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Development of a Model for Restaurant Food Serving Process using Hierarchical Timed Coloured Petri Nets

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Abstract
Restaurant industry is one of the most profitable industries in the world over where incessant long waiting time may not only lead to customers' dissatisfaction but also facilitate loosing of customers to other competitors which may consequently result to total closure of such business if not properly investigated. In order to provide solution to the problem of long waiting time of customers especially in restaurant industry, Hierarchical Timed Coloured Petri Nets Model formalism was employed in this paper to model Restaurant Food Serving Process with multiple servers that serially and consecutively attend to individual customer at each serving point for effective services using a renowned restaurant in Ibadan metropolis, Oyo state, Nigeria as a case study. The developed HTCPN model is made up of two modules highest hierarchical module (environment page) and four sub-modules (serving point 1, 2, 3 and 4 modules). The developed HTCPN model can be adaptable to solve queue problem in any restaurant industry or relevant scenarios.
Keyword: Restaurant industry, Food Serving Process, Hierarchical Timed Coloured Petri Nets, Multiple servers

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I. Introduction

Queuing is a major problem that can reduce effectiveness in service delivery especially in restaurant. Major aim of most restaurant industry is basically for profit making which may not be achieved due to incessant long waiting time of customers. Customers' satisfaction as a result of improvement in service delivery is a major contributing agent which determines the success of any organization whether it is meant for a product or service[1]. In the world over, restaurant industry is the most lucrative line of business that keeps going amidst any global economic challenge[2]. Waiting for service in restaurant industry has been an everyday event which causes needles delay and lowers effective service delivery in restaurant industries[3]. Hence, management of restaurant industries will do everything in their power to avoid losing their customers due to queue/ long waiting line.

Food restaurant business is highly competitive and requires that the service and production facilities be well carried out in order to effectively manage the peak demand since most of the sales do occur at the peak period. Customers' satisfaction, which is the real contributing factor towards achieving business goal, is generally enhanced through quality of service delivery. In a bid to minimize customers' dissatisfaction in restaurants, queue length and waiting time experienced by customers waiting to receive service must be of importance to the management of restaurant industry. Queue length and waiting time are two major factors which play significant roles in customers' general belief about the quality of service delivery in restaurants[4].

Queue usually occurs in restaurants mostly at the time of lunch and dinner and is a major factor which play significant role in customers' belief about the quality of service delivery[1]. Queuing has become one of the daily activities of human being. To improve any system, it is necessary to study and understand its mode of operation and experiment its possible future problems as a means of providing solution.

Simulation of any system first requires development of a model that represents the key characteristics and behaviour of the system. Then, the modelled system can be simulated by experimenting it so as to provide solution to its imminent problems of the modelled system(s). Simulation is important for understanding several scenarios in modelled systems. It can as well 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. As such, various systems such as restaurant industries, transport companies, banking sectors, telecommunication companies, health clinics, logistics and airport, among others can be modelled and

simulated[5]. Of all the various approaches capable of evaluating different modelling alternatives, simulation has great ability for evaluation of system's performance[6].

Coloured Petri Nets (CPN) is a high level Petri nets which combines the graphical components of ordinary Petri Nets with the strengths of a high level programming language, making them suitable for complex systems and modelling[6]. CPN is an extension of classical Petri Nets with colours (to model data), time (to model durations), and hierarchy (to model structure of large programs)[7]. A lot of researches had been done in literatures to model restaurant operations in order to reduce queue length/ waiting line in a busy fast food restaurant so as to increase throughput and efficiency of a busy restaurant service. Similarly, few studies have been carried out on reducing the waiting time, service time as well as improving the possibility of customer satisfaction in a restaurant using HTCPN. [8]modelled a restaurant serving operation using two (2) servers that operated independently with each server exclusively starts and ends service to each customer on queue in attending to customers. The model involved two server that served tea and coffee by different servers called Adam and Eve. The model used First in First out (FIFO) queue discipline while TCPN was employed to develop the model.

[9]modelled a take away restaurant food serving process with five servers using Timed Coloured Petri Nets. Server takes order from customer through phone call and delivers such after preparation. Cook prepares food while drink server takes care of drink preparation (that is, coffee, tea, or beer). An employee of the kitchen can only do one task at a time. Customers order only one item at a time (that is, breakfast, lunch or dinner). Each incoming order gets an order number to uniquely identify the request. It takes one minute to accept an order and to attach a number to it. The acceptance of an order triggers the production of food, drink and delivery as well.

