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Full Length Research Paper

Performance evaluation of law enforcement agency on crime information management using queuing network model

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One of the greatest challenges facing every society today is crime control and management. It could be as little as pick–pocketing, or human trafficking, or even as deadly as terrorism. As criminal's perfect ways of avoiding being detected, Law Enforcement Agencies (LEAs) must adopt innovative ways on crime prevention and control. This research applies Queuing Network (QN) model to evaluation the performance of LEAs on crime information management. The QN comprise two queuing theory models; single server (M/M/1) and multiple server (M/M/m) queuing models. To implement this model, crime data was collected from Eleme (2012) and Nsukka (2013) police stations with a table format to capture the timing such as case arrival time, service time (investigation and handling time) and termination time. The model was implemented using PHP programming language Excel application was used to plot some graphs to observe the system's behaviour. The case timing captured (input data) were used to calculate the queuing theory performance measures (model parameters). Results from the analysis shows how many cases were handled by how many staff members in a specified period of time. This model will make LEA's crime management system visible at different levels (local, state and federal) to both government, LEA's admins and general public. Government can assess the LEA's performance at any time. Use of this model will improve LEA's productivity and public security as well.

Key words: Crime management, information system, law enforcement agency, performance evaluation, queueing network, single server queuing model, multiple server queueing model.

INTRODUCTION

The driving force behind the continued adoption of information technology (IT) has been an ever increasing need to organize, and more rapidly access information necessary for the performance of various activities of government, non-governmental agencies, organizations and equally the Law Enforcement Agencies (LEA) (Texas Department of Public Safety, 2016). Today, appropriate application of IT is a very critical success factor for

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optimum functioning of any organization. LEA is one of the four major components of the criminal justice system along with prosecutors, courts and corrections agencies. LEAs at different levels of governments are charged with the responsibilities of providing first response to emergencies and threats to public safety, the protection of certain public facilities and infrastructure, maintenance of public order, and protection of public officials (Ehindero, 2006). The effective sustenance of any society is hinged on an efficient law enforcement process (Emmanuel, 2005). There are many LEAs and other governmental agencies established by government as a laudable effort towards crime prevention and control, yet crime is on the high rate of prevalence in the world today (Anthony, 2013).

In a developing country with high population density like Nigeria, it is becoming more difficult for the LEAs to control law and order, leading the society to an increase in the rising wave of crime. Unautomated static nature of the LEA's system has made crime information flow within LEA to be inefficient. This results to a long term crime information processing, bribery and corruption, lack of appropriate flow of information in difference levels of LEA, etc. Crime information in LEAs is sometimes handled indefinitely without any body querying what is happening in the system. Based on the aforementioned problems, there is need to use an appropriate modelling approach to support the operations of the LEA such as time of capturing crime data from an informant to an agency, and throughout the life of that crime case within any of the agencies. This enables visibility of the operations of LEA crime information management to the government and the public at large. For this purpose, queueing Network model as an aspect of queueing theory (QT) concept was adopted.

QT deals with one of the most unpleasant experiences of life, that is, waiting. It is the mathematics of waiting lines. It is useful in predicting and evaluating system performance (http://williams.comp.ncat.edu/comp755/Q.pdf). QT is often used when making business decisions about the resources needed to provide an effective service. Queuing models help managers make decisions that balance service costs with waiting-line costs.

This article deals with how LEAs especially in developing countries capture crime information electronically and manage it at different levels of their operation (local, state and federal). The focus of the research is to apply queuing network model to evaluate the performance of LEAs on crime information capture and management to support the LEAs in performing their duties.

In order to apply this queueing network effectively, an Integrated Crime Information System (ICIS) for LEAs was developed to enable electronic crime information to be reported to LEAs by an informant or any crime eye witness within the country. This system captures relevant time during the flow of this report such as: crime case arrival time, time it was received by a receptionist staff (e.g. police station), time the case was forwarded to an officer that will handle the case, time investigation started and ended. If this crime case is forwarded to a higher level (state or federal), the system captures the time for that level (Ugwuishiwu, 2016).

Queueing model input parameters; case arrival rate (λ) and case service rate (μ) were used to calculate the performance measures of the two models used in this work such as average number of customers in the system, average time a customer spends in the system, average number of crime cases waiting on the queue etc. Analysis was carried out on the result generated from the performance evaluation and some useful results were obtained. QN was used to determine the rate of crime information flow in LEA's system, how long it takes a reported crime case to be processed and terminated or forwarded to a higher level and the expected number of staff in LEA offices to control resource waste on redundant workers.

LITERATURE REVIEW

Crime is a threat to the economic, political and social security of a nation and a major factor associated with underdevelopment; because it discourages both local and foreign investments, reduces the quality of life, destroys human and social capital, damages relationship between citizens and the states, thus undermining democracy, rule of law and the ability of the country to promote development. So, the prevalence of crime in the world today is a cause for serious concern for all (Anthony, 2013). Government has adopted several strategies towards crime prevention and control such as establishment of security agencies like State Security Service (SSS), Independent Corrupt Practices and other offences Commission (ICPC), and the Economic and Financial crime Commission (EFCC) (Anthony, 2013). Government also approved community crime control and prevention strategies such as vigilante groups (Nwaeze, 2010) and yet as a matter of fact, many have lost faith in the security agencies going by the incessant increase in the crime rate. Due to the presence inefficiency of the LEA, a tool (QT) developed by Erlang in the beginning of 20th century is adopted as a strategy to assist LEAs in crime management for better performance.

QT constitutes a powerful tool in modelling and performance analysis of many complex systems, such as computer networks, telecommunication systems (e.g. telephone exchange), manufacturing systems and service systems (petrol station, supermarket, hospital etc.). Telephone exchange is the first problems (congestion problems) solved using queueing theory and was done by Erlang (Bandi et al., 2013; Quantitative Module D, 2009). His works inspired engineers, mathematicians to deal with queueing problems using

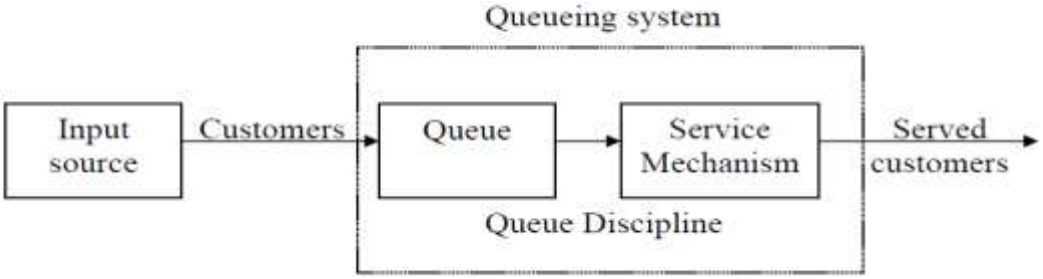


Figure 1. Basic queueing model structure (Balsam and Marin, 2007; Adan and Resing, 2015).

probabilistic methods (Filipowicz and Kwiecien, 2008; Sztrik, 2012).

