Waiting time and Resource Allocation for Out-patient Department: A case of Mwananyamala Hospital in Dar es Salaam, Tanzania

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Abstract

Long waiting time in Health care facilities remains a major problem in Tanzania, mostly due to increased demand, shortage of medical health professionals and underdeveloped health care system. We attempted to estimate the average waiting time and find the best scenario in reducing out-patient waiting time. Mwananyamala Hospital was selected purposively, as a Regional government hospital in Kinondoni District, Dar es Salaam. A total of 200 selected patients attended OPD from 16th July to 15th August 2018 were observed and recorded the arrival time at each one-minute interval. Results show that patients at Mwananyamala hospital spend an average waiting time of 167 minutes, with a maximum waiting time of 243 minutes (4 hours). Simulation time was 540 minutes (9 hours) under the assumption that the OPD operates from 7:00 am to 4:00 pm. Simulation results suggested the best resource allocation at the OPD be obtained after adding two more staff, a medical doctor and a registration staff, leading to an average waiting time of 38 minutes, which is almost 4 times less than the current situation. These findings demonstrate how simulation can be used to inform hospital management with valuable data to enhance efficiency in managing out-patients.

Keywords: simulation, outpatients, waiting times, Mwananyamala

1. Introduction

Health facilities in Tanzania have been experiencing an increasing number of out-patients due to increase in demand (population and health-related problems). Tanzania, like other Sub-Saharan African countries, faced a high population growth rate. The population of Tanzania has grown by 10,485,399 persons (NBS, 2012), approximately 30 per cent increase since 2002 (Agwanda and Amani, 2014). The growth of population leads to overcrowding at the health facilities particularly OPDs. This forces patients to spend considerable long waiting time at the OPD due to imbalance with resources such as inadequate funds, human resource deficiency (low doctor-patient ratio, shortage of drugs, poor management and institutional infrastructure.

Waiting for services has become an inevitable situation in our day to day life. Waiting time is among the very important parameters in evaluating the quality of the services and patients' satisfaction with services in health facilities (Tran et al., 2017). Castro (1993) indicated that patients flow and the waiting time are useful features in determining the efficiency of health care services as well as the satisfaction of patients at the Out-patient Department. Jamjoom et al. (2014) pointed out that the out-patient departments must work hard to reduce the waiting time to improve the quality of services they provide.

A study by Umar et al. (2011) found that a patient is more satisfied if he/she waits for a short time (less than one hour) and those who wait for more than an hour are dissatisfied with the service and they can leave the department even before getting the service. Khamis and Njau (2014) indicated that 80 per cent of patients attending hospitals/health facilities are out-patients. Thus, the OPD becomes the crucial area to assess the quality of health services provided by the health facility. This study is highly motivated by the experience of overcrowding at the hospitals' OPDs in Tanzania and many other African countries.

Several studies in Tanzania have been conducted to explore perceptions and satisfaction of health care services (Juma and Manongi, 2009; Leshabari et al., 2008; Khamis and Njau, 2014; and Festo, 2015). However, very limited studies in Tanzania studied patient waiting time and how to reduce the long out-patient waiting time (Mahfoudh, 2002 and Umar et al., 2011). Although these studies have been conducted, none has been done on the application of discrete event simulation in improving health care services. Application of discrete-event simulation time is very limited in countries like Tanzania through highly used in developed countries.

2. Methods

2.1 Study design and Sampling design

The study was a cross-sectional study. All out-patients seeking the health services at Mwananyamala hospital's OPD were considered as the study population. This study used simple random sampling and purposive sampling techniques. The Mwananyamala hospital's OPD was selected purposively. This hospital is a Regional Referral Hospital run by the government of the United Republic of Tanzania and is always overcrowded by patients.

Sample size determination

The sample size was calculated using a 95 per cent confidence interval and 7.2 per cent marginal error (e). Through simple random sampling, different sample sizes calculated by Weisberg and Bowen (1977) can be used as shown in Table 1 (see Rashidi, 2019).

