agents' skill by several authors [4,14]. The agents' skills for online routing of incoming calls were evaluated by several authors [4,15,16] looked into technology that enabled the present and the possible future of call centres. Furthermore, overview of some challenges in call centre was studied by Grossman et al. [17] while managements of customers in call centre were looked into by several authors [5,3] gave details to queuing models of scheduling in call centre.

From review of related works, it can be inferred that concerted efforts were made to improve call centres' performance metrics through modelling and simulation of inbound call centres. Most existing works modelled inbound call centres to simulate call types, agent skills and scheduling of the agents that would meet the frequency of customer calls with less emphasis on agent utilization and call abandon rate. That is, a vast amount of existing models do not capture agent utilization and call abandon rates which are also critical performance metrics that determine the acceptable level of customers' satisfaction and system operational efficiency in inbound call centres. In this paper, the significance of the two aforementioned metrics has motivated and necessitated the development of a computational model for an inbound call centre which is characterized by agent utilization and call abandon rates using Hierarchical Timed Coloured Petri Nets.

2. METHODOLOGY

In developing a model for an Inbound Call Centre (ICC)using HTCPN, the research approach being employed includes description of the case study; data collection and analysis; development of an HTCPN model for the ICC; simulation of the HTCPN model; and validation of the model.

2.1 Description of the Case Study

The call centre section of *SN* Nigeria Ltd. was used as a case study. *SN* is a networking firm located at Victoria Island, Lagos State, Nigeria. Fig. 1 depicts the activities of *SN* inbound call centre. The company's call centre section has three departments that handle the incoming calls within and outside the country; these are Sales department, Customer care department and Enterprise department. Arriving calls at the Centre first connect to a telephone switch. If the number of calls currently on hold is greater than 15, the caller receives busy signal and immediately hangs up. Otherwise, the call will be delivered to an automated Interactive Voice Response (IVR) unit. At the IVR unit, if the caller is a new customer then the call will be forwarded to Sales department where it will be processed. Also at the IVR unit, an existing customer (registered with the firm) can be forwarded to either Customer care department or Enterprise department. Any customer that wishes to speak with an agent will wait (listening to music) until the representative servicing the department becomes available and the caller hangs up after the completion of the call.

2.2 Method of Data Collection and Analysis

The data for the number of customer incoming calls and their arrival times were obtained from the *SN* inbound call centre. The data were used to generate input parameters for model development and simulation. The data being obtained include:

(i)   The total number of incoming calls to the call centre;
(ii) The total number of support agent, operations agent, in the inbound section; and
(iii) The inter arrival times of incoming calls

The obtained inter-arrival time of customers (incoming calls) were analyzed to determine the appropriate statistical distribution for the inter-arrival time using suitable distribution fitting software. In this case, the Input Analyzer of ARENA Simulation software was used. The distribution fitting software analyzed the best distribution method being employed in the sample analysis based on the least square error. It also calculated descriptive statistics such as frequencies, mean, mode, median, standard deviation, chi-squared test, probability density and cumulative distribution.

2.3 Development of an HTCPN Model for the Inbound Call Centre

Fig. 2 shows the developed HTCPN model for the inbound call centre under consideration. The model was structured in hierarchical levels. At the highest hierarchical level, the structure of the

HTCPN model consists of a top page (Call centre) and two sub-pages (modules): the *Call Arrival processes* and the *Call processes*. The top page of the model provides an overview of the call processing system in the entire inbound call centre. The *Call Arrival Processes* module shown in Fig. 3 modelled the process of arriving calls. The *Call Processes* module depicted in Fig. 4 consists of four sub-modules which include *Hangup Process, Sales Process*, *Customer Care Process* and *Enterprise Process.* The *Hangup process* sub-module shown in Fig. 5 abstracted the process of hanging up call while the *Sales Process* sub-module as depicted in Fig. 6 modelled the process of receiving call in the sales Department. The *Customer Care Process* sub-module as shown in Fig. 7 modelled the process of receiving call in the customer care department. The *Enterprise Process* sub- module as depicted in Fig. 8 modelled the process of receiving call in the enterprise department.
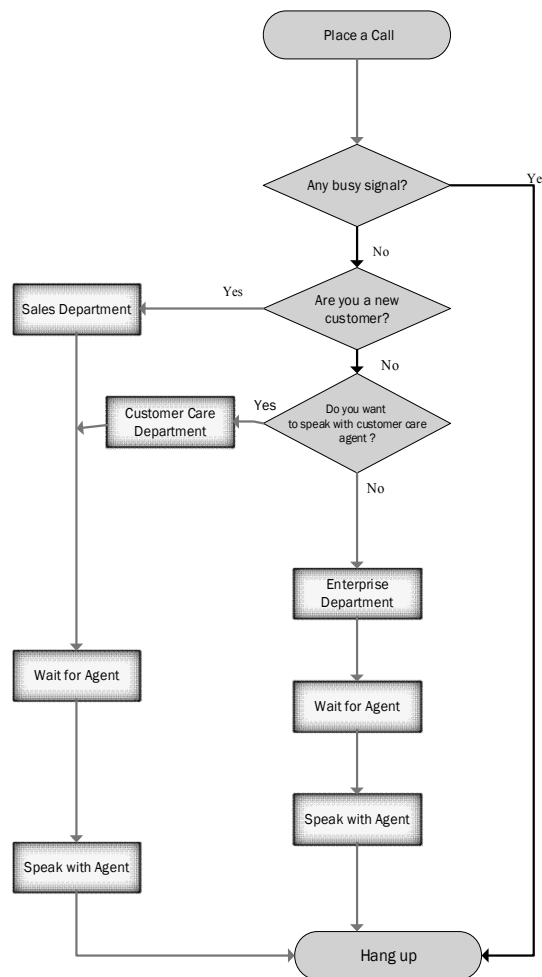

