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A Simulation Model As A Lean Tool To Improve Patient Flow And Utilization of Resources In Kenya's Public Hospitals: A Case Study of The Outpatient Department of Nyeri County Referral Hospital

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Abstract: *Simulation model is descriptive in nature, and mimics characteristics of a real system offering a better understanding of the system performance. However, over the years, it has been adopted in hospitals for improving healthcare processes and optimizing resources, but it has not been linked directly to the concept of lean management. Despite public hospitals in Kenya focusing on improving structures, communication technologies and adopting modern medical equipment, they have lagged behind in improving patients' preferences in relation to the care pathway processes and utilization of the available resources effectively. This paper reviews lean concept in healthcare, and how simulation can be adopted as a lean tool to improve patient flow in Kenya's public hospitals using the case study of a public hospital. The main waste identified in the care pathway was long patient waiting times, where often, patients at consultation room one waited for 0.94hrs, while for the pediatric room, the patient waiting time was as long as 0.64 hrs before they could consult the clinical officers. In the laboratory, patients tended to wait for a period of 0.66 hrs before being tested. To address these shortcomings, several processes were re-engineered using simulation model with a view of optimizing patient flow processes and utilization of available resource. The re-engineered processes included centralization of cash payment points, adoption of adjustable a capacity system for clinical officers, and addition of more resources at specific cash payment points, which were linked to long waiting times. Moreover, re-engineering was proposed for the filtering rooms and the laboratory to improve the patient flow.*

Key words: *Simulation, Lean, Patient Flow, Resources*

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I. Introduction

Lean concept started in Toyota Company with the intention to give the client quality goods quickly at minimum cost by utilizing the available resources efficiently and eliminating wastes in the chain processes. Over the recent years, lean concept has been applied in service industry particularly in healthcare to re-engineer clinical processes with a view of improving the patient flow and lessen waste (Fillingham, 2007).The key mandate of healthcare centers to is diagnose and treat patients at the right time and in the right way. This is achieved successfully only when the patient pathway is clearly defined and wasteful steps present in the care pathway eliminated. As statedby (Kannan, 2017), the lean thinking concept can be applied in healthcare to improve quality services, but the manner in which it is applied may contrast because clinical processes are sequenced uniquely, and different compared to manufacturing processes. Lean management in healthcare applies the value concept that quality healthcare service is delivered to the patient with minimal waiting time, from the time the patient arrives in the hospital until they are discharged (Joosten, Bongers, & Janssen, 2009).According to Slack, Brandon and Johnston, (2013)application of the lean concept in health care service not only improves the quality, but also ensures patient satisfaction by reducing delays and cost since it is based on patients' clinical needs and preferences. Simulation has become a decision-making tool for optimizing and analyzing patient flow as stated by Sheldon, Shane,and Swisher.,(2011), however, the approach is rarely discussed as a lean tool in the healthcare context Robinson,Radnor,Burgess and Worthington, (2012).Goienetxea, Zuniga and Urenda, (2005)alludes that the use of simulation saves considerable time, money, optimizes resources and may act as important basis for reducing the patient waiting times. In this regard, long waiting times are a wasteful step in care pathway according to Parr and Wicks, (2010), where on contrast, short throughput times directly relates to high patient satisfaction(Gentry, 2008). Therefore, elimination of wasteful steps in care pathways not only improves the quality of service but also enhances the patient satisfaction by reducing delays and cost (Slack, Brandon & Johnston, 2013).Quality in healthcare service is based on; time, effectiveness, efficiency, equity, safety and patient centered processes as indicated in the report by the Institute of Medicine(IOM, 2001).According to Friesen and McLeod,(2014), simulation offers opportunities of identifying bottlenecks and gives insights on the queue length, waiting time and number of patients waiting in a certain clinical process. The lean concept in healthcare is based on patients preferences and as stated by Gentry(2008), patients want to spend less time in queuing hence simulation should be adopted as a lean tool to achieve, quality services as per the patient's needs. The main deficiency of simulation as a lean tool is that it cannot model all practical situations which arise in the care pathway, and therefore there is always a margin of error considering processing time and routing probabilities according to patient severity (Armony, Israelit, & Mandelbaum, 2015);Hall et al.,(2006) and(Ghanes, 2016). Failure to adopt the lean principles in care pathways leads to several consequences which affect the quality of services offered to patients.

