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Modelling and Simulation of Deposit Slip Mode of Bank Cash Deposit Transactions Using Hierarchical Timed Coloured Petri-Nets

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Authors' contributions

This work was carried out in collaboration between all authors. Author OOO designed the study, collected the data used, modelled the system, performed the statistical analysis and wrote the first draft of the manuscript. Author EOO did the major supervisory work on the development of the project. Author SOO managed the mathematical aspect of the study. Author RAG did the major work in collaborating with Author OOO in model development and in prof reading the entire study. All authors read and approved the final manuscript.

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ABSTRACT

Significant investments are being made yearly to improve service quality and delivery in banking systems to minimise customers' dissatisfactions with long waiting time due to overcrowding. However, most existing empirical studies to address this problem employed the method where the system was modelled and then developed a program that will simulate, analyse and validate the developed model. This paper conceptualised modelling bank cash deposit transactions characterised by Deposit Slip (DS) using Hierarchical Timed Coloured Petri Nets (HCPN). The HTPC model developed was simulated using Coloured Petri Nets tools. The model was validated by comparing the simulated results with the real average flow time of the customers and utilisation rate

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of servers using statistical t-test at $p < 0.05$.
This model is useful for bank decision makers in capacity building to enhance service quality and delivery.

Keywords: Deposit slip; hierarchical timed coloured petri-nets (HTCPN); easy fit software.

1. INTRODUCTION

A major contributing factor that influences the success of any organisation is the increase in customer satisfaction through the improvement of service delivery. In any service organisation, the heads are mostly concerned about the time the customers are required to wait for receiving their service. Banks, being service organisation pay special attention to service quality and delivery as the most significant core competence. The queue length and waiting time are two matrices of banking service efficiency. Therefore, effective and efficient utilisation of facilities in a manner that will satisfy all stakeholders is always the utmost priority of bank management. However, achieving this feat had been a challenge to the banking industry for many years. This is again aggravated by the increased patronage of banking services by more people due to the awareness and desire for more reliable mode of financial management. Despite this challenge in the banking system, the quest to reduce operating cost has resulted in banks engaging minimal staff strength that are expected to attend to all the customers effectively and satisfactorily. However, this has resulted to poor service delivery and delay in service response culminating in customers waiting for a long time on the queue. Hence, the loss of goodwill of the customers by the banks. In solving this problem, there is a need for the application of different systematic approaches which are useful in evaluating alternative service configurations. Among the various approaches available for evaluating different alternatives, simulation technique such as Coloured Petri Nets has high capability for modelling and evaluation of the system's performance.

When time concepts are introduced into a Coloured Petri Net model, a Timed Coloured Petri Net (TCPN) model is obtained [1]. Thus, with a Hierarchical Timed Coloured Petri Net, it is possible to predict performance measures, such as the time at which a customer arrives and receives service, average flow time and percentage of customers attended to.

This paper is organised as follows: The introduction was written, and after the introduction, the related works were reviewed followed by the methodology. In the methodology, the case study was described. Briefly, Primary data were collected for this study at one of the Guaranty Trust bank (e-branch) in Nigeria on Deposit Slip modes of depositing cash (DS). Data were collected on customers' number (N), Inter Arrival Time (IAT), Service Time (ST) from Monday to Friday between the hours of 8:00 am and 4:00 pm for a week. These data were analysed statistically using the EasyFit Simulation software to determine the model parameters (the distribution of the inter-arrival times of customers entering the banking hall for DS services and the distribution of the service times for servers). These parameters were used as inputs into developing HTCPN model. The HTCPN model developed was simulated using Coloured Petri Nets tools. The model was validated by comparing the simulated results with the real average flow time of the customers and utilisation rate of servers using statistical t-test at $p < 0.05$ [2]. The statistical test carried out revealed there were no significant differences between the simulate and the real values.

The average values of N, IAT and ST for the data collected were (372 customers, 1.21 minutes and 2.12 minutes). The model was later used to determine the system behavior during the hours of the day and days of the week. The results were presented and discussed. Then the conclusion was introduced based on the results gotten.

