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Modelling Patient Flow Using Advanced Computer Simulation System

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Abstract

Analysis of hospital operations and processes in particular managing patient flows is essential to develop and improve practices, methods, policies and decision tools. Patient flow management and its modelling can help the decision makers to take appropriate decisions related to hospital planning (capacity), scheduling (appointments and operations) and allocations (human resources) to provide the quality healthcare. In last few decades, the concept and modelling of patient flow has gained remarkable attention by healthcare management professionals and researchers. This research paper aims to provide a basic framework of patient flow modelling, key performance indicators. Detailed analysis and simulation of patient flow can contribute to better and efficient functioning of healthcare system. Due to lack of awareness and technical training of open source software it is hardly ever incorporated in regular healthcare operations. Simantics System Dynamics-a free and open source simulation software tool is used in this research paper.

Key Words

Simantics System Dynamics, Patient Flow, Health Care, Open Source Software

INTRODUCTION

A model of flow is a set of different compartments, through which uninterrupted entities move. With special reference to healthcare applications,

patients are the most common entities. According to Coˆte´ (2000), patient flow can be understood in two different viewpoints; i.e. Operational perspective and Clinical perspective.

Operational Perspective	Patient flow (Entry, Movement and Exit) are outlined by clinical and administrative activities. (e.g. consulting a doctor, waiting for surgery)
	The phases represent diffent processes. (e.g. registration, consultation and investigation and treatment (e.g. Radiology, Blood Tests, Urine Test, ect.)
Clinical Perspective	Patient flow (Entry, Movement and Exit) are outlined by phase of the patient's health. (e.g. whether the patient has symptomatic heart disease, or the clinical stage of a patient's tumour)
	The phases represent patient's health status stage. (e.g. a patient admitted in a general ward for rehabilitative care which require them to stay in a hospital for a longer period of time.

Figure I : Perspectives of Patient Flow

In order to prepare a patient flow diagram;related information and factors should be incorporated. It will help to evaluate the influence of various factors on the patient flow. The list of factors are as mentioned in the following figure :

Patient Demographic	Patient Healthcare Requirements	Capacity Constraints	Availability of Staff	Availability of Various Resources
Time	Budget	Population of Patients	Types of Healthcare Services Provided by the Hospital	Physician Profiles / Specializations Available for Treatment

Figure II : Factors Affecting Patient Flow

After taking into consideration these factors, the system's performance may be evaluated in terms of average consulting time and patient waiting times. These outcomes can be helpful to track, observe, assess and improve the quality of healthcare delivery. Typical multispecialty hospital systems are consisting of a

number of sub-units / departments such as Outpatient Department (OPD), Emergency Department (ED), Inpatient Ward (Admission and Treatment), Operation Theatre (OT), Intensive Care Unit (ICU), Critical Care Unit (CCU), Labour Rooms, Neonatal Intensive Care Unit (NICU), Review and Diagnosis Units (such as Surgery, Orthopaedic, Gynaecology, Medicine, Ophthalmology, Paediatrics, Dental, and Physiotherapy, etc.) Each department is responsible for related functions.

PATIENT FLOW NETWORK COMPONENTS AND ITS CHARACTERISTICS

Table 1
Components and Characteristics of Patient Flow Network

Elements of a Patient Flow Network	It includes a structure, consisting of entrance and exit points, nodes (single-server or multi-server), the paths which connect the nodes, entities flowing in the network – the patients, and the human and physical resources. The nodes generally represent the health condition and a location / department a patient is approaching. (Xie, Chaussalet and Millard (2005), Cote and Stein (2007)).
Patient Flow Stages	According to Kortbeek, Hans, Bakker, and Hulshof (2012), patient flowis considered as multistage and multiphase process. (Irrespective of clinical or operational, process of care (OPD, ED, Surgical care or IPD)). Various activities involved in each phase are : arrival, waiting in queue / waiting area, review, diagnosis, treatment/service, and exit. A very simple patient flow may have a very few stages. For example, a patient visiting a hospital for a second follow-up, just have to go through registration process-consult a physician-and exit from the system.
Challenges and Complications of Patient Flows	Patient flows have uncertainties which are arising because of the unpredictable inter-arrival times, unscheduled / scheduled arrival of patients, no-show of the scheduled patients, severity of illness, uncertainty in service times, resource constrains, number of stages, precedence rules, policy (for the patients) for specific departments (e.g. Radiology).