1.1 Impacts of Wasteful Steps in Care pathway

According to Choi and Jamjoom, (2013) long waiting times in outpatients' clinics leads to uneven flow and contributes to three key negative effects namely; pressure on doctors to shorten treatment time while maintaining quality of service delivery, increased complaints from patients hence distresses the medical staff, and patient distrust in the clinical processes. Wasteful steps in care pathways leads to adverse medical outcomes, added cost, congestion, patient dissatisfaction and demoralized staff as indicated by (Hall, 2008) and (Thomas, Lewkonia, & Diane, 2010). In clinics and hospitals across Africa, uneven patient flow has resulted to long waiting time which has been linked to cause poor medication compliance, missed appointments, delayed implementation of clinical programs, and low healthcare worker morale (Sastry & Long, 2014). `Stevenson , (2009)implies that waiting lines lead to loss of money if patients leave the line before being served and results to congestion in some stages of the patient flow.

1.2 Problem Environment

Globally public healthcare has faced challenges in rise of primary health services demand, while facilities and the number of specialists are not growing commensurately Jin and Lim,(2013), a challenge which can be overcomed by hospitals applying lean management principles to deliver quality services efficiently and effectively.As stated by Ahlsrom,(2004)quality service delivery is better translated to lean operations, but many public hospitals in developing countries tend to rely on regulations, standards from accreditation bodies and audits reports for improving the quality of healthcare services (Mate & Rooney, 2014). The government of Kenya in its health sector strategic and investment plan outlines key focus point which include; physical infrastructure, medical equipment, information and communication technologies and transport, however, strategies for improving clinical care pathway processes and patient outcomes are not mentioned(KHF, 2016). Donabedian,(1966) suggests that quality of healthcare services should be based on structures, clinical processes and outcomes and this shows the gap where often, less than optimal effort has been directed to address concerns surrounding clinical processes in view of achieve quality healthcare services, especially in Kenya's public hospitals. The study therefore, focused on evaluating clinical processes at outpatient department in Nyeri County referral hospital by using simulation model as a lean tool with a view to recommending strategies for eliminating wasteful steps present in the care pathway.

1.3 Case Study Hospital

Nyeri County referral hospital is a level five public hospital and the largest government healthcare center in Nyeri County.The outpatient department has filtering (rooms) clinics for patients with common health problems, follow up (consultation) clinics, eye clinic, dental clinic, Mother Child Healthcare and Family Planning (MCH/FP) clinic, Comprehensive Care Clinics (CCC), Ear Nose and Throat (ENT) among other clinics. The CCC clinics usually manage their patient records individually and all the services offered are free of charge. On average the outpatient unit serves seven hundred patients per day and as the patient volume increases, the hospital resources often become more strained, hence bottlenecks arise in the health system hindering provision of efficient, high quality patient care. Thus, this study proposes an adoption of lean management strategy to improve quality of services with the resources available.

II. Related Work

Hong et al., (2013) alludes that future studies should focus on quality improvement at the outpatient departments since previous studies have focused more on the emergency department. Their study formed the basis of choosing the outpatient department in place of inpatient and recommended equitable resource allocation, through use of optimization techniques. Several researchers have used discrete event simulation to model healthcare systems.Ibrahim, Najmuddin and Ismail, (2010) focused on improving patient waiting time in the gynecology department and observed long waiting times at the consultation room. The study recommended analysis of resources utilization, with a view of reducing idle time by the medical staff. Mocarrzel 2013) proposed a simulation model of patient admission in a multi- specialty outpatient clinic and found out there was an unbalanced in the patient schedule between those of new and existing patients throughout the day. However, they omitted the front desk services, and suggest future studies should focus on such services too.Takakuwa and Wijewickrama, (2008) performed a computer simulation study to optimize staff schedule in view of patient satisfaction for an outpatient hospital, where they examined the patient waiting times and queue lengths. This study only considered utilizing staff with an appointment system but did not consider patients requiring healthcare services without an appointment system.Elkhuizen et.al, (2008) used computer simulation to model strategies aimed at reducing access time for the outpatient departments, where the model indicated that 86%of the current capacity was sufficient to achieve a service level of 95%, when properly utilized. However, they failed to consider patients arriving at the outpatient department without appointments.Thomas, Lewkonia and Diane, (2010) used simulation modeling to model improvement strategies for patient flow processes at an outpatient orthopedic clinic. The study found out that performance improvements clearly resulted in less waiting time for patients and further recommended future work may entail identifying ways of avoiding adding staff first, by utilizing the available ones before adding more