2. RELATED WORKS

Some studies have been carried out on shortening the queueing time in banks. For example, [3] proposed a model for service delivery system that is based on concepts of server operating system that manages the processes and resources within a service delivery system. This work is a good starting point but cannot be used for building a differentiated QoS based service delivery system. [4] suggested a generalised optimisation model and framework for delivering differentiated QoS. However, the model has accurately helped the organisation to realign their focus around essential customers and services by segmenting its customers as well as functions to make it attractive for essential customers and customers coming for revenue generating transactions (like fund transfers).

[5] suggested a solution to the problem by increasing the service personnel at the branch and have dedicated counters for different types of transactions or services. However, this would lead to a substantial increase in the operating cost of the bank which makes it an undesirable alternative. Also, [6] simulated the effect of specialised teller for deposit transactions (customers making deposits were segregated from all others) on customer wait times in the system.

Several efforts have been made for shortening the queuing length and waiting time as earlier highlighted. All the studies above employed the method where the system was modelled and then developed a program that will simulate, analyse and validate the established model.

This paper employed the use of HTPC model to overcome the weaknesses of the previous works done on shortening the queueing length and waiting time in banks while depositing cash in the banking hall. The concept of HTPC was employed because CPN has some unique features that made it the most suitable method for the task. CP-nets have a well-defined semantics which unambiguously defines the behaviour of each CP-net. It is the presence of the semantics which makes it possible to implement simulators for CP-nets, and it is also the semantics which forms the foundation for the formal analysis methods. CP-nets offer hierarchical descriptions.

Easy Fit as commercial software for fitting data into statistical distributions support both discrete and continuous distributions; have both automatic and manual settings and possesses integrated help system [7]. It supports Bernoulli, Binomial, Discrete Uniform, Geometric, Hypergeometric, Logarithmic and Poisson distributions [8].

3. METHODOLOGY

In this paper, the following basic definitions of Coloured Petri Nets (CPN) and Timed Coloured Petri Nets (TCPN) were employed in developing a Hierarchical Timed Coloured Petri Nets (HTCPN) model for bank cash deposit transactions:

A Coloured Petri Nets is a tuple CPN = (Σ, P, T, A, N, C, G, E, I) where:

(i) Σ is a finite set of non-empty types, also called colour sets.
(ii) P is a finite set of places.
(iii) T is a finite set of transitions.
(iv) A is a finite set of arcs such that: $P \cap T = P \cap A = T \cap A = Ø$.
(v) N is a node function. It is defined from A to $PxT \cup TxP$.
(vi) C is a colour function. It is defined from P into Σ.
(vii) G is a guard function. It is defined from T into expressions such that: $\forall t \in T$: [Type (G (t)) =B ∧ Type(Var(G(t))) $\subseteq \Sigma$].
(viii) E is an arc expression function. It is defined from A into expressions such that: $\forall a \in A$: [Type(E(a)) = $C(p)_{MS}$ ∧ Type(Var(E(a))) $\subseteq \Sigma$] where p is the place of N(a).
(ix) I am an initialisation function. It is defined from P into closed expressions such that: $\forall p \in P$: [Type(I(p)) = $C(p)_{MS}$].

A timed non-hierarchical Coloured Petri Nets is a tuple TCPN = (CPN, R, $_or$) such that:

(i) CPN satisfies the above definition.
(ii) R is a set of time values, also called *timestamps.* It is closed under + and including 0.
(iii) $_or$ is an element of R called the *start time* [8,1,9].

The basic idea behind hierarchical CPNs is to allow the modellers to construct a large model utilising some small CPNs. This is similar to the situation in which a programmer creates a massive program by using a set of modules. In a hierarchical CPN, it is possible to relate a transition to a separate CPN, providing a more precise and detailed description of the activities represented by the transformation. The hierarchical CPN definitions are analogous to the non-hierarchical CPNs [8].

3.1 Description of the Case Study

The cash deposit transactions characterising one of reputable Guaranty Trust Bank (GTB) branches in Nigeria were used as case study in the model development. The department uses Deposit Slip (DS) mode of depositing money. The bank utilises three tellers in the banking hall attending to customers paying through DS.