A queueing system most life scenario consists of three main components namely: inputs source, queue and servers at service centres as shown in Figure 1. Generally, it consists of one or more servers for serving customers arriving in some manner and having some service requirements. The customers (entities) represent users, jobs, crime cases, machines, customer order, electronic messages, transactions or programs. They arrive at the service facility for service, wait if the service cannot start immediately, and leave the system after being served. Sometimes customers are lost. Queue might be a physical line, customers on hold, jobs waiting to be printed, planes circling airport etc (https://www.me.utexas.edu/~jensen/.../powerpoint/or.../14_queuing.ppt).

The queueing systems are described by distribution of inter-arrival times, distribution of service times, the number of servers, the service discipline and the maximum system capacity etc.

How long customer waits on queue depends on a number of factors; number of people served before, the number of working servers, queuing system design and the amount of time it takes to serve each customer. Any time there is more demand for a service than can be provided, a queue forms (Waiting Line Models Supplement C, 2001).

In a queuing system, managers must decide what level of service to offer; a low level of service may be inexpensive, at least in the short run, but may incur high costs of customer dissatisfaction leading to lost future business and costs of complaints, while high processing costs of complaints. A high level of service will cost more to provide and will result in lower dissatisfaction costs. Because of this trade-off, management must consider the optimal level of service to be provided.

Types of queuing models

In this work, two queuing models were used among the existing varieties of them. These queuing models include: Single server (M/M/1) and Multiple-Server M/M/m queuing model.

Single-server queuing model (M/M/1 queue)

Figure 2 shows single server queueing model (M/M/1), first M denotes exponentially distributed inter arrival time, second M denotes exponentially distributed service times and 1 denotes single server. The model follows some basic assumption such as: Poisson arrival process and exponential distribution service-times, First-in-First-out discipline, a multi-service phase (network of queues), the service rate is greater than the arrival rate (stability condition) and no item is discarded from the queue. Following the assumptions, the performance measures of the model is calculated. Performance measures are carried out to help managers make decisions that balance service costs with waiting-line costs.

Multiple-server queuing model (M/M/m)

The M/M/m model assumes *m* identical servers as shown in Figure 3 with the following assumptions, M/M/1 assumptions inclusive. All servers are equally loaded (parallel) and all servers have the same mean service time (µ). The parameter measures for this model provides the same information as in M/M/1. This model with infinite servers is called the M/M/∞ queue.

Queueing network

A queueing network model as a concept of queuing theory is composed of several interconnected stations, each with a queue. Customers, upon the completion of their service at a station, may re-enter the same service centre, moves to another station for additional service or leave the system according to some routing rules (deterministic or probabilistic). In a queueing networks, customers must receive service at some of or all the service facilities (Stallings, 2000; Wang, 2009; Bose, 2015). Queueing networks have been proved to be a powerful tool for performance analysis and prediction

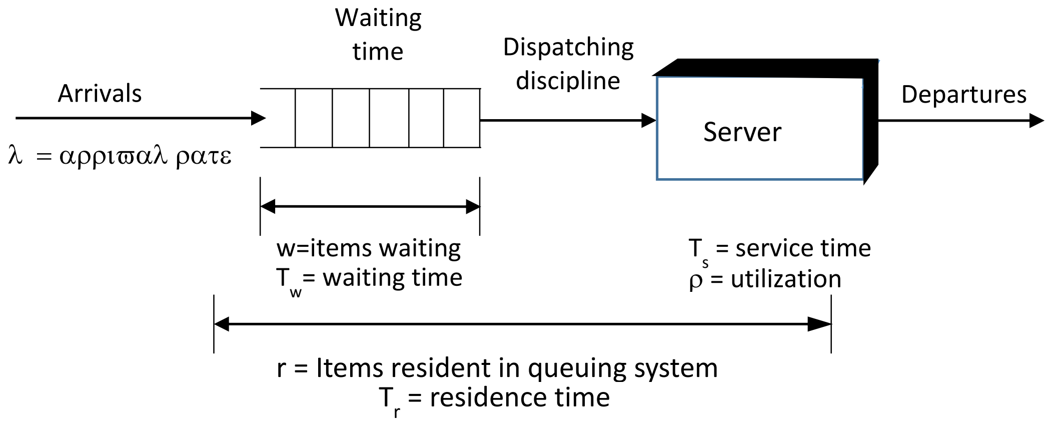


Figure 2. Queuing system structure for a single-server queue (Filipowicz and Kwiecien, 2008).

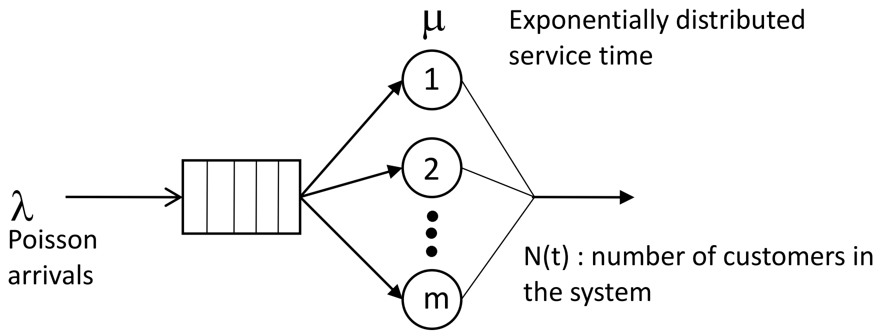


Figure 3. A multiple-server system Sztrik, 2012).

(Balsamo, 1988).

