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RE-ENGINEERING HOSPITAL INFORMATION SYSTEM WORKFLOW PROCESS IN A NIGERIAN DENTAL HOSPITAL

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ABSTRACT

The existing workflow process that dental patients undergo in hospitals is challenged with the problem of repetitive steps. This has led to redundancy and delay in ensuring the quality of healthcare service delivery. Thus, there is a dire need for a workflow process that will eliminate repeated procedures and reduce the waiting time of service delivery. This paper seeks to reengineer the workflow process in a dental hospital with a view to reducing the problems encountered by dental patients. Through interviews and observation, the time taken for each workflow process was obtained from the staff, doctors, nurses and patients of the Dental Clinic at Obafemi Awolowo University Teaching Hospitals Complex. The existing workflow process model was represented using Petri net and designed using Unified Modelling Language (UML) tools while the proposed model was represented using process maps and Petri net and designed using UML tools. The two models were simulated in the MATLAB environment using Simulink. The performance of the proposed model was evaluated by benchmarking it with the existing model using patient throughput and waiting time as performance metrics. The proposed model outperformed the existing one significantly. Patient waiting time reduced by 36.8% as a result of the reduction in the number of processes from 14 to 8. At 0.2 patients/sec, patient throughput in the new model was significantly higher. This paper concludes that the proposed model could facilitate effective and efficient healthcare service delivery.

Keywords: Hospital Informatics; Workflow management; Reengineering; Dental clinic

1. Introduction

The need for efficient healthcare service delivery cannot be overemphasised. According to Rodrigues (2010), healthcare is a service where reliable and timely information is a critical resource for planning and monitoring service provision at organisational, regional, national and international levels (Locatelli *et al*., 2012). At all the levels, the day-to-day operations are mostly governed by a set of cooperative business processes in which interactions with humans and information systems are involved. These make healthcare an increasingly cooperative business that involves many individuals and organisations. In many developed and developing countries, healthcare organisations such as hospitals are under increasing pressure to improve efficiency and reduce costs (Helfert *et al*., 2005). Specifically, in a developing nation like Nigeria, the demand for hospital services is rapidly growing (Hongoro, 2004).

Hospitals are recently faced with the challenge of finding ways to improve the quality of healthcare, reduce costs and increase revenue (Emanuele and Koetter, 2007). Thus, process optimization, effectiveness and efficiency have become important issues within the healthcare community as a means to achieving operational goals. For example, the number of patient visits to hospitals increases on a daily basis while hospital assets and infrastructure do not. Therefore,

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hospitals need to make better use of the limited assets and infrastructure, and also focus on excellent quality of healthcare delivery. In addition, hospitals need support in controlling and monitoring healthcare workflow processes for patients (Dadam *et al*., 2000) so as to increase the interest in changing hospital informatics to support clinical processes in more direct work. Hospital informatics comprises of various workflow processes with a variety of interrelated tasks which need to be optimized (Kaiser, 2003). Dental informatics is the branch of hospital informatics that is focused on dentistry (Masic, 2012) and manages the information, communication and application of new technologies in clinical practice and research.

Workflow management system is one of the suitable methods for improving hospital performance. This technology was accepted by hospitals as a way to improve their operational efficiency, achieve patient's safety and affect the quality of care delivered positively (Emanuele and Koetter, 2007). Hospitals have adopted Information Technologies to support and optimize their workflow processes. The implementation of workflow systems in a hospital environment is difficult because many hospitals organise their work with a focus on departments and not on processes. The need for investigating the workflow design includes adoption of new healthcare information technologies and treatment methodologies; patient flow improvement in terms of cost and efficiency; ensuring safety of patient and addressing other healthcare challenges.

The Dental clinic comprises of several treatment units which treat different sections of the oral cavity. Patients in dental hospitals often complain about repeated activities that they have to undergo to get healthcare service delivery, such as going back and forth to a particular office (e.g., cash office) to get a process (e.g., payment) done. This goes with queuing at each point and an increase in the time spent in the hospital. These repeated activities lead to fatigue, frustration and delay of patients in the hospital.

In this paper, an attempt was made to reengineer the workflow process in the dental hospital with a view to reducing the problems encountered by dental patients thereby enhancing activities in the hospital.

2. Related works

Over the years, a lot of research has been carried out around the world on how to reengineer the workflow process of hospitals. Different techniques of Business Process Reengineering (BPR) have been employed in the reengineering of the patient flow process at hospitals to address the problem of inefficiencies leading to redundancy and lack of interoperability. This has been done, for example, in Western Sydney area health service (Khandelwal and Lynch, 1999) and Singapore hospital operating theatre (Kumar and Ozdamar, 2004; Kumar and Shim, 2010; Khan *et al*., 2008; Cassettari *et al*., 2013). This has resulted in a drastic increase in efficiency of resource utilization in the hospital.

Also, it was observed that the patients in the hospitals witnessed long queues. This increases the inefficiency of the department and thereby hinders the performance of the hospital. Thus, in a bid to manage waiting times, inaccessible information, costs of healthcare delivery and medical errors for patients and to improve the workflow efficiency, Lee *et al*., (2010), Bakshi (2013), Dinesh *et al*., (2013) Mardiah and Basri (2013) Afrane and Appah (2014) proposed different BPR techniques. These studies found that application of the different BPR techniques caused a decrease in waiting time with an increase in resources.

In light of these, workflow technology has expanded substantially into the healthcare industry. It can be seen as a computer-assisted collection of activities related to a specific commitment, adding value to a product or service of the organisation. This technology is a valuable tool for managing day-to-day operations as well as improving business processes over time. It helps to automate and improve business processes, by performing an analysis of work processes in order to specify the people who do the work, information needed to carry it out, rules and regulations for how to carry it out, potential results and people who perform the next step in the process (Andrew, 2001). This technology was accepted by hospitals as a way to improve their operational efficiency, achieve patient's safety and affect the quality of care delivered positively (Emanuele and Koetter, 2007). Few studies have investigated the workflow of providers in a dental office (Schwei *et al.,* 2016). The generic workflow of a dental clinic is as presented in Figure 1 (Schwei *et al.,* 2016). This involves the processes of the dental clinic, showing the hierarchy of the processes, the key processes; and participation of each component of the process.