MODELLING PATIENT FLOWS

Aspects, such as the patient flow structure, configuration, patient arrival, service time distributions and transition probabilities need to be considered while developing a broad model of patient flow for a given hospital system.

The Structure of Model

- No. of Nodes / Servers (Single Server Model / Multi - Server Model
- States and probable transitions between the states

Arrival Distribution

- Arrivals of patients (Unscheduled, Without Appointments, Emergency) (OPD and ED)
- Modelled in the literature as non-homogenous Poisson arrivals
- In case of scheduled arrivals - the distribution of aggregate time by which patients arive early or late from their appointments

Transition Probabilities

- Common and Differnt routes for different services
- Analyzing past data on patient routings

Service Time Distribution

- Time taken for Registration, Billing desk, Consultation with the Doctor, Undergoing laboratory tests, Time taken for surgeries
- Service times are commonly assumeed to follow exponential distribution (for both OPD and IPD Services)

Figure III : Modelling Patient Flows

A typical patient flow in a hospital can be described as below:

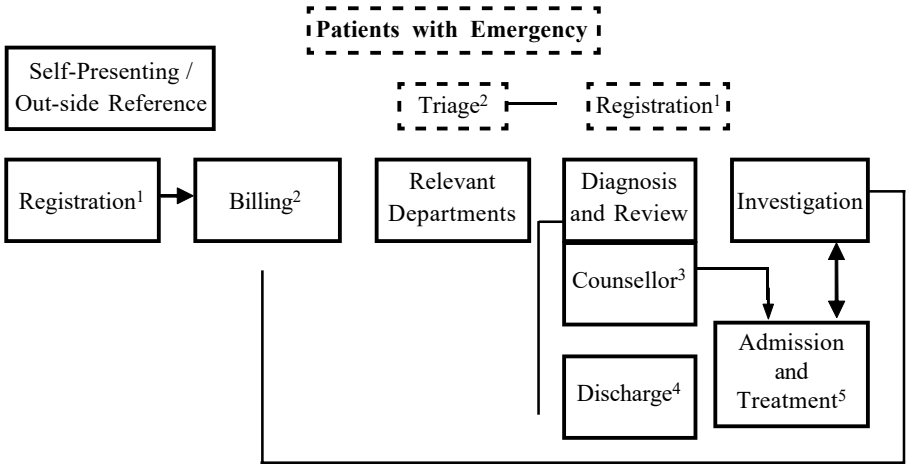

Figure IV : General Patient Flow in the Hospital

1. Registration (Types of cases) : New Cases | Old Cases | Privilege Cases, Basic Information of Patient through Form and Identification of Relevant Department(s) through Case History / Profile, Patient's Registration by Relative or Attendant (for old case, the information can be made available through Health Management Information System (HMIS))
2. Triage : Primary Assessment by Chief Medical Officer
3. Counsellor : Counselling about the Disease / Duration of Stay / Types of Rooms Available / Charges
4. Discharge : Home / Referral to Higher Centre / Govt. Hospital
5. Admission : General Ward | ICU | CCU | NICU | Special Rooms | Labor Room

SIMULATION MODELLING

Various techniques, based on computer simulation software, have been categorisedto address the various healthcare issues. (Fone *et al.* (2003), Eldabi *et al.* (2007); Gunal & Pidd, 2010; Jun *et al.*, 1999; Katsaliaki & Mustafee, 2011). The categorisation is are mentioned below :