3.2 Data Collection

Primary data were collected for this study at one of the Guaranty Trust Bank branches in Nigeria on Deposit Slip mode of depositing cash (DS). Data were collected on customers' number (N), Inter-Arrival Time (IAT), Service Time (ST) from Monday to Friday between the hours of 8:00 am and 4:00 pm for a week. These data were analysed statistically using the EasyFit Simulation software to determine the model parameters (the distribution of the inter-arrival times of customers entering the banking hall for DS services and the distribution of the service times for servers). These parameters were used as inputs into developing HTCPN model. The HTCPN model developed was simulated using Coloured Petri Nets tools. The model was validated by comparing the simulated results with the real average flow time of the customers and utilisation rate of servers using statistical t-test at $p< 0.05$.

3.3 The Development of Deposit Slip Mode of the HTCPN Model

The *'Banking Hall'* module was used to model the arrival of customers that want to use DS to deposit cash into the banking hall. Figure 1 shows the banking hall module of the developed HTCPN model of bank cash deposit transaction. The module has six (6) places and four (4) transitions, which include: TELLER Rate, NextTellerCustomerID, QUEUE, Free teller, Busy, Served TELLER_CUS, TELLER ARRIVE, DSStartServe, and serve, and measure served TELLER_CUS respectively. A token on the place 'NextTellercustomerID' determines when the new customer arrives. The colour set for the place is a timed colour 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 inscriptions **'**can and cn+1' on the arc from the place 'NextTellercustomerID' to the transition 'TELLER Arrives' were used to generate the addition of customer to the queue and checking the arrival of a new customer. The arc inscription '()@++monTIAT()' was used to determine the rate at which customers that are using Deposit Slip to deposit cash were coming into the banking hall. This time stamp was used to ensure that the first customer will not always arrive at time zero for different simulations. The transition 'TELLER ARRIVE' will occur only when the time stamp of the token on the places 'Teller rate' is equal to their corresponding time on the inscriptions. When the transition occurs, a new customer enters and bound to the variable 'customer' via the code segment of the transition. The arc inscription "cs^^[({CustNo = can, CustID = TELLER_CUS, Time = TIMES(), Tsr = model time(), Tss = modelTimeS(), Wt = 0.0, St = 0.0})]" on the arc to place 'Queue' was used to determine the time at which the customer using Deposit Slip joins the queue.

The serving of customers was modelled as two transitions, "DSStartService" and "Endserve". This was to indicate that the action of service is not instantaneous. Time was introduced by assuming the global clock representing the current model time. The time stamp was assigned to each token, indicating when the token can be consumed. The consumption of the token can only take place if its timestamp is less than or equal to the current model time. A token with a time stamp in the future as compared to the current model time can be regarded as a promise that at some point in the future, a token will be produced. The inscription on the place free teller, "Teller.all()@++10.0" Indicated the three tellers were available at time 10. On place "free teller", an initial marking of 1'teller(1)@10.0+++1'teller(2)@10.0+++1'teller(3) @10.0 was added specifying that the initially, teller(1), teller(2) and teller(3) were free for use. To join the tokens, **'+++'** was used. Place "queue" has first marked 1'[], indicating that the place contains a single token, an empty list.

Also, the expression 'c:: cs' on the input arc transition "DSstartservice" assigns the head of the list to c and the tail to cs. A transition "DSstartservice" is only enabled when the list on the corresponding input place contains at least one element. The time inscription of "DSstartservice" randomly draws a value from Poisson distribution with a mean of 2.18 on Monday, Uniform distribution with discrete boundary parameters 0 and 5 on Tuesday, Poisson distribution with a mean of 2.66 on Wednesday, Uniform distribution with discrete boundary parameters 0 and 4 on Thursday and Binomial distribution with 48 number of trials and the continuous success probability value of 0.96 on Friday for teller. Places "DoneS" and "DoneR" are of type 'Out'. The colour set CUSTOMERxTELLER is a product colour set that represents the period when a teller was busy attending to a customer. The arc expression '(c,to)' on the input arc of "Endserve" means a pair of customer and a teller.