Three types of Queueing network are: open, closed and mixed queuing network. Open queuing network allows jobs to enter and depart from the network. In a closed queuing network, jobs neither enter nor depart from the network. Queueing network is mixed if it is open for some types of customers and closed for other types of Customers. Open queuing networks has two types: Open feed forward and open feedback queuing networks. In an open feed forward queuing network, a job cannot appear in the same queue for more than one time. In an open feedback queuing network, after a job is served by a queue, it may re-enter the same queue (ITU{D SG 2/16 & ITC, 2001).

This research work adopted the open feed forward queueing network comprising single server queueing model (M/M/1) and multiple-server queueing (M/M/m) with Poisson Arrivals and Exponential Service-Times.

Queuing network systems have been developed and applied in many human endeavour as in products made in a plant that usually pass several production stages with different machines which may experience delays in packing and billing, a computer job may be delayed at several successive visits to a processor and to memory devices, and also at the printer and finally, a message traveling from sender to receiver along a path in a communication network may have to wait at the entrance to the network, and also in various switches between the successive channels (Boxma, 2008).

Filipowicz and Kwiecien (2008) developed Queueing Network-Model Human Processor (QN-MHP) to model human behaviour. The model integrated the queueing network and human cognitive system. It was used to determine the reaction time (delay) between stimulus presentation and response. Information traversing servers (different brain area) is regarded as the customers of queueing network. The QN-MHP consists of three subnetworks of queueing servers: perceptual, cognitive and motor. Each subsystem of QN-MHP is a single-channel server that follows FIFO queue discipline.

The performance analysis of information system as reviewed in Filipowicz and Kwiecien (2008) helps to identify system bottlenecks and compare design alternatives (Filipowicz and Kwiecien, 2008). Queueing network was used to solve the problem of quick access to information resources in information systems by minimizing search time (reduction time of delivering information to users). The work also evaluated response

Table 1. Queue network model notation descriptions.

Notations	Descriptions
λ_{Q1}	Arrival rate of cases to M/M/1 measured in months
Q_2	M/M/m queue where cases wait for investigation to be carried out on them.
Q_1	M/M/1 Queue where cases wait to be received.
μ_{Q1}	Single server of the M/M/1 system
μ_1, μ_2, μ_3	Parallel servers of M/M/m
P	Probability that a case is considered genuine and ready to be investigated upon. λ_{Q1} (P) is the arrival rate of crime cases to M/M/m system.
1-P	Probability that a case is considered non genuine and goes away from the network. P and 1-P follows Bernoulli probability distribution.
λ_{Q1} (1-P)	Departure rate of non-genuine cases out of the queueing system
P_{tt1}, P_{ts1}, P_{cc3}, P_{unk1}	Probabilities of cases being treated and terminated, handled and forwarded to state, handled and forwarded to court, and cases still ongoing respectively. This distribution follows Binomial probability distribution.

times for different system load conditions for selected information systems.

Fomundam and Herrmann (2007) deals with contributions and applications of queuing theory in the field of healthcare. This work covers processes that provide direct patient treatment and processes that provide auxiliary services such as pharmacy and medical laboratory processing. The result from this work was summarized in areas such as: waiting time and utilization analysis, system design, and appointment systems. The author reported that the main challenge encountered was how to reduce patient waiting time without greatly increasing server idleness. The goal is to provide sufficient information to analysts who are interested in using queuing theory to model a healthcare process.

Ameh et al. (2013) discussed application of queueing theory in computer networks. Vast volumes of data organized into packets and supervised by communications protocols are constantly flowing across telecommunications networks, usually via intermediate nodes. At node, the incoming packets are queued to be sent according to network availability. Here customers represent packets, the queues are at routers, and the service time is the time to send a packet, bit-by-bit through an output gate of a router, hence it is proportional to the size of the packet.

A research was also carried out on obtaining demographic characteristics and the time spent on the queue by patients before seeing a doctor, time spent with the doctor, their views about the time spent on the queue and useful suggestions on how to reduce the time spent on the queue. The queuing method employed at the clinic is the multiple single channel type and the service discipline is priority service (Wu and Liu, 2009).

Wu and Liu (2009) developed a Visual Basic Application in Excel (VBA) software package to predict human performance and mental workload in multiple task situations. The study showed that naive users without prior simulation language programming experience can model human performance and mental workload in a complex multitask situation within 3 min; and this software package can save 71% of modelling time and reduce 30% of modelling errors.

In Ritchey (1996), state-dependent importance sampling heuristics was developed to estimate the total network overflow probability for different types of networks. It applied simulation to minimize losses during the transmission. The networks that were considered include: Jackson networks of nodes in tandem, in parallel, feed-forward networks and networks with feedback, as well as a 2-node non-Markovian tandem queuing network.

From the above review, it is obvious that theory of queueing network could be applied in numerous areas of life including operations of the Law Enforcement Agency. In this work, the customers come in form of crime cases, the servers are the LEA’s staff, the queue is formed with the crime cases waiting to treated when all the servers (staff) are busy with other cases applying FCFS queueing discipline.

METHODOLOGY

This research adopted queuing network model concept in form of table as a research methodology as shown in Table 1. Data used for analysis and implementation in this work was collected from Eleme Police Station, Port Harcourt (2012) and Nsukka Police Station (2013) using a table format as shown in Table 1. This data was tested to prove that it follows the Poison and Exponential statistical distributions as mentioned on the assumptions of the model. To implement the queueing network model, a computer program was developed using PHP programming language. The program takes as inputs the case arrival rate (λ) which is calculated from inter-arrival time of cases as inverse of the expected inter-arrival time (1/expected inter-arrival time), case service rate (μ) which is calculated from service time of cases as the inverse of expected service time (1/expected service time), number of servers (that is, number of workers working on the arriving cases) and year the crime data was collected. Queueing model input parameters were used to calculate the performance measures of the two models: M/M/1 and M/M/m used such as