III. Methodology

The simulation model followed the outlined methodology as proposed by(Rossetti, 2015).

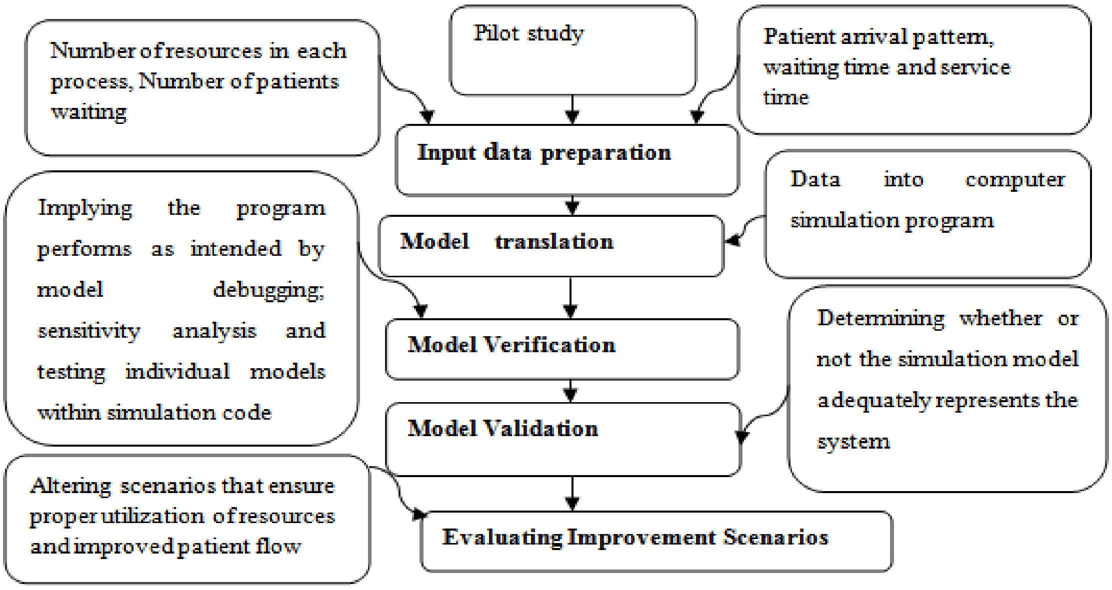
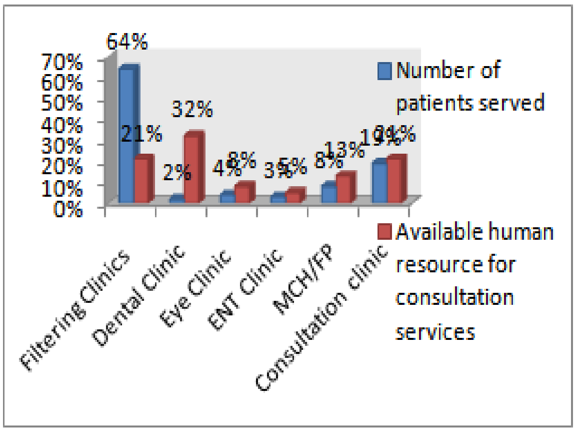