Table 1: Sample size with the maximum error

Sample sizes	Error
2,000	2.2
1,500	2.6
1,000	3.2
750	3.6
700	3.8
600	4.1
500	4.8
400	5.0
300	5.8

200	7.2
100	10.3

Source: Weisberg and Bowen (1977)

In this case, the sample size was 200. Indeed, this sample size was calculated using the following formula;

$$n = \frac{z_{\frac{\alpha}{2}}^{2} p(1-p)}{e^2}$$

where;
n = Sample size
z = Z score (ordinate of the standard normal curve at 95% confidence level)
α = Significance level
e = Specified margin of error
p = Proportion of attribute of interest

The study used 7.2% marginal error (e), 5% level of significance (α) and z value is 1.96 at 95% confidence level. Using this formula the sample size obtained is; $n = \frac{1.96^2 * 0.5 * 0.5}{0.072^2} = 185.26 \approx 185$. But the study increased the sample size to 200 respondents as suggested by Weisberg and Bowen (1977). A sample of 10 systematic units was observed per day that makes 200 observations in 4 weeks.

2.2 Data collection

Direct observation and interview approaches were used to collect the primary data for 200 outpatients for the study between 16th July and 15th August 2018. Data collection was conducted between 7:00 am to 4:00 pm. Patients with a critical condition (Patients with emergencies) and children were not included in the study. In performing Discrete Event Simulation X-ray/ultrasound section was excluded due to less information obtained and also it was observed that this service point is an independent department with very few patients from OPD.

2.3 Data Analysis

The data on arrival time was entered into Microsoft Excel and then analysed to determine the arrival distribution and inter-arrival time distribution of the patient arrivals. Therefore, the arrival of patients in this study was modelled as a Poisson process. The data on a patient path, average service time at each service point, service time distribution, arrival distribution and inter-arrival time distribution were used in Discrete Event Simulation (DES) under 5 scenarios. The analysis was done in R software using "Simmer" and "simmer. plot" packages.

The Mwananyamala hospital Patient path abstraction was designed under four service points namely; registration (with 4 staff), consultation rooms (9), LAB (technicians are 2) and pharmacy (with one staff).

