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Logistics performances of health care system using queue analysis: the case of St. Paul's hospital, Ethiopia

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Abstract

As there is a very high demand for health service that exceeds the available capacity, the public healthcare centers are overwhelmed with the long queues or they are delivering the service with relatively very low consultation time. In the existing conditions, patients go as early as they can to the healthcare facilities, waiting in queue, even before the opening and had to wait long time for examination, consultation and diagnosis. However, due to high number of patients at the outpatient departments relative to the number of physicians, it results in an increased workload on the physicians and it shortens the patient consultation time, which has an impact on the patients' health. The main objective of this research was to study the logistic performances of the healthcare system using queuing analysis. This research used three key performance indicators namely, patient queue length, patient waiting time and consultation time length. The performance evaluation was conducted based on data from patients who visited 69 clinical, surgical and diagnosis departments at the outpatient clinics of the hospital. Queue analysis was performed to determine the operational characteristics using a queue scenario with Poisson arrival, exponential service, infinite population, First Comes First Served (FCFS) discipline and multiple server arrangement. The study showed that the patients' arrival rate highly exceeded the service rate, in each respective clinical department. The outpatient clinics at the SPHMMC achieved an average total waiting time of 92 minutes to get consultation and nearly 70% of the patients waited for more than 95 minutes. The consultation time was as low as 5.71 minute at the Medical clinic and 6.16 minute at the Ophthalmology clinic and around 60% of the patients saw the doctor for a time less than 10 minutes. Therefore, this research recommends addressing the gaps in human resources and logistical supplies, to implement and enforce a staggered patient scheduling and appointment system and to have serious intervention and control on the dual practice, to ensure a smooth clinic process and to reduce waiting times.

Keywords: Consultation Time, Healthcare Logistics, Outpatient, Queuing Theory, Waiting Time

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Abbreviations

Is this list exhaustive? Where is the abbreviation of the hospital you used in text?

CT-Scan	Computerized Tomography Scan
EKG	Electrocardiogram
ENT	Ear, Nose, Throat diseases and disorders
OPD	Outpatient Department
OR	Operating Room
WHO	World Health Organization
SLU	Swedish University of Agricultural Sciences

1. Introduction

1.1. Background

According to the definition by WHO, health refers to the overall state of a complete social, emotional, mental and physical well-being that considered as a resource for living a full life, and therefore, the access for the highest achievable level of health is the basic rights of every human being without the distinction of social or economic conditions (WHO, 1948). Health is not as simple as the absence of disease; however, it is the ability to get well from ailment and/or other problems.

Healthcare in the other hand, an act delivered by the health professionals, is the maintenance of health through prevention, diagnosis and treatment from mental and physical impairments. Healthcare system exists to assure and help people, to maintain their optimal state. The improvement of health industry in a country is one of the indicators for the economic development and prosperity, as it is directly associated with the value of human resource.

mmm

Hospital logistics is one of important infrastructures that facilitates health care services. hospital logistics differentiate between three core flows: patient, material and information flows. The patient flow involves the movement of patients to get access for medical care and related resources, in the healthcare. The material flow includes the supply of medical, pharmaceutical and surgical consumables, medical equipment and devices necessary to support the medical personnel and unquestionably patients at the hospitals.

A time spent at the hospitals are often the unkind experiences for patients and are the causes for frustration. This could arise, along with other many, from long waiting times for both scheduled as well as non-scheduled appointments; and delay in diagnosis and treatments. Waiting time, in this research, is the time spent by the patient in waiting before he gets the desired consultation by the physician. The best service is the one that provides quick deliveries without a need to wait for a long, which will incur additional costs to the hospital as it requires addition of service facilities and technologies (Dachyar, Farizal, & Yafi, 2018).

These long waiting times for services or/and short consultation hours in healthcare systems can worsen the severity of disease and increase the socio-economic costs and may result unnecessary suffering, strained relationship between the physician and the patient which leads to patient dissatisfaction (Aeenparast, Farzadi, & Maftoon, 2012; Bruni, Laupacis, Levinson, & Martin, 2010).

In countries, like Ethiopia, the number of trained physicians is much less than what the system demands. Thus, the physicians are subjected to overloading, attending to outpatients in multiple centers and being required to show up at the in-patients in multiple hospitals. These results, the consultation hours to be limited for only a short period of time, usually either of forenoons or afternoons. Moreover, even in top of this short period of service, regrettably, the service often becomes inactive due to late arrival of physicians and other interruptions (Babes & Sarma, 1991).

Therefore, this research analysed the existing average consultation time at the outpatient department (OPD) and the extended waiting time that patients spent at the outpatient clinic, relative to the industry average consultation time as a basis for performance measurement. An outpatient clinic is a department at the healthcare devoted to diagnoses and consults an outpatient (American Heritage Dictionary, 2007; Zhu, Heng, & Teow, 2009). Since, shortening the patient processing time for various medical departments at the outpatient clinic of a hospital is needed to meet the requirements for the medical care system (Park, 2001).

According to FDRE Ministry of Health (2015), Ethiopia has 16,440 health posts, 3,547 health centers and 311 hospitals. Out of these figures, Addis Ababa shares about 0.59% of the health posts, 96 in number, around 25% of the health centers, 882 in number and 39 hospitals that count 12.54% of the total. The current study conducted to evaluate the performance of healthcare system in the country by taking one of the hospitals, namely, the St. Paul's Hospital Millennium Medical College (SPHMMC), as a case study.

The late Emperor Haile Selassie established SPHMMC in 1968. According to SPHMMC (2020), The hospital is a public, specialized, referral, and teaching hospital and has more than 2800 clinical, academic, administrative and supporting staffs to provide a healthcare service to the referral patients from every corner of the country. The hospital have more than 700 beds for the inpatient clinics and daily serves 1200 emergency and outpatient clinical customers, in average.

1.2. Statement of the problem

The existing healthcare system faces a need for re-designing the service system for each clinical department by taking the needs and expectations of both the patients and the professionals into considerations, whether in the private or public sector, for optimized service delivery. This optimization is necessary for fair, efficient and effective service delivery both in cost and quality aspects and to deliver value addition to the main targets of the health care system (Kriegel, Jehle, Dieck, & Mallory, 2013).

To achieve the expected excellency on the operational aspect and to ensure the clinical based quality at the hospitals, it is necessary to manage the patient flow in the outpatient department (Mardiah & Basri, 2019). Bahadori, Mohammadnejhad, Ravangard, and Teymourzadeh (2014) argues that it is necessary to accurately plan and manage the outpatient departments to handle the changes and challenges in the healthcare system.

In the existing condition, patients goes as early as they can to the healthcare facility, wait in the queue even before the opening of the facility and had to wait longer for examination, consultation and diagnosis. However, due to high number of patients at the OPD relative to the number of physicians, it results in an increased workload on the physicians and it shortens the patient consultation time, which has an impact on the patients' health as well as satisfaction. Longer consultation time is a sign for better care, as it helps the physician to identify the specific problem with the patients' health and to detect patients with chronic cases, to prescribe fewer drugs, to promote healthier lifestyle and to deal the psychosocial problems (Petek Ster, Svab, & Zivcec Kalan, 2008; Pollock & Grime, 2003; Wilson, McDonald, Hayes, & Cooney, 1992).

Unfortunately, this is not the case for many developing countries like Ethiopia. This research, therefore, seeks to bring new practical value that could help the Ethiopian healthcare system on decision making, by analysing the queuing performance of the case subjected hospital.

1.3. Research Question

To address the issues stated on the statement of the problems, the following dominant research questions were stated:-

1. How are the outpatient arrival and service pattern at SPHMMC OPD?
2. What is the level of the existing service utilization with respect to the minimum expected standard at SPHMMC OPD?
3. What advantages can we obtain with a queuing approach in managing the patient waiting times to improve the healthcare performance?
4. What measures needed to take place to reduce the length of queues in hospitals and increase patients' satisfaction?

1.4. Research Hypothesis

Based on the objectives of the study, the following research hypotheses were tested.

- in Ethiopia, due to the longer waiting time at SPHMMC OPD, the con
- sultation time is very low relative to the standard.

1.5. Scope of the study

This research was limited to a case study analysis and focuses only on the outpatient clinics, out of many, as OPD have the greatest queueing encounter relative to the other. The scope was also limited to focus only on the patient flow logistics and did not consider both the material and information logistics on the healthcare system. Besides, the patient was required to pass through other parts of the hospital before joining the waiting queue at the respective physician, like triage, registration and card departments, this research didn't consider the time the patient spend there, since it was negligible as compared to the time patients wait for consultation.