Fig1. Steps followed to build the simulation model

3.1 Pilot study results



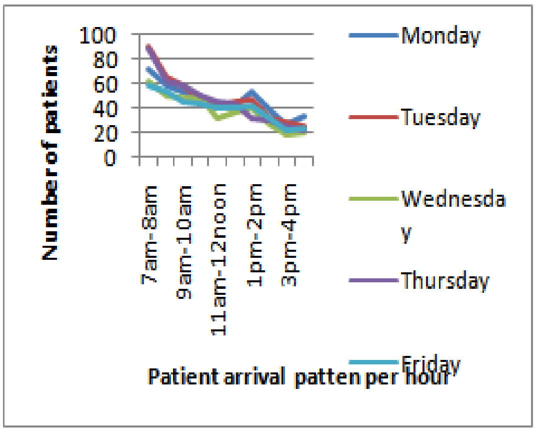


Fig 2. Average number of patients served daily **Fig 3.** Patient Arrival pattern

Source: Field data,(2017)

The study focused on the filtering (room) clinics due to the high number of patients served daily in relation to the number of medical staff available. The filtering clinics (rooms) included Gender Based Violence and Recovery Centre (GBRVC) for patients with gender based violence cases and for patients aged between 11 years and 24 years. The study also focused on room 1, for patients with common health problems who are aged above 24years. Room 6 was also evaluated and mainly serves patients below 11 years, while Room 5 for patients served patients with fractures and dislocations.
Patient arrives

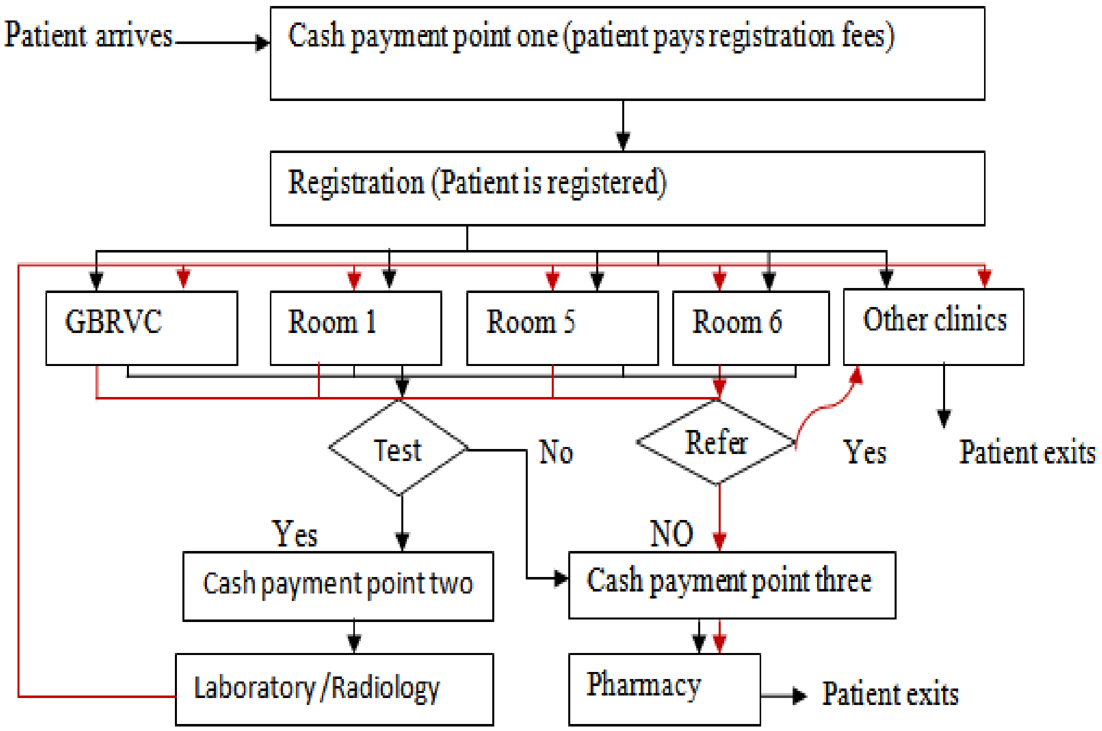


Fig 3 Care pathway of patients visiting the filtering rooms

IV. simulation

4.1Simulation Abstraction

Each cash payment point had one clerical officer, two health records officers at the registration point, one clinical officer in each filtering room, three laboratory technologists, one radiologist and one pharmacist.The patient arrival followed a schedule which captured on average, the number of patients arriving per hour.

