A STUDY OF APPLICABILITY OF WAITING LINE MODEL IN HEALTH CARE: A SYSTEMATIC REVIEW

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ABSTRACT
Healthcare is one of the most important services. Increasing population exert tremendous pressure on the healthcare system leading to chaos. In recent times many studies have been conducted to analyze the applicability of waiting line model in proper management of patients flow in a health care facility.

In the present research paper, 72 studies have been reviewed, on the theme of OR waiting line & Simulation model as well as their applicability in healthcare system. Towards the end, a synthesis of reviewed work has also been attempted.

Key Words: - Operation Research, Waiting Line Model, Simulation, Healthcare sector, Systematic Review.

INTRODUCTION
Due to population explosion demand for healthcare services has increased manifold. The Government hospitals have been facing problem of limited capacity. The private sector participation in healthcare system has assumed importance. These private sector hospitals are professionally managed on corporate line. It has been observed that major problems in managing the healthcare system are overcrowding & congestion in the system. If these problems are not managed properly it may result in large scale havoc & may even result in loss of human life.

The present research paper is focused on applicability of waiting line model in managing smooth flow of patients in the healthcare system. The waiting line model is a prominent model of operation research.

Its real life application entails use of simultaneous model. Hence in the present communication a systematic review of 72 papers have been done in the areas of operations research in general, operation research in healthcare, waiting line model in
general, waiting line model in healthcare, simulation in general, simulation in healthcare, waiting line & simulation model in healthcare.

Following table (1) gives an overview of referred and reviewed papers. As is clear from the table that more international papers have been referred and reviewed which leads us to the conclusion that these areas have been researched more internationally. In the Indian context these areas are still in its infancy stage.

### Table: 1 Overview of Reviewed papers

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**REVIEW OF OPERATION RESEARCH**

According to Attra, Wise Aime, Black & Aime (1961) "operations research" has led to a number of useful engineering analyses for optimizing field operational problems. One of these techniques, termed linear programming, is particularly interesting because of its potential applications to the study of complex oilfield operating problems. Linear programming is concerned with the problem of planning a complex set of interdependent activities in the best possible (optimal) fashion.

Duckworth & Lewis (1998) described it as a method for setting revised target scores for the team batting second when a limited-over’s cricket match has been forcibly shortened after it has commenced. It was designed so that neither team benefits or
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suffers from the shortening of the game and so it totally fair to both. They also demonstrated that “it is easy to apply, requiring nothing more than a single table of numbers and a pocket calculator, and is capable of dealing with any number of interruptions at any stage of either or both innings”.

As Analyzed by Board, Sutcliffe & Ziemba (1999) OR techniques play an important role in financial markets and, with the recent dramatic improvements in the real time availability of data and in computer speed, this role will increase. This will create the opportunity for OR techniques to play an even greater role in financial markets. They also contribute that Arbitrage and multi-period portfolio problems have been formulated as network models, while market efficiency has been tested using neural networks.

According to Rush (2000) Operation Research also known as systems analysis, quantitative analysis, and management science, is a scientific approach to decision-making he also explained Operations research is a relatively young discipline that can provide decision tools for multimillion dollar decisions.

As Studied conducted by Hetzer (2002) Research algorithms for Quality of Service and resource optimization using QORE common measurement and modeling data base for application Quality of Service (QoS) and traffic flows. Scenarios for capacity planning and resource allocation with different optimization constraints and criteria based on QORE. The QORE concept using operations research algorithms for the optimization of resource assignments of access channels (access, border and edge routers) under several constraints is proposed.

According to Royston (2011) Operational research methods are useful for the systematic identification of problems and the used for potential solutions. Whereas Mehandirattra, (2011) highlights that Operation research is a discipline of applying appropriate analytical methods for decision making.

REVIEW OF OPERATION RESEARCH IN HEALTHCARE

In the opinion of Hoot & Aronsky (2008) Emergency department (ED) crowding represents an international crisis that may affect the quality and access of health care. They conducted a comprehensive Pub Med search to identify that

- Studied causes, effects, or solutions of ED crowding;
- Described data collection and analysis methodology;
- Occurred in a general ED setting; and
- Focused on everyday crowding.

The study conducted by Paul, Jomon, Aliyas (2008) described that a hospital’s ability to function depends not only on the number of available staff, but also on the availability of intact medical equipments including laboratory, operating rooms, supplies of power, water, medical gases (e.g., oxygen), and the intactness of the building. Knowledge of the impact of facility damages on hospital operations is of major importance for the following reasons:
Hospital facilities must maintain their normal functions and attend to the sudden surge in demand for medical treatment.