1.6. Ethical considerations

Ethical approval was required and obtained from the hospital ethical clearance committee. The permission of the various heads of the outpatient departments was also sought while the data collection was done and all the research data remained confidential throughout the study.

2. Literature review

One of the broadly used descriptions of logistics is that of The Council of Supply Chain Management Professionals (CSCMP) who describes logistics as

> "that part of the supply chain process that plans, implements, and controls the efficient flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements" (Council of Supply Chain Management Professionals, 2015; Feibert, Andersen, & Jacobsen, 2019).

Hospital logistics, as discussed by Frichi et al. (2018), addresses different healthcare quality aspects, particularly those related with patient and physicians satisfaction and standards. They also argued that a well-managed hospital logistics could improve the healthcare efficiency by reducing the patient waiting time. To support this premises they mentioned the inadequacy in resource synchronization between resources and needs as the main cause for waiting time , as it attributes to the lack of planning, coordination and communication in healthcare logistics as discussed by Melo (2012).

Service quality performance in a healthcare is the patient's perspective based on his experience and determined by waiting times, staff interactions, perceived medical service quality, and the overall communication (Eitel, Rudkin, Malvehy, Killeen, & Pines, 2010). According to previous studies, waiting time (Watson, Marshall, & Fosbinder, 1999) and time spent during evaluation, and consultation time, (Hobbs, Kunzman, Tandberg, & Sklar, 2000) directly affect the patient satisfaction.

In recent years, outpatient medical services are increasingly becoming the main components in the healthcare system due to the greater attention given to the preventive medical practices and shorter period of stay at the hospitals (Cayirli & Veral, 2003). The services at the outpatient clinic includes the registration, medical examinations and the received prescriptions (Chand, Moskowitz, Norris, Shade, & Willis, 2009; Dachyar et al., 2018). The time management at the OPD is vital to the patient especially to those with bad injuries and seeks diagnosis to the critical illness (Aziati & Hamdan, 2018; Mittal, Chatterjee, Hasnain, & Varshney, 2016).

Though it is not realized in the existing public healthcare systems, due to high patient flow towards a limited resources, treating patients in a timely manner is an entirely accepted objectives of the healthcare system (Au-Yeung, Harrison, & Knottenbelt, 2006). Bahadori et al. (2014) showed in their research that in OPD patient waiting time (Aeenparast et al., 2012; Huarng & Lee, 1996; Scanzano et al., 2005) is the main quality assurance indicator, among many others, and the waiting and service times are considered for healthcare system improvement (Scanzano et al., 2005). From the studies conducted by many researchers, Alabduljabbar, Madhi, Medan, Alaqeel, and Alsubaie (2018), identified four causes as main factors for long waiting time; High number of patients, Understaffing at the healthcare facility, long and complicated registration process and system and equipment aging.

Yaduvanshi, Sharma, and More (2019), in their research shows, there have been waiting time studies on those seeks consultation at the hospitals (Park, 2001) and founds the characteristics of the healthcare providers, the characteristics of the consultation and the characteristics of the patients (Hwang, 2006), as the influential factors.

The key task in performance analysis and measurement is to quantify the gap between reality and anticipations in reference to certain standards and guidelines (Akachi & Kruk, 2017), to reveal the weak links where the improvement efforts shall concentrate (Frichi et al., 2018).

Patient Flow

Patient flow is among the major essentials that needs to be considered during healthcare system improvement actions. The management of patient flow in the outpatient department (OPD) requires to address the three basic aspects: the patient arrival, the queue and service processes (Mardiah & Basri, 2019).

Patient flow management is about forecasting the demand and then organizing the required resources to meet the demand. Therefore, the hospital capacity planning need to follow the procedure of forecasting the demand and the matching the delivery of resources to the predicted demand. To arrive at reasonably accurate demand prediction there needs to be an understanding of the arrival variations on the courses of the day, that begins with getting the daily historical rate of incoming patients over the hours for the week (Eitel et al., 2010).

Even though, the mortality rate due to medical errors are very high, these deaths are unmeasured and the discussion regarding their prevention is limited to a number of confidential forums, like a hospital based committee, and the lesson learnt from these incidents are not distributed beyond the institution (Makary & Daniel, 2016). These researches and reports shows that the healthcare system is not as safe as we all expect it to be. Yet it is found to be difficult to have a conclusive idea about the epidemiology of these errors, we can see from the existing conditions that most errors are the results of actions taken by physicians that are forced to give the healthcare assistance through excessive clinical workloads.

The work load is found to be very high for the resident physicians that the fatigue is increasing the medical errors and this scenarios has likely increased, with the current high economic pressure on hospitals and restrictions of physicians work hours (Michtalik, Yeh, Pronovost, & Brotman, 2013). After their research, they concluded that, there are around a minimum of 40% of report for unsafe workloads in monthly basis.

In addition, nearly quarter of the hospitalists report that the excessive workload adversely affected the patient outcomes as it hinders full discussion of treatment options, while 22% of the physicians reported they ordered potentially unnecessary medical tests, consultations or procedures due to a lack of adequate time to evaluate their patient in person.

Queue theory

Queueing theory is a mathematical way of studying the waiting lines, the queues, and developed to predict the waiting time and the queue lengths. A queueing system at the healthcare consists of arriving patients and one or more physicians, providing service (Eitel et al., 2010). This theory was originated in the field of research by the

Danish Engineer cum mathematician Agner Krarup Erlang, to develop models that could describe the telephone exchange.

Queue theory is generally considered as a branch of operation research due to the outputs are mostly used to make business decisions regarding the resource allocation. Queueing models are popular among researchers since they provide reasonably accurate system performance evaluations due to their analytical nature and provision of quick answers to the "what-if" analyses (Prabakaran & Kumar, 2019).

In the healthcare system, the patient queuing effect in relation to the time spent by patients for treatment is gradually becoming a concern to the modern society (Agarwal & Singh, 2018). Queues are formed when the patient's arrivals rate exceeds the rate of service delivery (Bahadori et al., 2014). Quantitative tools, like queening models, can help to make decisions regarding resource planning, resource utilization and scheduling, as these all are affected by the flow of patients as the queue performance measures like the time spent in the system and the traffic intensity have a direct correlation with the patient flow characteristics (Mardiah & Basri, 2019).

Bailey (1952), documents that queueing theory is valuable to make adjustment between patient waiting time and the healthcare system idle time and service utilization rates (Zonderland & Boucherie, 2012). Over the years, the variety of applications examined can be summarised into waiting time, utilization analysis, system design and problem solving (Cayirli & Veral, 2003; Creemers & Lambrecht, 2007; Fomundam & Herrmann, 2007; Lakshmi & Iyer, 2013; Luo, Wu, Gopukumar, & Zhao, 2016; Moore, 1977; Palvannan & Teow, 2012; Preater, 2002; Wang, Guan, Koong, & Koong, 2016; D. Worthington, 1991; D. J. Worthington, 1987).

Queuing theory has increasingly become a common decision making management tool in the developed world, though it has insignificantly used in many African countries (Afrane & Appah, 2014), including Ethiopia. Green (2006) showed the application of queuing theory in the healthcare system, by discussing the relationship amongst delays, number of servers and utilisations using the basic M/M/s model (Lakshmi & Iyer, 2013) .

Fomundam and Herrmann (2007), in their research, showed waiting time and service utilization can be used as analytical tool in predicting the healthcare facility configurations effect on the delay in delivering service and resource utilization (Aziati & Hamdan, 2018). They researchers argued that, in queueing system, minimizing the time that patients have to wait and maximizing the utilization of physicians are conflicting issues.