Description of flow of processes in various systems like restaurant industry could be done by discrete event simulation modelling language like CPN and Hierarchical Timed Coloured Petri Nets (HTCPN). The introduction of time and hierarchy concepts to Coloured Petri Nets led to the inception of HTCPN model[10,13]. Consequently, with Hierarchical Timed Coloured Petri Net, there is possibility of predicting performance measures such as: the time at which customer arrives to receive service, average flow time and percentage of customers which need to be attended to within stipulated time frame.

2.1 Research Methodology

In this paper, Hierarchical Timed Coloured Petri Nets (HTCPN) formalism was used to develop the model for the restaurant Food Serving Process under consideration. The formalism as discussed by [6,11, 12 and14] includes hierarchy concept (modules) to Timed Coloured Petri Nets.

2.2 Modelling Approach

The basic definition of Hierarchical Coloured Petri Nets (HTCPN) was adopted in the modelling of the restaurant Food Serving Process. The HTCPN tuples are as defined as:

HTCPN = (S, SN, SA)

HTCPN = (S, SN, SA, PN, PT, PA, FS, FT, PP, R, $r0$) where:

(i) S is a finite set is a finite set of pages,

(a) $\forall s \in S$: s is a non-hierarchical coloured Petri net.

(b) $\forall s1, s2 \in S: s1 \neq s2 \Longrightarrow (Ps1 \cup Ts1 \cup As1) \cap (Ps2 \cup Ts2 \cup As2) = \phi$

(ii) $SN \subseteq T$ is a set of substitution nodes.

(iii) SA is a page assignment function. No page is a subpage of itself.

(iv) $PN \subseteq P$ is a set of port nodes.

(v) PT is a port type function. PT: $PN \rightarrow \{in, out,$ i/o, general$\}$.

(vi) PA is a port assignment function. It is defined from SN into binary relations.

(a) $\forall$ t$\in$ S: (t) $\subseteq$ X(t)x$\square$ $PN_{SA(t)}$

(b) $\forall$ t $\in$ SN, $\forall$ (P1, P2) $\in$ PA(t): PT (p2) $\neq$ general $\rightarrow$ ST(p1, t) =PT(p2)

(c) $\forall$ t$\in$ SN, $\forall$ (p1, p2) $\in$ PA(t): C(p1) = C(p2) $\wedge$(p2)

(vii) FS$\subseteq$Ps, is a set of fusion sets.

$\forall$fs $\in$ FS, $\forall$ (p1, p2) $\in$ fs: C(p1) = C(p2) $\wedge$(p1) = I(p2)

(viii)FT is a fusion type function. FT: $FS \rightarrow \{global, page, instance\}$.

(ix) PP $\in$ S_{MS} is a multi-set of prime pages.

(x) R is a set of time values, also called time stamps.

(xi) r_0 is an element of R called the start time (14)

2.3. Description of the Case Study

In this paper, the food serving process at a recognized International Institute Restaurant (IIR) located in Ibadan, Oyo State, Nigeria was used as a case study. Fig. 1 shows the flowchart of the Food Serving Process of the restaurant. The case study comprises four terminals (serving points) with distribution of two servers at each

serving points. The serving points were in parallel arrangement and the same type of food is served at each of the serving points which mean that any arriving customer can approach any of the terminals for food. Also, the restaurant operates between 11.30 and 1.30 for five working days of the week. Customers arrive randomly and can approach any serving point that is free or join any queue if all the servers are busy at the time of entry.