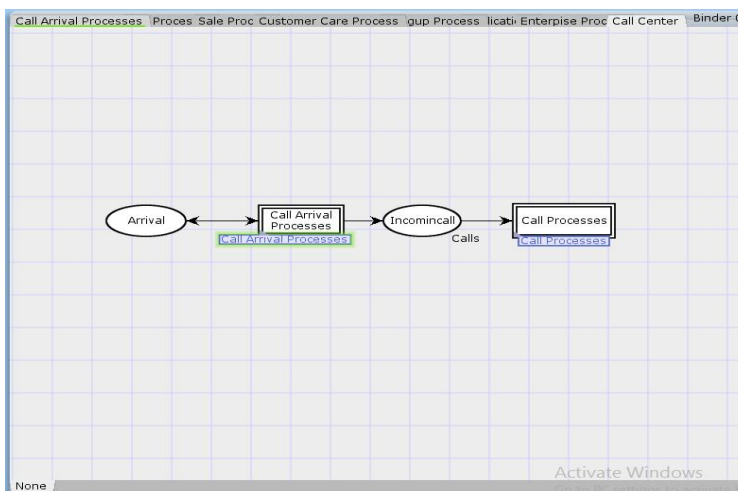**Fig. 1. Flowchart of inbound call process of SN Nigeria Ltd**

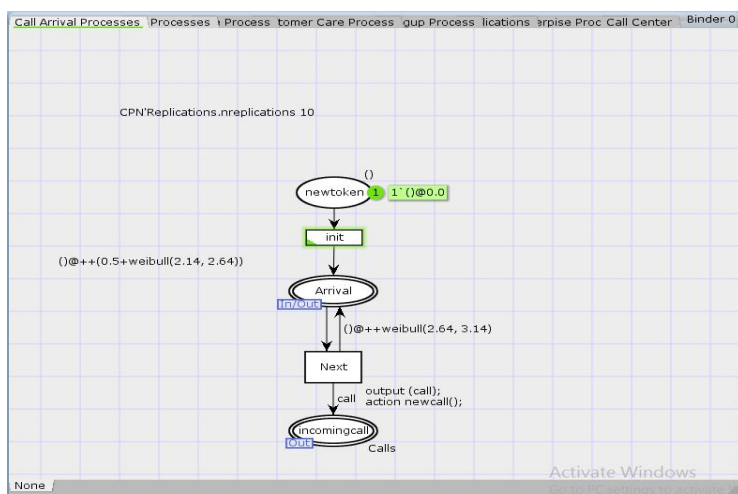**Fig. 2. The developed HTCPN model (top page) for the inbound call centre**

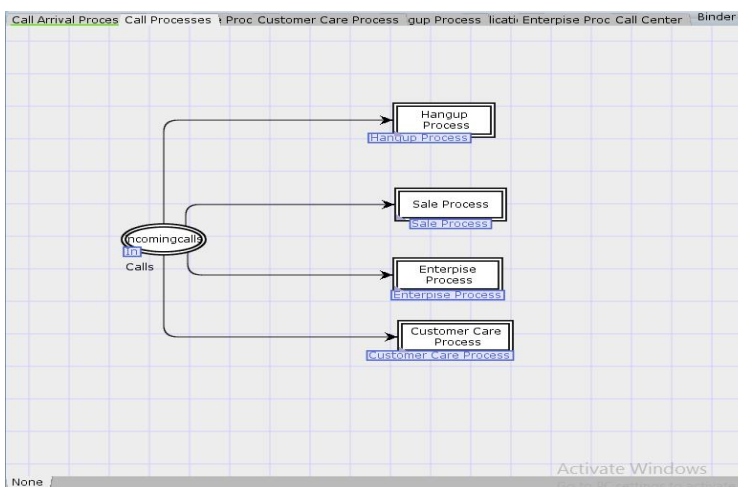**Fig. 3. The call arrival processes module of the developed HTCPN model**