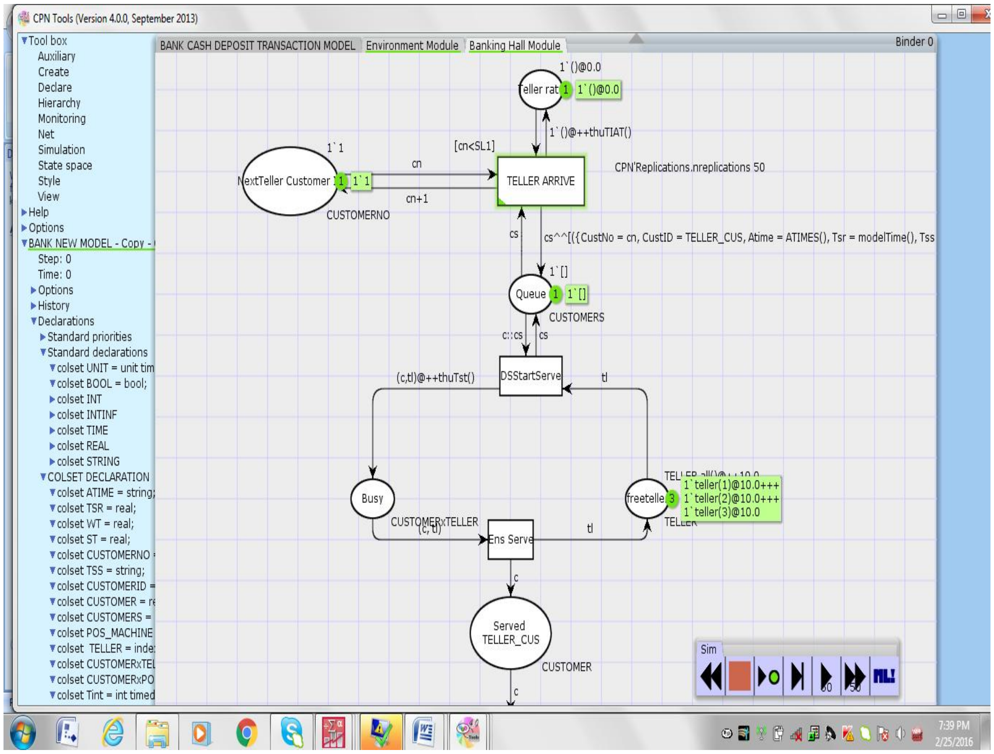

Fig. 1. The banking hall module of the developed HTCPN model

3.4 The Assumption Made in the Developed HTCPN Model

In developing the Hierarchical Timed Coloured Petri Nets (HTCPN) model for the Cash Deposit Transactions in banking system under consideration, the following assumptions were made:

(i) One time stamp unit represents one minute in the HTCPN model.
(ii) The customers arrive at the banking premises randomly.
(iii) The bank opens for 480 minutes per day (60*8 hours).
(iv) In the banking hall, servers are in parallel (all servers provide the same type of service, and a customer need only pass through one server to complete service).
(v) First Come First Serve (FCFS) queue discipline was adopted.

3.5 Validation Result of the Developed Htcpn Model

The statistical analysis was carried out on the simulation results and the real average flow time of customers and the average utilization rate of the tellers using the Statistical Package for the Social Sciences software (version 17.0). Statistically, there were no significant differences between the simulated and real average values at 5% confidence interval since their p- values ≥ 0.05. Hence, the developed HTCPN model of bank cash deposits transaction is valid and accurately represents the bank under consideration.

4. RESULTS AND DISCUSSION

The model was used to determine the system behaviour during hours of the day and days of the week. The hours of the day were divided into two: Morning (between the hours of 8 am and 12 pm) and afternoon (between the hours of 12 pm and 4 pm) from Monday to Friday. The simulation results revealed that there was an average of 17 customers waiting in the queue in the process of serving 210 customers by tellers (servers) conveniently on Monday morning as shown in Table 1. The average Queue length of 219 customers was observed in the process of serving 250 customers conveniently. Also, the simulation results revealed that there was no Queue on Tuesday morning and afternoon in the

Table 1. Summary of teller simulation results based on days of the week and hours of the day