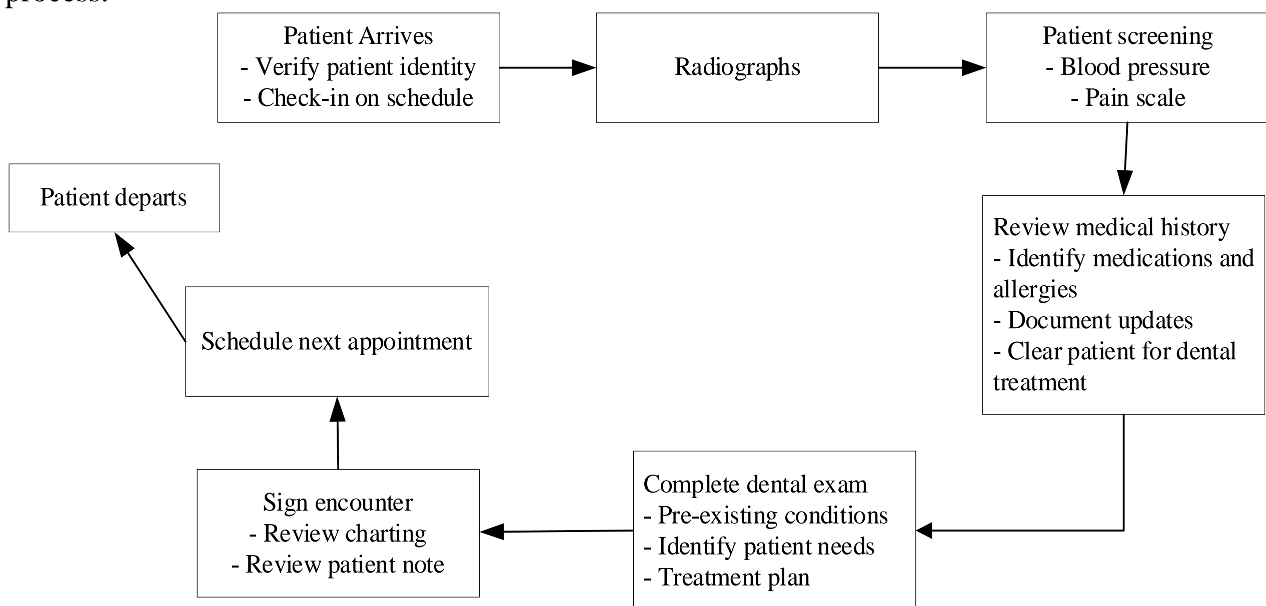

Figure 1: Workflow of Dental Clinic

3. Analysis of the case study

In this research, the workflow processes of a Nigeria hospital, Obafemi Awolowo University Teaching Hospital Complex Dental Clinic (OAUTHCDC), located inside Obafemi Awolowo University, Ile-Ife was used as a case study. Information was gathered using interviews and observation. Interviewees included medical record officers, cashiers, nurses, radiographers, pharmacists, and specialist/doctors at nine different treatment units in dental clinic, each of which treats different sections of the oral cavity, namely:

a) Oral and maxillofacial dentistry
b) Restorative dentistry
c) Endodontics dentistry
d) Pedodontics dentistry (Paedodontics)
e) Orthodontics dentistry
f) Periodontics dentistry
g) Oral medicine dentistry
h) Oral pathology
i) Community dentistry

3.1 Existing dental hospital information workflow process in OAUTHCDC

The workflow procedure at OAUTHCDC to achieve treatment at the time of information gathering is such that the patient:

i. Goes to cash point for payment of registration/consultation.
ii. Takes the receipt to record office to open the case note.
iii. Has the case note taken to oral diagnosis for consultation?
iv. Referred to radiology for x-ray.
v. Returns to cash point to pay for a specific radiograph.
vi. Returns to radiology with the receipt for radiography.
vii. Returns to oral diagnosis with the x-ray result.
viii. Is referred to the appropriate clinic for proper management.
ix. Returns to the cash point to pay for specific management.
x. Returns to the clinic with receipt for management.
xi. Goes to the pharmacy with the prescription list.
xii. Returns to the cash office to pay for the drug(s).
xiii. Returns to the pharmacy with the receipt for drug(s)

Based on the interviews conducted, the dental hospital information workflow process in OAUTHCDC is depicted in Figure 2 with cloud symbols showing the area with identified problems. The flowchart of the existing workflow is as shown in Figure 3. Also, the Petri net representation of the existing workflow process is as shown in Figure 4. The patient flow in the Petri net representation is either a new patient, that is, a patient coming to the hospital for the first time who will follow *q0,q1,q3,q4,q3,q5,q6,q4,q6,q5,q7,q5,q7,q8,q9,q4,q9,q10* path or an appointed patient, that is, a patient coming for a scheduled appointment who will follow the path *q0,q2,q3,q4,q3,q7,q8,q9,q4,q9,q10*.

