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Expansion of a Timed Colored Petri Nets Model for a Patient Health Care Center Flow Processes

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Abstract: Hospital deals with human lives which are often at risk and where everything depends on quick response to diverse medical conditions. Thus, the need for efficient and effective management of patient care flow processes in a hospital is being one of the main leading goals in health sector. Here in this research, a Timed Colored Petri Nets (TCPN) formalism is used to develop a simulation model for patient care flow processes with strain on medical record area and examination rooms using Pondicherry Medical Centre, Pudhucherry Union Territory of India as a case study. The developed TCPN Model consists of a main model (arrival and evaluation module) and a sub-model (treatment module). The main model abstracts the arrival and operation (pre-treatment test) in the medical record area while the sub-model describes the operation (treatment) taking place in the examination room of the patient health centre. The developed TCPN Model was simulated using CPN tools while its validation was explored by comparing the simulated and actual number of patients of the patient health centre under study. The results obtained from the simulation of the TCPN Model revealed 33 (5 inpatients and 28 outpatients), 34 (9 inpatients and 25 outpatients), 29 (9 inpatients and 20 outpatients), 33 (10 inpatients and 23 outpatients) and 25 (6 inpatients and 19 outpatients) as the average numbers of patients entering the health centre during the 1st, 2nd, 3rd, 4th and 5th working days under consideration, respectively. Statistically, there were no significant differences between the simulated and real number of patients entering the health centre at 5% level. This give a confirmation that the developed TCPN Model accurately described the patient care flow processes of the health centre under study. The developed TCPN Model could serve as a referential model for studying and improving patient care flow processes in a named health centre.

Key words: TPCN Model, colored petri nets, patient, health, petri nets, simulation model

INTRODUCTION

Management of health care systems has significantly evolved during the last decade. A modern health care system can be viewed as a multifaceted network of medical units with a large diversity of health care professionals (both clinical and administrative), medical equipment and complex material flows connected through various information systems (Billington *et al*., 2008; Ferrin *et al*., 2007). Appropriate coordination of these entities is needed to provide; better access, continuity and quality of care to patients, better working conditions for health care professionals while compressing operating costs and investments in new technology and infrastructures. Health care organizations such as hospitals and medical care centre are often compared to manufacturing systems and techniques from industry are adapted to solve various organization problems such as operating theater scheduling, patient transportation planning, Doctor's availability scheduling, logistic organization, etc. However, the health care field presents several important special features such as complex patient flows, numerous human resources, dynamic evolution of patient's health state, coordination of separate medical units, etc. This implies a wide range of complex decision processes and behavior models. Thus, most existing studies (Billington *et al*., 2008; Jun *et al*., 1999) rely on case-specific models although the goals are often similar.

Some basic notions of petri nets: An ordinary Petri Net (PN) is a 4-tuple $R = (P, T, F, M_0)$ where P and T are two disjointed sets of nodes called, respectively places and transitions, $F \subseteq (P \times T) \cup (T \times P)$ is a set of directed arcs, M_0: $P \rightarrow N$ is the initial marking of the net. The set of input (resp. output) transitions of a place $p \in P$ is denoted by $\cdot p$ (resp. $p\cdot$). Similarly, the set of input (resp. output) places of a transition $t \in T$ is denoted by $\cdot t$ (resp. $t\cdot$).

A transition $t \in T$ is said to be enabled at M_0 if for all $p \in \cdot t$, $M_0(p) = 1$. A transition may fire if it is enabled. The firing of a transition t at marking M removes one token from each of its input places and puts one token to each

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of its output places. This leads to a new marking, say M'. This process is denoted by $M_0[t>M'$. If M' is not explicitly mentioned, the process is denoted by M[t> which means that t is enabled at M. These notations are also extended to sequences of firings, i.e., M[σ>M' where σ is a sequence of transitions that brings M to M' and M[σ>, if M' is not explicitly mentioned. The set of all markings reachable from M_0 is denoted by $R(M_0)$. The structure of a petri net can also be represented by its incidence matrix $U = [u_{ij}]$ for $i\in\{1, ..., |P|\}$ and $j\in\{1, ..., |T|\}$ with $u_{ij} = 1$ if tj∈·pi, $u_{ij} = -1$ if tj∈pi· and $u_{ij} = 0$ otherwise. Given the incidence matrix, the state equation is $M = M_0+U\sim\sigma$ where M is the marking obtained by firing the sequence σ of transitions at M_0 and ~σ called the firing count vector is a |T|×1 column vector whose ith entry denotes the number of times that transition ti appears in σ.