3. Research aims and objectives

The main objective of this research work was to study the logistics performances of the healthcare system using queuing analysis. While, the specific objectives were to:

1. Determine the mean number of patient arrivals per hour (λ) in SPHMMC OPD.

2. Determine the mean number of patients served per hour (μ) in SPHMMC OPD.

3. Determine the average time a patient spent waiting in the queue before seen by a physician in SPHMMC OPD.

4. Analyse the waiting line of patients in SPHMMC OPD.

5. Analyse and recommend service optimization options for SPHMMC OPD.

4. Methodology

Queuing is an occurrence formed when people or things undergoes through a process of arriving at the queue, entering to the queue and waiting for a turn to get a service due to their confrontation with delays at the service system. Depending on the number of service channels, the queue length can be limited or unlimited. To analyse the waiting time the queue line is divided into the following parts (Heizer & Render, 2008; Mardiah & Basri, 2019).

i. Arrival : it is the inputs to the system and have distinctive size and statistical distribution behaviour

ii. Discipline : it is the characteristics of the queue

iii. Service facility : there are four types of queuing model, which are single channel single phase system, single channel multiphase system; multiple channel single phase system and multiple channel multiple phase systems

The basic notations to describe the queue analysis were created by the statistician David Kendall (Kendall, 1953). To make readers familiar with the notations, known as the Kendall Notation (A/B/C/D/E/F), they are described in brief as under.

A: Arrival Process: ??

B: Service Process: ??

C: Service Mechanism: In our case, it is the number of physicians.

D: System Capacity: The maximum number of customers be in the system at any time. In our case, it was assumed to be infinite.

E: Population: ??

F: Queue Discipline: ??

Kendall's Notation use some standard code letters for the arrival process A and the service process B. In this research, we use M to represent the Markovian arrival and service rate distributions.

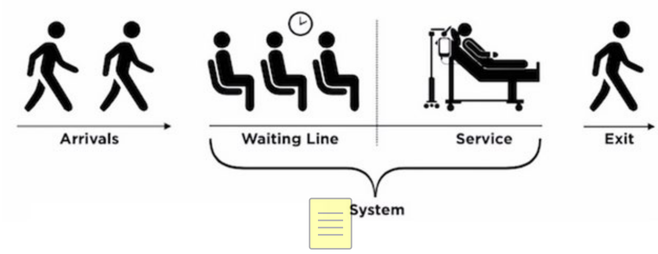

Figure 1. M/M/1 Queuing Model

The multi-server queue M/M/s is the model used most in analysing service stations with more than one server such as banks, checkout counters in stores, check-in counters in airports, and the like. The customers' arrival were assumed to follow a Poisson process, and service times were assumed to have an exponential distribution. The number of servers S, were also considered to provide service independently to one another. The research also assumed that the arriving customers form a single queue and the one at the head of the waiting line entered into service as soon as a server was free. No server stayed idle as long as there were customers to be served. Note that the service rate μ was the same for all servers.

Clearly, the arrival rate did not change with the number of customers in the system (i.e., λ was the constant arrival rate).

Whether there was a single doctor or there were multiple doctors on the OPD, each doctor gave service and had control for decisions regarding the process flow to his/her patients only, not to/on other doctors' patients (Yeon, Lee, & Jang, 2010). Therefore, we took the number of physicians, in each clinic at the OPD, as the number of the servers in that respective clinic. Therefore, we considered M/M/s queueing model for the analysis.

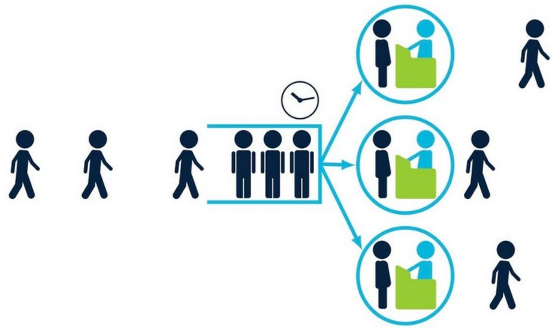

Figure 2. M/M/s Queue

The measurement scales for the queueing system included the average number of customers in the queue (Lq), the average number of customers in the entire system including the entity being served (Ls), the average waiting time in the queue (Wq), and the average waiting time in the entire system (Ws) (Cho, Kim, Chae, & Song, 2017) and the consultation time length. For this research, the three key performance indicators for the measurement of the hospital outpatient clinic were patient **queue length**, patient **waiting time** and **Consultation time** length.

To conduct the performance analysis, the research focused on the two fundamental parameters, from the collected data for queueing analysis, the **arrival rate (λ)** and the **service rate (μ)**, to conduct the performance analysis. Using these arrival rates and the service rates data, the average waiting time in a queue (Wq) were calculated. Almost all queueing models assumed an exponential distribution for the service time and Poisson distribution for the patient arrival per unit of time (Cho et al., 2017). The Poisson process distribution considers an independent and exponentially distributed probabilistic inter-arrival times for the patients that originate from the large population. An exponential distribution service delivery system uses a probability distribution that is convenient for getting systematically traceable results.

The trend in the OPD queueing at the hospital showed that patients arrived randomly and the queue capacity was assumed to be unlimited (Yin, 2010). The number of physicians at the respective outpatient clinic, the number of machines at the diagnostic imaging tests and scans centers represented the number of servers at the healthcare system. Therefore, the research assumed the same probability distributions for this paper and the patients got the healthcare service in the manner they arrived, simply in First Come First Served (FCFS) queue discipline.

Since the arrivals of the patients followed scattered nature and did not occur at a regular interval (Agarwal & Singh, 2018), this research assumed the Poisson distribution arrival. Patient arrivals were considered to be random, due to their nature that each patient's arrival were independent of one another and their occurrence couldn't be predicted exactly. In the Poisson distribution assumption, the constant λ, which is independent of any random property of the queue, was used.

Therefore, P (the arrival probability between time ”t” and “t + δt”) = λ δt

For a small δt interval, the probability of “n” arrivals in time “t” is defined as :

$$P_n(t)=(\lambda t)^n.e^{-\lambda t}/n! \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{Eq. 1}$$

Where: n= a random discrete variable, that obeys a Poisson-distribution, representing the number of arrivals in the given time interval

.t=??? what is t and its unit?

This research paper defines terms in the calculation to be similar with the way they defined in most literatures and books. Accordingly, λ was□□□□□□□□□to be the patient arrival rate expressed in numbers per hour, μ to be the service rate and both with the same unit. This research assumed steady state system consideration, in which the patient arrival rate, the service rate and the number of servers (Physicians/number of beds/number of machines, in our case) were assumed to stay constant over time. Wq was the expected time that a patient could spent in line. The expected time that the patient spent in the system, including the time spends in line and in service, was represented by Ws.

The research considered the M/M/s queue in which patients arrived to the respective clinical department at a rate λ, and each patient got service from one server among the many and waited in queue when all the servers were occupied. The maximum service rate is the product of the number of servers S and the individual server service rate μ (Zonderland & Boucherie, 2012).

The next critical challenge was to select the clinical departments that needed special focus or those that were very fundamental for the performance analysis. The hospital on the case study, SPHMMC, had 35 Medical Clinics, 20 Diagnostic Imaging Tests and Scans Centers, 4 Minor Operation Centers and 10 Major Operation Centers. Each are listed under according to their classification.

Table 1. Medical Clinics at SPHMMC

Item No.	Clinic*	Item No.	Clinic
1	Adult Emergency	19	PAC
2	Anti-natal	20	Palliative
3	Anti-rabies	21	Paediatric Emergency
4	Cervical Ca Screening	22	Paediatric OPD
5	Chest Clinic	23	PEP
6	Dental Clinic	24	Physiotherapy
7	Dermatology	25	PITC
8	Endoscopy	26	PMTCT
9	ENT	27	Post-natal
10	Family Planning	28	Psychiatry
11	Gynaecology Emergency	29	Referral Surgical
12	Haematology	30	Regular Gynaecology OPD
13	Kidney Transplant	31	Surgical
14	Medical	32	Sexual Assault
15	Nephrology	33	Staff Clinic
16	Neurology	34	Student Clinic
17	Oncology	35	VCT
18	Ophthalmology		

Table 2. Diagnostic Imaging Tests and Scans centers at SPHMMC

Item No.	Test Center *	Item No.	Test Center
1	Angiography	11	Gastroscopy
2	Angiograph screening	12	Ligation
3	Audiometry	13	MRI

4	Bronchoscopy	14	Optometry
5	Colonoscopy	15	Pathology
6	CT scan	16	Polypectomy
7	Dialysis	17	TEE
8	ECG	18	Ultrasound
9	ECHO	19	Valvetomy screening
10	Endourology	20	X-ray

Table 3. Minor Operation Centers at SPHMMC

Item No.	Minor Operation Center *
1	E & C
2	ENT
3	OR
4	Ophthalmology

Table 4. Major Operation Centers at SPHMMC

Item No.	Major Operation Center *	Item No.	Major Operation Center *
1	Constructive	6	Neuro-Surgery
2	ENT	7	Ophthalmology
3	General Surgery	8	Orthopaedic
4	Gynaecology/ Obstetrics	9	Paediatric
5	Maxillo facial	10	Urology

* Listed in Alphabetical order

However, the data were collected for all clinics and departmental centers listed above, it was necessary to focus on certain key departments and clinics to got a representative sample for measuring the characteristics performances. Therefore, the Pareto principle was applied, to screen and select clinics and departments from each categories tabled above.