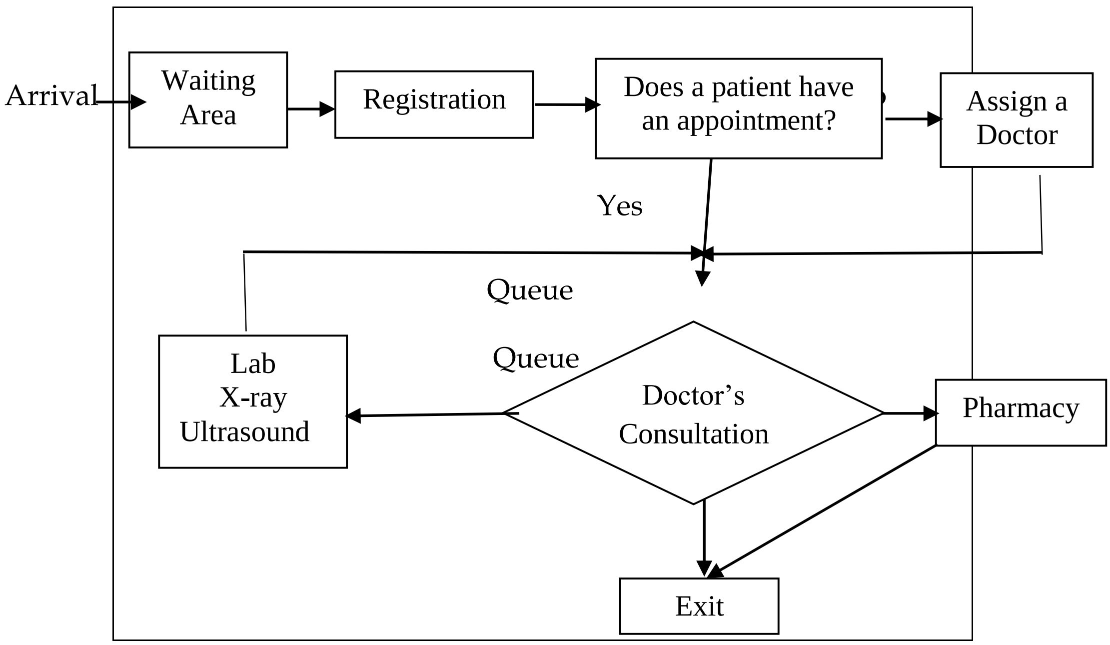


Figure 1: Abstraction of Patient Flow for outpatient department

2.4 Ethical considerations

The permission to conduct the study was sought and obtained from the UDSM and the office of Regional Commissioner of Dar es Salaam Region. Research permit and ethical clearance were obtained from the management of Mwananyamala. Patients who participated were asked and fill-out has written consent before participation. Confidentiality was highly maintained whereby names of respondents or diseases were not asked or written anywhere in a questionnaire. Identification numbers were assigned to every respondent.

3. Results

3.2 Average waiting time

The average waiting times were computed and summarized in Table 2. It is clearly shown that patients experience longer waiting time at various service points, at the doctor's room with an average waiting time of 46 minutes (Pre/Post Consultation), followed by registration point with an average waiting time of 26 minutes.

Table 2: Descriptive statistics of average waiting time at the OPDs

Service point	*Mean*	*Median*	*Std. Deviation*
Registration	26.45	11.00	43.66
Pre-Consultation	45.59	30.00	46
Laboratory	40.77	34.50	31
Post-Consultation	45.48	39.00	37
Pharmacy	8.53	6.00	8
Overall	166.82		

At the OPDs the average waiting times of both pre-visit and post-visit give total average waiting time of 91 minutes. The overall average waiting (queuing) time at the OPDs is 167 minutes. These results show that in the waiting time before seeing a doctor is much longer than waiting time in other service points.

3.3 Patients' system time

This refers to the overall time spent by the patient in a system while waiting for the service and time when a patient is with health personnel receiving the service. Patients' waiting time in the system is presented in Table 3. It shows that more than 46 per cent of out-patients spend more than three (3), 3.5 per cent spend 1 to 2 hours and 2 per cent spend less than an hour.

Table 3: Patients' system time

System Time (minutes)	*Number of patients (per cent)*
Less than 30	1(0.5)
30-60	3(1.5)
61-120	7(3.5)
121-180	20(10)
181-300	92(46)
more than 300	77(38.5)
Total	200(100)

3.4 Arrival process

Patient arrivals during one-minute intervals during a day were observed and recorded in a form that shows the arrival time and number of patients who arrived. The data were analyzed using the arrivals recorded from 7:00 am to 4:00 pm. The analysis of the arrival process began with the computation of the arrival rate (number of arrivals per minute). The computed arrival rate was then approximated to = 1.4 as shown in Table 4.

Table 4: One-minute interval Arrivals

No. of Arrivals	*No. of One-minute intervals*	*No. of Arrivals * No. of intervals*
0	114	0
1	199	199
2	147	294
3	59	177
4	13	52
5	6	30
6 or more	2	12
Total	540	764

Arrival rate (λ) = $\frac{\sum(\text{No.of arrivals} * \text{One-minute interval})}{\sum \text{One-minute interval}}$ = 764/540= 1.41

The probabilities (P_n) were computed using a Poisson distribution with λ = 1.4. The Expected frequencies were then computed by multiplying the probabilities by the total number of one-minute intervals, in this case, 540.