Table 1 The service time at each unit

UNIT	Expression (Minutes)
All Cash payment points	Triangular (0.6,0.8,1)
Registration	Weib (1.41,1.38)
Triaging	Triangular (1, 1.63,3.31)
Consultation	Expo (4.84)
Laboratory	ERLA (9.37 , 2)
Radiology (X ray)	Triangular ((3,4,5)
Pharmacy	BETA(0.713 , 1.4),

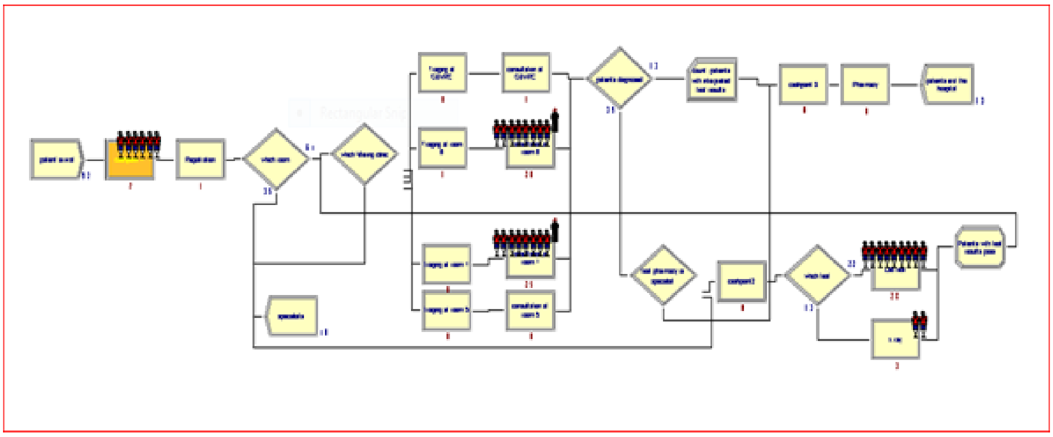


Fig 4. Arena simulation model of filtering clinics at outpatient department

To incorporate effect of deviation, 5 replications were modeled to represent the five days where all units in Outpatient Department are operational .The outputs of the model are the averages of the replication results.

4.2Performance measures

The main objective of the study was to improve patient flow and utilization of resources. The researcher therefore focused on the utilization of the available resources, and clinics where patients spend more time waiting for clinical services, and the number of patients waiting in each clinic.

4.3Verification and Validation of the simulation model.

The researcher verified the simulation by debugging the model and clearing all errors such as failure to release the resources. The researcher also performed sensitivity analysis by verifying factors to ensure compliance with anticipated behavior. This was tested by increasing the number of patients and this would imply that the resources especially in the Room1, Room6 , laboratory and clerical officer at payment point one will be more strained. By comparing the observed waiting time and the simulation waiting time the question of whether the model represented the current situation and was valid was answered.