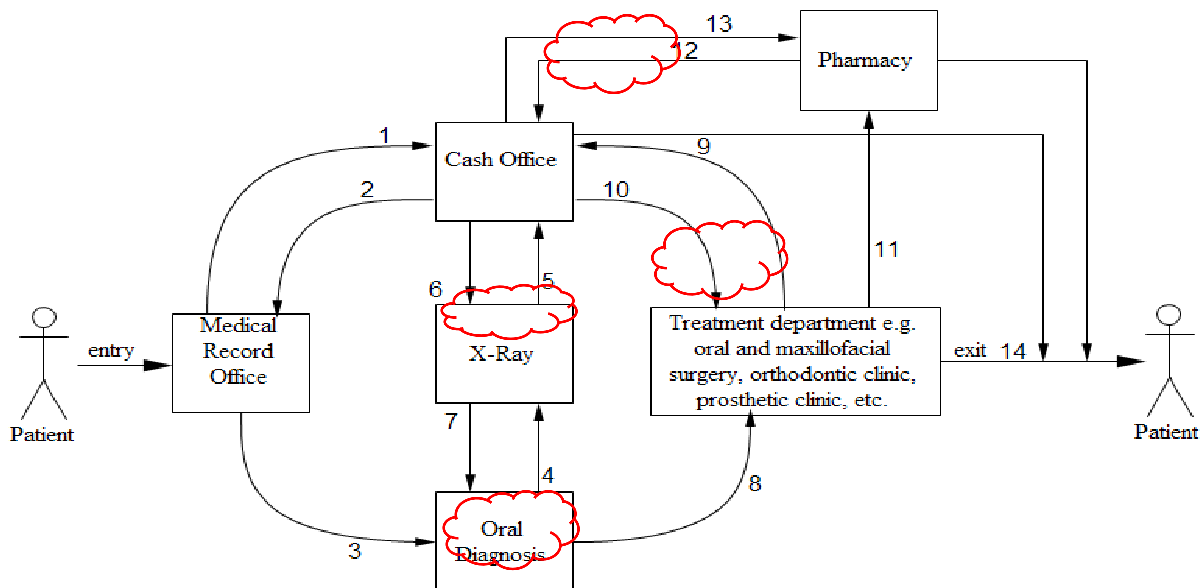

Figure 2: Conceptual View of Existing Manual Patient Flow in OAUTHCDC

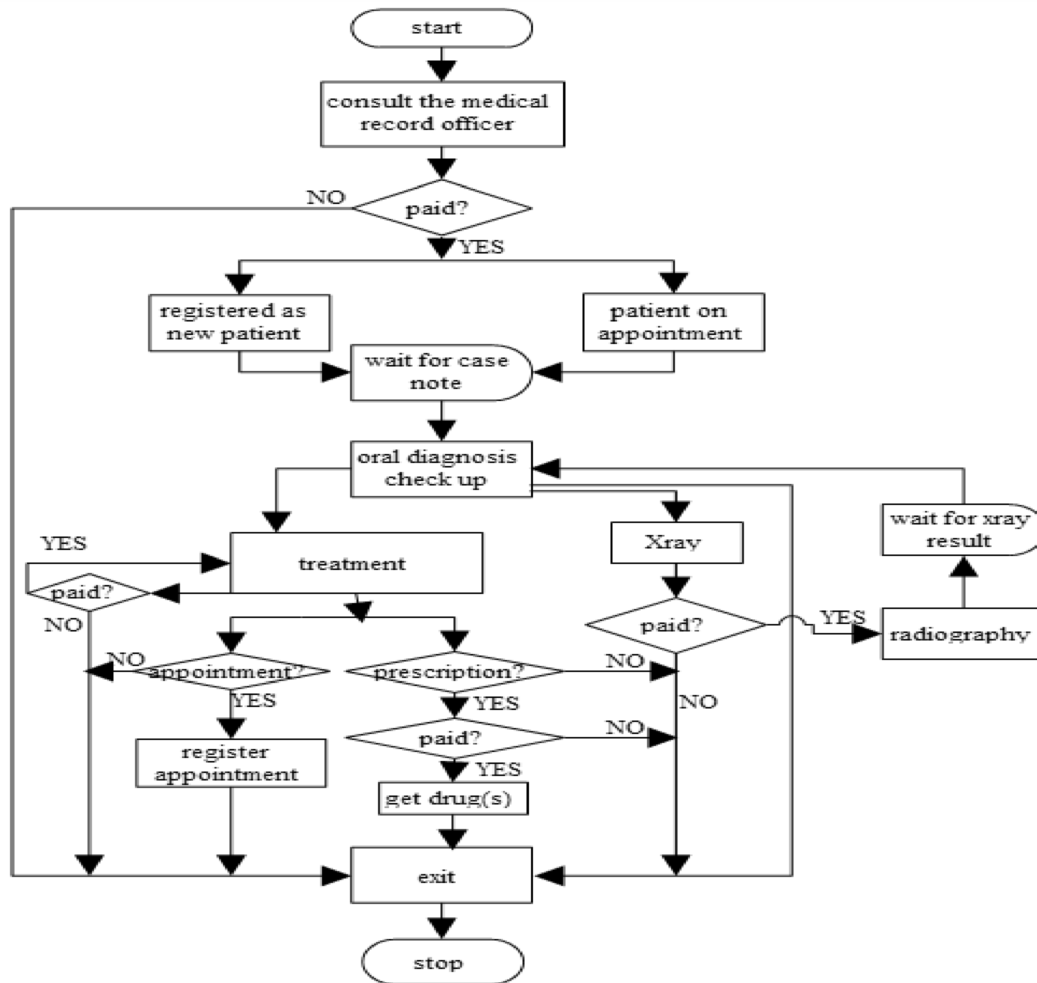

Figure 3: Flowchart of the Existing Workflow Process

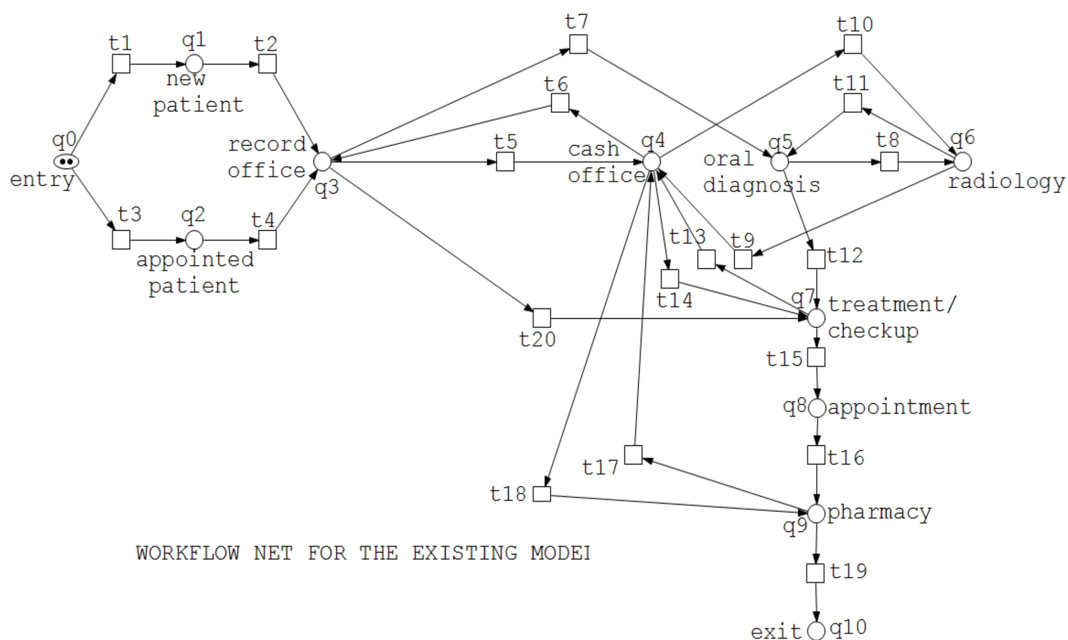

Figure 4: Petri net Representation of the Existing Workflow Process

3.2. Problems identified with the existing workflow process

The problems identified with the existing manual operation of the workflow process in OAUTHCDC are as follows:

- **i.** The problem of the patient going back and forth in order to achieve success in a particular step or activity. For example, the patient moves from oral diagnosis to X-ray (to get the price of the specified X-ray) to cash office (to pay) and back to X-ray (to tender evidence of payment) before the radiographer will attend to them. The patient will then go back to oral diagnosis to get direction to the appropriate treatment unit. The same thing happens when the patient gets to the treatment unit. She/he is directed to go and pay at the cash office then come back for treatment. All these may lead to fatigue, frustration and probably death of a patient with chronic illness.
- **ii.** These movements of the patient cause a delay in getting treatment as they are to wait so that they can be attended to in batches (e.g. at the medical record office), or have to wait before their result (e.g. radiography result) will be ready as it will be processed in batches At times, they have to queue at the cash office before they can make payment and patients that are registered with National Health Insurance Scheme have to go to Obafemi Awolowo University Teaching Hospital Complex (OAUTHC) located at a considerable distance away from the hospital, to get clearance. All these also lead to a delay in treatment delivery to the patients.
- **iii.** It was observed that most patients were given appointment in the morning making the clinic crowded and leading to long waiting time.

4. Methodology

To develop an improved workflow process model that will ensure time efficient and redundancy-free dental healthcare service delivery, this study employs queuing theory, which is the mathematical study of the congestion and delays of waiting in line. Queuing theory has helped users make informed business decisions on how to build efficient and cost-effective workflow systems. Business process reengineering is considered in this study because of the various stages it has which aids the understanding and improvement of the patient workflow process in OAUTHCDC. This procedure is based on the steps defined by Khodambashi (2013) in implementing reengineering.

4.1 Data Collection and Analysis

The research data, that is, time taken for a process and the flow of patient within the hospital, were gathered using interviews and observation from the case study. From the interviews, it was discovered that there was no existing document on the time it takes the patient to be done with a process. Thus, the interviews and observation were focused on the treatment/process time because this study is centred on time and patient movement in the hospital. Details on the data collected during the interviews and observation is as shown in Table 1. The number of patients attended to was gathered from the nurses at each point because they have logbook of all the patients that come in either for treatment or consultation. From the logbook, the number of patients per day was taken for 1 month (average presented in Table 1). Patients' name was not reviewed during this process as it is not ethical in the hospital. The samples used for the survey is 150 which is sufficient to obtain estimates at a 95% Confidence level.

Table 1: The Research Data: time spent at key contact points in the clinic

ACTIVITY	AVERAGE TIME TAKEN (mins/days(′)/wks)	AVERAGE NUMBER OF PATIENTS PER DAY	NUMBER OF CHAIRS
Registration	5	23 (N), 17 (O)	-
Oral Diagnosis	30	15 – 25	6
Radiography	15	20 – 25	-
Treatment Unit			
i. Oral and Maxillofacial surgery	-	15 – 20	3
ii. Restorative clinic			
a. Conservative	20 – 30	15	9
b. Prosthetics	60	12 – 3	10
iii. Endodontics clinic	120	7 – 8	8
iv. Pedodontics clinic	60	7 – 10	10
v. Orthodontics clinic	-	5	5
vi. Periodontics clinic	45	6	9
vii. Oral Medicine clinic	15′ – 2wks	9	9
viii. Oral Pathology	12′	8 – 10	-
ix. Community Dentistry	-	-	-
Pharmacy	7	20	-

4.2. Proposed Model Design

The re-engineering process is as follows:
When a patient enters the clinic, (s)he is first attended to by the medical record officer who makes a formal request for payment at the cash office for registration. Then, the patient comes back to the medical record officer to pick the case note. A patient attending the clinic for the first time goes to oral diagnosis from where (s)he is directed to the radiography unit (not all patient goes for radiography) while patients coming on appointment go to see the doctor for check-up. If there is no improvement on the patient's tooth, s(he) is referred back to the radiography unit to take an X-ray. Required fees for procedures are obtained at the work station from where (s)he proceeded to the cash office to make payment.