The Pareto´s principle is a concept that was first applied in economics and then becomes one of the governing rules in different arenas. Named after the 19th century Italian economist Vilfredo Pareto, the principle is as: 80 percent of effects always come from 20 percent of the causes. Since he published these findings, the magical ratio of 80:20 (or the "80-20 rule") has been applied in many of our day-to-day encounters. Accordingly, the principle could be interpreted as, 20 percent of the products covers 80 percent the company's profits; 20 percent of the roads accommodate 80 percent of the traffic; and 80 percent of food production is generated from 20 percent of the crops. This is why the 80-20 phenomenon is the often cited as a universal baseline for most of the distributions.

For the case in this research, the consideration was 80 percent of the patients flows into 20 percent of the clinics and we can apply this into each of the categories. From this consideration and calculation, the busiest clinical departments, the vital few, which accounts to give consultation for the trivial many were sorted out. The Pareto analysis used to categorize data and to identify which clinical departments´ processes have the most effect on a quality of care outcome of the hospital. Since it is critical to devote efforts in the vital few clinical departments, it is valuable to use Pareto analysis when there are many clinical departments that contributes to the hospital performance.

Therefore, the following 13 clinical departments, 4 Diagnostic Imaging Tests and Scans ceneters, 4 Minor Operation centers and 6 Major Operation centers were selected for performance analysis based on their respective patient flow numbers recorded for eighteen months.

Table 5. Medical Clinics selected for analysis at SPHMMC

Item No.	Clinic	Percent share of the patient flow
1	Medical	17.59

2	Surgical	12.50
3	Ophthalmology	8.91
4	Paediatric OPD	5.76
5	Regular Gynaecology OPD	5.74
6	Anti-natal	5.17
7	Psychiatry	4.37
8	ENT	3.60
9	Adult Emergency	3.58
10	Neurology	3.11
11	Dental Clinic	3.08
12	Gynaecology Emergency	2.98
13	Dermatology	2.75

Table 6. Diagnostic Test centers selected for analysis at SPHMMC

Item No.	Test Center	Percent share of the patient flow
1	X-ray	33.05
2	Ultrasound	31.74
3	MRI	9.62
4	CT scan	7.86

Table 7. Minor Operation centers selected for analysis at SPHMMC

Item No.	Minor Operation Center	Percent share of the patient flow
1	OR	42.87
2	Ophthalmology	31.23
3	MRI	23.18
4	E & C	7.86

Table 8. Major Operation centers selected for analysis at SPHMMC

Item No.	Major Operation Center	Percent share of the patient flow
1	General Surgery	23.98
2	Ophthalmology	21.12
3	Orthopaedic	16.54
4	Urology	7.65
5	Neuro-Surgery	7.48
6	Paediatric	5.59

Population

The study population, for this research, were all outpatients treated and consulted at the SPHMMC.

Samples

Sampling is the process of selecting a predetermined number of observations for further statistical analysis to draw conclusions applicable to the larger population. To determine the sample of our study, we had used the following formula:

$$n = \frac{z^2 p(1-p)}{E^2} = \left(\frac{z_c}{E}\sigma\right)^2 \qquad \text{--eq.???}$$

Where:

Z = Z-score (1.96 for 95% confidence level)

p = Healthcare service utilization rate in the hospital

E = Margin of Error (Confidence Interval); assumed to be 5%

Z_c ----------??

.σ ---????

NB: The above sample size calculation provided us, the recommended number samples required to estimate the true proportion mean with the required margin of error and confidence level. We took 50% sample proportion out of the total population and 100,000 outpatients as a total population, as recommended by statistical books when there is uncertainty on the exact population and likely sample proportion.

The sample size for each clinical department was calculated using the above formula, and a minimum of 384 hours of outpatients' secondary data were selected to determine the arrival rate, service rate and other related data to perform the patients flow and queuing network performance variables.

Table 9. Sample size calculations

Z_c	p	E	$\boldsymbol{\sigma}$	$\boldsymbol{n}$
1.96	0.5	5%	100,000	384

Data collection

Initially the secondary data that were required to analyse the patients' arrival patterns and their average waiting times for treatment, were collected from November 2019 to January 2020, from all the medical clinics in the hospital at the case study. Patients queue data, both new and repeated, who visited 69 clinical, surgical and diagnosis departments at the outpatient clinics of the hospital, in last 18 months from October 2019, were analysed to evaluate the hospital performance. After the initial diagnosis and treatment in the first visit, if the patient returns back to the hospital for check-up, having symptoms of sickness, having complication from previous treatments, or any other related issues, then from the next arrival onwards that patient is categorized as the repeated patient.

In addition, the number of physicians in each clinical department of the hospital were collected. As it is in most healthcare settings, with no appointment system in place, the existing system in the hospital was in such a way that the physicians met, for the medical procedure, with both the new and repeated patients in First Comes

First Served (FCFS) basis. The data were analysed using STATA statistical software and Microsoft Excel Spreadsheet.

Calculation of arrival rate

The arrival rate was calculated as the average number of arrivals per unit time. The calculation was performed by dividing the total number of customers, in this research case patients, per day to the total working hours per day, usually eight hours, unless and otherwise stated to be different based on the special characteristics of the clinic in analysis. For the early arrivals, the earliest time that the facility opened for the waiting and the average number of patients during service opening hour was considered. This research was limited to use this approach due to the unavailability of patient arrival data collected or registered on the system, to record the arrival time of the patient.

If the arrival time registry had done, we could simply take the ratio of the difference between the first patient’s arrival time and the last patient’s arrival time to the inter arrival time to be the number of patient arrived during that time interval. In this paper, for the sake of simplicity, an assumption of no baulking (no patients refused to join the waiting line because it were too long), no reneging (no patients left the waiting line due to long waiting for service), or no jockeying (no patients switch between waiting lines by perceiving they will get served faster by so doing) taken into consideration.

Though the arrival pattern of patients who are looking for healthcare services, at the hospital, is always random in nature, they demand to get immediate services by that time. If the hospital service facility is working at its peak capacity when the patients arrive, they are required to wait with patience until their turn. This is where a queue, the number of patients waiting to be served, is formed due to the difference between patient arrival and the time taken for the service delivery. Due to the characteristics of medical services, it is very difficult to predict exactly when a patient will arrive and how much time will be taken for the service (Cho et al., 2017). Thus, the absolute objective of queueing theory is to attain an economic equilibrium between the service cost and the patients' waiting time (ibid.).

Calculation of service rate

In most developing countries hospitals, including Ethiopia, digital data recording system that includes Patients consultation durations was not found to be applicable. Therefore, it was not possible to get the consultation hour and the service rate, for each patient or for whole patients arrived and consulted per day. Therefore, the calculation of average service rate was done by dividing the total serviced patients per day to the total working hour per day. The effective consultation hour was then calculated by considering the average time lost during transition from this patient to the next patient.

Consulting time varies from country to country and even from hospital to hospital, as it depends on the patient and physician characteristics (Ahmad, Khairatul, & Farnaza, 2017). The American Academy of Family Physicians, after the survey conducted in 2013, a physician spends nearly 93.2 hours weekly, in healthcare activities and which is the equivalent of consulting 19 patients per day and a family physician spends around 22 minutes per encounter with a patient (Bernstein, 2014). Therefore, an assumption of 19 patients consultation per day was taken as a reference for service rate calculation. For emergency service clinics 15 minutes of average consultation time as recommended by Samuel, Aldeen, Gravenor, and Malik (2015) was taken. For gynaecology and obstetrics emergency OPD an assumption of 390 minutes were taken as the average treatment and diagnosis time as discussed by Ocak, Bekdas, Duran, Göksügür, and Küçükbayrak (2013). All physicians were assumed as punctual at their duty station. In addition, the consultation time difference among physicians was considered as insignificant, hence similar consultation time between patients.

