

MODELLING AND SIMULATION OF DEPOSIT SLIP MODE OF BANK CASH DEPOSIT TRANSACTIONS USING HIERARCHICAL TIMED COLOURED PETRI- NETS

ABSTRACT

Significant investments are being made yearly to improve service quality and delivery in banking systems to minimize 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 conceptualized modelling bank cash deposit transactions characterized by Deposit Slip (DS) using Hierarchical Timed Coloured Petri Nets (HCPN). The HCPN 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 utilization rate 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.

1. INTRODUCTION

A major contributing factor that influences the success of any organization is the increase in customer satisfaction through the improvement of service delivery. In any service organization, the heads are mostly concerned about the time the customers are required to wait for receiving their service. Banks, being service organization 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 utilization 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 (Ganiyu *et al.*, 2011a). 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.

2. QUEUEING THEORY

A queueing system is any system in which arrivals place demands upon a finite-capacity resource and basic phenomena such as the waiting time, the throughput, the losses and the number of items in a queue are described in queueing theory (Piet, 2006). Queueing systems are basically characterized by input source, queue discipline and service mechanism (Hillier and Lieberman, 2015). The input source describes arrival of customers at the system and its three major characteristics are size of the population, behaviour and statistical distribution of arrival (Houda *et al.*, 2006; Raczynski, 2006).

3. BANK AS A SERVICE SYSTEM

Bank as a system mostly involves tellers, ATM machines, loan officers, and so on ordinarily. Customers representing system entity arrive to the service system, request the service, receive the service, and leave the service system (Wiley, 2009). For instance, customers arrive at a bank and select/request the kind of service they wish to do such as making deposits, withdrawals, money transfers, and so on. Other examples include patients at an hospital and customers at a restaurant (Wiley, 2005).

4. HIERARCHICAL PETRI NETS

Although, timed colour Petri nets allow for a succinct description of many business

65 processes, precised specification for real system have a tendency to become large and
66 complex.

67 This is the reason a hierarchy construct is provided, called sub net. A sub net is an aggregate
68 of a number of places, transitions, and subsystems. Such a construct can be used to construct
69 large processes. At one level, a simple description of the process is given (without having to
70 consider
71 the details). At another level, a more detailed behavior is specified. The extension of
72 hierarchy allows for such an approach (Jensen, 1990).

73

74 **5. RELATED WORKS**

75 A number of studies have been carried out on shortening the queueing time in banks.
76 For example, Ramaswamy and Banavar (2008) proposed a model for service delivery system
77 that is based on concepts of service operating system that manages the processes and
78 resources within a service delivery system. This work is a good starting point but cannot be
79 used for building a differentiated QoS based service delivery system. Chafle *et al.* (2009)
80 suggested a generalized optimization model and framework for delivering differentiated QoS.
81 However, the model has accurately helped the organization to realign their focus around
82 important customers and services by segmenting its customers as well as services to make it
83 attractive for important customers and customers coming for revenue generating transactions
84 (like fund transfers).

85 Sameep *et al.* (2011) suggested a solution to the problem by increasing the service
86 personnel at the branch and have dedicated counters for different types of transactions or
87 services. However, this would lead to a substantial increase in the operating cost of the bank
88 which makes it an undesirable alternative. Also, Dhillon *et al.* (2009) simulated the
89 effectiveness of specialized teller for deposit transactions (customers making deposits were
90 segregated from all others) on customer wait times in the system.

91 Several efforts have been made for shortening the queueing length and waiting time as
92 earlier highlighted. All the aforementioned studies employed the method where the system
93 was modelled and then developed a program that will simulate, analyze and validate the
94 developed model.

95 This paper employed the use of HTCPN model to overcome the weaknesses of the
96 previous works done on shortening the queueing length and waiting time in banks while
97 depositing cash in the banking hall. The concept of HTCPN was employed because CPN has
98 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.

6. DATA COLLECTION

Primary data were collected for this study at one of the Guaranty Trust bank branch 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 analyzed 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 utilization rate of servers using statistical t-test at $p < 0.05$

7. 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, Freeteller, Busy, Served TELLER_CUS, TELLER ARRIVE, DSStartServe, EndServe, and measure served TELLER_CUS respectively. A token on the place 'NextTellercustomerID' determines when new customer 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 inscriptions 'cn 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 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 = cn, CustID = TELLER_CUS, Atime = ATIMES(), Tsr = modelTime(), 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. Time stamp was assigned to each tokens, indicating when the token can be consumed. The consumption of the token can only take place if its time stamp 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 freeteller, “Teller.all()@++10.0” indicated the three tellers were available at time 10. On place “freeteller”, 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. In order to join the tokens, ‘+++’ was used. Place “queue” has initial marking 1’[] , indicating that the place contains a single token, an empty list.