A source transition is a transition without any input place. A source transition is always enabled. A sink transition is a transition without any output place. When firing a sink transition, all tokens are removed respecting usual rules but no tokens are generated. A T-timed petri net is a 5-tuple $R = (P, T, F, \theta, M_0)$ where θ: T>N assigns to each transition t its transition firing time $\theta(_t)$. Firing a timed transition t at time d removes immediately one token from each input place but add tokens to its output places only at time d+θ(t). A colored petri net is a 7-tuple $CPN = (P, T, C, A, W+W-, M_0)$ where C: (P∪T)→ Ω, C(p), p∈P is the set of colors associated to a place p (i.e., the set of colors that place p may have) C(t), t∈T is the set of colors associated to a transition t (i.e., the set of ways to fire t), W-p, t: C(t)→N|C(P)| is the pre-condition of a transition in relation to a color which defines for each way of firing t the required combination of tokens of different colors in different places, W+t, p: C(t)→N|C(P)| is the post-condition of a transition in relation to a color which defines for each way of firing t the combination of tokens of different colors added to different places. Let, ~w be a t-invariant of a petri net N, i.e., U~w = 0 where, U is the incidence matrix of N. The petri net N~w is ~w-derived from the petri net N if:

- The set of transition of N~w is ||~w||
- ∀t∈||~w||, ·t and t· are identical in N and N~w
- Each arc of N~w has the same weight as the corresponding arc in N. We call ~w-CFIO (Conflict Free net with Input and Output transitions) of N where ~w is a t-invariant of N, the petri net N~w~w-derived from N having the following properties:
  - p· is unique for all places of N~w (each place has exactly one output transition)
  - There is at least one transition t1∈||~w|| and one transition t2∈||~w|| as ·t1 = ⊗(t1 is a source transition) and t2· = ⊗(t2 is a sink transition)
  - N~w has no cycle. Let, N be a petri net and ~w1, ..., ~wk a set of t-invariants of N such as: the nets N~wi~wi-derived from N are ~wiCFIO with i∈{1, ..., k}; the ~wi-CFIO covers N: N = N~w1∪, ..., ∪N~wk . Then, N is said to be decomposable

MATERIALS AND METHODS

Overview of the modelling approach: In this study, Colored Petri Nets (CPN) and Timed Colored Petri Nets (TCPN) formalisms stated in Eq. 1 and 2 will be used to model the patientcare flow processesof the health centre under consideration. A colored petri net and timed colored petri nets are tuples defined as (Jeng and DiCesare, 1995):

$$CPN = \Sigma, P, T, A, N, C, G, E, I \quad (1)$$

Where:
Σ = A finite set of non-empty types called color sets
P = A finite set of places
T = A finite set of transitions
A = A finite set of arcs such that: P∩T = P∩A = T∩A = ∅
N = A node function. It is defined from A into P×T∪T×P
C = A color function. It is defined from P into Σ
G = A guard function. It is defined from T into expressions such that: ∀t∈T: [Type (G (t)) = Bool∧Type (Var(G(t)))⊆Σ]
E = An arc expression function
I = An initialization function

A Timed Colored Petri Net is a tuple; $TCPN = (CPN, R, r_o)$ (2)

Where:
CPN = Satisfying the above definition
R = A set of time values, also called time stamps. It is closed under + and including 0
r_o = An element of R called the start time

Description of the case study: Here in this research, the patients' process flow of Pondicherry Medical Centre, Pudhucherry Union Territory of India will be used as a case study. The hospital under study consist of registration, admission and discharge unit and four inpatient areas: two for male and the other two for female with fifteen in patient beds each. The health centre works three shifts (8 h per shift) a day with five medical attendants, four nurses and three doctors. Patient arriving at the health centre follows a flow processes depicted in Fig. 1. The flow chart depicted in Fig. 1 is based on the

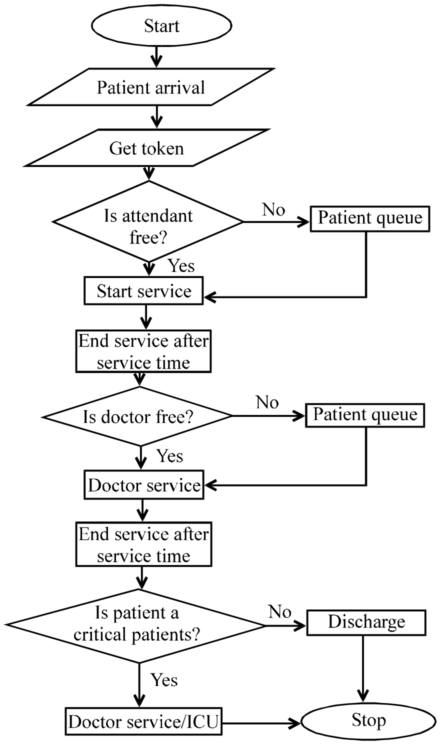


Fig. 1: Patient care flow processes of pondicherry healthcentre, pudhucherry

observation of the processes, studying and surveying the health centre at the current situation. The process of service started when a patient arrives at the medical record area and ends when a patient is admitted or discharged. On arrival, the patient goes to the registration counter for get tokenand write down his/her name and the time he/she arrives. Then, the patient goes to the waiting area where chairs are provided for patients to sit and waiting to be called upon by any of the available medical attendants. The medical attendant makes an initial evaluation of the patient temperature, blood pressure, body weight and height then refers the patient to any of the available doctor. However, if all the doctors are busy attending to patient then the patient will be on the queue. The doctor attends to patient in a specified service time and the final decision about the patient including discharge (patients in non-critical condition) or admit (patients in critical condition) is being taken by the doctor.