The number of servers

This research paper assumed the number of physicians in the specified clinic, the number of beds in surgical and delivery wards, and the number of machines in the testing and diagnosis labs to be the number of servers as these are the main constraints throughput, respectively.

Data Processing and Analysis

For data analysis and interpretation of the results, computer software, namely Microsoft Excel and STATA Statistical software were used. The collected secondary data was entered in Excel Spreadsheets to organize, sort and compile and then exported to STATA and descriptive statistical analysis carried out. The figures and tables, from both applications, were interpreted accordingly to arrive at meaningful conclusions and recommendations.

The queue system performance parameters used in this research were defined as follows:

λ: Arrival rate of patients at the subjected OPD per hour;

μ: Service rate of the subjected OPD per hour;

s: Number of servers in the respected OPD for consultation.

S Russell, W Taylor, Castillo, and Vidyarthi (2011) discusses the formulas for determining the operational characteristics of a queue scenario with Poisson arrival, exponential service, infinite population, First Comes First Served (FCFS) discipline and multiple server as follows

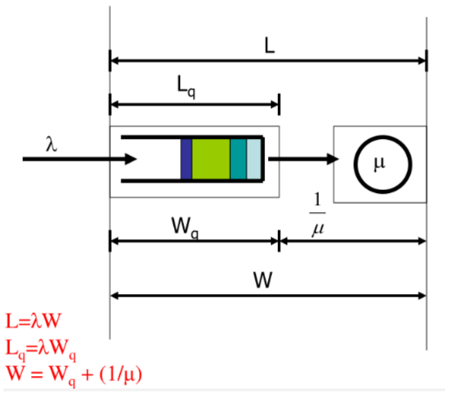

Figure 3. Little's law

The probability of no patients in the system (all physicians are idle) is

..

$$P_0 = \frac{1}{\left[\sum_{n=0}^{n=s-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n\right] + \frac{1}{s!}\left(\frac{\lambda}{\mu}\right)^s \left(\frac{s\mu}{s\mu - \lambda}\right)}$$

The probability of n customers in the queuing system is

..

$$P_n = \begin{cases} \frac{1}{s!s^{n-s}} \left(\frac{\lambda}{\mu}\right)^n P_0, \text{ for } n > s \\ \frac{1}{n!} \left(\frac{\lambda}{\mu}\right)^n P_0, \text{ for } n \le s \end{cases}$$

The probability that a customer arriving in the system must wait for service (i.e., the probability that all the servers are busy) is

..

$$P_W = \frac{1}{s!} \left(\frac{\lambda}{\mu}\right)^s \frac{s\mu}{s\mu - \lambda} P_0$$

Avg. no. of patients in system

..

$$L = \frac{\lambda\mu(\lambda/\mu)^s}{(s-1)!(s\mu-\lambda)^2} P_0 + \frac{\lambda}{\mu}$$

Avg. time patients spend in system

..

$$W = \frac{L}{\lambda}$$

Avg. no. of patients in queue

Eq.no.??

$$L_q = L - \frac{\lambda}{\mu}$$

Avg. time patients spend in queue

Eq.no.??

$$W_q = W - \frac{1}{\mu} = \frac{L_q}{\lambda}$$

Service Utilization

Eq.no.??

$$\rho = \frac{\lambda}{s\mu}$$

Queue Intensity (measure of how busy a system is)

$$\rho = \lambda/\mu$$

5. Results

For the selected medical clinics at SPHMMC the analysis result is tabulated at follows.

Table 10. Queue performance at clinical departments

Clinical Department	Total working hour in a week	Average number of patients per day	Number of Servers in the clinic, s, (physicians or as stated)	Average patients arrival rate, λ (hr^{-1})	Average service rate hr^{-1}, per server (μ)	Average number of patients in the system (L)	Average patients in Queue (Lq)	Average Time Spent, in min, in System (W)	Average time waiting, in min, in line (Wq)
Medical	48	351	6	35. 10	7.31	68.13	63.33	116.46	108.25
Ophthalmology	40	189	4	18.90	5.91	41.13	37.57	117.50	107.35
Surgical	40	78	9 beds	11.14	1.08	23.40	13.11	126.00	70.61
Paediatric OPD	40	98	4	9.80	3.06	17.21	14.01	105.39	85.80

Clinical Department Clinical Department	Total working hour in a week	Average number of patients per day	Number of Servers in the clinic, s, (physicians or as stated)	Average patients arrival time, λ (hr^{-1})	Average service rate, hr^{-1}, per server (μ)	Average number of patients in the system (L)	Average patients in Queue (Lq)	Average Time Spent, in min, in System (W)	Average time waiting, in min, in line (Wq)
Regular Gynaecology OPD	40	138	4	11.50	4.31	26.84	24.18	140.05	126.14
Anti-natal	40	132	8	14.67	2.06	21.03	13.92	86.02	56.93
Psychiatry	40	72	2	10.29	4.50	7.20	4.91	42.00	28.66
ENT	40	76	2	7.60	4.75	16.16	14.56	127.54	114.91
Adult Emergency	168	40	10	2.50	1.2	2.00	-	48.01	-
Neurology	24	134	3	13.40	5.58	24.21	21.81	108.41	97.66
Dental Clinic	40	65	7	6.5	1.16	14.31	8.71	132.06	80.37
Gynaecology Emergency	168	13	7 beds	0.81	0.67	0.65	-	48.00	-
Dermatology	40	62	2	6.89	3.88	5.70	3.93	49.67	34.19

Table 11. Service time performance at selected clinical departments

Clinical Department	Existing Average service time in minute	Average standard service time in minute	System stability and utilization
Medical	5.71	22.00	Unstable
Ophthalmology	6.16		Unstable
Surgical	35.38		Stable, Under utilized
Paediatric OPD	16.59		Unstable
Regular Gynaecology OPD	10.91		Unstable
Anti-natal	25.59		Stable, well utilized
Psychiatry	10.83		Unstable
ENT	9.63		Unstable
Adult Emergency	44.26	15.00	Stable, Under utilized
Neurology	8.25	22.00	Unstable
Dental Clinic	47.69	22.00	Stable, Under utilized
Gynaecology Emergency	46.50	15.00	Stable, Under utilized
Dermatology	11.48	22.00	Unstable

Table 12. Queue Performance at selected test centers

Test Center	Average number of patients per day	Number of machines in the clinic (s)	Average patients arrival time, λ (hr^{-1})	Average service rate, hr^{-1}, per server (μ)	Average number of patients in the system (L)	Average patients in Queue (Lq)	Average Time Spent, in min, in System (W)	Average time, in min, waiting in line (Wq)
X-ray	98	2	4.45	2.08	4.90	2.72	65.97	36.58
Ultrasound	76	6	8.44	1.58	4.17	-	29.64	-
MRI	137	1	13.70	17.13	10.50	9.70	45.99	42.48
CT scan	104	1	10.40	13.00	17.60	16.80	101.54	96.92

Table 13. Queue Performance at Minor Operation Center

<table>
<tr><th>Minor Operation Center</th><th>Average number of patients per day</th><th>Number of beds in the clinic (s)</th><th>Average patients arrival time, λ (hr^{-1})</th><th>Average service rate, hr^{-1}, per server (μ)</th><th>Average number of patients in the system (L)</th><th>Average patients in Queue (Lq)</th><th>Average Time Spent, in hr, in System (W)</th><th>Average time, in hr, waiting in line (Wq)</th></tr>
<tr><td>OR</td><td rowspan="4">19</td><td rowspan="4">4</td><td rowspan="4">2.71</td><td rowspan="4">0.59</td><td rowspan="4">8.46</td><td rowspan="4">3.89</td><td rowspan="4">187.09</td><td rowspan="4">86.04</td></tr>
<tr><td>Ophthalmology</td></tr>
<tr><td>ENT</td></tr>
<tr><td>E & C</td></tr>
</table>