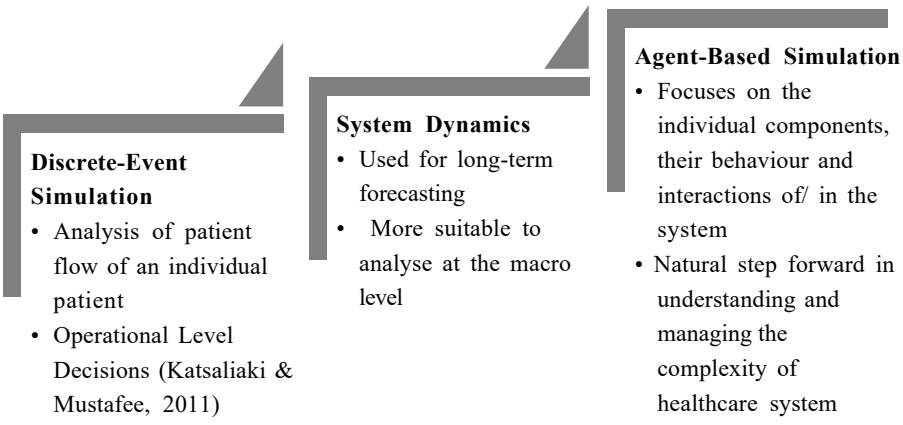

Figure V : Types of Simulation Modelling Techniques

KEY PERFORMANCE INDICATORS

In the past decade, the healthcare industry in the world is undergoing a major policy and radical changes. These reforms have stimulated healthcare organisations to review their healthcare metrics which are considered as Key Performance Indicators (KPIs) which decide if the organization is meeting

thestandards.In order to improve the patient flow, one can do various analyses. It can be done by identifying and calculating the key performance indicators of each sub – units / departments. The list of key performance indicators (sub – unit wise) are mentioned below :

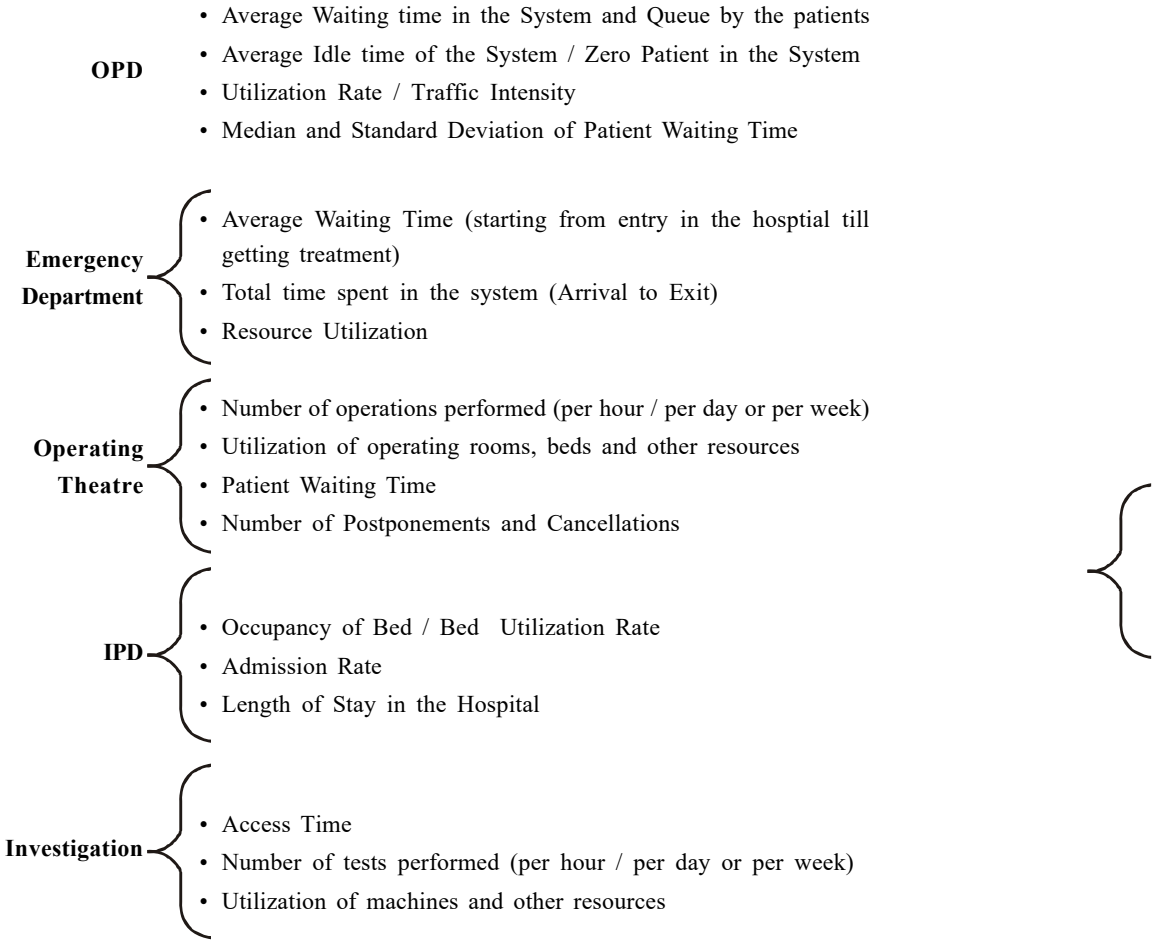

Figure VI : Key Performance Indicators of the Patient Flow

A GENERIC MODEL OF PATIENT FLOW IN A HOSPITAL (SELF-PRESENTING PATIENTS)