Data collection and analysis: Data acquisition is crucial because the results and findings of a simulation study in the best case are as good as the input information. In this study, different methods were used to collect data from the Pondicherry health centre under consideration. These

Table 1: Inter-arrival time of patients on day 1

Patient No.	Arrival time	Inter-arrival time (min)
1	09.05 a.m.	-
2	09.08 a.m.	3
3	09.15 a.m.	7
4	09.45 a.m.	30
5	09.49 a.m.	4
6	09.58 a.m.	9
7	10.08 a.m.	10
8	10.18 a.m.	8
9	10.25 a.m.	7
10	10.38 a.m.	13
11	10.47 a.m.	9
12	10.52 a.m.	5
13	11.16 a.m.	24
14	11.48 a.m.	32
15	11.58 a.m.	10
16	12.04 a.m.	6
17	12.55 a.m.	51
18	01.15 p.m.	20
19	01.50 p.m.	35
20	02.35 p.m.	45
21	02.50 p.m.	15
22	03.05 p.m.	15
23	03.15 p.m.	10
24	03.25 p.m.	10
25	04.04 p.m.	39
26	04.15 p.m.	11
27	04.27 p.m.	12
28	04.35 p.m.	8
29	04.38 p.m.	20
30	04.40 p.m.	2
31	04.45 p.m.	5
32	04.55 p.m.	10
33	04.59 p.m.	4

include review of the patient admission log book at the registration counter (get token for further treatment), direct observation and interview with the staff in the health centre. The number of the patients and their arrival times into the health centre for 5 working days (Monday to Friday) between the hours of 9:00 a.m. and 5:00 p.m. were collected. These data is needed to simulate the model to be developed. Table 1-5 show the obtained interarrival time of patients coming to the health centre for the period of 5 working days.

However, the collected data were analyzed using the input analyzer in the ARENA Simulation Software to determine the statistical distribution of the collected data (that is the interarrival time (Table 1-5) of patients entering the Pondicherry health centre, Pudhucherry). The input analyzer in the ARENA allows user to enter raw data and obtain the appropriate statistical distribution for input to the model. After employing the input analyzer in the ARENA Simulation Software, the analysis of the inter-arrival times of patients entering the health centre to receive care between Monday and Friday are depicted in Fig. 2-7. These statistical distributions are summarized in Table 6.

According to the interview conducted with the medical attendants and the doctors in the examination

Table 2: Inter-arrival time of patients on day 2

Patient No.	Arrival time	Inter-arrival time (min)
1	09.00 a.m.	-
2	09.06 a.m.	6
3	09.25 a.m.	21
4	09.35 a.m.	10
5	09.40 a.m.	5
6	09.55 a.m.	15
7	10.18 a.m.	23
8	10.28 a.m.	10
9	10.35 a.m.	7
10	10.40 a.m.	5
11	10.50 a.m.	10
12	10.55 a.m.	5
13	11.10 a.m.	15
14	11.40 a.m.	30
15	11.55 a.m.	5
16	12.15 a.m.	20
17	12.25 a.m.	10
18	01.05 p.m.	40
19	01.10 p.m.	5
20	02.05 p.m.	55
21	02.20 p.m.	15
22	03.25 p.m.	5
23	03.45 p.m.	20
24	03.55 p.m.	10
25	04.15 p.m.	20
26	04.25 p.m.	10
27	04.40 p.m.	15
28	04.45 p.m.	5
29	04.46 p.m.	10
30	04.48 p.m.	2
31	04.50 p.m.	2
32	04.55 p.m.	5
33	04.58 p.m.	3
34	04.59 p.m.	1

Table 3: Inter-arrival time of patients on day 3

Patient No.	Arrival time	Inter-arrival time (min)
1	09.10 a.m.	-
2	09.15 a.m.	5
3	09.25 a.m.	10
4	09.38 a.m.	13
5	09.49 a.m.	11
6	09.55 a.m.	6
7	10.10AM	15
8	10.30 a.m.	20
9	10.35 a.m.	5
10	10.45 a.m.	10
11	10.50 a.m.	5
12	10.58 a.m.	8
13	11.05 a.m.	7
14	11.15 a.m.	10
15	11.30 a.m.	15
16	12.35 a.m.	5
17	12.45 a.m.	10
18	01.10 p.m.	25
19	01.15 p.m.	5
20	02.25 p.m.	65
21	02.40 p.m.	15
22	03.45 p.m.	5
23	03.55 p.m.	10
24	03.58 p.m.	3
25	04.10 p.m.	12
26	04.15 p.m.	5
27	04.25 p.m.	10
28	04.35 p.m.	10
29	04.50 p.m.	15

Table 4: Inter-arrival time of patients on day 4

Patient No.	Arrival time	Inter-arrival time (min)
1	09.02 a.m.	-
2	09.10 a.m.	8
3	09.20 a.m.	10
4	09.45 a.m.	25
5	09.49 a.m.	4
6	09.58 a.m.	9
7	10.10 a.m.	12
8	10.28 a.m.	18
9	10.35 a.m.	7
10	10.45 a.m.	10
11	10.50 a.m.	5
12	10.55 a.m.	5
13	11.05 a.m.	10
14	11.28 a.m.	23
15	11.40 a.m.	12
16	12.10 a.m.	30
17	12.25 a.m.	15
18	01.35 p.m.	10
19	01.50 p.m.	15
20	02.15 p.m.	25
21	02.20 p.m.	5
22	03.45 p.m.	25
23	03.55 p.m.	10
24	04.00 p.m.	5
25	04.05 p.m.	5
26	04.15 p.m.	10
27	04.17 p.m.	2
28	04.25 p.m.	8
29	04.30 p.m.	5
30	04.35 p.m.	5
31	04.44 p.m.	9
32	04.50 p.m.	6
33	04.56 p.m.	6