After treatment, the doctor fixes an appointment date and gives a prescription which is written in the case note and the patients' clinic card. The case note will be dropped with the nurse at the treatment department who schedules appointments for patients. The patient then goes to the pharmacy to get the drug's price, pays and get the drugs. The appointments per department would be fixed based on the number of chairs in each clinic. For example, the prosthetic clinic has nine chairs; therefore, seven patients can be attended to at a time with the remaining two chairs reserved for cases of emergency.

Patient's appointment batch would be scheduled at 90 minutes interval because it is expected that the patient's appointments would last for 60 minutes and 30 minutes for cleaning up of each cubicle by dental nurses. However, a comprehensive study was carried out on time per procedure per patient in each of the departments which were used to set up realistic schedules for the patients. The system will also send a reminder message to the patient a day before the appointment date stating the date and time to come for the check-up. The various existing points for the patient due to one or two reasons are the medical records office, oral diagnosis or pharmacy. The proposed workflow process is represented by Figure 5. This proposed workflow process will reduce the time spent in the hospital by patient due to the elimination of the time in

queue for a process and reduction in the going forth and back to a particular point like the cash office.

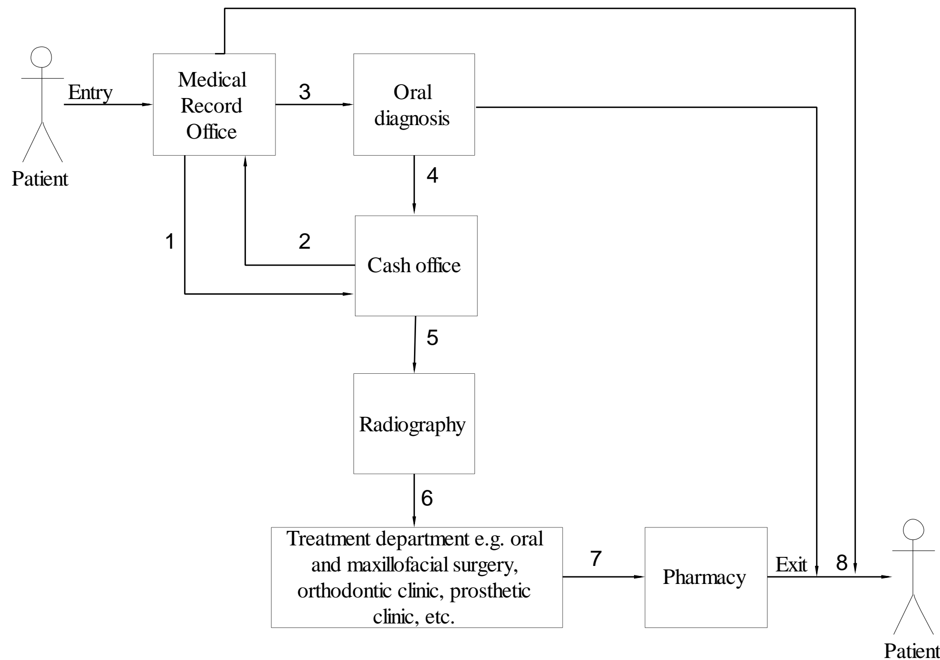

Figure 5: Proposed Work Process Flow

4.3 Proposed model assumptions

In this study, some assumptions were made which are as listed below:

i. There will be a point-of-sale terminal at the cash office for patients that do not have enough cash on them but have money in their account. Patients can also pay online. They do not need to go to the cash office for payment, thereby reducing the population at the cash office and the time spent there.

ii. A computer system which contains the price list for x-rays, treatments and other dental procedures will be stationed at the oral diagnosis station. It will also be used to access the National Health Insurance Scheme (NHIS) website to check for patient's name if they are eligible to benefit from NHIS or membership status.

iii. Available point of payment at the pharmacy.

iv. Patients and Doctors are available

v. The appointment scheduling system adopted is a block rule, and the time for the appointment will be within the working hours.

The model specification and representation approach used in the study are UML, process maps and Petri net. The UML models consist of use case diagram, sequence diagram and activity diagram. The process maps model consists of a flowchart and process definition chart. Petri net shows the two possible flows that the patient can follow for either treatment or check-up.

4.4 Model representation using process maps

The order a patient has to go through in achieving treatment process in the dental hospital is represented by the flowchart in Figure 6 while the process definition chart showing the various input and hospital resources required for each activity to be carried out to achieve patient treatment in the proposed workflow model is shown in Figure 7.

4.5 Model representation using Petri net

Patient movement from one point to another within the hospital is represented using Petri net. The new patient goes through the processes (scenario 1), that is, from point q0 to q1 when transition t1 is fired, and from q1 to q3 to make payment for registration as new patient when transition t2 is fired. Patients on appointment who come for check-up/review go straight to the treatment unit after making payment at the cash office and collecting his/her file from the medical record officer (scenario 2), that is, from point q0 to q2 when transition t3 is fired, and from point q2 to q3 when transition t4 is fired to make payment for consultation and so on. These are represented below in Figure 8. The patient flow for the scenario 1 is q0,q1,q3,q4,q3,q5,q4,q6,q7,q8,q9,q10 and q0,q2,q3,q4,q3,q7,q8,q9,q10 for scenario 2. The transition table in Table 2 shows the various point a patient can be when a transition is fired.