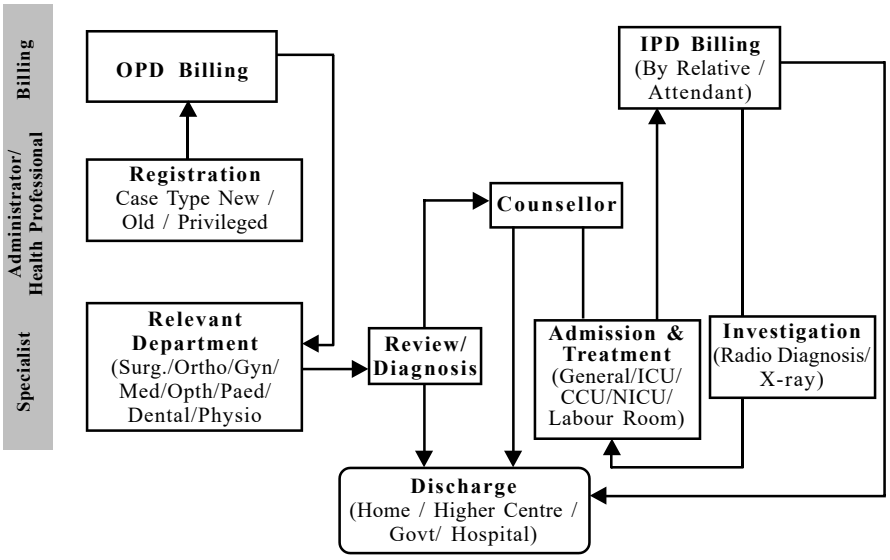

Figure VII : Generic Patient Flow in the Hospital (Self-Presenting Patients)

The same model can be developed in the open sourced / licenced software such as Simantics System Dynamics1, Jaam Sim[2], Simul8[3]. The patient flow model prepared in Simantics is as mentioned below :

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[1] Simantics System Dynamics is an open source system dynamics modelling and simulation software (large hierarchical models with multidimensional variables)to understand various organizations, systems (which are complex in nature) and markets and their behaviour. The models are created includingcausal loop diagrams and stock & flow diagrams. The results generated through Simulation can be analysedusing various visual tools. More details of the software can be accessed through : *http://sysdyn.simantics.org*

[2] Jaam Sim is an open source simulation software. The models are created including drag-and-drop user interface, interactive 3D graphics, I / O processing, and model development tools and editors. More details of the software can be accessed through : *https://jaamsim.com*

[3] SIMUL8 is a commercial software. It provides a visual, animated and interactive approach to represent the system. It enables the researcher to demonstrate various scenarios and generate the impact of changes. More details about the software can be accessed through : https://www.simul8.com