Table 5: Inter-arrival time of patients on day 5

Patient No.	Arrival time	Inter-arrival time (min)
1	09.30 a.m.	-
2	09.40 a.m.	10
3	09.55 a.m.	15
4	10.05 a.m.	10
5	10.15 a.m.	10
6	10.26 a.m.	11
7	10.40 a.m.	14
8	10.45 a.m.	5
9	10.55 a.m.	10
10	11.00 a.m.	5
11	11.10 a.m.	10
12	11.15 a.m.	5
13	11.25 a.m.	10
14	11.48 a.m.	23
15	11.58 a.m.	10
16	12.04 a.m.	6
17	12.55 a.m.	51
18	01.15 p.m.	20
19	01.50 p.m.	35
20	02.35 p.m.	45
21	02.50 p.m.	15
22	03.05 p.m.	15
23	03.15 p.m.	10
24	03.25 p.m.	10
25	04.10 p.m.	45

room, the time the medical attendant takes to carry outan initial evaluation of the patient temperature, blood pressure check up, height and weight of the patient in the medical record area is 5 min. On the other hand, the time

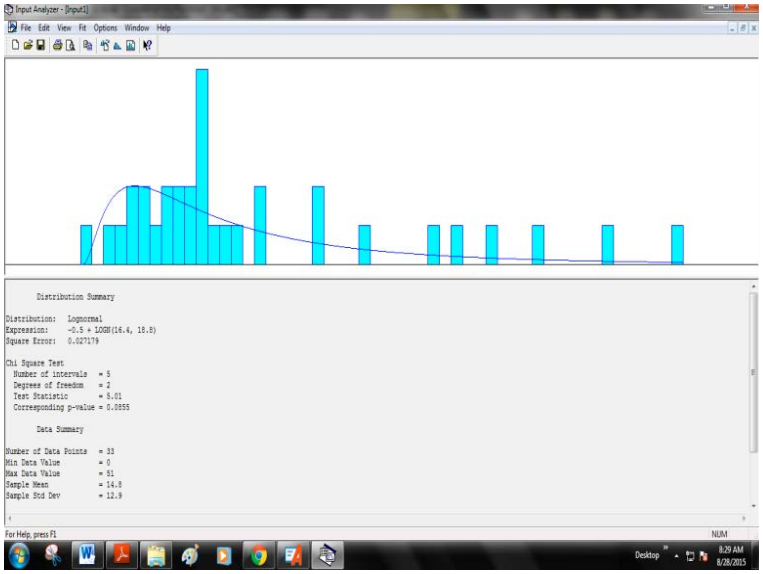


Fig. 2: Patients arrival distribution on day 1

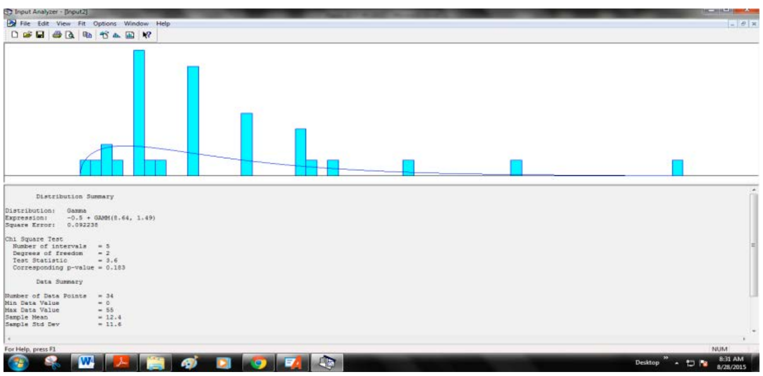


Fig. 3: Patients arrival distribution on day 2

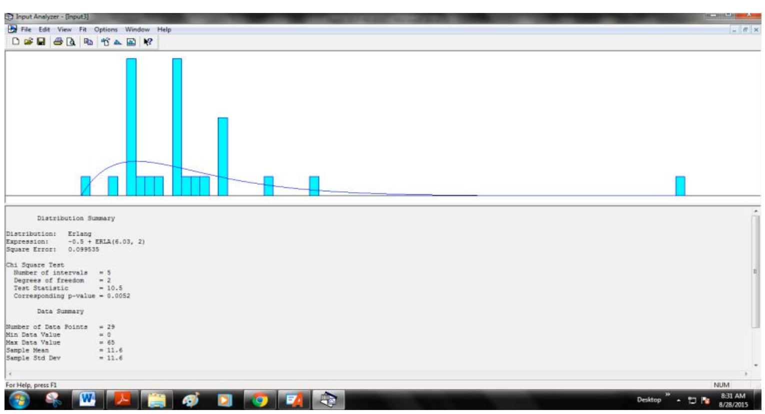


Fig. 4: Patients arrival distribution on day 3

it takes the doctor to service the patient in the examination room is between 5 and 20 min (uniform distribution: uniform (5.0, 20.0)). Patients entering into the health centre are classified into: critical patient and non-critical patient.