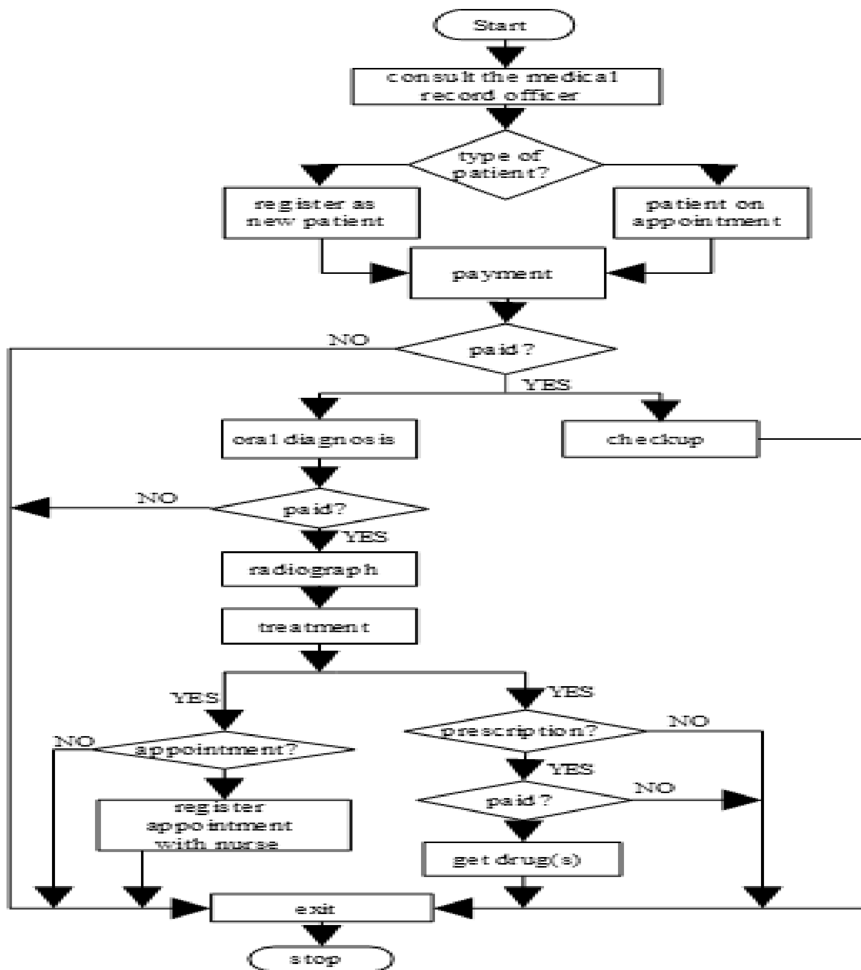

Figure 6: Flowchart of the Proposed Workflow

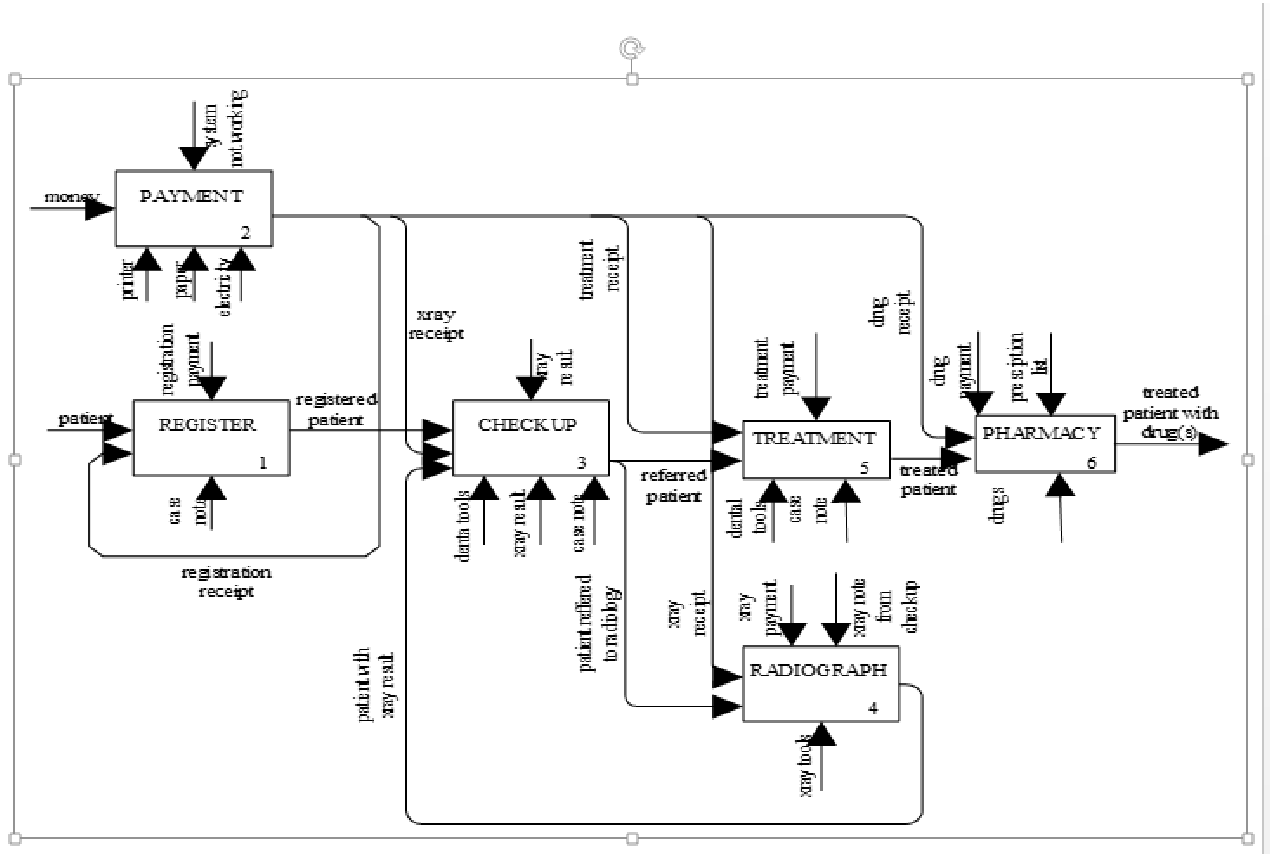

Figure 7: Process Definition Chart of the Workflow

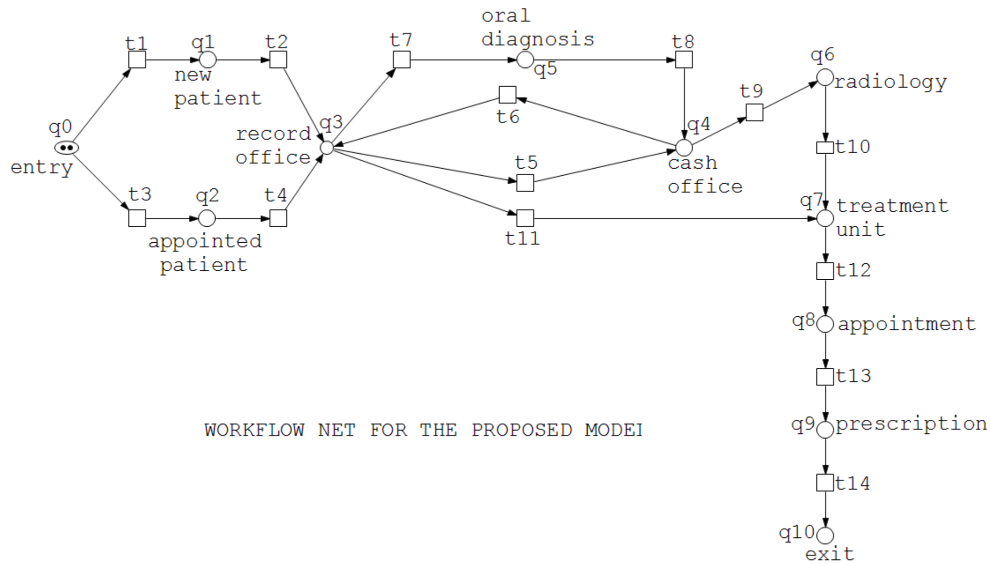

Figure 8: Proposed Workflow Process Representation using Petri net

Table 2: Transition Table of the Proposed Model

Transition / Place	q0	q1	q2	q3	q4	q5	q6	q7	q8	q9	q10
t0	2	0	0	0	0	0	0	0	0	0	0
t1	1	1	0	0	0	0	0	0	0	0	0
t2	1	0	0	1	0	0	0	0	0	0	0
t3	0	0	1	1	0	0	0	0	0	0	0
t4	0	0	0	2	0	0	0	0	0	0	0
t5	0	0	0	1	1	0	0	0	0	0	0
t5	0	0	0	0	2	0	0	0	0	0	0
t6	0	0	0	1	1	0	0	0	0	0	0
t7	0	0	0	0	1	1	0	0	0	0	0
t6	0	0	0	1	0	1	0	0	0	0	0
t11	0	0	0	0	0	1	0	1	0	0	0
t8	0	0	0	0	1	0	0	1	0	0	0
t9	0	0	0	0	0	0	1	1	0	0	0
t12	0	0	0	0	0	0	1	0	1	0	0
t10	0	0	0	0	0	0	0	1	1	0	0
t13	0	0	0	0	0	0	0	1	0	1	0
t14	0	0	0	0	0	0	0	1	0	0	1
t12	0	0	0	0	0	0	0	0	1	0	1
t13	0	0	0	0	0	0	0	0	0	1	1
t14	0	0	0	0	0	0	0	0	0	0	2