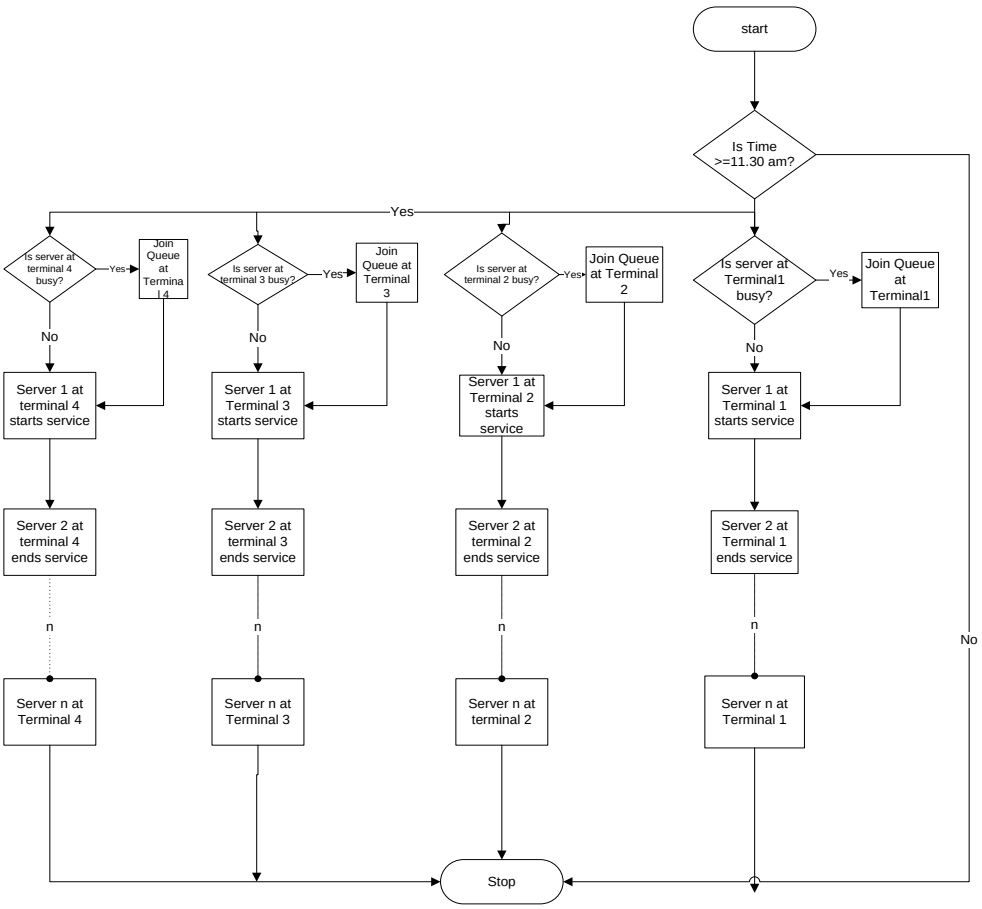

Fig. 1: Flowchart of the food serving process at IIR

The restaurant Food Serving Process involves two servers that serially and completely attended to each and every customer on the four (4) available serving points. The restaurant is located inside an international research institute in Ibadan with overall number of eight (8) servers being distributed into four (4) serving points with arrangement of two servers per one customer for each of the four serving points. The restaurant food serving process is distributed in such a way that the first server collects meal ticket and start service for the customer while the second server completes the already established service for the same customer.

Customers on entry can join queue if there is any or move straight to the server for request if the servers are free. Servers are responsible for serving food ordered or requested by the customers at the four available serving points.

II. Data Collection

The data that was used for the development of the HTCPN model for the restaurant food serving process in this paper was collected primarily by direct observation at the IIR. The collected data were number of customer, corresponding arrival time and service time of the customers from Monday to Friday. The collected data were recorded in minutes and later converted to seconds for easy analysis. Inter- arrival time was obtained from the arrival time of customers while service time was obtained from both start and end of service time for each of the customers. Both inter-arrival time and service time were input into the input analyzer of Arena simulation software for the generation of arrival pattern and service pattern that was used in the model development.

3.1 Modelling of the Restaurant Food Serving Process using HTCPN

CPN Tools version (4.0.1) was used for the construction of the HTCPN model. The HTCPN model was developed such that each serving point is represented as a module for easy modification. Structurally, the developed HTCPN model consists of an environment page and four sub-pages (modules) which are: *Serving Point1, Serving Point2, Serving Point3* and *Serving Point4.* A special transition in the environment page called substitution transition (rectangle with double border lines) was used to represent the four modules. The *environment* page of the developed HTCPN model represents the highest hierarchy level and provides an overview of the entire processes. Description of the major places and transition, colours set and variables used in the development of the HTCPN modes are as described in Tables 1, 2, 3 and 4.