Table 14. Queue Performance at Major operation centers

<table>
<tr><th>Major Operation Center</th><th>Average number of patients per day</th><th>Number of beds in the clinic (s)</th><th>Average patients arrival time, λ (hr^{-1})</th><th>Average service rate per server (μ)</th><th>Average number of patients in the system (L)</th><th>Average patients in Queue (Lq)</th><th>Average Time Spent, in min, in System (W)</th><th>Average time, in min, waiting in line (Wq)</th></tr>
<tr><td>General Surgery</td><td rowspan="3">19</td><td rowspan="3">4</td><td rowspan="3">2.71</td><td rowspan="3">0.59</td><td rowspan="3">8.46</td><td rowspan="3">3.89</td><td rowspan="3">187.18</td><td rowspan="3">86.04</td></tr>
<tr><td>Urology</td></tr>
<tr><td>Paediatric</td></tr>
<tr><td>Ophthalmology</td><td rowspan="3">63</td><td rowspan="3">8</td><td rowspan="3">9.00</td><td rowspan="3">0.98</td><td rowspan="3">31.50</td><td rowspan="3">22.35</td><td rowspan="3">209.97</td><td rowspan="3">149.02</td></tr>
<tr><td>Orthopaedic</td></tr>
<tr><td>Neuro-Surgery</td></tr>
</table>

6. Discussion and Recommendation

Although waiting time is a worldwide phenomenon that affects healthcare organisations throughout the globe (Ghazali et al., 2011) , in Ethiopia there is still much to be done in order to reduce patient waiting time in public hospitals. On this study, it is clearly shown that the patients' arrival rate highly exceeds the service rate, in each respective clinical department. On average, there was about 351 patients on the medical clinic with an average arrival rate of 35.10 patients per hour, which is the highest among the clinics. The least rate of arrivals were on the Gynaecology and Adult emergency clinics and this could be why there was no overcrowding and serious performance issues on the clinics. If this was not the case, a crowded or poorly structures emergency clinic could be dangerous.

Arrival time pattern of the patients showed that around 15 to 25% patients in most clinical departments and around 50% of the patients at the surgical clinics comes as early as 6 am in the morning and waited there until the clinic opened for service. However, the hospital administration argued as they gave service to anyone arrived during the working time; practically the clinics stopped to accept patients as early as one hour before the closure of the clinic and consulted only those who were already on the queue.

This could be because the public healthcare in Ethiopia is in a state of excess demand, where the demand for subsidised healthcare far outstrips the supply; given the fact that public healthcare in the country is almost free at the point of delivery. Furthermore, the huge fee differential between public and private healthcare also contributes to this kinds of unbalanced demand. Seeking the healthcare at the private sectors, commonly not available for complicated cases, entails much higher payments, which is not, at almost all times, in the economic means of the average citizens.

Regarding the service capacity per hour, the research showed there was as high as 7.31 patients per hour load at the medical clinic and 5.91 patients per hour at the ophthalmology clinic. While as expected it is very low, 0.67 patients per hour in the gynaecology emergency and this would give enough time for the consultation. The service capacity was higher at the medical and ophthalmology clinics due to a relatively higher number of patients with respect to the number of physicians. As each physicians was expected to cover many patients per unit time to cover the high number of patients with relatively lower stuff numbers, they had higher service rate.

A study conducted in 2011 at the outpatient clinics in Malaysia showed that the average waiting time to get consultation was 60 minutes (Ahmad et al., 2017; Ghazali et al., 2011) and according to Ghazali et al. (2011) it could go as high as 64 minutes. A study conducted in India showed that the average waiting time for consultation ranges from the minimum 7.5 minutes at the paediatric OPD to a maximum 61 minutes at the cardiac OPD (Yaduvanshi et al., 2019). In Nigeria, the average waiting time was found to be 73 minutes as per the study conducted in University College Hospital Ibadan (Bamgboye, Erinoso, & Ogunlesi, 1992). In comparison, the outpatient clinics at the SPHMMC achieved an average total waiting time of 92 minutes to be consulted and nearly around 70% of the patients waited more than 95 minutes. This indicates that, as we hypothesised, a high percentage of patients were in an extended long waiting time to see the physician.

Meanwhile, the available consultation time per patient in the emergency OPD departments was more than the placed average standard consultation duration, 15 minutes, as it was found to be 44.26 minutes in the Adult Emergency and 46.50 minutes in the Gynaecology Emergency. However, the consultation time, in most of the clinics, as hypothesised in this paper, was found to be lower than the 22-minute consultation time specified as standard. The average consultation time was as low as 5.71 minute at the Medical clinic and 6.16 minute at the Ophthalmology clinic, while the average in the OPD clinics was 15.98 minutes and around 60% of the patients saw the doctor for a time less than 10 minutes. Nevertheless, the Anti-natal care clinic was found to be the only clinic that meets the standard, even had a better consultation time.

In the current healthcare environment, patient waiting time is the main aspect in performance measurement. Patient satisfaction is becoming increasingly important variable in healthcare quality assessment and it’s difficult to satisfy patients with longer waiting times (M Oche & Umar, 2011; Mackey & Cole, 1997). A satisfied patient believes that the healthcare facility do understand his/her needs and demands (Ny Net & Chompikul, 2007).

This research identified that this long waiting time and hence shorter consultation time was due to long queues caused by an early arrival of patients’, even way before opening of the clinic, for the service and extended arrival of patients during the lunch break time, hence arriving at the same time in large numbers. The imbalanced number of patients to the available number of physicians or diagnostic equipment, according to their respective clinic, was the other reason for longer waiting time and shorter consultation duration.

Lack of proper staffing, low deployment, in quantity, of physicians in the clinics and beds and equipment in the diagnosis and surgical clinics, is a known contributor to lengthy waiting time (Ahmad et al., 2017; MO Oche & H Adamu, 2013) and shorter consultation duration. This claim is supported with the fact that, though, WHO recommends doctor to population ratio to be one per 1000, and according to the reports Ethiopia have less than one per 36,000 (Abera, Alemayehu, & Herrin, 2017). This is due to high physician attrition rates, rapid population growth, low physicians production rate, and increased post-graduate enrolment (Berhan, 2008; Health, 2010).

Too many patients early arrival before service opening was also another factor. According to the research data, from 15% up to 50% of the patients in most clinics arrived early before the opening of the respective clinic. The dynamic nature of service operations at the hospitals makes it difficult to make predictions on the number of patients arrivals at any moment and to assure the immediate availability of the service (Yaduvanshi et al., 2019). Ahmad et al. (2017) argues that even despite the warnings and the reminders given to the patients to arrive at the scheduled time, early arrivals were common and have significant impact on waiting time length (Su & Shih, 2003).

Physician dual practice was the other factor for the shorter consultation and longer waiting times. Dual practice refers to full-time salaried physicians at the public sector practicing simultaneously in the private firms and clinics (Ferrinho & Van Lerberghe, 2004; Socha & Bech, 2011). Public-on-private dual practice is like physician retention mechanism at the public sector, particularly in low- and middle-income countries and is often upheld as a means to complement a lower government salary grade (Abera et al., 2017; Bir & Eggleston, 2003; Ferrinho et al., 1998; Macq, Ferrinho, De Brouwere, & Van Lerberghe, 2001; Russo, McPake, Fronteira, & Ferrinho, 2014).

Unfortunately, this practice reduced the current quality of healthcare at the public sector as the physicians were diverting their attention and resources to the private and prefred to spend less time around the public hospitals (Abera et al., 2017; Bir & Eggleston, 2003; Ferrinho & Van Lerberghe, 2004; Kuhn & Nuscheler, 2013; Socha & Bech, 2011). Many patients also accused their Physicians that they were diverting them to public clinics where they worked at or to the private medical scheam that was conducted on the hospital after 4:00 pm, either by direct referral or by more subtle acts, like manipulating increased public sector waiting times in order to stimulate demand for their those services.

Agarwal and Singh (2018), argued as unnecessary waste of time in the healthcare centres may lead to patients' health complications that could worsen the cases to eventual death, which could be avoided. Among the several alternative ways, towards improving the situations in improving patient flow, and thus reducing waiting time for the patients, they recommends to make adjustment on the system by increasing the number of servers and managing the arrival rate.

The number of servers can be increased by deploying more physicians, beds and equipment, in each respective clinic accordingly, which shall present an immediate improvement in healthcare services, and shall eliminate the crowd in the waiting-room, and thus increase the service efficiency. The arrival rate can be controlled by arranging a schedule time for the follow-up patients to come at the non-peak hours preferably at the afternoon. Implementing a thicket numbering will help the patients to be aware of the number of patients ahead of them and the time they will wait before the service.