5. Results and Discussions

The existing workflow process model and the proposed workflow process model were simulated in the same MATLAB environment, using Simulink tools. The pseudocode representation of both the existing (i.e. manual) and the proposed workflow process used to develop the state flow chart in Simulink are presented in Figures 9 and 10. The generated MATLAB codes were treated offline in this paper. The two models were tested with the same input using the generated dataset in Table 1. This was to ensure that the patient gets the same treatment quality in both models. Simulink extension state flow was designed by specifying the discrete control logic and the modal behaviour of the two systems using the information in Table 2. Some of the various state transitions involved in existing and proposed models are as shown in Figures 11 and 12 respectively. The simulation results showed that the total time taken for the existing workflow process model was 2624.1 seconds (43 minutes 7 seconds). For the proposed workflow process model, total time taken was 1212.2 seconds (20 minutes 2 seconds).

```
1.  initialise (Medical record office)
2.  determine patient status
3.      if patient is on appointment
          generate checkup bill
          send patient to cash office
4.          if patient pays
              send patient back to medical record office
              queue patient for case note
              send patient for checkup
              exit
5.          else exit
6.          end if
7.      else if new patient
          generate registration bill
          send patient to cash office
8.        if patient pays
            send patient back to medical record office
            queue for case note
            send patient to oral diagnosis
            send patient to radiography
            generate radiography bill
            send patient to cash office
9.          if patient pays
              queue patient for radiology
              take radiography
              queue patient for radiography result
              issue radiography result
              send patient back to oral diagnosis
10.         else exit
11.         end if
            direct patient to treatment unit
            issue treatment bill
            send patient to cash office
12.         if patient pays
              send patient back to treatment unit
              treat patient
              issue appointment
              give prescription
              send patient to pharmacy
              issue drug price
              send patient to cash office
13.           if patient pays
                go back to pharmacy and get drug
14.           else   exit
15.           else   exit
16.     end if
17. End
```

Figure 9: Pseudocode of the Existing Model

```
1.  Initialise
2.  determine patient status
3.  if patient is on appointment
      generate checkup bill
      send patient to cash office
4.    if patient pays
        proceed to checkup
5.      if patient is fine
          exit
6.      else
          send patient to oral diagnosis
7.      end If
        exit
8.    else exit
9.    end if
10. else
11. if patient is new
      register patient
      send to oral diagnosis
      generate medical bills
12.   if patient pays
        proceed to radiography
        send to treatment unit
        treat patient and give appointment and prescription
        check appointment status
13.     if given appointment
           assign date and time to the patient
           exit
14.     end if
15.     if given prescription
          send patient to pharmacy
          issue drug price
          send patient to cash office
16.       if patient pays
            go back to pharmacy and get drug
17.       else exit
18.       end if
19.     else exit
20.   end if
21. End
```

Figure 10: Pseudocode of the proposed Model

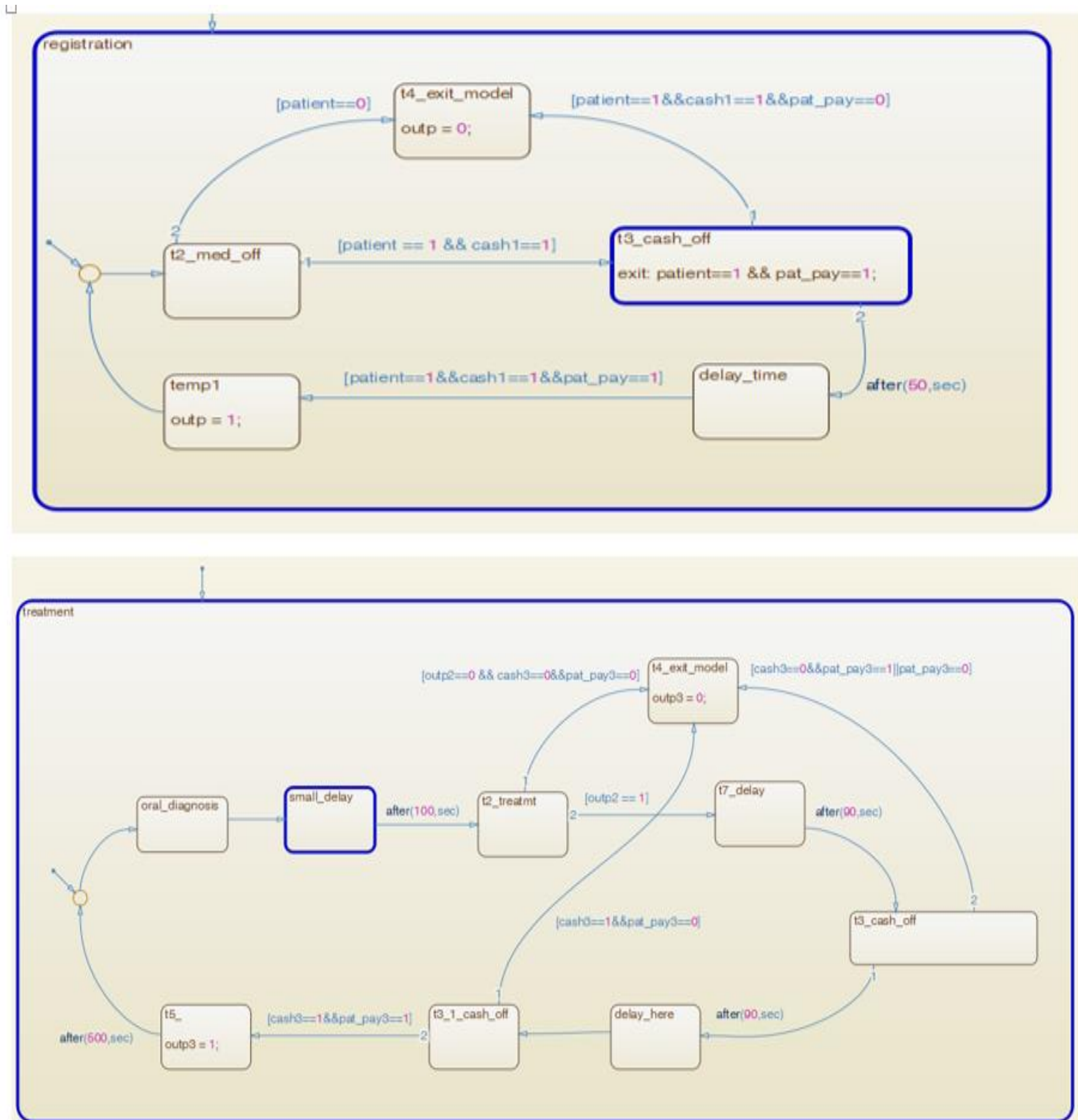

Figure 11: State transition flow of the Registration and treatment process of the existing model