Environment page of the developed HTCPN model consist of five places and four transitions. The places (*Next Customer ID, Arrival at serving point1, Arrival at serving point2, Arrival at serving point3 and Arrival at serving point4*) which are the conditions that hold for the state of servers at each serving points. The place *Next Customer ID* holds new customer entrance (that is arrival of new customer) into any available serving point while places *Arrival at serving point1, Arrival at serving point2, Arrival at serving point3 and Arrival at serving point4* hold the customer that arrived at first serving point, second serving point, third serving point and fourth serving point respectively.

Environment page of the developed model consists of four transitions *'Create Customer1', 'Create Customer2', 'Create Customer3',* and *'Create Customer4'*. The execution of any of these transitions would make the customer to arrive at serving point1, serving point2, serving point3 and serving point4 respectively. Environment page also consists of four sub-pages (that is rectangles with double border lines) which represent *Serving Point1*, *Serving Point2*, *Serving Point3*, and *Serving Point4.* These four sub-pages (modules) model the queue, service and departure process of customer at serving point1, serving point2, serving point3 and serving point4 respectively.

Table 1: Definitions and Interpretations of the Colours used in the HTCPN Model

Colour	ColourData Type	Colset Declaration	Interpretation
INT	Integer	closet INT = int;	It describes an integer value e.g. serial numbers of customer
REAL	Real	colset REAL = real;	It describes a real value e.g. time
Res	Unit	colset Res =with server;	It describes name of a server
Staff	Compound (Product)	colset Staff = product INT*REAL*REAL timed;	It describes the serial number of customer, operation start time and total process time
QUEUE	Compound (List)	colset QUEUE = list Staff;	It describes the list of customer in a queue

Table 2: Definitions and Interpretations of Decision Variables used in the HTCPN Model

Variable	Variable Type	Variable Declaration	Interpretation
I	Integer	var i:INT;	It describes information such as identity number of customer
P	Compound(Integer, Real)	var p:Staff;	It describes the identity number of customer and the operation time
R	Unit	var r1:RESOURCE;	It describes resources whose number is not fixed and quantified
t, p1, p2	Real	var t,p2,p1:REAL;	They describe timing in the model

Table 3: Description of Places employed in the development of the HTCPN Model

Place	Description
Next Customer ID	Models next customer to arrive at any available serving point
Arrival at serving point1	Models the arrival of customer at serving point1
Arrival at serving point2	Models the arrival of customer at serving point2
Arrival at serving point3	Models the arrival of customer at serving point3
Arrival at serving point4	Models the arrival of customer at serving point4
Queue at point1	Models the number of customer waiting at serving point1
Queue at point2	Models the number of customer waiting at serving point2
Queue at point3	Models the number of customer waiting at serving point3
Queue at point4	Models the number of customer waiting at serving point4
Server free point1	Models a state in which the servers are idle at point1
Server busy point1	Models a state in which the servers are busy at point1
Server free point2	Models a state in which the servers are idle at point2
Server busy point2	Models a state in which the servers are busy at point2
Server free point3	Models a state in which the servers are idle at point3
Server busy point3	Models a state in which the servers are busy at point3
Server free point4	Models a state in which the servers are idle at point4
Server busy point4	Models a state in which the servers are busy at point4
Customer to exit at point1	Models customer that had been served and ready to exit at point1
Customer to exit at point2	Models customer that had been served and ready to exit at point2
Customer to exit at point3	Models customer that had been served and ready to exit at point3
Customer to exit at point4	Models customer that had been served and ready to exit at point4

Table 4: Description of major Transitions employed in the development of the HTCPN Model