Fig. 4. The call processes module of the developed HTCPN model
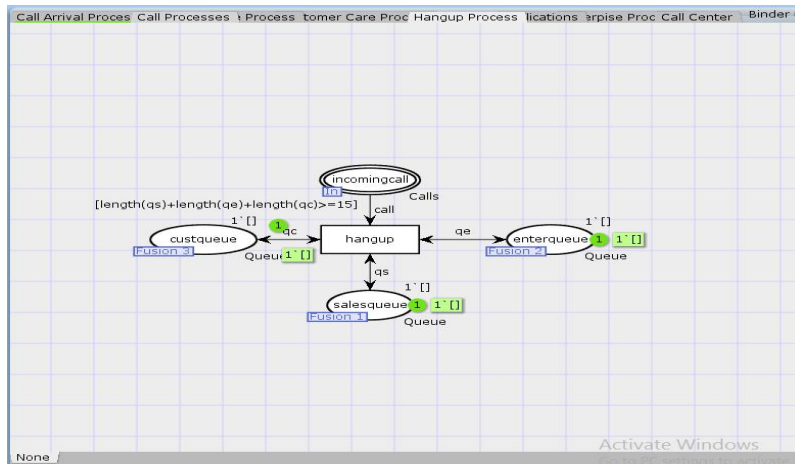
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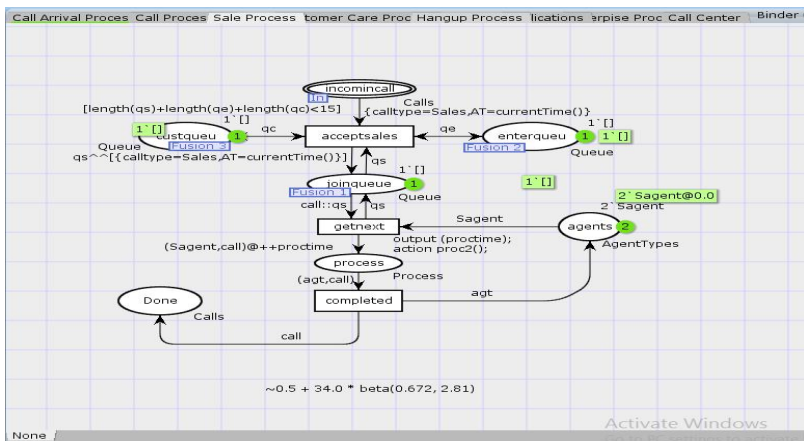**Fig. 5. The hang up processes sub-module of the developed HTCPN model**

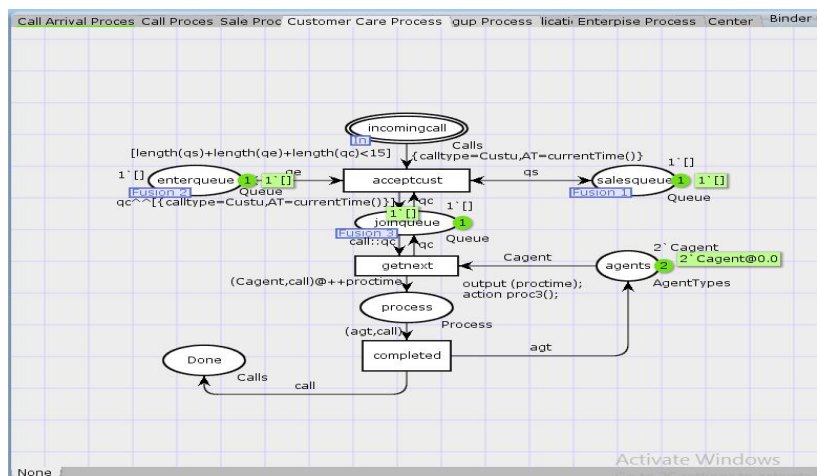**Fig. 6. The sale processes sub-module of the developed HTCPN model**

Fig. 7. The customer care process sub-module of the developed HTCPN model

2.3.1 The top hierarchy model of the inbound call centre system

The Top page captured the most abstract representation of the inbound call centre system. The top page consists of two sub modules that were modelled by the two substitution transitions, *Next* and *process*. The place *Arrival* models the arrival of token that represent incoming call. The color set of the place is a unit color set. The place *Incomingcall* models the type of call which is a record that contains the type of call and the arrival time field. Calls are added to the place *Incomincall* from the *Next* module, and calls are removed from the place *Incomincall* in the *Process* module.