• In contrast to other types of buildings, hospitals accommodate a large number of patients, who, due to their disabilities, are unable to evacuate a building in the event of a disaster caused by natural hazards, such as an earthquake;
• Hospitals have a complex network of electrical, mechanical, and sanitary facilities, as well as expensive equipment, all of which are essential for the routine operation of the hospital and for emergency care; and
• The ratio of the cost of non-structural elements to the total cost of the building is much higher in hospitals than in other buildings.

Yurtkuran, & Emel (2008) described it as the best option that minimizes the turnaround times of the orders while evaluating different scenarios. Since the resources are restricted by the pharmacy budget, only changing the staff number between shifts are considered. International heath care standards require a central pharmacy unit in hospitals that maintains and provides the inpatient pharmacy needs (Joint Commission International, 2000). The hospital pharmacy unit has located in the base floor of the hospital and has three main tasks to be fulfilled;

• Checking the orders,
• Preparation of drugs according to orders,
• Distribution of the prepared medications to the clinics.

According to Foster, Hosking & Ziya (2010) the tools for healthcare analysis have been developed over decades by researchers in Operations Research (OR). An OR perspective typically frames a complex problem in terms of its essential mathematical structure. They employ queuing models as an illustration.

Achieving major improvements in global health will require some fundamental changes, including advances in research and analysis of organization and delivery of health care. Operational research and management science approaches can inform a range of important design and delivery issues, but need to pay more attention to success factors and to draw on a broader range of analytical methods, with more interchange with wider operational research work. With greater capability in this field, operational research and management science can play a significant role in global health. (Royston, 2011).

Mehandiratta (2011) highlights that Operation research embodies wide range of techniques that can improve the way we plan and organize health services. Operation Research focuses on the application of analytical methods to facilitate better decision-making.
REVIEW OF WAITING LINE MODEL

Queuing theory was developed to study the queuing phenomena in commerce, telephone traffic, transportation, business-industrial servicing systems, variable reservoirs etc. (Cooper, 1981; Gross and Harris, 1985).

As analyzed by Fink & Gillett (2006) the cost of a dissatisfied customer is not negligible, they described Waiting in line is a primary source of dissatisfaction. They mentioned that a well known queuing theories and integrating theory behind the Taguchi Loss Function, a manager can derive the costs associated with this dissatisfaction & that customer dissatisfaction is not just an issue at the upper specification limit, but rather for each moment in time beyond the targeted wait time. They illustrated by using the Taguchi Function, it can then be seen that these costs increase beyond the upper specification limit. However, by assessing these costs and then taking measures to reduce either the actual or perceived waiting times, organizations can quantitatively determine the cost-benefit relationship of improved waiting lines.

Chin (2007), investigated the submittal review/approval process and used queuing theory to determine the major causes of long lead times. Under his study, he explored the underlying causes of waiting in a process flow and found the improvement methods from the queuing perspective.

REVIEW OF WAITING LINE MODEL IN HEALTHCARE

Yeung et al (2002), conducted research on large hospitals with the help of Laplace transform of the probability density function of customer response time in networks of queues with class-based priorities. He obtained the mean & standard deviation of total patient service time for large hospitals mainly for accident and emergency department. The widespread problem of extended waiting times for health services was examined by Georgievskiy (2002) in the context of the Emergency Department (ED) at a regional hospital.

A study of Georgievskiy et al (2002) examined OR to reduce the waiting time in the hospital-admitting department. They conducted their study in five faces, from the collection of data to actual improvement in the quality of the health care delivery system.

According to Koizumi (2002) the current trend toward downsizing and closing of state mental health institutions has led to an over-utilization of many local mental health facilities. This problem has often been intensifying by a shortage of long-stay psychiatric hospitals and community-type accommodations. He specifically examines blocking in interrelated mental health facilities, including (a) acute hospitals (where patients wait to enter extended acute hospitals), (b) extended acute hospitals (where patients wait to enter residential facilities), and (c) residential facilities (where patients wait to enter supported housing). System has experienced severe congestion problems since 1992.
Singh (2006) found that the queuing theory in health care organizations is very beneficial. He used Queuing model to achieve a balance or trade-off between capacity and services delays & used the POM-QM Software for to demonstrate it.

Fomundam et al. (2007) described the contributions and applications of queuing theory in the field of health care. They summarized a range of queuing theory results in areas of waiting time and utilization analysis, system design and appointment system.