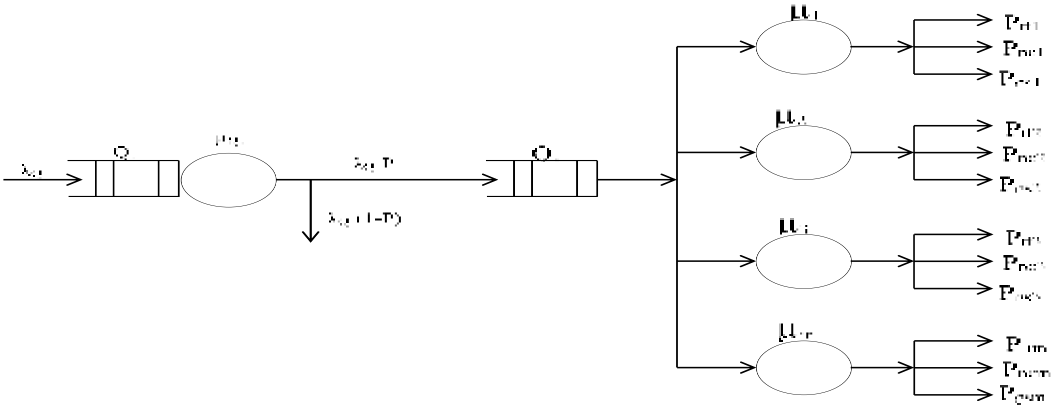


Figure 4. Queueing network model structure.

average number of customers in the system, average time a customer spends in the system, average number of crime cases waiting on the queue, average time a case spends waiting in the queue, utilization factor for the system etc. Analysis was carried out on the results generated from the performance evaluation and some useful results were obtained.

Figure 4 shows the queueing network system structure of M/M/1 and M/M/m queuing models that was built by handling each of these two models independently before merging the result in accordance with Burke's theorem (Balsamo and Marin, 2007). The queueing network system captures the time of arrival, departure time of each case both in M/M/1 and M/M/m system, service time (departure time – arrival time) inter arrival time of two consecutive arrivals (case 2 arrival time – case 1 arrival time). These are input data to the system from where arrival rate and service rate are calculated.

The Queueing Network System notation descriptions and algorithm

Table 1 shows the definition of notations in Queueing Network Model structure. The pseudo code below shows the steps followed in implementing the Queueing Network used to determine how long a crime case stays in the crime information system.

```
Read crime data/information from the database
Input the number of servers and year.
Sort the crime data into months (January, February, …December).
Loop through the months (January to December) of the selected year
Read a month
Read up all the arrival time of cases to M/M/1 system recorded in a specific month.
Read up all the departure time of cases from M/M/1 system recorded in a specific month.
Calculate inter-arrival time of cases to M/M/1 system (time difference in two successive arrivals measured in days).
Calculate mean inter-arrival time of cases to M/M/1 system (total of inter-arrival time/total number of arrivals in a month).
Calculate arrival rate ($\lambda_{q1}$) of cases to M/M/1 system (inverse of mean inter-arrival time)
Calculate the service time at M/M/1 system (departure time of a case - arrival time of a case).
Calculate mean service time of M/M/1 system (total service time/total number of cases serviced in a specified month).
Calculate the service rate ($\mu_{q1}$) of M/M/1 system (inverse of mean service time).
Read up all the arrival time and departure time of cases in M/M/m system.
Calculate the service time at M/M/m system (departure time of a case - arrival time of a case).
Calculate mean service time of M/M/m system (total service time/total number of cases serviced in a specified month).
Calculate the service rate ($\mu_{q2}$) of M/M/m system (inverse of mean service time).
Calculate the probability that a case is considered genuine at M/M/1 node denoted as P (total number of genuine crime cases/total number of reported crime cases)
```

Calculate the arrival rate ($\lambda_{q2} = \lambda_{q1} * P$) of M/M/m model (1)

Calculate the queuing parameter measures

Calculate the utilization factor ($\rho_{q1} = \lambda_{q1}/\mu_{q1}$) of M/M/1 model (2)

Calculate the utilization factor ($\rho_{q2} = \lambda_{q2}/\mu_{q2}$) of M/M/m model (3)

Calculate the prob of n_i jobs in the i^{th} queue of M/M/1, $P(n_i) = (1 - \rho_i) \rho_i^{ni}$… (4)

Calculate the prob that no customer is in the sys:

$$P_0 = \frac{1}{\sum_{k=0}^{m-1}\left(\frac{\rho^k}{k!}\right) + \left(\frac{m\rho}{m!(m-\rho)}\right)} \quad (5)$$

Calculate the prob of k customer in the system: $P_k = \frac{P_0\rho^k}{k!}$ $P_k = P_0 \frac{\rho^k}{m!m^{k-m}}$ .. (6)

k≤m k>m

Calculate the total expected number of waiting cases in the entire system, L_q

M/M/1 queue:

$$Lq1 = \frac{{\lambda_{q1}}^2}{\mu_{q1}(\mu_{q1} - \lambda_{q1})} \quad (7)$$

M/M/m queue:

$$Lq2 = \frac{\left(\frac{(m\rho)^m}{m!}\right)\left(\frac{\rho}{(1-\rho)^2}\right)}{\sum_{k=0}^{m-1}\frac{(m\rho)^k}{k!} + \frac{(m\rho)^m}{m!}\left(\frac{1}{1-\rho}\right)} \quad (8)$$

Entire system: $L_q = L_{q1} + L_{q2}$

Calculate the expected busy server of M/M/m; $\beta = \frac{\lambda_{q2}}{\mu_{q2}}$ (9)

Table 2. Notation description.

Notations from algorithm	Descriptions
L_{q1}	Expected queue length (number of cases on queue) in M/M/1
L_{q2}	Expected queue length M/M/m
L_q	Expected queue length of the entire queuing network system (L_{q1} + L_{q2})
L_1	Expected number of customers in M/M/1
L_2	Expected number of customers in M/M/m
L	Expected number of customers in the entire system (L_1 + L_2)
W_{q1}	Expected time cases spent in M/M/1 queue (doesn't include service time)
W_{q2}	Expected time cases spent in M/M/m queue
W_q	Expected time cases spent in both queues (W_{q1} + W_{q2})
W_1	Expected time cases spent in M/M/1 system (W_{q1} + service time in M/M/1)
W_2	Expected time cases spent in M/M/m system (W_{q2} + M/M/m service time)
W	Expected time cases spent in the entire system (W_1 + W_2)
P_{tt1}, P_{ts1}, P_{cc3}, P_{unk1}	Probabilities of cases being treated and terminated, handled and forwarded to state, handled and forwarded to court, and cases still ongoing respectively. This distribution follows Binomial probability distribution.