Transition	Description
Create Customer1	Execution of this transition models arrival of customer at serving point1.
Create Customer2	Execution of this transition models arrival of customer at serving point2.
Create Customer3	Execution of this transition models arrival of customer at serving point3.
Create Customer4	Execution of this transition models arrival of customer at serving point4.
Serving Point 1	This is a substitution transition which models process of attending to customer at serving point1.
Serving Point 2	This is a substitution transition which models process of attending to customer at serving point2.
Serving Point 3	This is a substitution transition which models process of attending to customer at serving point3.
Serving Point 4	This is a substitution transition which models process of attending to customer at serving point4.
Move Customer to Queue 1	Execution of this transition move customer to queue at serving point1
Move Customer to Queue 2	Execution of this transition move customer to queue at serving point2
Move Customer to Queue 3	Execution of this transition move customer to queue at serving point3
Move Customer to Queue 4	Execution of this transition move customer to queue at serving point4
Start of service at Serving point1	Execution of this transition make server busy by attending to next customer in serving point 1
Start of service at Serving point2	Execution of this transition make server busy by attending to next customer in serving point 2
Start of service at Serving	Execution of this transition make server busy by attending to next customer in serving point 3
	Execution of this transition make server busy by attending to next customer in serving point

point3	4
Start of service at Serving point4	Execution of this transition transit server to free after attending to next customer in serving point 1
End of service at Serving point1	Execution of this transition transit server to free after attending to next customer in serving point 2
End of service at Serving point2	Execution of this transition transit server to free after attending to next customer in serving point 3
End of service at Serving point3	Execution of this transition transit server to free after attending to next customer in serving point 4
End of service at Serving point4	

THE DEVELOPED HTCPN MODEL

Fig. 2 shows the developed HTCPN model environment page (model) of the restaurant Food Serving Process under consideration while the sub-pages (sub-models) were shown on Fig. 3, 4, 5 and 6. The model was separated into modules for easy adoption of the model in any related system as well as easy reusability.

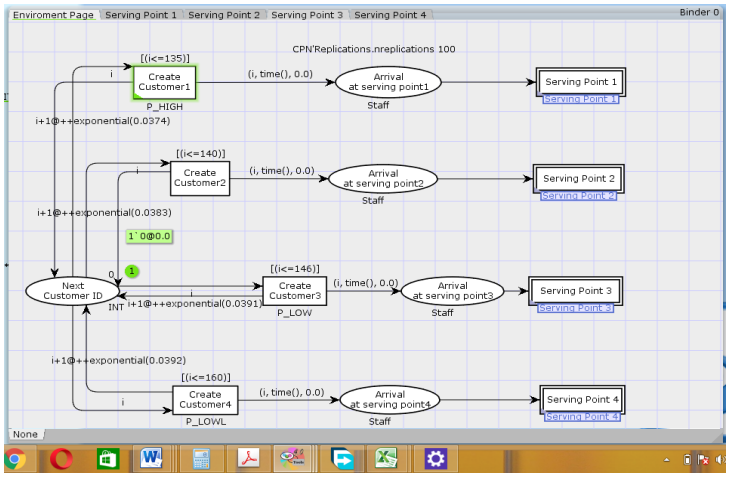

Fig. 2: The environment page of the developed HTCPN model of the restaurant food serving process