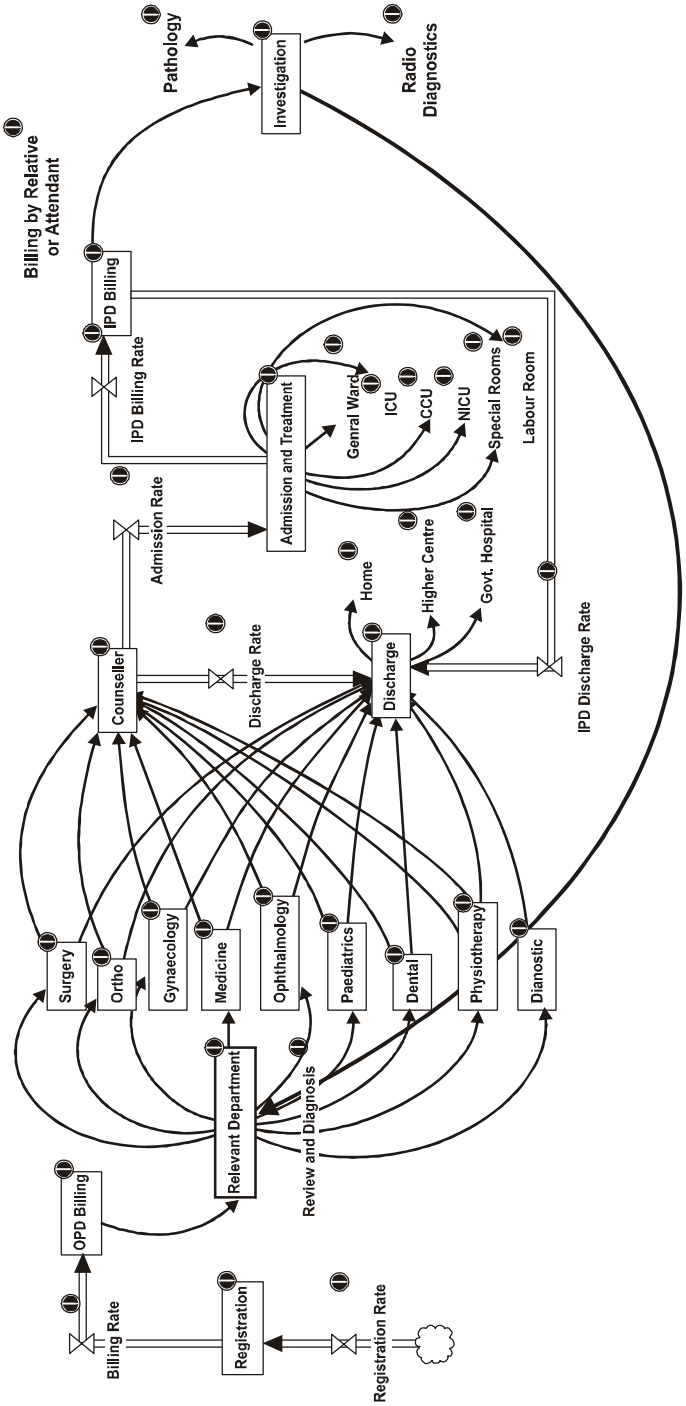

Figure VIII : Generic Patient Flow Diagram in the Hospital-Generated in Simantics System Dynamics(Self-Presenting Patients)

A GENERIC MODEL OF PATIENT FLOW IN A HOSPITAL (EMERGENCY DEPARTMENT)

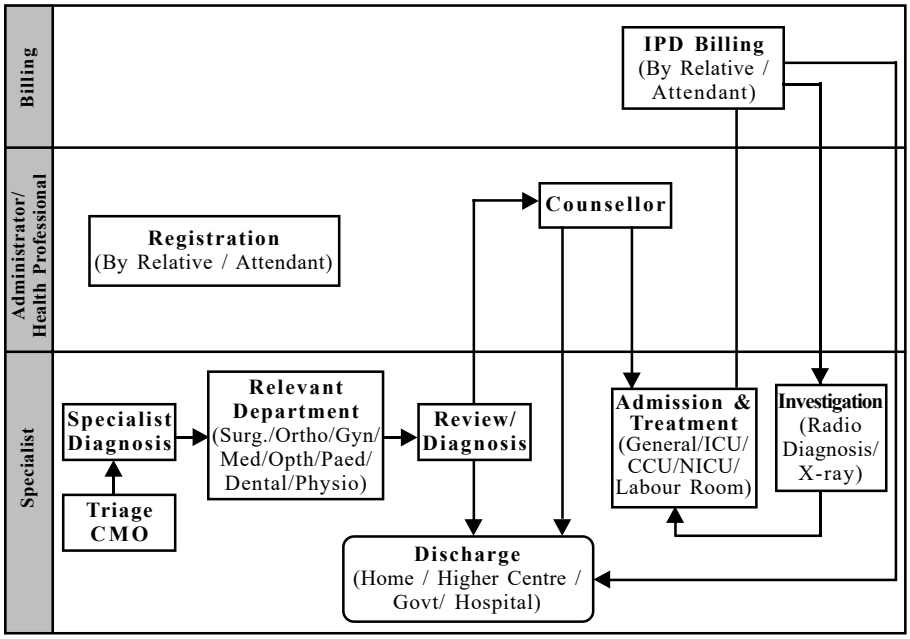

Figure IX : Generic Patient Flow in the Hospital (Emergency Department)