Table 3. Queueing network data collection format.

S/N	Crime type (e.g. car theft)	Date of crime report	Time of crime report	Date investigation started	Time investigation started	Date investigation ended	Time investigation Ended/case status
1							
2							

Calculate the expected number of customers in M/M/m system L.

M/M/1 system: $L_1 = \frac{\lambda_{q1}}{\mu_{q1} - \lambda_{q1}}$ (10)

M/M/m system: $L_2 = L_{q2} + \beta$ (11)

Evaluate total no of customers in the entire system (L) = $L_1 + L_2$ (12)

Calculate expected waiting time for both queues, W_q

M/M/1 Queue: $W_{q1} = \frac{L_{q1}}{\lambda_{q1}}$ (13)

M/M/m queue: $W_{q2} = \frac{L_{q2}}{\lambda_{q2}}$ (14)

Evaluate $W_q = W_{q1} + W_{q2}$ (15)

Calculate the expected response time in the entire queuing network, W.

M/M/1 system: $W_1 = \frac{L_1}{\lambda_{q1}}$ (16)

M/M/m system: $W_2 = W_{q2} + \frac{1}{\mu_{q2}}$ (17)

Evaluate $W = W_1 + W_2$ (18)

Calculate the Prob of status of each case handled by the agency (local level).

Prob. that a crime case handled was treated and terminated P_{tt} ....

Prob. that a crime case handled was transferred to state level of the agency P_{ts}: ……..

Prob. that a crime case handled was charged to court P_{cc}:…..

Prob. that a crime case handled was undetected or pending P_{un}: ...

Check the last month used

If month is not equal to December then repeat step 2.1- 2.12.3

4.1 Else go to step 5.0

Display Results

Print all the results in tabular form

End

Some of the algorithm parameters definition

Here definitions of some parameters in the algorithm that were not clearly defined within the algorithm are presented as shown in Table 2.

Study input and output designs

The input designs used in the research work is as shown in Table 3. Table 3 is the table format used to collect real data manually from the two Police stations.

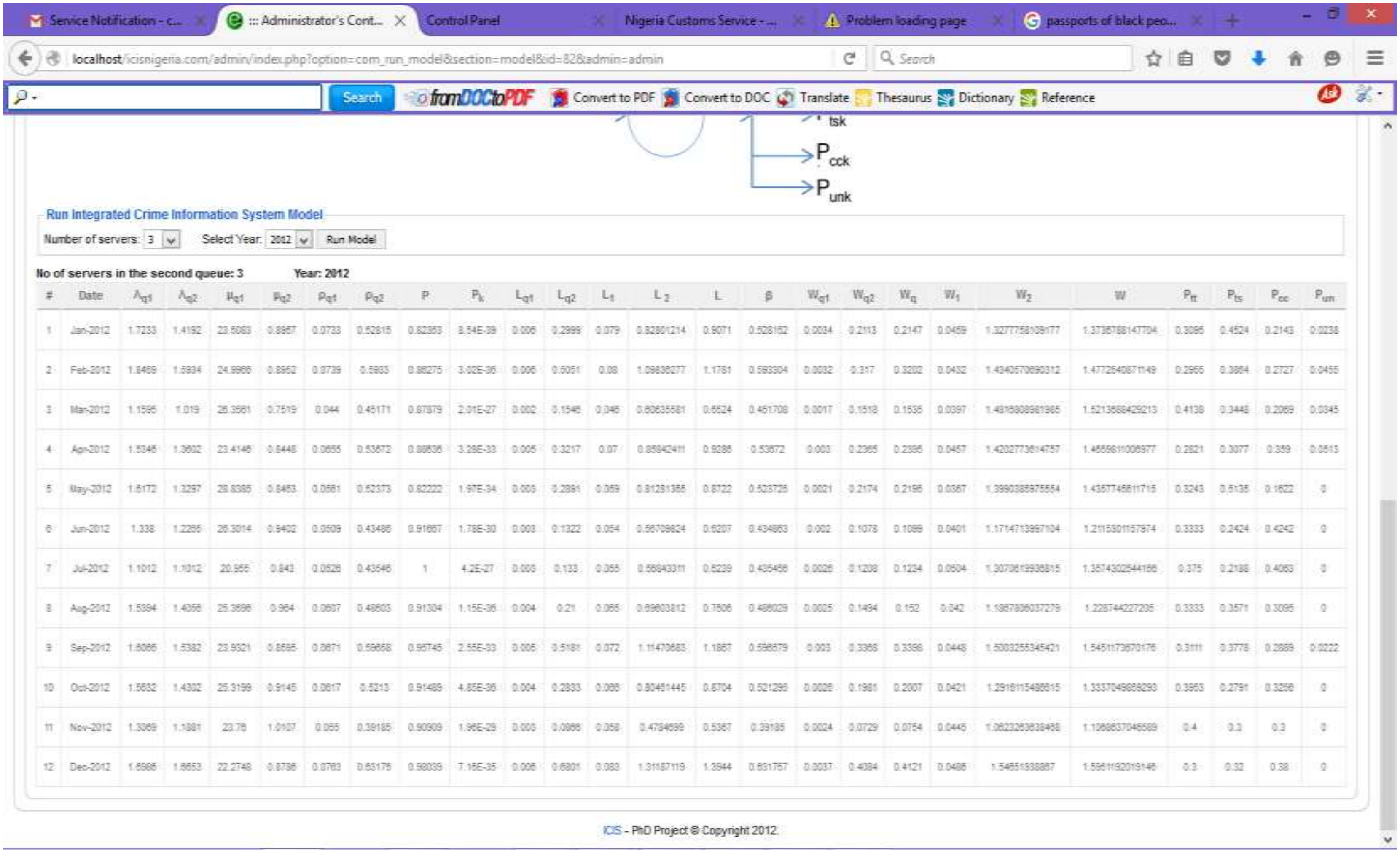
Table 4 shows the queuing model output design. The output is made of 12 rows numbered 1 to 12 with months January to December. This table displays the values of parameters obtained from queuing network model implementation. These parameters were defined in the algorithm above that led to the implementation.

RESULTS AND DISCUSSION

Here showed results, its analysis and discussions obtained from implementation of the queueing network model using 2013 crime data collected. Figures 5 and 6

Table 4. Queuing Model results output design.