2.3.2 The arrival sub-model of the inbound call centre system

The arrival of calls to the system was modelled on the page *Next*. A token on the place *Arrival* determines when new call arrives. The color set for the place is a timed color set, and the time stamp of the token on the place determines when the *Next* transition can occur. There is no token on the place in the initial marking. The *Init* transition is the only transition that is enabled in the initial marking. The transition is used to put a token on the place *Arrival*. The time inscription *@()@++(0.5+weibull(2.14, 2.64))* on the arc from the transition in it to the place *Arrival* was used to create a time stamp for the token that is added to the place . The *Weibull* function will return a value from the *weibull random* distribution function. This time stamp was used to ensure that the first call will not always arrive at time zero for different simulations. The transition *Next* will occur when the time stamp of the token on the place *Arrival* is equal to current model time. When the transition occurs, a new call enter and bound to the variable *call* via the code segment of the transition. The new call is then added to the place *Calls* by the arc inscription call on the arc from *Next* to place *Calls*. The time inscription *()@++(0.5+weibull(2.14, 2.64))* on the arc to place *Arrival* was used to determine the time at which the next call will arrive. The inter-arrival times were weibully distributed with a mean of 2.40 time units.

2.3.3 The call routing sub-model of inbound call centre system

The routing of incoming calls was modelled on the *Process* page in the net. This page models the arrival of calls to be processed at various departments. The *hangup* module models the

calls that were not accepted into any of the departments, the *Sales Process* module models the calls that were accepted into sales department, the *Enterprise Process* modules models the calls accepted into enterprise department while the calls that were accepted in the Customer care departments were modelled by the *processconsu* module.

2.3.4 The hang up sub-model of inbound call centre system

The subnet module *hangup* modelled the number of calls that received busy signals on the switch. The place *incomingcall* is a record colour set consisting of the incoming call type and the arrival time. The condition checked by the *hangup* transition guard *[length(qs)+length(qe)+length(qc)>=15]* indicated that if there are already 15 calls waiting to be processed, a busy signal will be issued and the caller hangs up. The CPN firing rules guarantee that this transition will not fire if the condition is not met.

2.3.5 The sales department sub-model of inbound call centre system

The *SalesProcess* subnet represents the model of the calls that were accepted in the sales department. Here, a call will be routed into the department if it is a new customer according to Fig. 1. The arc inscription *{calltype=Sales,AT=currentTime()}* on the outgoing arc of *incomincall* place indicates that the call is of sales type. The call will be accepted if the maximum on hold limit is not reached, shown by *[length(qs)+length(qe)+length(qc)<15]*. If this condition is met, the transition *acceptsales* fires and the call with its arrival time is added to the end of the queue of place *joinqueue*, as determined by the arc inscription *qs^^ [{calltype=Sales,AT=currentTime()}]* on the arc from *acceptsales* to place *joinqueue*. The place *joinqueue* models the queue of calls. The color set of the place is alist color set. There is a single token on the place in the initial marking of the net, and there will be a single token on the place in every reachable marking. The single token on the place represents the queue of calls. In the initial marking the list is empty, that is, the queue of calls is empty in the initial marking. Calls are added to the queue in the *acceptsales* transition while calls are removed from the queue in the *getnext* transition.

The places *AgentTypes* and *process* were used to represent the status of the sales department.

A call can start to be processed if a sales agent is available (denoted by arc inscription *Sagen*' on the arc from place *AgentTypes* to transition *getnext*) and if there is at least one call in the queue of place *joinqueue* (call::qs) on the arc from place *joinqueue*. When the transition *getnext* occurs, the *proc2( )* function is called in the code segment, and the value that it returns is bound to the variable *proctime* which determines the processing time for the call that was removed from the head of the queue. Processing times for calls were betally distributed with a mean processing time of 20.72 time units. The *completed* transition will become enabled when an agent finishes processing a call. The transition will become enabled when the time stamp of a token on place *process* is equal to current model time. When the transition occurs, the call will be added to the place *Done* and the agent will become available or idle and returned to place *AgentTypes* (as denoted by the arc inscription '*agt*' from transition completed to place '*AgentTypes*').