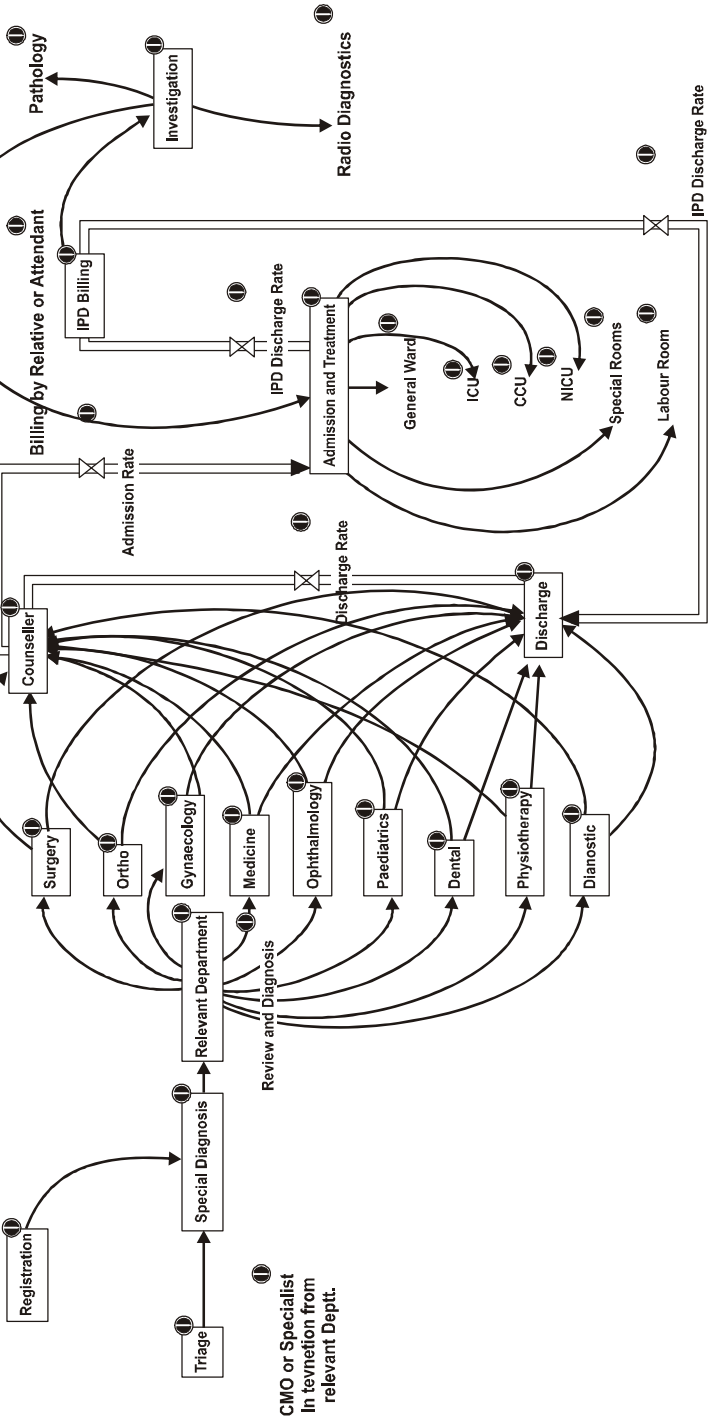

Figure X : Generic Patient Flow Diagram in the Hospital-Generated in Simantics System Dynamics(Emergency Department)

CONCLUDING REMARKS

As the hospitals are offering varieties of healthcare services, there are several possible combinations of care pathways to be created. The overall performance of the hospital depends on the performance by all the departments/ sub-units (having various issues). Moreover, because of limited resource availability, there are possibilities of forming queues at each stage of the services. Queuing networks can represent the patient flow. Decision makers of the hospital can analyse the performance of these queuing networks so as to improve the overall efficiency of the system. This can be done using Markov chain analysis or using various computer based simulation software. These analyses and effective planning of capacity, resource allocation and appointment scheduling may help to reduce the waiting time, ideal times of servers, congestions, avoiding/ eliminating unnecessary or redundant activities, performing parallel activities and improve the overall efficiency of the hospital. The challenge for a research is to define and take into consideration the complex and unsystematic nature of healthcare components in a patient flow.

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