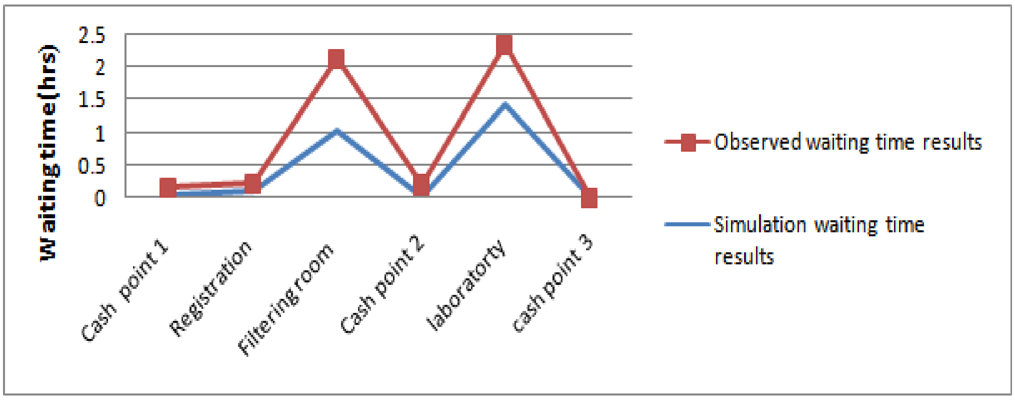


Fig 5.Simulation waiting time and observed waiting time

Table 2 Comparison of Simulation waiting and Observed waiting time

Unit	Simulation Results	Observed Result	Deviation
Cash point 1	0.03	0.128	-0.098
Registration	0.1	0	0.1
Room one	1.03	2.3	-1.27
Cash point 2	0	0	0
Laboratory	1.44	1.55	-0.11
Cash point 3	0	0	0

According to Kelton et al., (2007) deviations that stay below 10% suggest that the model mimics the systems flow and reality. Figure 5 showed that the simulation model mimicked the real system since the deviation for all cash payment points and the registration were less than 10%. Even though, filtering room and laboratory slightly deviated from observed time, part of this was due to clinical officers leaving the filtering rooms to attend to emergencies, health breaks, handover at the end of shifts, and medical staff reporting late to work. Such factors were not considered by the simulation model since the issues were out of scope of this study.

4.4Simulation Results

The simulation model highlighted three areas which needed improvement where patients spend more time waiting and where often staff was underutilized. This included the cash payment point one, which compared to other payment points, was often associated with long waiting times. Other areas where staff were underutilized included Room 5 and GBRVC , which contrasted to the Room 1, Room 6 and the Laboratory.

Table 3 Simulation results

Unit	Waiting time(hrs)	Scheduled utilization	Number of patients in the queue
Cash payment point 1	0.02	0.64	1
Cash payment point 2	0.00	0.22	0
Cash payment point 3	0.00	0.20	0
Registration	0.00	0.49	0
Room 1	0.94	1.00	45
GBVRC	0.18	0.42	0
Room 5	0.02	0.38	0
Room 6	0.64	1.00	8
Laboratory	0.66	0.91	6
Radiology	0.04	0.46	0
Pharmacy	0.00	0.09	0

Improvement Scenario (What –if Analysis)

Cash payment points

In the cash payment points, control points were modeled, which in this study, included the number of clerical officers. The responses on the other hand to the modelled control points included the number of patients queuing in each payment point and also the percentage utilization of the clerical officers.

	Scenario Properties			Controls			Responses					
	S	Name	Reps	Cashier 1	Cashier 2	Cashier 3	cashpoint 1.Queue.NumberInQueue	cashpoint 3.Queue.NumberInQueue	cashpoint2.Queue.NumberInQueue	Cashier 1.Utilization	Cashier 2.Utilization	Cashier 3.Utilization
1		Current Status	5	1.0000	1.0000	1.0000	1.439	0.032	0.037	0.638	0.218	0.206
2		Two cashiers at payment point one	5	2.0000	1.0000	1.0000	0.055	0.022	0.029	0.316	0.224	0.206
3		A set of three cashiers at point one	5	1.0000	1.0000	1.0000	0.022	0.003	0.009	0.348	0.346	0.351
4		Three clerical officers at point one	5	3.0000	1.0000	1.0000	0.007	0.035	0.042	0.207	0.226	0.217

Table 4 Process analyzer improvement scenarios at payment points

The main bottleneck in revenue unit was at payment point one where the clerical officer was 63.8% utilized compared to clerical officers at payment point two and three who were 21.8% and 20.6 % utilized respectively

Filtering rooms

In the filtering rooms, the control points modeled were the number of clinical officers in each filtering room, while the responses here included the number of patients in each queue and the utilization of the clinical officers.