2.3.6 The enterprise department sub-model of inbound call centre system

The *EnterpriseProcess* subnet represents the model of the calls associated with Enterprise department**.** The model is similar to the sales department page except the number of agents and agent type. The arc inscription *{calltype=Enter,AT=currentTime()}* from outgoing arc of place *incomingcall* to transition *acceptenter* denoted the kind of call routed to the department and the arrival time. The initial inscription (2`Eagent) in the place agent shows that there were two agents in the Enterprise department initially; this can changed during the course of simulation for performance analysis.

2.3.7 The customer care department sub-model of inbound call centre system

The '*Customer Care Process*' subnet represents the model of the calls associated with Customer care department**.** The model is similar to the enterprise department page except the number of agents and agent type. The arc inscription *{calltype=Custu,AT=currentTime()}* from outgoing arc of place *incomingcall* to transition *acceptcust* denoted the kind of call routed to the department and the arrival time. The initial inscription 2`Cagent in the place agent shows that there were two agents in the Customer care

department initially and this can change during simulation for performance analysis.

2.3.8 Assumptions made in the developed HTCPN model

The assumptions made in model development are:

i. The music duration when each customer was waiting for the representative of servicing department (agent) to become available was added to the calls processing time.
ii. The agents and customers' personal attitudes which might lead to call abandonment, queue abandonment and outbound calls were not taken into cognizance in the model.

2.4 Simulation and Validation of the Developed HTCPN Model

The developed HTCPN model was simulated using Colour Petri Nets (CPN) Tools (Version 4.0.1).The simulation input parameters include agent processing times and the number of agent at various department in the inbound call centre. The department and number of agent in the considered call centre system are revealed in Table 1. Due to the fact that the HTCPN model is stochastic, fifty simulation runs were carried out on the model in order to obtain the average values for agent's utilization rate and call abandon rate (that is number of call rejected per day). The HTCPN model was validated by carrying out a statistical analysis (t-Test) between the output of the simulation model (that is agent utilization rate and abandon call rate) with the average number of abandon call per day from the real system at 5% level of significance.In order to improve the performance of the call centre departments of the case study under consideration, the following two performance metrics were investigated in the HTCPN model to experiment the present working condition (Scenario A) of the considered call centre system and the future working condition (Scenario B). The model was used to experiment Scenario B in order to determine the number of abandoned calls and agent utilization rates in the possibility of increasing from two to three the number of agents responding to customers in each of the three departments of the inbound call centre.
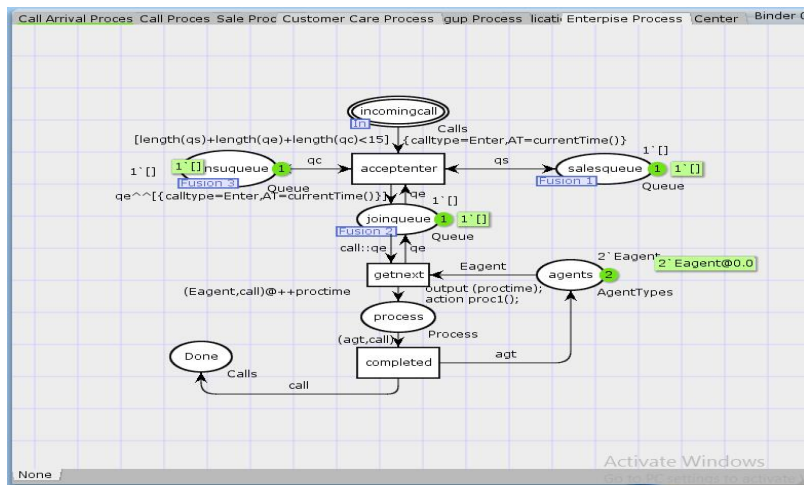
Fig. 8. The enterprise process sub- module of the developed HTCPN model

Table 1. Department and number of agents at various departments in the call centre system

Department	Agent name	Number of agent
Sales	Sales Agent	2
Customer care	Customer Agent	2
Enterprise	Enterprise Agent	2

3. RESULTS AND DISCUSSION

3.1 Simulation Results of the Developed HTCPN Model

The simulation results for Scenario A as depicted in Fig. 9 revealed that out of 524 calls that were accepted at the customer care department, a total of 453 calls were serviced. Enterprise department accepted 568 calls of out of which 561 were serviced. The sales department accepted 531 calls with a total of 423 calls being serviced. Thus, customer care, enterprise and sales departments recorded 71, 7 and 108 abandon calls, respectively. It could be inferred from the results that sales departments had the highest number of abandon calls followed by customer care and enterprise department respectively. The simulation results as depicted in Fig. 10 revealed that customer care agent and sales agent had higher utilization rate of 96% each while the enterprise agent had the utilization rate of 50%.