Table 6: Computation of the Expected number of one-minute intervals

Number of Arrivals	*No. of one-minute intervals*	*Probability of arrivals*	*Expected Value*
(n)	**(O)**	**(P_n)**	**(E)**
0	114	0.2466	133.164
1	199	0.3452	186.408
2	147	0.2417	130.518
3	59	0.1128	60.912
4	13	0.0394	21.276
5	6	0.0111	5.994
6 or more	2	0.0032	1.728
Total	540	1	540

In Table 6 the probabilities were computed using the table of cumulative Poisson probabilities. Some of the cells for expected frequencies contain values less than 5 which do not satisfy the condition of using a chi-square test. The chi-square test requires that the expected frequency of each cell be greater or equal to 5. Hence the cells with 5 and 6 or more arrivals were combined and their probabilities as well.

Table 7: χ^2 test of goodness of fit for Poisson arrivals

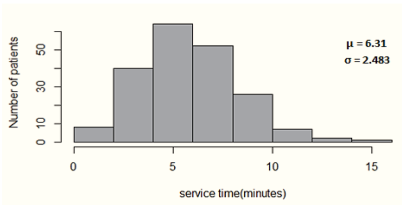
Number of Arrivals (n)	*Observed frequency* (O)	*Probability of arrivals* (P_n)	*Expected Value* (E)	*(O-E)²*	$\frac{(O-E)^2}{E}$
0	114	0.2466	133.164	367.2589	2.757944
1	199	0.3452	186.408	158.5585	0.850599
2	147	0.2417	130.518	271.6563	2.081371
3	59	0.1128	60.912	3.655744	0.060017
4	13	0.0395	21.276	68.49218	3.219222
5 or more	8	0.0143	7.722	0.077284	0.010008
Total	**540**	**1**	**540**		**8.9792**

Table 7 shows that, computed chi-square value (χ^2)≈ 8.98. The number of intervals remaining after combining some intervals is 6, one (1) parameter ($\boldsymbol{\lambda}$) was estimated and therefore degrees of freedom is 4. However, the tabulated chi-square values at 5percent and 1percent levels of significance with 4 degrees of freedom are 9.49 and 13.28 respectively. This implies that the assumption of arrivals to follow a Poisson distribution is not rejected, and concluded that the arrivals follow a Poisson distribution with mean arrival rate $\boldsymbol{\lambda}$ =1.4 patients per minute with the mean $\frac{1}{\lambda}$ = 0.71429≈0.7 minutes, which is the average time between arrivals.

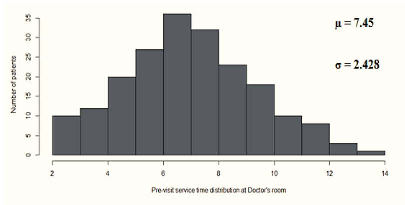
3.5 Service times

The test of normality of service times indicates that registration and pre-consultation tend to follow a normal distribution as visualized in histograms in Figure 2 (a) and (b). As for the other three service points; laboratory, doctor's post-visit consultation and pharmacy, their p-values are less than the significance level 0.05 and hence we rejected the hypotheses that they tend to follow the normal distribution.

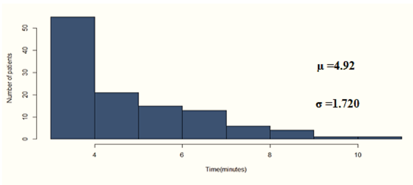
The histograms in Figure 2 (c) and (d) show that the service time distributions at the pharmacy and Laboratory resemble an Exponential distribution while for 2 (e) resembles the uniform distribution. Test for uniformity was carried out by using the Kolmogorov- Smirnov test (K-S test) and obtained a p-value of 0.09 which is greater than the significance value 0.05, therefore the hypothesis that the post-visit consultation follows the uniform distribution is not rejected and concluded that the post-visit service time follows the uniform distribution.