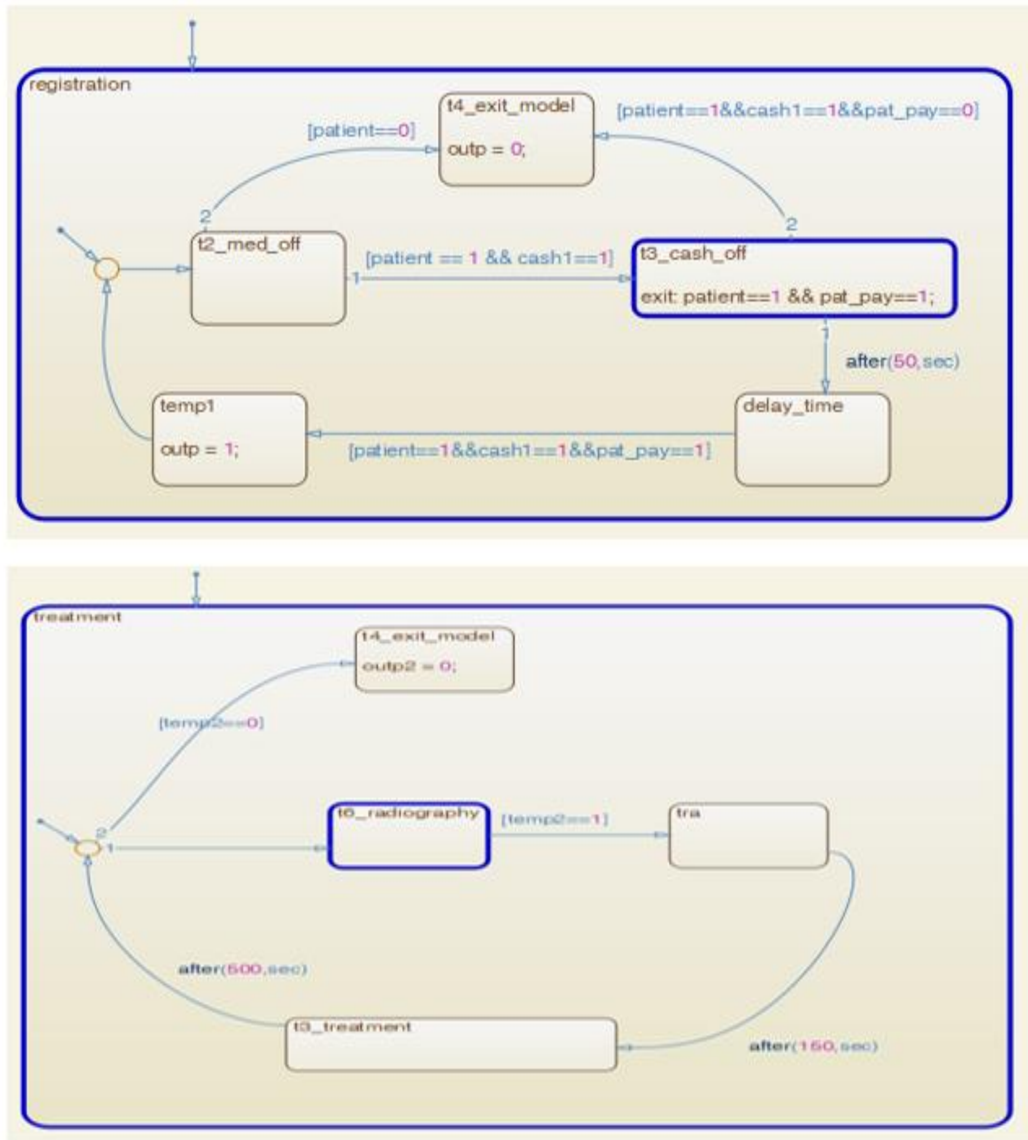

Figure 12: State transition flow of the Registration and treatment process of the proposed model

Thus, the departure time for the existing model is 08:43:07 hh:mm:sec and for the proposed model is 08:20:02 hh:mm:sec. This is presented in Tables 3 and 4 and Figure 13. The results showed that the simulation time for the proposed model is significantly less than that of the existing model. This reduction in time is due to the fact that patients normally go to same cash point to make payment for respective services to be given to them in the hospital which has been eliminated in the proposed workflow process.

The performance of the proposed workflow process was evaluated by benchmarking it with the performance of the existing workflow process using Patient waiting time (Dinesh *et al*., 2013), and Patient throughput (Cole, 2004) as performance metrics. The result presented in Figure 14 showed that the Patient waiting time of the proposed model is significantly reduced as compared to that of the existing model. It was observed that the patient waiting time in the existing model is 1411.9 seconds (23 minutes 54 seconds) more than the proposed model. That is, there is a

36.8% decrease in the total time patient spends in the hospital. Also, it was observed that the total patient throughput for the existing workflow is 0.462 patient/sec and 0.651 patient/sec for the proposed workflow (Table 5 and Figure 15). It is seen from the results that the patient throughput of the proposed model is significantly higher than that of the existing model.

Table 3: Simulation Result of the workflows

Activity/Time	Existing Workflow (sec)	Proposed Workflow (sec)
Registration	50.5	50.5
Oral diagnosis	891.0	240.5
Treatment	1000.9	790.5
Pharmacy	681.7	130.7
TOTAL	2624.1	1212.2