By increasing the number of agents from two to three at each departments, the simulation results for Scenario B as depicted in Fig. 11 revealed that out of 619 calls that were accepted at the customer care department, a total of 582 calls

were serviced. The enterprise department accepted 856 calls, out of which 852 were serviced while sales department accepted 715 calls with a total of 613 calls being serviced. Also, by increasing the number of agent from two to three at each department, the simulation results as depicted in Fig. 12 revealed that customer care agent and sales agents recorded utilization rates of 84 and 92% respectively while the enterprise agent had the utilization rate of 50%.

3.2 Validation Results of the Developed HTCPN Model

Figs. 13 and 14 depict the result of the validation of the developed HTCPN model. Fig. 13 compares the simulated average abandon calls with actual average of abandon calls of the considered case study while Fig. 14 compares the simulated average utilization rate with the actual average utilization rate. The statistical analysis of the simulated results and actual data through statistical package for Social Sciences software (version 20.0) as revealed in Table 2 shows that there were no significant differences between simulated and real data value at 5% significance level. Thus, the model simulation results were consistent with that of actual system data.
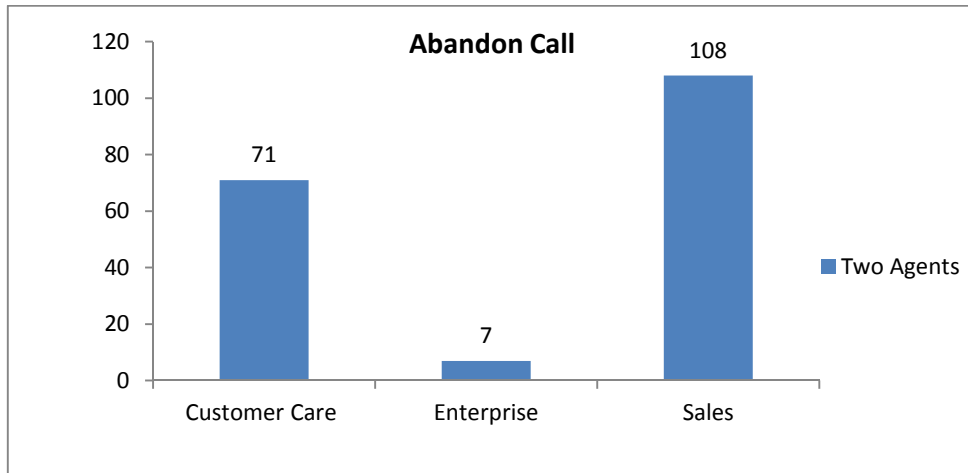
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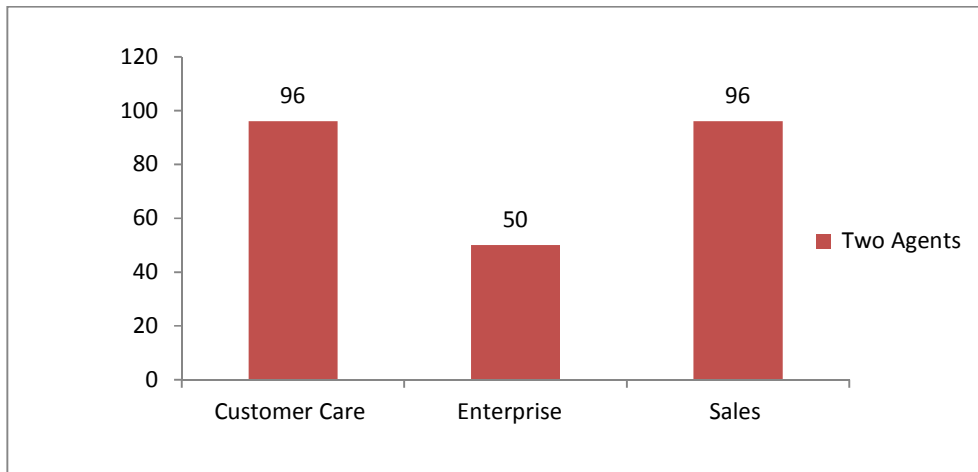
Fig. 9. Simulation result of abandon calls with two agents
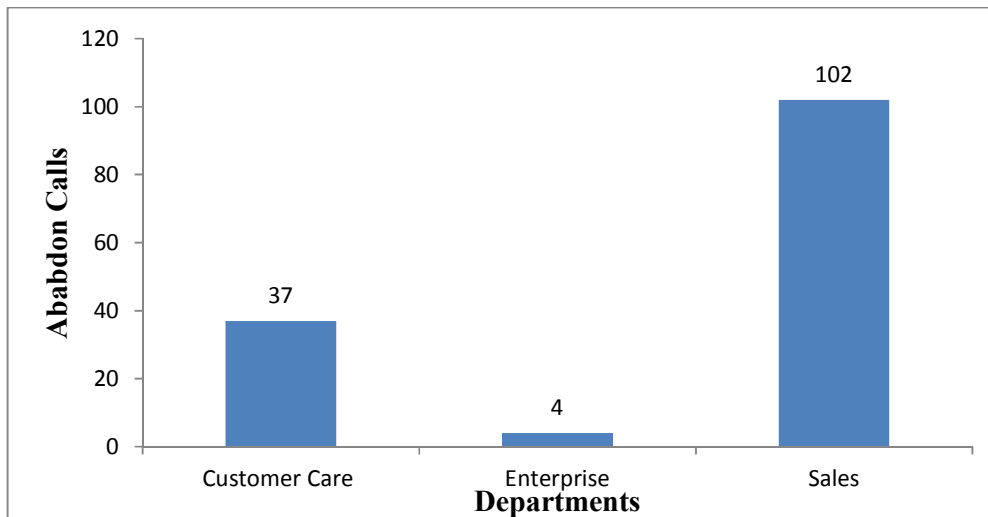