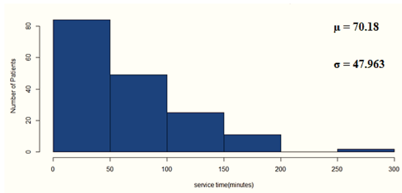
(a) Registration



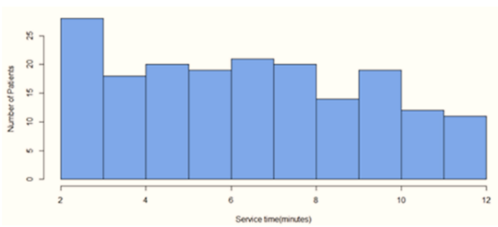
(b) Pre-visit consultation



(c) Pharmacy



(d) Laboratory



(e) Post Consultation

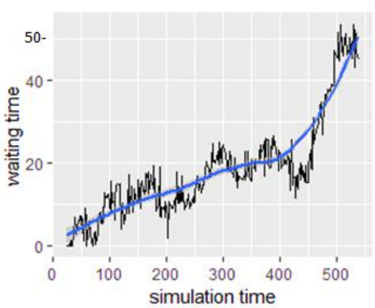
Figure 2: Histogram of service time distribution

3.6 Simulation Scenarios for reducing waiting time at the OPD

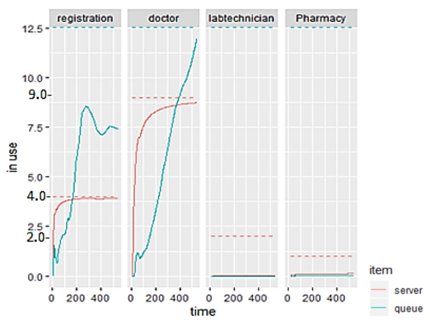
The parameters representing the current situation at the OPD which are needed for simulation were obtained from the initial information from the OPD in charge. It was informed that the OPD has four (4) staffs at registration, nine (9) doctors, two (2) LAB technicians, and only one (1) pharmacist. OPD operates 24 hours but for this study, the simulation was done based on the 9 hours/540 minutes (from 7:00 am to 4:00 pm) of work for which the data were collected. Based on the analysis of arrival and service time at four service points selected the following: Service at registration is *Normal (6.31, 2.483)*; Consultation (pre-visit) time is *Normal (7.45, 2.428);* Pharmacy is *Exponential*(4.92 minutes); Laboratory is *Exponential(70.18 minutes)* and post-visit consultation is *Uniform[2,12]* minutes.

Scenario 1: Current situation

First, DES was performed using current inputs at the OPD to observe the bottleneck service points. Figures 3 (a) show average waiting time and (b) the simulation results for the current parameters. Figure 3 (a) shows that the average waiting time patient spends before service start is 50 minutes. The dotted red lines in Figure 3 (b) indicate the number of servers at each service point. The results show that doctor's consultation point is facing long queue than any other service point and followed by registration point.



(a) Average waiting time

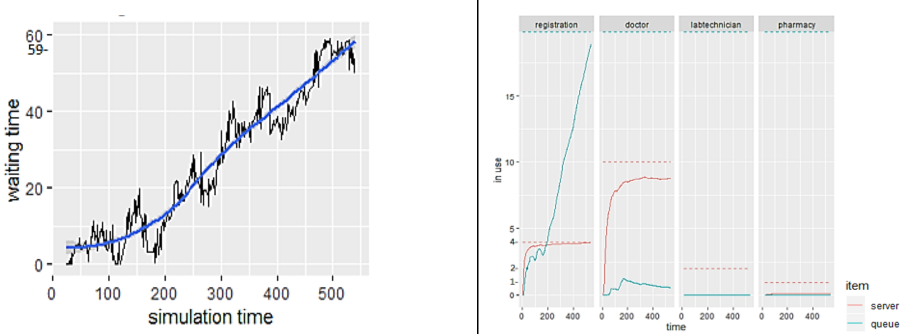


(b) Resource usage and queue length

Figure 3: Average waiting time, resource usage and queue length for the Current Situation