An empirical study conducted by Creemers et al. (2007) found that the capacity and variability analysis in a health care environment results in queuing models that are different from queuing model in industrial setting. He also showed the relationship between the capacity utilization, waiting time and patient (customer) service.

According to Biggs (2008) Elective surgery waiting lists are used to manage access to public hospital elective surgery services and give priority to those in most urgent need of care. They have become an integral feature of our health system, and allow limited health resources to be allocated or ‘rationed’ on the basis of need. Waiting lists also provide health consumers with an indication of how long they can expect to wait for their surgery.

According to Kolkar (2008) the discrete event simulation model is more flexible; give more information than queuing analytic theory. Also demonstrates why in most cases DES is superior and preferred to QA.

Queuing theory is very volatile situation which cause unnecessary delay and reduce the service effectiveness of establishments. Apart from the time wasted, it is also leads breakdown of law and order. Many lives and property had been lost in queues at filling stations in past. (Adeleke, Ogunwala, Halid 2009).

Schoenmeyr et al. (2009) analyzed that healthcare organizations function with very small net margins, so decisions about committing resources must be made with a high degree of confidence that the investment will lead to the desired result. The queuing approach is useful because it enables the investigation of future scenarios for which historical data are not directly applicable.

Waiting times assist in measuring the rate of turnover on hospital waiting lists and are considered a more reliable indicator of hospital performance than the size of the waiting list. In some cases the patient may be removed from a waiting list. Reasons may include that they no longer require the procedure, are instead admitted as an emergency patient, receive their treatment at a different hospital or are transferred to the waiting list of a different hospital, are untraceable or die.

Foster, Hosking & Ziya (2010) observed that Queuing models are useful in that they provide solutions to problems of waiting that are particularly relevant in health care. More generally, they illustrate the strengths of modeling in health care research and service delivery.

Obamiro (2010) studied the waiting line for expectant women in Antenatal care unit. The results of the study evaluated the effectiveness of a queuing model in identifying
the ante-natal queuing system efficiency parameters. He used Tora Optimization system to analyze data collected from ante-natal care unit of a public teaching hospital in Nigeria over a three-week period. The study showed that pregnant mothers spent less time in the queue and system in the first week than during the other succeeding two weeks.

Agrawal & Saxena (2010) analyzed the use of queuing theory in healthcare centre of IIT-K and the benefits accrued from the same and they conceptualize an appointment system in which customers who are about to enter service may have a probability of not being served and may rejoin the queue. In their investigation, they found that the capacity utilization is 76%, average number of people waiting in queue is 2.57 calculated by the Poisson distribution method.

As Examined by Mehandiratta (2011) with rapid change and alignment of health care system, new lines of services and facilities to render the same, server financial pressure on the health care organizations and extensive use of expanded managerial skills in healthcare setting, use of queuing models has become quite prevalent in it. Queuing models are used to achieve a balance or tradeoff between capacity and service delays.

**REVIEW OF SIMULATION**

In the opinion of enneyan (1997) healthcare continuous to become more competitive, the ability to assess tradeoff between resources utilization, services, & operating costs grows in importance, such as with respect to appointment access, waiting delays & telephone services. More recently simulation has been used to study and improve the quality of clinical laboratories, such as the diagnostic accuracy Pap smear, mammogram, HIV, Hepatitis result.

As studied by Szymanski (2003) the simulation provided quantifiable performance data which were used to input executive decision making. He focused on the simulation project approach which included five major phases:

- Develop conceptual model, 
- Programming, 
- Testing (Verification and Validation), 
- Experimentation, 
- Presentation.

Simulation to aid project leaders in advancing to the next level of sophistication with Six Sigma. Six Sigma Teams were created to review and analyze discrete sub-processes of the overall patient experience.

As it is analyzed by Hartvigsen (2004) SimQuick runs considerably more quickly as compared to others. This allows more simulations to be performed in a reasonable amount of time, which leads to more accurate results. As a result, more simulations are allowed. With process simulation, it can begin by building a computer model of a real-world process. The initial goal is to have the computer model behave in a way similar to the real process, except much more quickly & various ideas for efficiency.
improvements on the computer model and use the best ideas on the real process. With the help of this, thus, a lot of time and money can be saved.

Merkuryeva (2005) observed that Simulation model are abstraction of a reality, which simplify or eliminate some features in order to gain insight into the interconnections and behavior of other aspects of system. By the analysis of the output data received from simulation experiments and solving optimization problem, Metamodeling approach provides tools for manipulation with simulation model and their analysis through a systematic application of metaconcepts such as metamodel, metaclass, metaknowledge, metarule, metaheuristics etc.