Fig. 10. Agent utilization for two agents

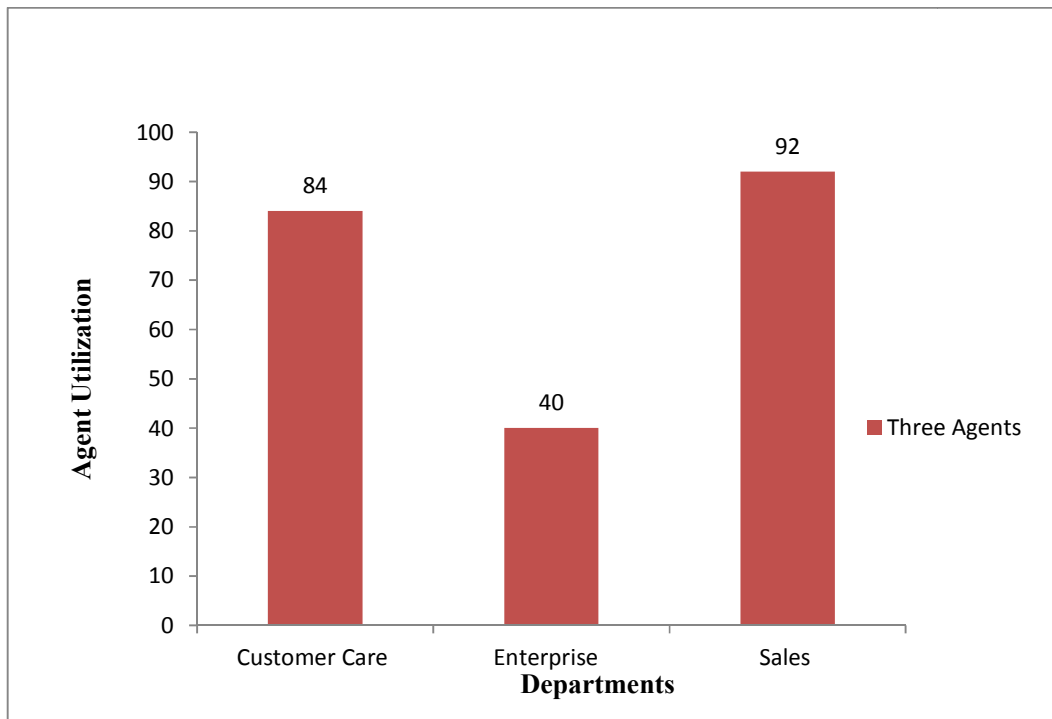**Fig. 11. Abandon call for three agents**

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Fig. 12. Agent utilization for three agents

Table 2. Summary of statistical analysis of the validation results of the developed model