Scenario 2: Waiting time after adding one more doctor

In this scenario, one more doctor was added and keeping the same number of staffs in remaining service points. The analyses of results are shown in Figure 4 (a) and (b). Results in Figure 4 shows that waiting time (queuing time) has increased when only one more doctor was added. Waiting time increased to 59 minutes while queue shifted to registration point (see Figure 4). Figure 4 (b) shows that the queue shifted to registration with more than 20 patients waiting. This means that the increasing number of doctors alone is not a solution to the issue. The dotted red lines in Figure 4 (b) indicate the number of servers at each service point.



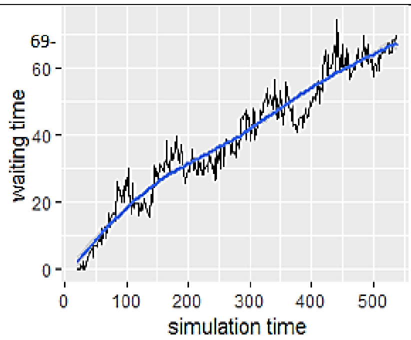
(a) Average Waiting Time

(b) Resource usage and queue length

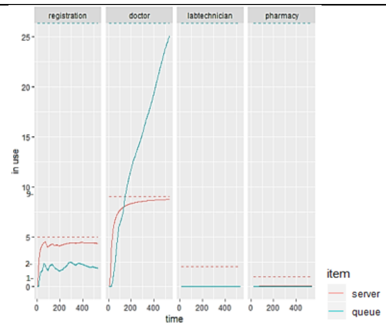
Figure 4: Average waiting time, resource usage and queue length when one doctor was added

Scenario 3: Waiting time after adding one more registration staff

In this scenario registration staffs increased to 5 and keeping the same number of staffs in other service points and the results are in Figure 5 (a) and (b). Waiting time increased to 69 minutes when one more registration staff was added. Figure 5 (a) and (b) shows that the bottleneck shifted to doctors' consultation with queue length at consultation point being 25 patients. Therefore, an attempt to increase more staff at the registration point alone cannot help to reduce waiting time.



(a) Average Waiting Time

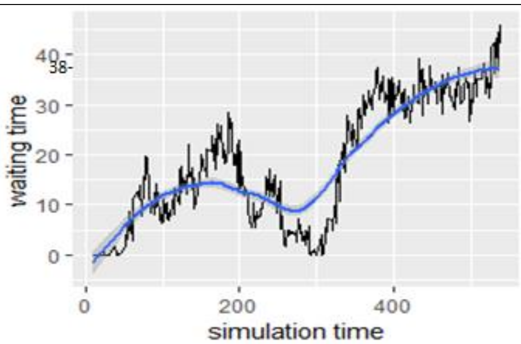


(b) Resource usage and queue length

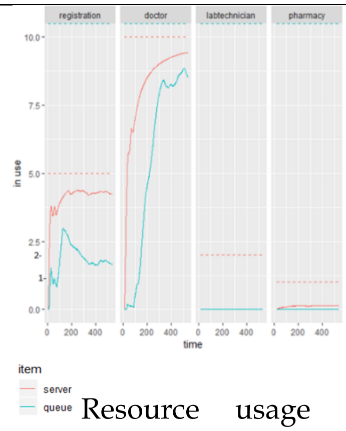
Figure 5: Waiting time evolution when one more staff at the registration was added

Scenario 4: Waiting time after adding one more doctor and one more registration staff

Under this scenario, we increase the number of doctors to 10 (one doctor added) and registration staffs to 5 (one registration staff added) and then keeping the same number of staffs in other service points. The result of waiting time is shown in Figure 6.