#	Date	λ_{q1}	λ_{q2}	μ_{q1}	μ_{q2}	ρ_{q1}	ρ_{q2}	P	P_k	L_{q1}	L_{q2}	L_1	L_2	L	β	W_{q1}	W_{q2}	W_q	W_1	W_2	W	P_{tt}	P_{ts}	P_{cc}	P_{un}



Run Integrated Crime Information System Model

Number of servers: 3 Select Year: 2012 Run Model

No of servers in the second queue: 3 **Year: 2012**

#	Date	λ_{q1}	λ_{q2}	μ_{q1}	μ_{q2}	ρ_{q1}	ρ_{q2}	P	P_k	L_{q1}	L_{q2}	L_1	L_2	L	β	W_{q1}	W_{q2}	W_q	W_1	W_2	W	P_{tt}	P_{ts}	P_{cc}	P_{un}
1	Jan-2012	1.7233	1.4192	23.5083	0.8957	0.0733	0.52615	0.82353	8.54E-39	0.006	0.2999	0.079	0.82801214	0.9071	0.528152	0.0034	0.2113	0.2147	0.0459	1.3277758109177	1.3736788147704	0.3095	0.4524	0.2143	0.0238
2	Feb-2012	1.8469	1.5934	24.9986	0.8952	0.0739	0.5933	0.88275	3.02E-36	0.006	0.5051	0.08	1.09838277	1.1781	0.593304	0.0032	0.317	0.3202	0.0432	1.4340570890312	1.4772540871149	0.2955	0.3864	0.2727	0.0455
3	Mar-2012	1.1595	1.019	26.3561	0.7519	0.044	0.45171	0.87879	2.01E-27	0.002	0.1546	0.046	0.60635581	0.6524	0.451708	0.0017	0.1518	0.1535	0.0397	1.4816808981965	1.5213568429213	0.4138	0.3448	0.2069	0.0345
4	Apr-2012	1.5346	1.3602	23.4146	0.8448	0.0655	0.53672	0.88636	3.28E-33	0.005	0.3217	0.07	0.85842411	0.9286	0.53672	0.003	0.2365	0.2395	0.0457	1.4202773614757	1.4655611006977	0.2821	0.3077	0.359	0.0513
5	May-2012	1.6172	1.3297	28.8385	0.8453	0.0561	0.52373	0.82222	1.97E-34	0.003	0.2891	0.059	0.81281365	0.8722	0.523725	0.0021	0.2174	0.2195	0.0367	1.3990385975554	1.4357745611715	0.3243	0.5135	0.1622	0
6	Jun-2012	1.338	1.2265	26.3014	0.9402	0.0509	0.43486	0.91667	1.78E-30	0.003	0.1322	0.054	0.56709824	0.6207	0.434863	0.002	0.1078	0.1099	0.0401	1.1714713997104	1.2115301157974	0.3333	0.2424	0.4242	0
7	Jul-2012	1.1012	1.1012	20.955	0.843	0.0526	0.43546	1	4.2E-27	0.003	0.133	0.055	0.56843311	0.6239	0.435456	0.0026	0.1208	0.1234	0.0504	1.3079619936815	1.3574302544166	0.375	0.2188	0.4063	0
8	Aug-2012	1.5394	1.4056	25.3896	0.964	0.0607	0.48603	0.91304	1.15E-36	0.004	0.21	0.065	0.69603812	0.7606	0.486029	0.0025	0.1494	0.152	0.042	1.1867806037279	1.228744227205	0.3333	0.3571	0.3095	0
9	Sep-2012	1.6066	1.5382	23.9321	0.8595	0.0671	0.59658	0.95745	2.55E-33	0.006	0.5181	0.072	1.11470683	1.1867	0.596579	0.003	0.3366	0.3396	0.0446	1.5003255345421	1.5451173670176	0.3111	0.3778	0.2889	0.0222
10	Oct-2012	1.5632	1.4302	25.3199	0.9145	0.0617	0.5213	0.91489	4.85E-36	0.004	0.2833	0.066	0.80451445	0.8704	0.521296	0.0026	0.1981	0.2007	0.0421	1.2916115486615	1.3337049868293	0.3953	0.2791	0.3256	0
11	Nov-2012	1.3069	1.1881	23.76	1.0107	0.055	0.39185	0.90909	1.96E-29	0.003	0.0866	0.058	0.4784699	0.5367	0.39185	0.0024	0.0729	0.0754	0.0445	1.0823263838466	1.1268637046589	0.4	0.3	0.3	0
12	Dec-2012	1.6986	1.6853	22.2748	0.8786	0.0763	0.63176	0.98039	7.16E-35	0.006	0.6801	0.083	1.31187119	1.3944	0.631757	0.0037	0.4084	0.4121	0.0486	1.54551938867	1.5961192019146	0.3	0.32	0.38	0