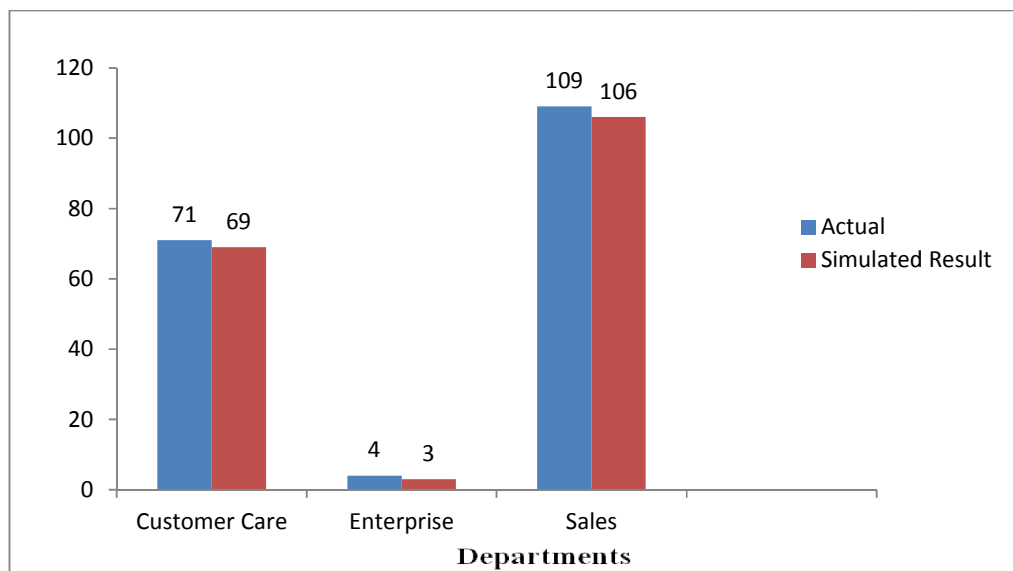| Variable	t-value	p-value	Remark
Pair 1 Call_Centre_Real – Call_Centre_Simulated	-0.450	0.697	Since p-value is greater than 0.05, there is no significant difference between the real data and simulation data (call centre) at 5% significant level

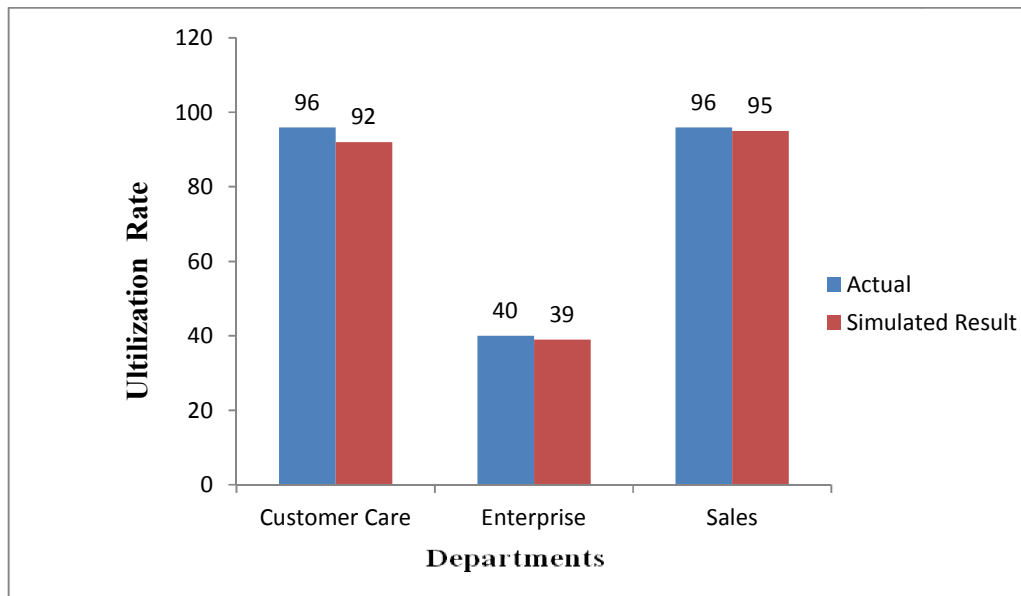**Fig. 13. Comparison between simulated and actual abandon call**

Fig. 14. Comparison between the simulated and actual agent utilization rates

4. CONCLUSION

In this paper, the HTCPN model abstracting the activities of inbound call centre of *SN* Nigeria Ltd has been developed, simulated and validated based on agent utilization and call abandon rates.The simulation results of the model revealed that by increasing the number of identified critical resources (agent and time) in the inbound call centre, the qualities of service was increased and the rate of abandonment on the part of the customer reduces. Besides, the developed model revealed valid representation of the servicescharacterizing theinbound call centre. This is evident from the result of the statistical analysis, which showed that there were no significant differences between the simulated and the average time utilized in the two scenarios obtained from the real system at 5% level. Thus, the developed HTCPN model could accurately describe the services of an inbound call centre under consideration.The HTCPN model developed is an executable model through which agent utilization and call abandon rates characterizing an inbound call centre can be experimented in order to determine the amount of manpower required for effective services.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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