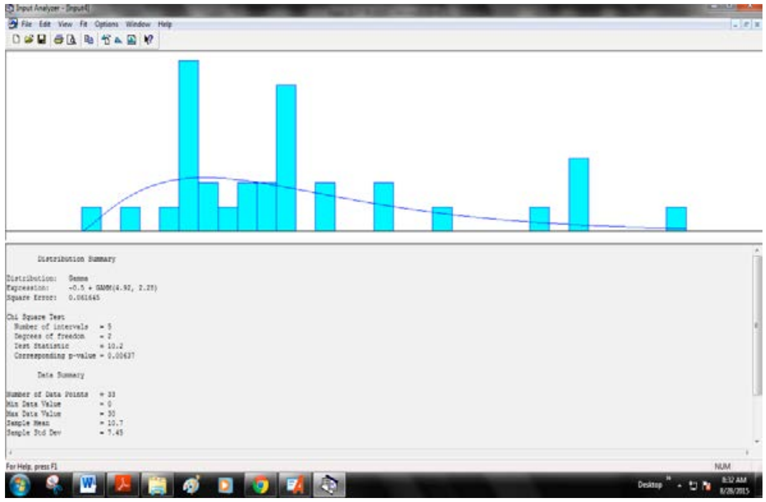


Fig. 5: Patients arrival distribution on day 4

Fig. 6: Patients arrival distribution on day 5

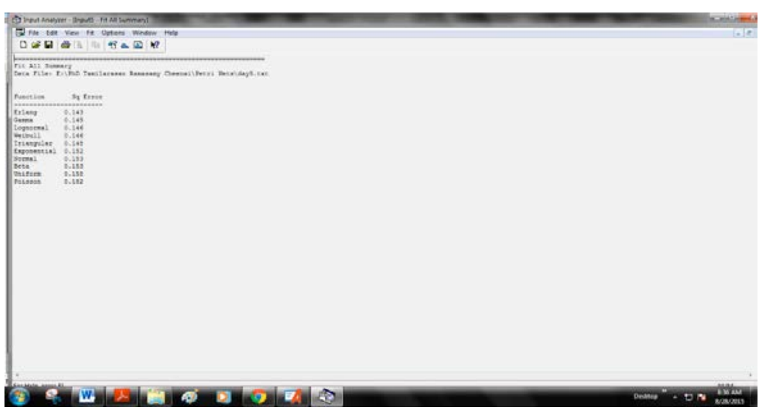


Fig. 7: Cumulative summary of patients arrival distribution on day 5

The critical patient will be admitted into the health centre as inpatient while the non-critical patient will be discharged after treatment. Based on the information obtained from the medical staff in the health centre, the

Table 6: Description of major places in the TCPN Model

Place	Description
Next patient	Model entry of new patient
Waiting patients	Model list of patient waiting to be served by the medical attendants
Busy	Number of attendant(s) busy in the centre
Free	Number of attendant(s) free in the centre
pwfdasse	Patient waiting for doctor in a queue
Treatment room	Patient in the treatment room
Doctor	Number of doctor(s) available for service
End	Indicate end of treatment
Admit	Indicate Inpatient (IP)
Discharge	Indicate Outpatient (OP)
Attendant	Medical attendants for medical service

Table 7: Description of major transitions in the model

Transition	Description
Arrivalpatient	Execution of this transition models arrival of new patient
Start service	Execution of this transition models start of service by medical attendant(s)
Finished	Execution of this transition models end of service by medical attendant
Examination room	A substitution transition
Start assessing	Execution of this transition models start of service by doctor(s)
End treatment	Execution of this transition models of end of service by the doctor(s)
Critical patient	Execution of this transition models of list of critical patients
Non critical patient	Execution of this transition models oflist of non-critical patients (ready for discharge)

ratio of the critical patient to non-critical is currently 1:4. The model to be developed will contain resources such as medical attendants and doctors. At the time of this study, there are five medical attendants, there are four nurses and three doctors and one doctor per shift in the health centre.

Development of the TCPN simulation model for the patient care flow processes: CPN Tools (Version 4.0.1) was used in constructing a Timedcolored petri nets simulation model for the considered patient care flow processes. The proposed TCPN simulation model consists of 16 places and 12 transitions.

Simulation model, places are draw as ovals while transitions are drawn as rectangle. Places and transitions are connected with directed arcs which model the relations among the individual elements of the developed model. The arcs with their arc expressions define the flows of tokens in the net. The descriptions of the major places and transitions in the proposed TCPN simulation model are stated in Table 6 and 7, respectively. The color sets, variables, initial parameters and functions that are needed in developing the TCPN simulation model of the patient care flow processes are depicted in Fig. 8.

The color sets, variables, initial parameters and functions that are needed in developing the TCPN simulation model of the patient care flow processes are depicted in Fig. 7.