(a) Average Waiting Time



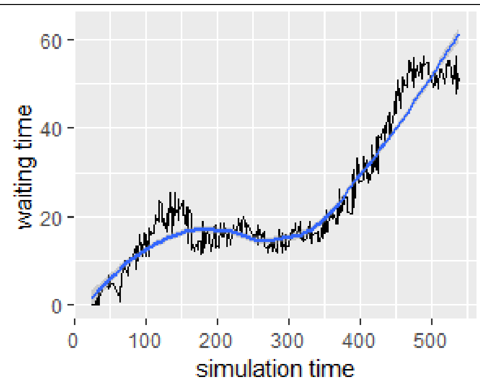
Resource usage and queue length

Figure 6: Waiting time evolution when one doctor and one staff at the registration was added

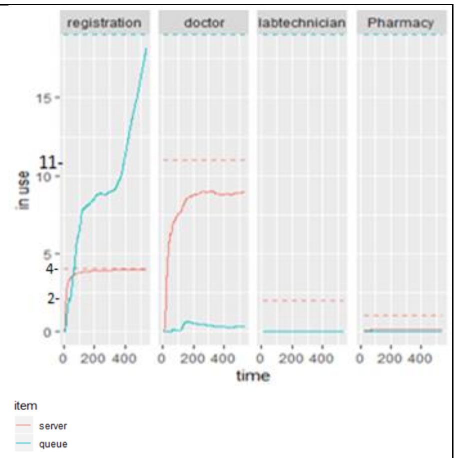
Figure 6 shows that the allocation of five (5) staff at registration and ten (10) doctors reduces the waiting time to 38 minutes. Resource usage and queue length are shown in Figure 6 (b) which shows that the queue reduced from registration and also is short at the consultation point. This suggestion gave the best results on the waiting time of all the previous suggestion. The study also tried to suggest another scenario to see if it could be better than this.

Scenario 5: Waiting time after adding 2 more doctors

Under this scenario, the number of doctors increased to 11 doctors while keeping the same number of staffs in other service points. The results are presented in Figure 7 (a) and (b). Figure 7 shows that the average waiting time is now more than one hour if only doctors increased by 2 (Number of doctors increased to 11). The waiting time in Figure 7 is still longer than average waiting time in scenario 4 and an attempt to increase only the number of doctors brings no relief on the waiting time at the registration point. The queue is still higher than in the previous scenario.



(a) Average Waiting Time



(b) Resource usage and queue length

Figure 7: Average waiting time when the only number of doctors changed to 11

4. Discussion and Conclusion

Health care services have been experiencing overcrowding and inefficient in the provision of services because management has not been able to control the flow of excessive patients Overcrowding should be managed by evaluating inputs at different service points. Because of Musinguzi (2015), this study aims at improving waiting times at health facility, under the hypothesis that waiting times is not a result of few medical doctors in the health facility.

Based on the service point results, patient waiting time is the longest at consultation (pre-visit) with an average waiting time of 45.59 minutes whereas the service point with the shortest waiting time being a pharmacy with an average waiting time of 8.5 minutes. The bottleneck of waiting time is at consultation pre-visit and consultation post-visit which are approximately 46 minutes and 45 minutes respectively.

Let us return to the hypothesized statement that increasing the number of doctors may lower the waiting time and therefore, improve overcrowding. A discrete event simulation suggests that Mwananyala hospital can reduce the average waiting time (queuing time) from 166 minutes to 38 minutes by allocating 5 registrars at the entry point, 10 medical doctors, 2 laboratory technicians and 1 pharmacist, as indicated in scenario 4.

The results agree with the findings of Hamrock et.al (2013) that increasing the number of doctors alone does not improve the waiting time as indicated in scenarios 2 and 5. Solving this problem requires adding a medical doctor as well as registration staff, as indicated in scenario 4. Therefore, Scenario 4 remains the best way to allocate the resources (doctors/physicians, administrative staffs) at the Mwananyamala OPD to improve the queue length as well as the waiting time.

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