Hours of the day (minutes)	Days of the week	Number of customers	Average queue length (customers)	Average utilization rate (%)	Average flow time (minutes)
8 am- 12 pm	Monday	210	17	74.20 and 75.02	4.64 and 4.69
12 pm-4 pm	Monday	250	219	72.60 and 74.20	3.39 and 3.64
8 am- 12 pm	Tuesday	176	Nil	32.87 and 33.55	1.48 and 1.51
12 pm-4 pm	Tuesday	182	Nil	12.75 and 12.97	2.97 and 3.02
8 am- 12 pm	Wednesday	79	1	29.72 and 30.68	3.50 and 3.57
12 pm-4 pm	Wednesday	105	1	32.63 and 33.39	3.47 and 3.53
8 am- 12 pm	Thursday	164	Nil	12.08 and 12.20	2.00 and 2.01
12 pm-4 pm	Thursday	213	Nil	33.06 and 33.65	2.00 and 2.02
8 am- 12 pm	Friday	238	Nil	24.83 and 25.21	1.50 and 1.51
12 pm-4 pm	Friday	245	65	64.30 and 65.55	2.17 and 2.22

process of serving 176 and 82 customers. The average Queue length on Wednesday morning and afternoon for 79 and 105 customers using deposit slip were 1 customer in the morning and 1 customer in the afternoon. The model showed that on Thursday, there was no Queue when serving 164 and 213 customers. On Friday morning, the simulation results revealed that there was no Queue when servicing 238 customers by a teller.

The average Queue length of 65 customers to conveniently served 245 customers on Friday afternoon.

The mean number of customers in Busy with 95% confidence utilisation is between 74.20% and 75.02% for teller on Monday morning. The confidence utilisation is between 72.60% and 74.20% for teller on Monday afternoon. The simulation results also established that use on Tuesday morning and afternoon for teller are between 32.87% and 33.55% and 12.75% and 12.97%. On Wednesday morning and afternoon, the use is between 29.72% and 30.68%, 32.63% and 33.39%. Also, on Thursday morning and afternoon, the utilisation falls between 12.08% and 12.20%, and 33.06% and 33.65% while Friday morning and afternoon, the use falls between 24.83% and 25.21%, and 64.30% and 65.55%.

The simulation results also established that the average flow time of served customers with 95% confidence on morning and afternoon is between 4.64 and 4.69 minutes, 3.39 and 3.64 minutes respectively for Monday, 1.48 minutes and 1.51 minutes, 2.97 minutes and 3.02 minutes respectively for Tuesday. On Wednesday, the average flow times of served customers in the morning and afternoon are between 3.50 and 3.57, 3.47 and 3.53 minutes. Also, the simulation results showed that on Thursday, the average flow time of served customers in the morning and afternoon falls between 2.00 and 2.01, and 2.00 and 2.02 minutes while that of Friday falls between 1.50 and 1.51, and 2.17 and 2.22 minutes respectively.

From the presented results, it can be concluded that there was a queue on Monday morning, Monday afternoon and Friday afternoon for customers depositing money. The line was as a result of the utilisation rate of the Tellers; the utilisation rate represents the average proportion of time which the server is occupied. When the arrival rate was less than the service, the queue was undersaturated, when it was equal to service rate, the line was saturated, but when it was higher than service rate, it was oversaturated. Also, when the utilisation rate was less than 1(100%), there was no queue, but as the utilisation rate tends towards 1(100%), line began to build. This can also be explained from the business point of view because on Mondays; customers will want to save the money they have realised over the weekend and even on Fridays; they will not want to go home with the money they have achieved for the week. So this factor as mentioned earlier is responsible for the queue experienced on these days of the week, this also accounted for the long waiting time of customers in the system (flow time).

5. CONCLUSION

This research work has been able to model, simulate and validate bank cash deposit transactions. Based on the development of HTCPN model of bank cash deposit transactions in this study, the following conclusions can be drawn:

i. The simulated result was adequately compared with the real average flow time of the customers and utilisation rate of servers using a statistical t-test, and there were no significant differences between the simulated and observed average customers' flow time
ii. and server utilisation rate at $p \geq 0.05$.
iii. The developed HTCPN model is a representation of the bank cash deposits transactions consisting of the states of the system and the events or transitions that cause the system to change its state.
iv. There were queues on some days of the week for customers depositing cash. The line was as a result of the utilisation rate; the utilisation rate represents the average proportion of time which the server is occupied. When the utilisation rate was less than 1, there was no queue, but as the utilisation rate tends towards 1, line began to build.
v. The validity of the developed model shows that the model is useful for bank decision makers in managing overcrowding problem to enhance service quality and delivery.
vi. It can also be concluded that the present facilities of the system studied (bank cash deposit transactions) could not cater for the calling population due to the backlog of customers waiting on the queue to be served.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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