Table 8: Simulation output of the TPCN Model for 5 days

Days	Inpatient (IP) simulation	Outpatient (OP) simulation
1	16	84
2	26	102
3	12	57
4	20	72
5	17	65

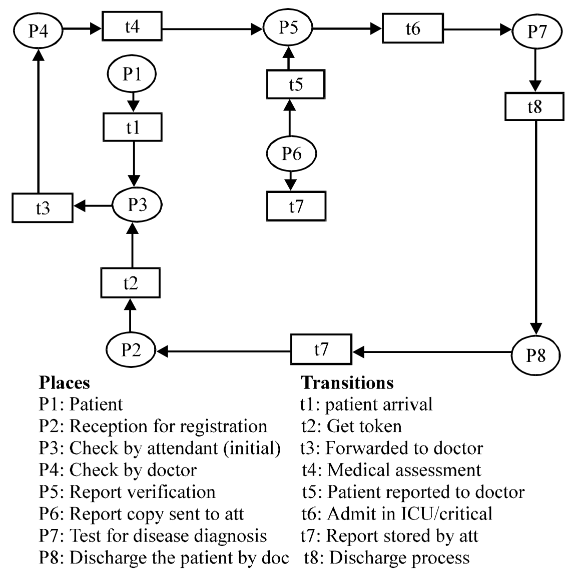


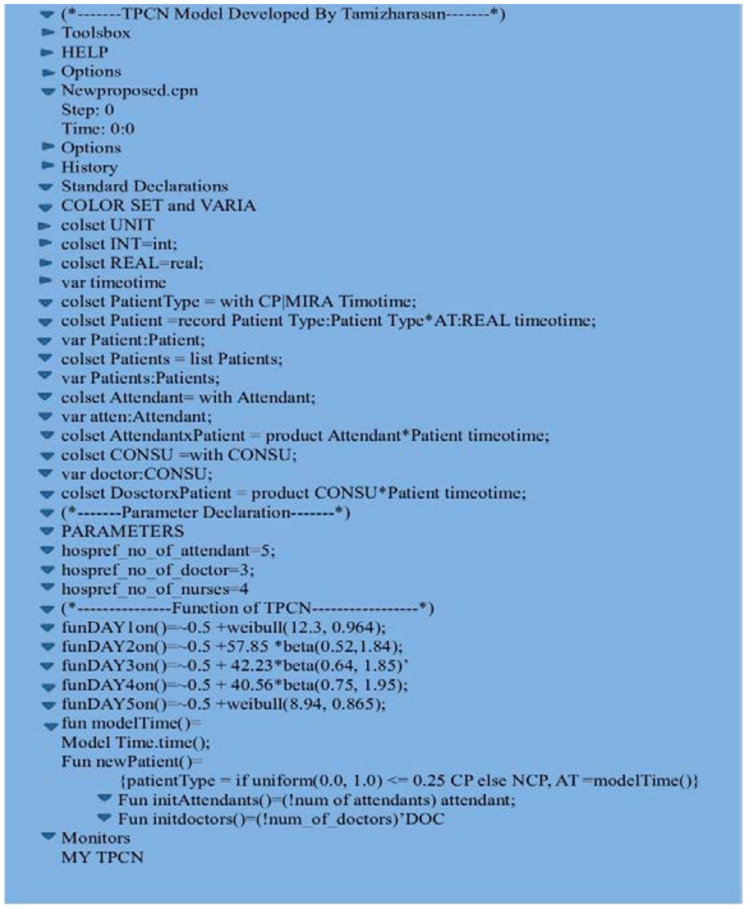
Fig. 8: Petri net flow diagram of patient health care process

The simulation of the proposed TCPN Model was carried out using CPN tools. Due to the fact that the simulation model is stochastic, it is necessary to execute several simulation runs with the proposed model in order to compute mean value. Hence, several replications were run for each day and average of each was calculated. Besides, validation is important for the correctness and credibility of the model (Jeng and DiCesare, 1995). Validation is to determine the model which will be a representation of the real system (Jun *et al*., 1999; Jensen *et al*., 2007).

Thus, the proposed Timed Colored Petri Net Model was validated by comparing the output of the simulation model (i.e., number of inpatients and number of outpatients) for 5 consecutive days with the number of inpatients and of outpatients (Table 8) of the actual system.

RESULTS AND DISCUSSION

Figure 8 shows the developed TCPN simulation model of patient care flow processes of the patient health centre under consideration. This figure depicts the main page which models the arrival of patients and process at the medical record area ofthe case study. Figure 9 depicts



```
(*-------TPCN Model Developed By Tamizharasan-------*)
Toolsbox
HELP
Options
Newproposed.cpn
Step: 0
Time: 0:0
Options
History
Standard Declarations
COLOR SET and VARIA
colset UNIT
colset INT=int;
colset REAL=real;
var timeotime
colset PatientType = with CP|MIRA Timotime;
colset Patient =record Patient Type:Patient Type*AT:REAL timeotime;
var Patient:Patient;
colset Patients = list Patients;
var Patients:Patients;
colset Attendant= with Attendant;
var atten:Attendant;
colset AttendantxPatient = product Attendant*Patient timeotime;
colset CONSU =with CONSU;
var doctor:CONSU;
colset DosctorxPatient = product CONSU*Patient timeotime;
(*-------Parameter Declaration-------*)
PARAMETERS
hospref_no_of_attendant=5;
hospref_no_of_doctor=3;
hospref_no_of_nurses=4
(*---------------Function of TPCN-----------------*)
funDAY1on()=~0.5 +weibull(12.3, 0.964);
funDAY2on()=~0.5 +57.85 *beta(0.52,1.84);
funDAY3on()=~0.5 + 42.23*beta(0.64, 1.85)'
funDAY4on()=~0.5 + 40.56*beta(0.75, 1.95);
funDAY5on()=~0.5 +weibull(8.94, 0.865);
fun modelTime()=
Model Time.time();
Fun newPatient()=
        {patientType = if uniform(0.0, 1.0) <= 0.25 CP else NCP, AT =modelTime()}
    Fun initAttendants()=(!num of attendants) attendant;
    Fun initdoctors()=(!num_of_doctors)'DOC
Monitors
MY TPCN
```