The findings of this research study indicated that for a patient to saw a physician for a consultation time a lower than 10 minutes, he or she had to wait for about two hour. If we took into account the traveling time to and from the hospital, getting access to healthcare within the system would actually be a daunting task. Though, patients prefer to have longer time with physicians, many research works like Deveugele, Derese, van den Brink-Muinen, Bensing, and De Maeseneer (2002), and Ogden et al. (2004) argued there are no universal guideline in placing the best length of time for consultation. Ghazali et al. (2011) showed in their works that, the average consultation time in Malaysia was 15 minutes (Ahmad et al., 2017).

Consultation time is dependent on individual patients and their illnesses, the type of visit, the physician's characteristics, and the physician's workload. However, Slower and longer consultation with physicians is expected to identify psychosocial problems, more accurate exploration and presenting of complaints, prescribe less and offer more advices towards preventative cares and physicians that consult for a time less than 7 minutes, mostly misses most of these points (Wilson & Childs, 2002).

Observational evidences suggest that the consultation time is directly interrelated with the service quality (Chen, Farwell, & Jha, 2009; Mechanic, McAlpine, & Rosenthal, 2001). Though, patients prefer longer consultation as discussed above, the same literatures debated the conflicting objective of reduction on the patients waiting times and trade-off between speed and quality becomes a main concern (Srivatsa Srinivas & Marathe, 2020). According to Anand, Paç, and Veeraraghavan (2011) queuing theory have been implemented in the past to design such systems and to get the optimal speed-quality trade-off.

Accordingly, the following recommendations was made to reform the number of physicians, beds and equipment to cope with the tasks by considering, speed-quality trade-off. These recommendations considered an acceptable emergency room wait time of 15 min (Ocak et al., 2013), and 30 minutes of waiting time as recognized by the institute of medicine (O'Malley, Fletcher, Fletcher, & Earp, 1983; M. Oche & H. Adamu, 2013). For the test and operation centers, the numbers of servers was calculated by assuming a 30 minutes average waiting time only, since the service time was dependent on the test and surgical procedure type.

Table 15. Recommended number of servers at clinical departments by assuming 22 min consultation time

Clinical Department	Average number of patients per day	Existing number of servers in the clinic, s, (physicians or as stated)	Existing average service rate, hr^{-1}, per server (μ)	Recommended number of servers in the clinic, s, (physicians or as stated)	Change in number of servers in the clinic
Medical	351	6	7.31	18	+12
Ophthalmology	189	4	5.91	11	+7
Surgical	78	9 beds	1.08	6	-3
Paediatric OPD	98	4	3.06	5	+1
Regular Gynaecology OPD	138	4	4.31	7	+3
Psychiatry	72	2	4.50	4	+2
ENT	76	2	4.75	4	+2
Adult Emergency	40	10	1.2	5	-5
Neurology	134	3	5.58	7	+4
Dental Clinic	65	7	1.16	4	-3
Gynaecology Emergency	13	7 beds	0.67	5 beds	-2
Dermatology	62	2	3.88	4	+2

Table 16. Expected service improvement at clinical departments with targeted 22 minutes consultation time

Clinical Department	**Improved average service rate, hr^{-1}, per server (μ)**	**Average number of patients in the system (L)**	**Average patients in Queue (Lq)**	**Average Time Spent, in min, in System (W)**	**Average time waiting, in min, in line (Wq)**	**Average consultation time in minute**
Medical	2.44	32.23	17.83	55.09	30.48	22.12
Ophthalmology	2.15	18.29	9.49	58.07	30.13	23.94
Surgical	1.63	8.73	3.93	67.17	30.25	21.92
Paediatric OPD	2.45	8.96	4.96	54.83	30.34	20.99
Regular Gynaecology OPD	2.46	12.68	7.08	55.15	30.88	21.35
Psychiatry	2.25	6.69	3.49	55.72	29.05	24.17
ENT	2.38	7.19	3.99	56.77	31.50	22.26
Adult Emergency	0.33	3.62	-	150.21	-	171.09
Neurology	2.39	12.53	6.93	56.10	31.02	22.07
Dental Clinic	2.03	6.52	3.32	60.18	30.64	25.54
Gynaecology Emergency	0.34	2.32	-	185.07	-	204.30
Dermatology	1.94	6.89	3.34	60.03	29.06	25.97

Evaluating from the standard consultation time perspective, the above tables shows that there was an over assignments on the surgical (3 excess beds), Adult Emergency (5 excess physicians), Dental (3 excess physicians) and Gynaecology Emergency clinics (2 excess beds). Therefore, the hospital shall make adjustments accordingly by conducting other related assessments to efficiently utilize the very scarce resource of the country. However, major improvement was needed on the Medical clinic (12 additional physicians required), Ophthalmology (7 additional physicians required), Neurology (4 additional physicians required) and Regular Gynaecology (3 additional physicians required). Nevertheless, deployment of this much physicians per hospital is almost impractical, considering the scarcity of the physicians in the country.

As Ethiopia is ranked as 180th in the WHO ranking, out of 191 countries, of health systems, which was a lower rank than its neighbours like from Somalia (179th), Eretria (158th), Djibouti (157th), Kenya (140th), Sudan (134th) it is difficult to expect a consultation time that closes to the expected standard consultation time. Therefore, we need to have another reference for a stage-by-stage improvement on the sector. Thus we can approach to the solution using two alternatives, by taking the maximum and minimum time from the average consultation time found from other studies which is 10-15 minutes (Ahmad et al., 2017; Britt, Valenti, & Miller, 2002; Cape, 2002). First, let us consider 15 minute of consultation time as a reference and by excluding clinics those already meet the standard consultation time.

Table 17. Recommended number of servers at clinical departments by assuming 15 min consultation time

Clinical Department	Average number of patients per day	Existing number of servers in the clinic, s, (physicians or as stated)	Existing average service rate, hr^{-1}, per server (μ)	Recommended number of servers in the clinic, s, (physicians or as stated)	Change in number of servers in the clinic
Medical	351	6	7.31	13	+7
Ophthalmology	189	4	5.91	8	+4
Paediatric OPD	98	4	3.06	4	-
Regular Gynaecology OPD	138	4	4.31	5	+1
Psychiatry	72	2	4.50	3	+1
ENT	76	2	4.75	3	+1
Neurology	134	3	5.58	5	+2
Dermatology	62	2	3.88	3	+1

Table 18. Expected service improvement at clinical departments with targeted 15 minutes consultation time

Clinical Department	Improved average service rate, hr^{-1}, per server (μ)	Average number of patients in the system (L)	Average patients in Queue (Lq)	Average Time Spent, in min, in System (W)	Average time waiting, in min, in line (Wq)	Average consultation time in minute
Medical	3.38	28.43	18.03	48.60	30.82	15.28
Ophthalmology	2.95	15.94	9.54	50.59	30.27	16.32
Paediatric OPD	3.06	8.20	5.00	50.19	30.60	16.59
Regular Gynaecology OPD	3.45	11.03	7.03	47.96	30.57	14.39
Psychiatry	3.00	5.98	3.58	49.83	29.83	17.50
ENT	3.17	6.23	3.83	49.16	30.22	15.95
Neurology	3.35	10.78	6.78	48.28	30.37	14.91
Dermatology	2.58	6.08	3.41	52.93	29.71	18.23

Again by evaluating from the 15 minute consultation time target, the above tables shows that there is still a major improvement needed on the Medical clinic (7 additional physicians required) and Ophthalmology (4 additional physicians required) clinics while Neurology requires an additional of 2 physicians and the remaining except Paediatric OPD requires an additional of single server each. The Paediatric OPD only requires patient arrival management without any additional server and can meet the required consultation time.

For the clinics that requires an additional server, we can consider an optimization with the minimum recommended consultation time, which is 10 minute, as shown in the following tables.