	Scenario Properties			Controls				Responses							
	S	Name	Reps	CEO at room 1	CEO at room 5	CEO at room 6	C E O at GBVRC	C E O at GBVRC.Utilization	CEO at room 1.Utilization	CEO at room 5.Utilization	CEO at room 6.Utilization	consultation at GBVRC.Queue.NumberInQueue	consultation at room 1.Queue.NumberInQueue	consultation at room 5.Queue.NumberInQueue	consultation at room 6.Queue.NumberInQueue
1		adjustable capacity	1	1.0000	1.0000	1.0000	1.0000	0.924	0.974	0.996	0.964	3.353	5.930	10.513	3.809
2		current status	5	1.0000	1.0000	1.0000	1.0000	0.374	1.000	0.374	0.850	0.316	42.359	0.332	4.203
3		2 CEO at rm 1	5	2.0000	1.0000	1.0000	1.0000	0.375	0.965	0.485	0.939	0.155	7.702	0.500	8.596
4		3 CEO at rm 1	5	3.0000	1.0000	1.0000	1.0000	0.395	0.666	0.543	0.933	0.221	0.464	0.413	7.474
5		,3 CEO at rm 1 , 2 at rm 6	5	3.0000	1.0000	2.0000	1.0000	0.406	0.638	0.466	0.513	0.229	0.433	0.286	0.349
6		4 CEO at rm 1, 2 at rm 6	5	4.0000	1.0000	2.0000	1.0000	0.435	0.479	0.573	0.582	0.317	0.060	0.454	0.618
7		2 CEO at rm 1, 2 at rm 6	5	2.0000	1.0000	2.0000	1.0000	0.459	0.947	0.562	0.588	0.451	9.009	0.543	0.811

Table 5 Process analyzer improvement scenarios at filtering rooms

Bottlenecks in filtering rooms were at room 1 and room six where the clinical officers at room one and room six were 100% and was 85.8% utilized compared to clinical officers at room 5 and GBVRC 33.2% and 31.6 % utilized respectively.

Laboratory

The controls included laboratory technologists and the responses in terms of the number of patients in queue, the number of patients waiting time and the utilization of the technologists.

	Scenario Properties			Controls			Responses				
	S	Name	Reps	technologist 1	Technologist 2	Technologist 3	Lab test.Queue.NumberInQueue	Lab test.Queue.WaitingTime	Technologist 3.Utilization	Technologist 2.Utilization	technologist 1.Utilization
1		current	5	1.0000	1.0000	1.0000	5.445	0.556	0.899	0.901	0.893
2		add one technologist	5	2.0000	1.0000	1.0000	1.099	0.106	0.794	0.775	0.664
3		add two technologists	5	2.0000	2.0000	1.0000	0.329	0.031	0.753	0.583	0.655
4		add three technologists	5	2.0000	2.0000	2.0000	0.171	0.016	0.494	0.506	0.492
5		add four technologists	5	3.0000	2.0000	2.0000	0.016	0.002	0.503	0.498	0.330

Table 6 Process Analyzer improvement scenarios at the laboratory

The utilization of laboratory technologists was over 85 percentage and patients still experienced long waiting time

Conclusion

Payment points

For the payment points, several scenarios were evaluated. Adopting the lean concept, the best scenario was having a set of three clerical officers rather than adding more clerical officers at payment point one. Adding more clerical officers would lead to increased labour. A set of three clerical officers would imply that the payment points to be centralized and have a balanced utilization of 34%.

Filtering rooms

Clinical officers at room 1 and room 5 were 100 % utilized as illustrated in Table 5 .Basing the decision on lean management principles adopting adjustable capacity system for clinical officers would lead to 90% utilization of all clinical officers. The adjustable capacity system, involves ability to use available employees at any given time. The clinical officers therefore should be trained to treat all patients with common health problems. However, if clinical officers are bound to see patients in their area of specialization then, the hospital should consider adding two clinical officers in room 1 and one more clinical officer in room 6.

Laboratory

The best improvement scenario would be adding three technologists in the laboratory in order to reduce the waiting time of patients as illustrated in Table 5.

Future Work

Future studies should focus on the other of patient flows, with the aim of reducing the waiting time for the patients and utilizing the resources more optimally too, including the medical devices and beds in the inpatient unit . For a hospital to be entirely lean it should incorporate the suppliers. The future studies should assess the pull strategy system of supply chain, the lead times and reorder points of medical stock in order to reduce inventory waste but ensure patient wants are catered for.

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