Fig. 9: Declarations for the TCPN Model of the CNP

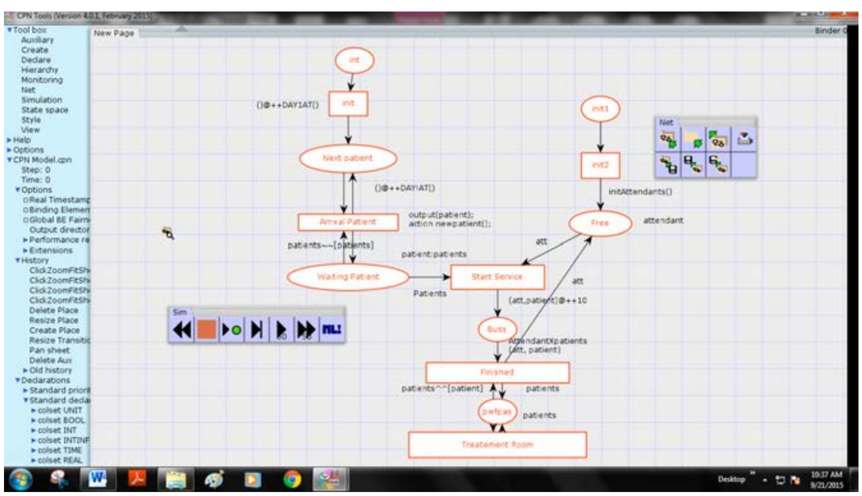


Fig. 10: The main page of the developed TCPN Model

a subnet layer (TREATMENT sub-module) of the main model (Fig. 10). It models operation in the examination room of the health centre under study.

From Fig. 10, entry of each patient to the health centre is modelled by a token on the place next patient (Fig. 11). This place has the color set UNIT and the color

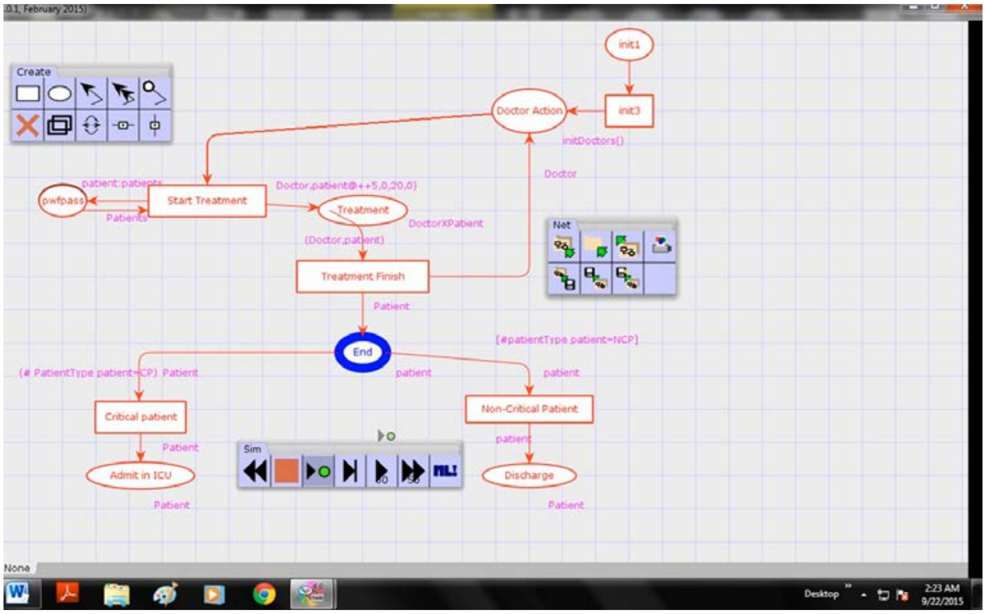


Fig. 11: The TREATMENT page of the developed TCPN Model

set UNIT is defined to be equal to unit timed type as depicted in the declarations block (Fig. 6) of the developed model. The color set UNIT is used to model arrival time of patient based on the time stamp such as @++Day1AT() attached to the arc that runs from transition in it to place next patient (Fig. 7a). Based on the evaluation of the distribution expression: ~0.5+weibull (12.3, 0.964), function Day1AT() is used to generate the arrival time of new patient into the system. From Fig. 6, color set patient type is used to represent types of patient entering the patient health centre. It is enumerated type of CP (Critical Patient) and NCP (Non-Critical Patient). The place waiting patients has the color set patients defined to be set of list patient. The color set patients is used to model the queue of patients to be attended to. The color set patient models a patient as a record consisting of two fields. The first field denoted with patient type is of type patient type and represents type of the patient. Second field is denoted with the title AT is of type real and represents arrival time of a patient. The color set AttendantxPatient is a product color set defined as product attendant x patient timed. This color set is used to represent the attendant when he/she is busy serving patient. Also, the color set DoctorxPatient is to represent the doctor when he/she is busy treating patient. The function Day1AT() uses Weibull distribution with the expression: ~0.5+weibull (12.3, 0.964) to generate arrival times of patients for day 1. This distribution is used instead of lognormal distribution because currently CPN tools (Version 4.0.1) does not support lognormal distribution. The place waiting patients and the place pwfdasse are used to model the queue of patients at the registration counter unit and examination room, respectively. The single token on each of the places waiting patients and the place pwfdasse represents the queue of patients. In the initial marking the lists are empty. The places free and busy are used to represent the status of the medical attendant. A token on the place free indicates that the medical attendant is not serving a patient at that time. The parameter hospref_no_of_ attendant = 5 and function fun in it Attendants() = (!num_ of_attendants)' attendant in Fig. 6, show that there are 4 tokens on the place free in the initial marking. A token on the place busy indicates that the medical attendant is busy attending to a patient and the value of the token indicates which patient is being processed. The initial marking of busy is empty.