Table 19. Recommended number of servers at clinical departments by assuming 10 min consultation time

Clinical Department	Average number of patients per day	Existing number of servers in the clinic, s, (physicians or as stated)	Existing average service rate, hr^{-1}, per server (μ)	Recommended number of servers in the clinic, s, (physicians or as stated)	Change in number of servers in the clinic
Medical	351	6	7.31	9	+3
Ophthalmology	189	4	5.91	6	+2
Regular Gynaecology OPD	138	4	4.31	4	-
Psychiatry	72	2	4.50	2	-
ENT	76	2	4.75	2	-
Neurology	134	3	5.58	4	+1
Dermatology	62	2	3.88	2	-

Table 20. Expected service improvement at clinical departments with targeted 10 minutes consultation time

Clinical Department	**Improved average service rate, hr^{-1}, per server (μ)**	**Average number of patients in the system (L)**	**Average patients in Queue (Lq)**	**Average Time Spent, in min, in System (W)**	**Average time waiting, in min, in line (Wq)**	**Average consultation time in minute**
Medical	4.88	25.30	18.10	43.24	30.94	9.81
Ophthalmology	3.94	14.37	9.57	45.63	30.39	11.24
Regular Gynaecology OPD	4.31	10.17	6.97	44.23	30.31	10.91
Psychiatry	4.50	7.20	4.91	42.00	28.66	10.83
ENT	4.75	5.50	3.90	43.42	30.79	9.63
Neurology	4.19	9.94	6.74	44.52	30.19	11.33
Dermatology	3.88	5.08	3.31	44.27	28.79	11.48

From the 10-minute consultation time target optimization, we can see that the Medical clinic requires 3, the Ophthalmology clinic 4 and the Neurology clinic requires 1 additional physicians to fulfil the minimum requirement. While, the remaining clinics can be optimized by only managing the patient arrival. As we expected, this is relatively the minimum first step towards improved service delivery and can be taken as a first step towards phase-by-phase optimization.

The next thing is optimization of the test and surgical centers. It is very difficult to put an average consultation time for both centers as the time it took for the test is dependent on the machine type, model, test complication and other factors. Similarly, it is also difficult to standardize the average time it took for a surgical procedures. In most cases, surgical procedures usually takes hours and then after the patient is expected to go to recovery room for two to three hours before admitting back to the hospital floor. Therefore, for both the test and the surgical centers, due to the difficulty of placing an average diagnosis and operation period, this research only considered an average waiting time of 30 minutes for the optimization.

Table 21. Recommended number of servers at test centers

Test Center	**Average number of patients per day**	**Existing number of machines in the clinic (s)**	**Existing average service rate, hr^{-1}, per server (μ)**	**Recommended number of machines in the clinic (s)**	**Change in number of servers in the clinic**
X-ray	98	2	2.08	2	-
Ultrasound	76	6	1.58	6	-
MRI	137	1	17.13	2	+1
CT scan	104	1	13.00	2	+1

Table 22. Expected improved service performance at test centers

Test Center	Improved average service rate, hr^{-1}, per server (μ)	Average number of patients in the system (L)	Average patients in Queue (Lq)	Average Time Spent, in min, in System (W)	Average time waiting, in min, in line (Wq)
X-ray	2.08	4.90	2.72	65.97	36.58
Ultrasound	1.58	4.17	-	29.64	-
MRI	8.56	8.12	6.52	35.54	28.54
CT scan	6.50	7.56	5.96	43.59	34.36

From this system optimization, there will be an improvement in the average waiting time at MRI center from the existing 42.48 minutes into 28.54 minutes, which is around 33% reduction. Moreover, deploying one additional test machine at the CT scan center will improve the existing 96.92 minutes of average waiting time into 34.36 minutes, which in turn is a progress on the waiting time by around 65%.

Table 23. Recommended number of servers at Minor Operation Center

<table>
<tr><th>Minor Operation Center</th><th>Average number of patients per day</th><th>Existing number of beds in the clinic (s)</th><th>Existing average service rate, hr^{-1}, per server (μ)</th><th>Recommended number of beds in the clinic (s)</th><th>Change in number of servers in the clinic</th></tr>
<tr><td>OR</td><td rowspan="4">19</td><td rowspan="4">4</td><td rowspan="4">0.59</td><td rowspan="4">5</td><td rowspan="4">+1</td></tr>
<tr><td>Ophthalmology</td></tr>
<tr><td>ENT</td></tr>
<tr><td>E & C</td></tr>
</table>

Table 24. Expected service improvement at Minor Operation Center

Minor Operation Center	Improved average service rate, hr^{-1}, per server (μ)	Average number of patients in the system (L)	Average patients in Queue (Lq)	Average Time Spent, in min, in System (W)	Average time waiting, in min, in line (Wq)
OR Ophthalmology ENT E & C	0.48	7.16	1.45	158.36	32.04

An addition of one surgical server on the minor operation center will improve the existing service by reducing the average waiting time from 86.04 minutes into 32.04 minutes, which is about 63% reduction and accordingly the average operation time will improve from 101.05 minutes into 126.32 minutes, which is a 25% improvement.

Table 25. Recommended number of servers at Major Operation Center

Major Operation Center	Average number of patients per day	Existing number of beds in the clinic (s)	Existing average service rate, hr^{-1}, per server (μ)	Recommended number of beds in the clinic (s)	Change in number of servers in the clinic
General Surgery Urology Paediatric	19	4	0.59	5	+1
Ophthalmology Orthopaedic Neuro-Surgery	63	8	0.98	11	+3

Table 26. Expected service improvement at Major Operation Center

Major Operation Center	Improved average service rate, hr^{-1}, per server (μ)	Average number of patients in the system (L)	Average patients in Queue (Lq)	Average Time Spent, in min, in System (W)	Average time waiting, in min, in line (Wq)
General Surgery Urology Paediatric	0.48	7.16	1.45	158.36	32.04
Ophthalmology Orthopaedic Neuro-Surgery	0.72	17.32	4.75	115.45	31.65

An addition of one surgical server on the General surgery operation center will improve the existing service by reducing the average waiting time from 86.04 minutes into 32.04 minutes, which is about 63% improvement and accordingly a 25% the average time improvement, which is from 101.14 minutes into 126.32 minutes. Meanwhile, the ophthalmology surgical operation center requires an additional three servers to improve the waiting time from 149.02 minute into 31.65 minute, which is around 79% improvement. In the meantime, the surgical operation time gets to improve from the existing 60.95 minute into 83.80 minute.

7. Conclusions

Findings from this study have showed that nearly three-quarter of the patients waited for more than 90 minutes, with high patient load coupled with few physicians being the main cause. To make the healthcare system more accessible and effective, there is an urgent need for the healthcare system to address the gaps in the human resources, equipment and logistics so as to manage the long waiting and short consultation times, thus to ensure effective and efficient health care delivery system.

As the current operating philosophy is "First Comes First Served" and unless the healthcare places an appointment system to implement a patient scheduling scheme, patients believe that a physician can see them earlier if they come earlier. Implementing and enforcing a staggered appointment system for patients and improve the clinics patient scheduling system, will ensure a smooth clinic process and will reduce the waiting times.

The healthcare needs to have a serious intervention on the dual practice, and regulate the existing poor implementations and lack of any significant control to ensure the positive outcomes and minimize its drawbacks.

Applying the queue theory from time to time will assure and support the healthcare managers and decision makers to apply a more effective and efficient scheduling system, in some probabilistic assumptions, and to standardize the consultation time duration and to minimize the time wasted in waiting.

In the meantime, the hospital shall take measures to reduce the patient boredom during this lengthy waiting time, within the constraints of the public healthcare delivery system. These measures can be using digital signage at the waiting area, as it is a proven action in effectively minimizing the perceived patient wait time. The patient will feel like they were there for a shorter waiting time because they were being entertained.

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If you want to give special thanks to someone that has helped you with your thesis, you can do it here.

Comments and questions (Bosona)

1. **Strong/weak parts**:
   -important topic
   -good data compiled
   -original work and less studied area/topic in Ethiopia
   Less strong part
   -A lot of undefined abbreviations (e.g. MRI,
   -methodology is less clear
   -assumptions are not clearly put
   -location explanation (and map is missing)
   -why this hospital was selected?
   -less introduction (and review work) about Ethiopia/addis health issues and situation at the selected hospital
   -data processing method is less explained (e.g. Table 10, you provide average values but how many data entries were there is not clear)
   -Why St.P. hospital is sellected ?
   -conclusion is weak and doesn't focus on addressing the objectives

2. You have many references. But only one article from Ethiopia (and 4 docments/reports). Why only one scientific article?
3. How was the historical service /queue condition before some years ago? Government institutions in Ethiopia have been implementing "service improvement plans" such as BPR (business process reengineering)? Do you think your result could be the same if the study was conducted 10 -15 years ago?
4. Edit carefully date/years----eg 2019 is written as 2020

5. If the study is repeated at other public hospitals in Addis, do you expect huge variation of results? What if private hospitals are considered?

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