REVIEW OF SIMULATION IN HEALTHCARE

Barnes (1997) et al, found the application of simulation appropriate with well-defined steps and boundaries. A computer simulation model of an outpatient clinic could be built within the specified time frame given for each study. Once the computer model was set up in “Microsaint” simulation runs were executed to track patients moving through the network, emulating patients going through the steps of an actual clinic visit.

According to Denney (1997) activity based costing functions have been carefully designed to solve unique hospital and healthcare specific simulation problems. The easy to use menus permit the accumulation of activity data for locations, resources, and entities. The tool, assumptions and short-cuts that have routinely characterized healthcare and hospital simulations, are no longer necessary. Rather, it is now possible to model complex healthcare systems accurately and with confidence in the results.

As it is studied by Exter & Hopwood (1999) the Computer simulations is useful to maximize OR utilization, control of the surgical date must be moved from the surgeon and patient to the OR suite also Developed an OR scheduling strategy to maximize OR utilization. Block time is allocated based on expected total hours of elective cases.

Sanchez (2000) et al, found simulation an outstanding tool for Health Care. It is an objective way to describe an operational area to compliment other methods. Additionally, its true power lies in the ability to explore “what if” scenarios and make decisions accordingly.

One tool simulation now widely accepted as an effective method to assist management in evaluating different operational alternatives. It can help improve existing emergency department and assist in planning and designing new emergency department. In order to increase acceptance of simulation in healthcare system in general and emergency department in particular. Hospital management should be directly involved in the development of these projects. Such involvement also bolsters the simulation credibility. The foundation of the development of a simulation tool which is general, flexible, intuitive, simple to use and constraints default values for most of the system parameters (Sinreich and Marmor, 2004).
Gunal & Pidd (2005) found the significant use of (DES) Discrete event simulation model in the healthcare systems for different objectives such as performance improvement, resource planning and facility design. They describe the DES as the policy-oriented model.

In a study conducted by Sinrich & Marmor (2005) Hospitals have been vigorously searching for ways to reduce costs and improve productivity. Tool, simulation, is now widely accepted as an effective method to assist management in evaluating different operational alternatives. It can help improve existing Emergency Departments (EDs) and assist in planning and designing new EDs. In order to increase the acceptance of simulation in healthcare systems in general and EDs in particular, hospital management should be directly involved in the development of these projects.

In a study conducted by Niu, Peng, Mekkawy & Tan (2007) Simulation has been a very useful tool for healthcare systems. A discrete event simulation tool is used for modeling the operating rooms operation. It is an efficient tool for identifying problems and improving performance of healthcare systems. The simulation model is valuable to present the current workflow and to predict the bottleneck in healthcare systems. It also provides a reasonable assessment of operating rooms efficiency, resource utilizations and other performance measures. By using the simulation, a useful evaluation for the operating rooms provides a chance to analyze and improve the current operation processing. The output of the simulation shows the analysis result with a verity of formation. The graphical user interface provides an effective tool for decision-making of the OR operation.

According to Brailsford (2007) two main simulation approaches used for healthcare types of model are namely Discrete Event Simulation (DES) and System Dynamics (SD). In DES, entities have characteristics which determine their pathway through the network, in exactly the same way as patients have individual characteristics which determine their pathway through the hospital system & DS model designed to explore the relationships between waiting times in the emergency room and hospital bed closures.

Kumar & Shim (2007) examined the simulation, once verified was used to compare the utilizations of the doctors and the consultation rooms with the time patients spend waiting in the queue. The queuing theory served as a good gauge to compare the simulation results to confirm the validity of the model.

As studied by Erik et al (2009) a number of resource allocation strategies in the youth health care sector were used including an extensive set of constraints and behaviors from the real world system. The model successfully simulated many of the complex relations between the involved parties in the system. They demonstrated the ability of the model to incorporate different allocation strategies while maintaining an overall structure which deals with the common tasks outside the allocation procedure. The postponement of the actual allocation in strategy ensures a higher level of fairness in treatment provision by the care providers because they cannot avoid the difficult cases anymore. Simulation approach incorporates additional complexities of the case at hand which turn out to be relevant for the queuing strategy decision.
Observations of Barjis (2011) attempted to emphasize the potential of healthcare simulation both as a tool for intervention and a method for an in-depth study of clinical processes, healthcare delivery, patient flow, scheduling and forecasting of capacity, and strategic planning. He summarized the major aspects of healthcare in which simulation yields benefits.