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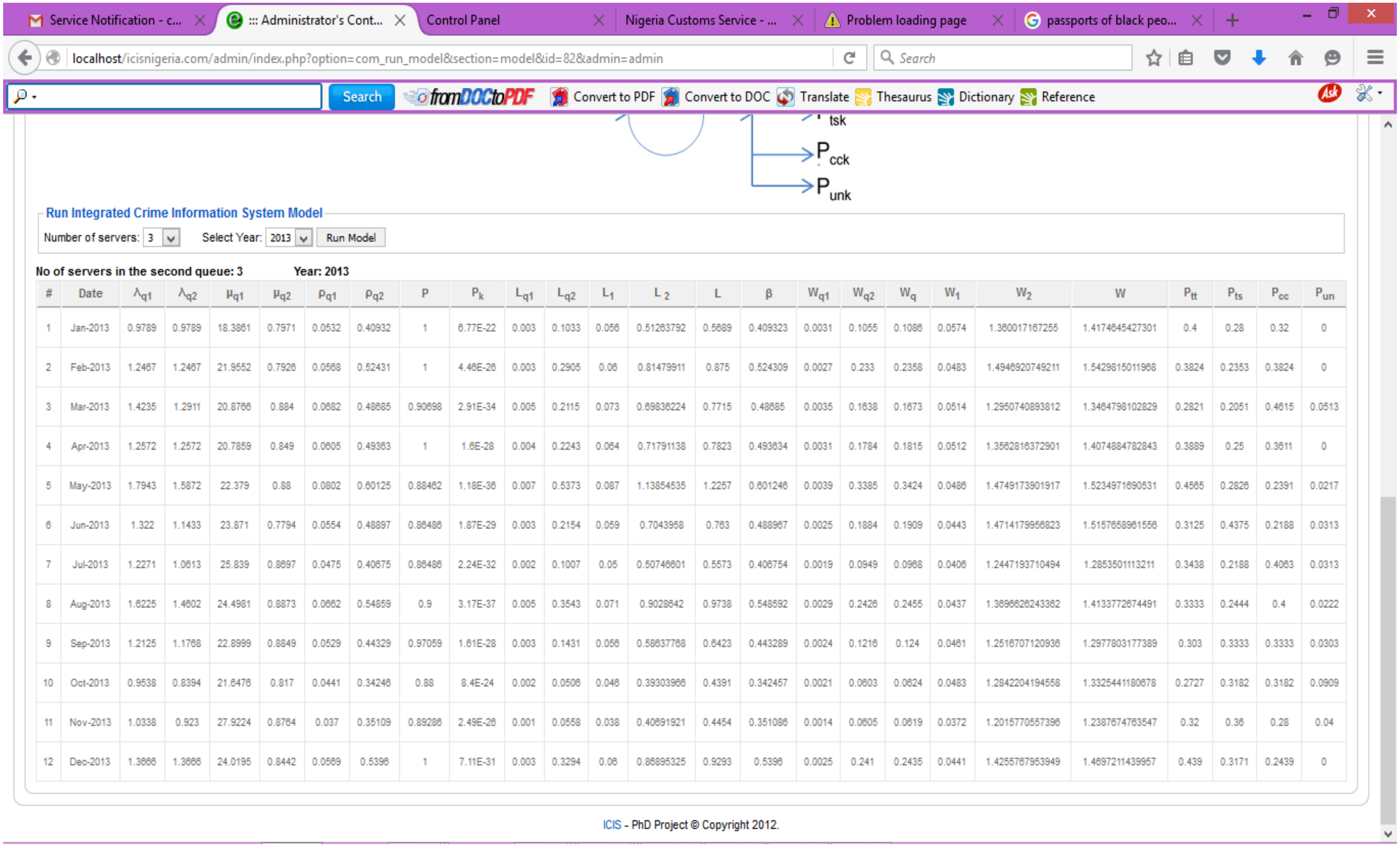
Figure 5. Result from Queueing Theory, 2012 data.



Run Integrated Crime Information System Model

Number of servers: 3 Select Year: 2013 Run Model

No of servers in the second queue: 3 **Year: 2013**

#	Date	λ_{q1}	λ_{q2}	μ_{q1}	μ_{q2}	ρ_{q1}	ρ_{q2}	P	P_k	L_{q1}	L_{q2}	L_1	L_2	L
1	Jan-2013	0.9789	0.9789	18.3861	0.7971	0.0532	0.40932	1	6.77E-22	0.003	0.1033	0.056	0.51263792	0.5689
2	Feb-2013	1.2467	1.2467	21.9552	0.7926	0.0568	0.52431	1	4.46E-26	0.003	0.2905	0.06	0.81479911	0.875
3	Mar-2013	1.4235	1.2911	20.8766	0.884	0.0682	0.48685	0.90698	2.91E-34	0.005	0.2115	0.073	0.69836224	0.7715
4	Apr-2013	1.2572	1.2572	20.7859	0.849	0.0605	0.49363	1	1.6E-28	0.004	0.2243	0.064	0.71791138	0.7823
5	May-2013	1.7943	1.5872	22.379	0.88	0.0802	0.60125	0.88462	1.18E-36	0.007	0.5373	0.087	1.13854535	1.2257
6	Jun-2013	1.322	1.1433	23.871	0.7794	0.0554	0.48897	0.86486	1.87E-29	0.003	0.2154	0.059	0.7043958	0.763
7	Jul-2013	1.2271	1.0613	25.839	0.8697	0.0475	0.40675	0.86486	2.24E-32	0.002	0.1007	0.05	0.50746601	0.5573
8	Aug-2013	1.6225	1.4602	24.4981	0.8873	0.0662	0.54859	0.9	3.17E-37	0.005	0.3543	0.071	0.9028642	0.9738
9	Sep-2013	1.2125	1.1768	22.8999	0.8849	0.0529	0.44329	0.97059	1.61E-28	0.003	0.1431	0.056	0.58637768	0.6423
10	Oct-2013	0.9538	0.8394	21.6476	0.817	0.0441	0.34246	0.88	8.4E-24	0.002	0.0506	0.046	0.39303966	0.4391
11	Nov-2013	1.0338	0.923	27.9224	0.8764	0.037	0.35109	0.89286	2.49E-26	0.001	0.0558	0.038	0.40691921	0.4454
12	Dec-2013	1.3666	1.3666	24.0195	0.8442	0.0569	0.5396	1	7.11E-31	0.003	0.3294	0.06	0.86895325	0.9293

#	Date	β	W_{q1}	W_{q2}	W_q	W_1	W_2	W	P_{tt}	P_{ts}	P_{cc}	P_{un}
1	Jan-2013	0.409323	0.0031	0.1055	0.1086	0.0574	1.360017167255	1.4174645427301	0.4	0.28	0.32	0
2	Feb-2013	0.524309	0.0027	0.233	0.2358	0.0483	1.4946920749211	1.5429815011968	0.3824	0.2353	0.3824	0
3	Mar-2013	0.48685	0.0035	0.1638	0.1673	0.0514	1.2950740893812	1.3464798102829	0.2821	0.2051	0.4615	0.0513
4	Apr-2013	0.493634	0.0031	0.1784	0.1815	0.0512	1.3562816372901	1.4074884782843	0.3889	0.25	0.3611	0
5	May-2013	0.601246	0.0039	0.3385	0.3424	0.0486	1.4749173901917	1.5234971690531	0.4565	0.2826	0.2391	0.0217
6	Jun-2013	0.488967	0.0025	0.1884	0.1909	0.0443	1.4714179956823	1.5157658961556	0.3125	0.4375	0.2188	0.0313
7	Jul-2013	0.406754	0.0019	0.0949	0.0968	0.0406	1.2447193710494	1.2853501113211	0.3438	0.2188	0.4063	0.0313
8	Aug-2013	0.548592	0.0029	0.2426	0.2455	0.0437	1.3696626243362	1.4133772674491	0.3333	0.2444	0.4	0.0222
9	Sep-2013	0.443289	0.0024	0.1216	0.124	0.0461	1.2516707120936	1.2977803177389	0.303	0.3333	0.3333	0.0303
10	Oct-2013	0.342457	0.0021	0.0603	0.0624	0.0483	1.2842204194558	1.3325441180678	0.2727	0.3182	0.3182	0.0909
11	Nov-2013	0.351086	0.0014	0.0605	0.0619	0.0372	1.2015770557396	1.2387674763547	0.32	0.36	0.28	0.04
12	Dec-2013	0.5396	0.0025	0.241	0.2435	0.0441	1.4255767953949	1.4697211439957	0.439	0.3171	0.2439	0