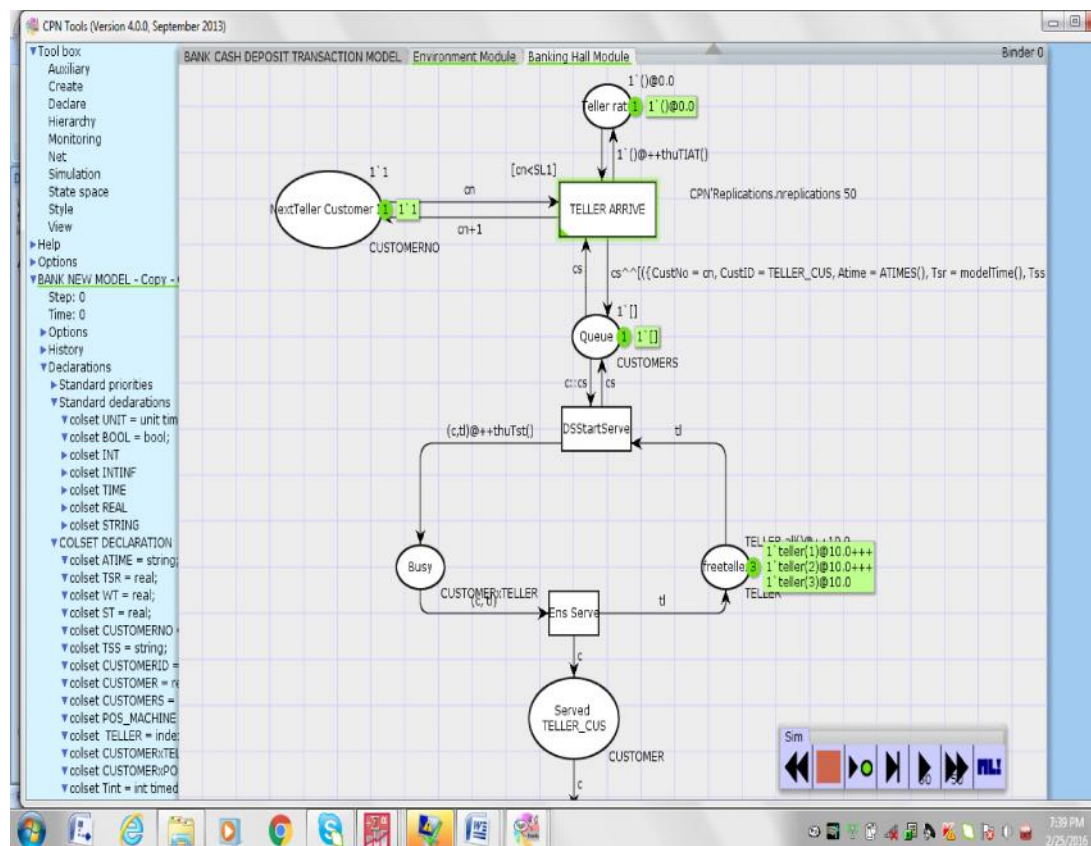


Figure 1: The Banking Hall module of the Developed HTCPN Model

Also, the expression ‘ $c::cs$ ’ on the input arc of 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 color set CUSTOMERxTELLER is a product color set that represents the period when a teller was busy attending to a customer. The arc expression ‘ (c,tl) ’ on the input arc of “Endserve” means a pair of customer and a teller.

8. 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 480minutes per day (60*8hours).
- (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.

9. 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.

10. RESULTS AND DISCUSSION

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

201 The average Queue length of 65 customers in order to conveniently served 245 customers on
202 Friday afternoon.

203 The mean number of customers in Busy with 95% confidence utilization is between 74.20%
204 and 75.02% for teller on Monday morning. The confidence utilization is between 72.60% and
205 74.20% for teller on Monday afternoon. The simulation results also established that
206 utilization on Tuesday morning and afternoon for teller are between 32.87% and 33.55% and
207 12.75% and 12.97%. On Wednesday morning and afternoon, the utilization are between
208 29.72% and 30.68%, 32.63% and 33.39%. Also, on Thursday morning and afternoon, the
209 utilization falls between 12.08% and 12.20%, and 33.06% and 33.65% while Friday morning
210 and afternoon, the utilization falls between 24.83% and 25.21%, and 64.30% and 65.55%.

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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)
8am- 12pm	Monday	210	17	74.20 and 75.02	4.64 and 4.69
12pm-4pm	Monday	250	219	72.60 and 74.20	3.39 and 3.64
8am- 12pm	Tuesday	176	Nil	32.87 and 33.55	1.48 and 1.51
12pm-4pm	Tuesday	182	Nil	12.75 and 12.97	2.97 and 3.02
8am- 12pm	Wednesday	79	1	29.72 and 30.68	3.50 and 3.57
12pm-4pm	Wednesday	105	1	32.63 and 33.39	3.47 and 3.53
8am- 12pm	Thursday	164	Nil	12.08 and 12.20	2.00 and 2.01
12pm-4pm	Thursday	213	Nil	33.06 and 33.65	2.00 and 2.02
8am- 12pm	Friday	238	Nil	24.83 and 25.21	1.50 and 1.51
12pm-4pm	Friday	245	65	64.30 and 65.55	2.17 and 2.22

The simulation results also established that the average flow time of served customers with 95% confidence on morning and afternoon are 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 were queue on Monday morning, Monday afternoon and Friday afternoon for customers depositing money. The queue was as a result of the utilization rate of the Tellers, the utilization 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 queue was saturated but when it was greater than service rate, it was oversaturated. Also, when the utilization rate was less than 1(100%), there was no queue but as the utilization rate tends towards 1(100%), queue began to build. This can also be explained from business point of view because on Mondays, customers will want to save the money they have realized over the weekend and even on Fridays; they will not want to go home with the money they have realized for the week. So this aforementioned factor 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).

11. 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 utilization rate of servers using statistical t-test and there were no significant differences between the simulated and observed average customers' flow time
- ii. and server utilization 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 queue was as a result of the utilization rate, the utilization rate represents the average proportion of time which the server is occupied. When the utilization rate was less than 1, there was no queue but as the utilization rate tends towards 1, queue 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.

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