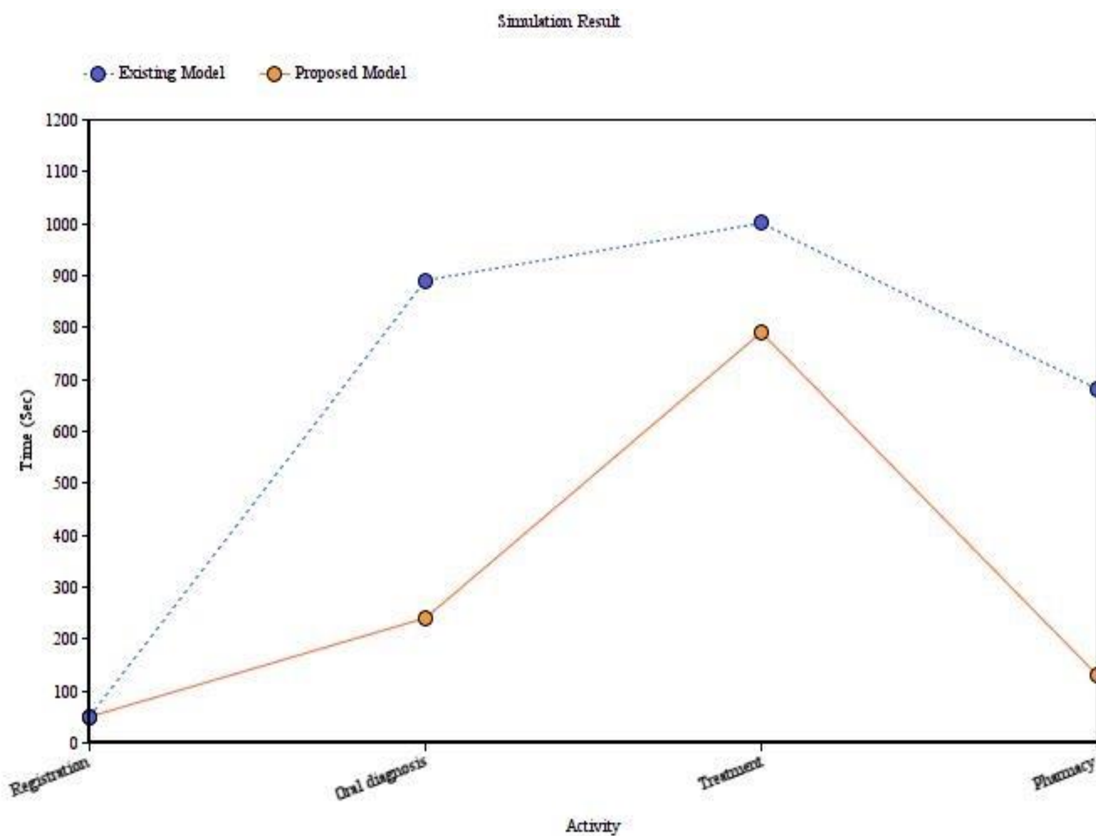

Figure 13: Simulation result of both models

Table 4 Summarization of Total Number of Patients Attended

ACTIVITY		AVERAGE NUMBER OF PATIENTS PER DAY
Registration		23 (N), 17 (O)
Oral Diagnosis		15 – 25
Radiography		20 – 25
1.	Oral and Maxillofacial surgery	15 – 20
	Restorative clinic	
	a. Conservative	15
2.	b. Prosthetics	12 – 3
3.	Endodontics clinic	7 – 8
4.	Pedodontics clinic	7 – 10
5.	Orthodontics clinic	5
6.	Periodontics clinic	6
7.	Oral Medicine clinic	9
8.	Oral Pathology	8 – 10
9.	Community Dentistry	-
Pharmacy		20

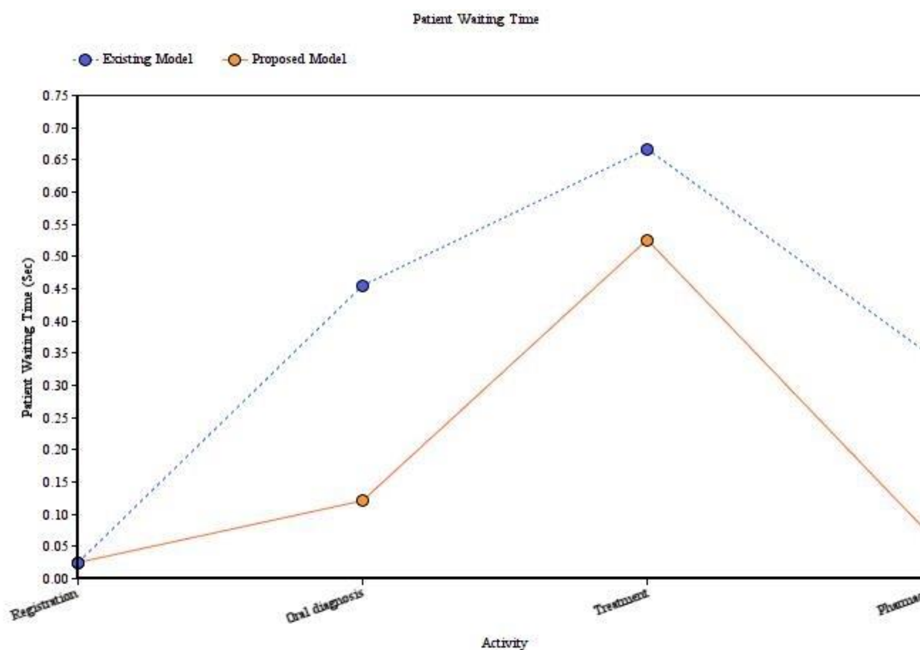

Figure 14: Evaluation result of the Patient Waiting Time of both Models

Table 5: Patient Throughput Summarization

Activity/Patient throughput	Existing Model (patient/sec)	Proposed Model (patient/sec)
Registration	0.396	0.396
Oral diagnosis	0.022	0.083
Treatment	0.015	0.019
Pharmacy	0.029	0.153
Total	0.462	0.651

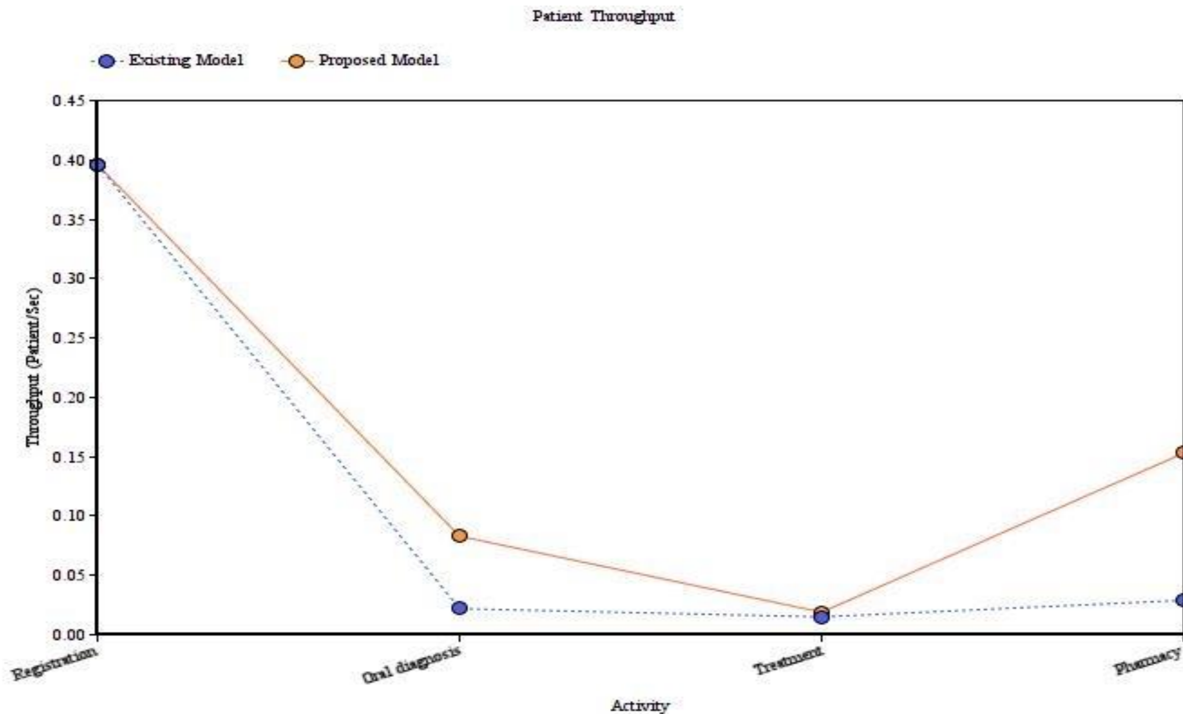

Figure 15: Evaluation result of Patient Throughput of both models

6. Conclusion

Applying Business Process Reengineering to the existing OAUTHDC workflow process solved the identified problem in this study, by reducing the time it takes a patient to get healthcare service delivery with a reduced number of processes that they have to follow without compromising treatment quality. From the results obtained, there is an apparent decrease (1411.9 seconds, 36.8%) in the time spent by the patients in the hospital. The existing model took 2624.1 seconds (i.e., 68.4%) to run while the proposed model took 1212.2 seconds (that is, 31.6%). This implies that the patient gets healthcare delivery services in the dental clinic at a faster and easier way as there is a reduction in the number of processes the patient will go through, and in the patient waiting time. Also, the rate at which the patient moved from one process to another in the hospital during treatment increased because the patient does not have to wait for a service/process before getting attended to. This is due to the fact that there is a reduction in the number of patients waiting to be attended to. Based on these, the hospital will benefit from resource utilization through the efficient use of their resources as more patients will be attended to within speculated time. Therefore, it is recommended that Nigerian hospitals adopt this proposed model to generate more income as they will be operating at a more effective and efficient way.

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