**REVIEW OF WAITING LINE MODEL & SIMULATION IN HEALTHCARE**

Queuing theory with Monte Carlo simulation shows that the adverse effects are accumulated to the maximum amount in terms of 4 bottles of beer in the body waiting for removal, in means ± SEM (1.52 ± 1.03 bottles, Fig. 2B) & the maximum length of time waiting is 28.45 h (7.87 ± 7.24 h/bottle). (WU, 1998)

Saxena et al. (2002) developed a flexible simulation model for healthcare to determine the best configuration of the healthcare as flexible system. They present a simulation model of the healthcare service system (HSS) as flexible system. Due to the large amount of variability that can take place within an HSS, The system sought the use of simulation to help evaluate their operations and possible solutions to their problems. The objective of the model is to develop various healthcare scenarios as flexible system and create a model which depicts the current operations and evaluate possible alternatives to reduce the overall patient make span with flexibility and efficiency. The results give useful insight and new directions for healthcare system improvement. Their research efforts are continuing to enrich this domain.

According to Koizumitthe, Naoru (2002) the blocking phenomena between three types of mental facilities are namely extended acute hospitals, residential facilities and supported housing. A queuing network model of the Philadelphia system was constructed and analyzed both in terms of mathematical steady-states and numerical simulations. The simulation and the mathematical analyses provided almost identical results with the exception of that obtained for extended acute hospitals (EACs). The analysis showed that both residential facilities and supported housing experience serious congestion in steady state. The simulation results for EACs indicated autocorrelation. Most important finding from the mathematical analysis was that, in contrast to popular perception, system congestion is not always a simple cumulative effect of shortages across all facility types.

In the opinion of the Lie & Bernt (2008) some possible solutions for improving the patient in flow and predicting the number of the patient in different departments with the help of Queuing theory and Markov Chain and he introduced (DES) Discrete event Simulation.

The model for the Obstetrics and Gynecology Department was developed by Najmuddin & Ibrahim (2010) based on the results of multiphase patient flow simulation with a view to reduce the waiting time of the patients.
OTHERS

Joel Zhang Laifu (2000) has evaluated the performance of single-channel and multiple-channels queues using the discrete-event simulation technique. The input to the simulators is based on live data. A customer can hop to a shorter queue but the service time needed by the customers in the queue may be longer thus resulting in an even longer waiting time.

In his study, Ahmed (2003) found that The Accident & Emergency Department is the dedicated area in a hospital that is organized and administered to provide a high standard of emergency care to those in community who perceived the need for or in need of acute or urgent care including hospitals admission.

Yeung et al. (2006) examined that the prioritization of treatment for patient with minor illness treatment or trauma over major patients with several illness can lead to the counter –intuitive outcome that mean response times for ambulance arrivals are not adversely affected.

As examined by Kumar & Shim (2008) the (BPR) Business Process Reengineering is essential to improve the efficiency in Emergency Department.

SYNTHESIS

After the thorough review of available literature, it is abundantly clear that waiting line model has come to be used in healthcare system. Originally developed for analyzing the telephone traffic density, waiting line model has now found tremendous applications in almost all the service areas such as ATM, Banks, Petrol pumps queues, retail shops etc.

Many studies have come to the notice of researchers which focus upon use of waiting line model in developed countries. There are good numbers of applicability of OR in healthcare. Various model of OR which are found to be useful in healthcare system are as follows Health Care Operations Improvement: Scheduling and workforce planning, Inventory management, Supply chain management, Logistics planning and modeling, Equipment planning, Planning, Facility location and layout, Workforce & workload models, Decision support systems, Performance measurement & modeling, Queuing models, Quality management. Economic Analysis: Equipment evaluation & selection models, Optimal pricing and costing models, Demand forecasting and planning models, Impact of policies on health care demand, Technology assessment. Public Policy: Regional planning and network models, Access and availability population models, Technology diffusion models, Disease prevention, Health care coverage, Vaccine modeling, Organ allocation models, Disease screening, Resource allocation, Drug policies, Blood supply management policies. Clinical Applications: Risk assessment and analysis, Clinical diagnosis and decision making, Decision support systems, Disease modeling (individual level), Treatment design and planning, Drug selection models, Optimal dosing models, Vaccine models, and Clinical quality.
Many studies related to the applicability in general as well as in healthcare system have been reviewed. This systematic review reveals that this model is extremely useful in various aspects of functioning of healthcare system.

Certain countries have conducted specific studies on healthcare system. A comprehensive analysis of the available literature reveals that very few studies have been conducted on this theme in present scenario. The proposed work is an attempt to fill this gap.

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WEB LINKS


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