The medical attendant can start attending to patient (transition startservice), if the medical attendant is free and if there is at least one patient in the queue of patients (patient::patients on the arc from place waiting patients to transition start service).

From Fig. 11, after treatment, the doctor would decide whether to admit the patient (critical patient) or to discharge the patient (non-critical patient).

The decision will depend on the outcome of the treatment. The guard functions [# patientType patient = CP] on transition Critical Patient and

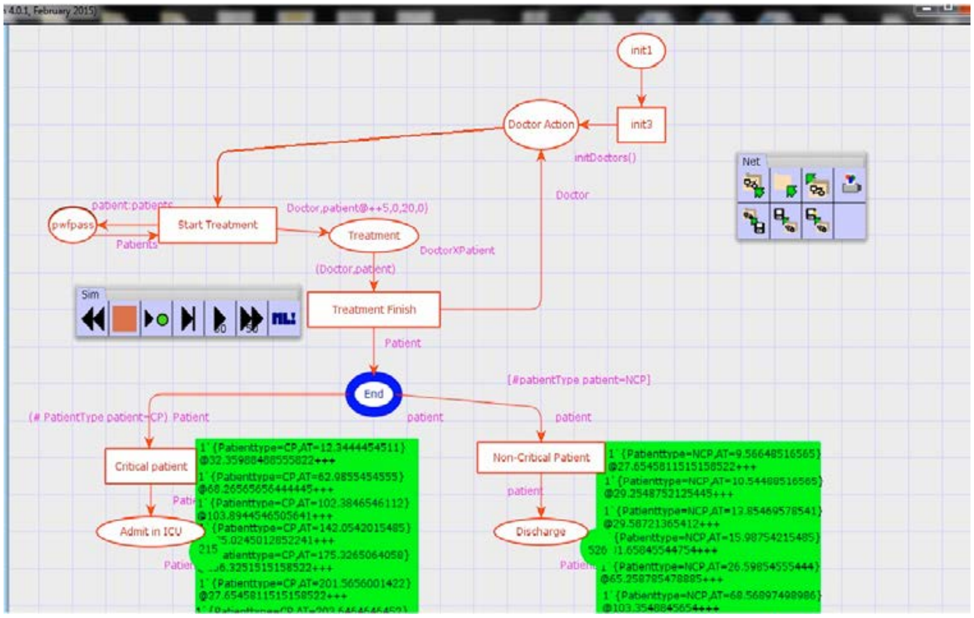


Fig. 12: Depicts the screenshot of the simulation of the developed TCPN Model

[# patient type patient = NCP] on transition non critical patient were used to achieve this goal (Fig. 12).

CONCLUSION

In this study, we have been able to develop a Timed Colored Petri Net (TCPNs) simulation model for patient care flow processes with emphasis on medical record area and examination room using Pondicherry Health Centre, Pudhucherry of India as a case study. The developed Timed Colored Petri Net simulation model reveals valid representation of the patient care flow processes of the considered health centre. This is evident from the result of the statistical analysis which shows that there were no significance differences between the simulated and real number of patients entering the health centre at 5% level. Thus, the developed TCPN simulation model could accurately describe the patient care flow processes of the health centre under study or any other related health flow processes.

REFERENCES

Billington, J., A.K. Gupta and G.E. Gallasch, 2008. Modelling and Analysing the Contract Net Protocol-Extension Using Coloured Petri Nets. In: Formal Techniques for Networked and Distributed Systems-FORTE 2008, Suzuki, K., T. Higashino, K. Yasumoto and K. El-Fakih (Eds.)., Springer-Verlag, Berlin, Heidelberg, ISBN: 978-3-540-68854-9, pp: 169-184.

Ferrin, D.M., M.J. Miller, D.L. McBroom, 2007. Maximizing hospital financial impact and emergency department throughput with simulation. Proceedings Simulation Conference. December 9, 2007, IEEE Press, Piscataway, NJ, USA., pp: 1566-1573.

Jeng, M.D. and F. DiCesare, 1995. Synthesis using resource control nets for modeling shared-resource systems. IEEE Trans. Robot. Automat., 11: 317-327.

Jun, J.B., S.H. Jacobson and J.R. Swisher, 1999. Application of discrete-event simulation in health care clinics: A survey. J. Oper. Res. Soc., 50: 109-123.