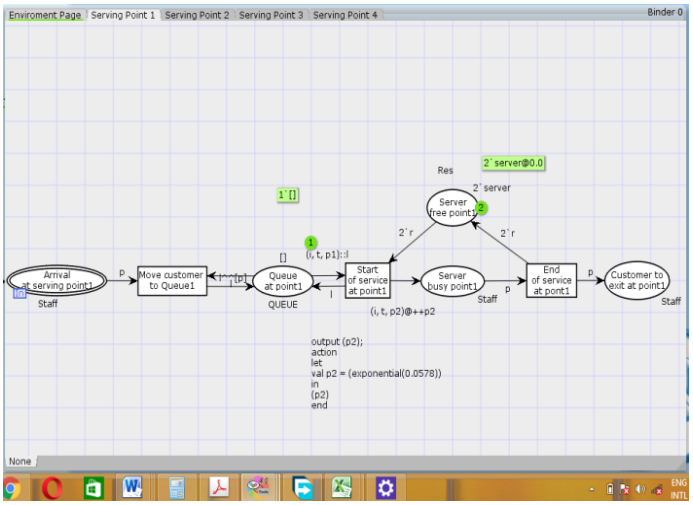

Fig. 3: Serving point 1 module of the developed HTCPN model

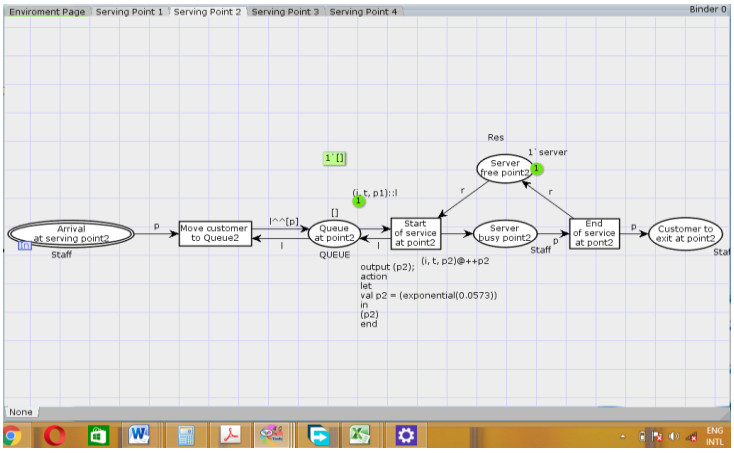

Fig 4: Serving point2 module of the developed HTCPN model

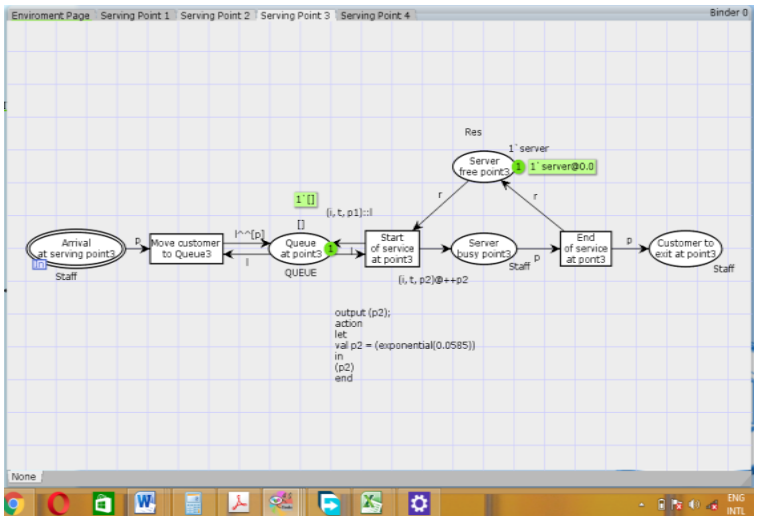

Fig.5: Serving point3 module of the developed HTCPN model

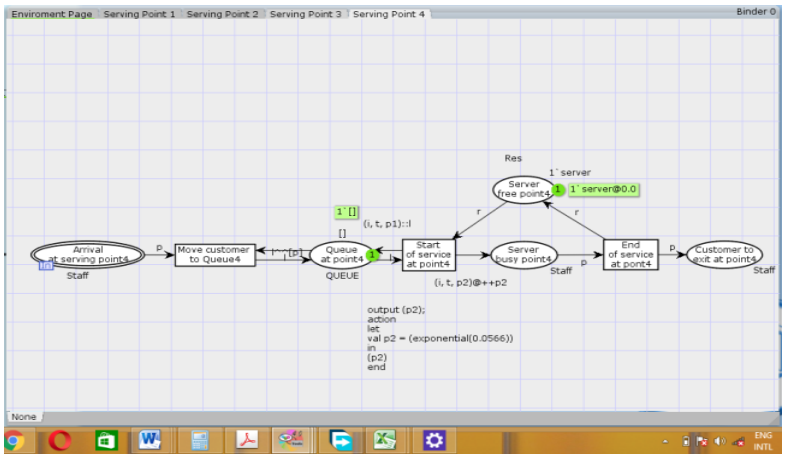

Fig. 6: Serving point 4 module of the developed HTCPN model

III. Conclusion and Future Work

In this paper, a Hierarchical Timed Coloured Petri Nets (HTCPN) model for restaurant food serving process of an International Institute restaurant in Ibadan, Oyo State, Nigeria as a case study was developed. The developed HTCPN model can be modified to suit future modifications through its associated modules and as well be utilized to study and manage the issues of long queue and waiting time towards ensuring restaurant service quality and delivery. Furthermore, it is recommended that future research may be geared towards validating and analyzing the performance of the developed HTCPN model through simulation based analysis technique.

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