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Figure 6. Result from Queueing Theory (2013) data.

are the snapshot results of parameters as shown in Table 2 for the years 2012 and 2013. Also, the analysis and discussion of results obtained from the queueing network model is as shown in graphs in Figures 7 to 13. The analysis was done by performing sensitivity analysis on the different parameters of the model to observe or study the entire system behaviour. Sensitivity analysis is done by keeping one or more parameter(s)

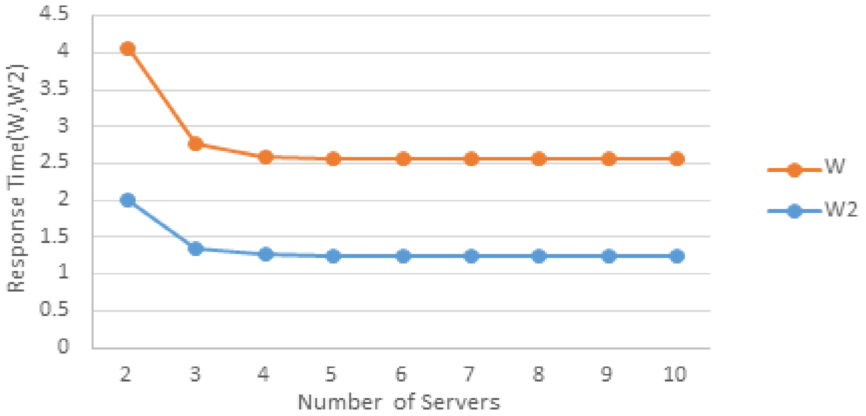

Figure 7. Response time of system 2 and the entire system against servers for January 2013.

constant and varying the other in order to understand the behaviour of the modelled object. These graphs were plotted using MS Excel application. Figure 6 shows the queuing model results that was analysed to plot some graphs earlier mentioned.

Analysis of Queueing Network results

Here contains a presentation of analysis of the queuing network result in a graphical form.

Response time (w) and w_2 of M/M/m and the entire system *against the Number of servers*

Figure 7 shows that arrival rate and service rate remain constant while the number of servers vary. Here, it is observed that beyond five servers, the response time remains approximately constant regardless of the increase in the number of servers. This means that system needed maximum of five servers for its effective operation and keeping more than 5 workers makes them redundant which leads to waste of resources. From the graph, it is observed that it remains constant instead of tending to zero. The reason is because, provided that there are cases in the system, time must be spent in handling them. It is expected to have zero time when there are no cases in the system. The minimum time required is always dependent on the case ongoing (serious or less serious).

Comparison of parameters: The findings in the above graph is summarized as follow:

1) Increase in the number of servers decreases the response time
2) There is always an optimal number of servers (5) beyond which response time remains constant.

Graph of W_2 and W look alike because the bulk of the whole job is at the second queue (M/M/m) where the cases are actually investigated on and handled.

Response Time of M/M/1 against number of servers

Figure 8 shows that the arrival rate and service rate are constant while the number of servers vary. It is observed that as the number of servers increase, response time remains constant because increase in the number of servers does not affect the M/M/1queuing model.

Response Time of w1, w2, w against number of servers for March 2013

Figure 9 shows the relationship between Number of Server, Response Time of M/M/1 model (W1), M/M/m model (W2) and the entire system (W1 + W2 =W) at constant Arrival and service rates. It is observed from this graph that increase in the number of server does not affect the time spent on the M/M/1 system and cases usually spend less time in the said system than in M/M/m system. We can also observe that the bulk of the whole work is in the M/M/m system where the case is actually being handled. This is the reason time spent in M/M/m is very close to the total time spent in the entire system (W).

Queue length of M/M/1 queue against Utilization factor

It is expected that in Figure 10, increase in queue length increases the utilization factor. Utilization factor is the percentage of time a server is busy. The reason is that servers can only be busy when there are customers on the queue. The zig-zag nature of the graph might be that the server has been busy handling a severe case that requires a very long time. That is at almost constant

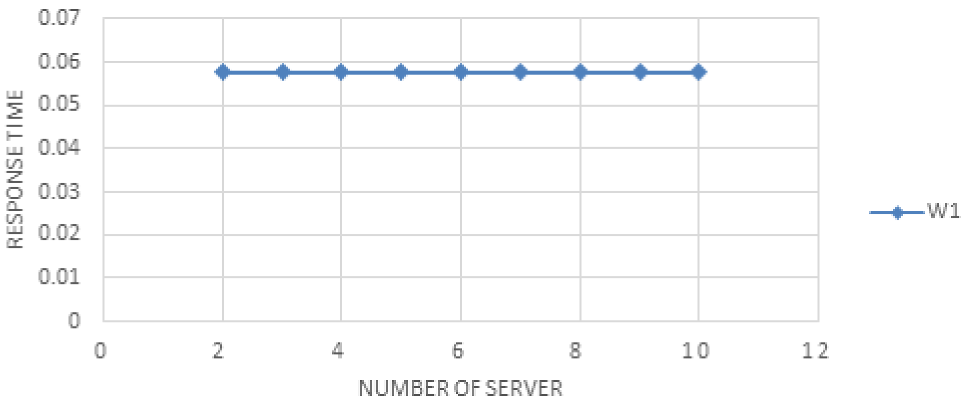

Figure 8. Response time of M/M/1 against number of servers for January 2013.

Figure 9. Response time of W_1, W_2 and W against Number of Servers for March 2013.

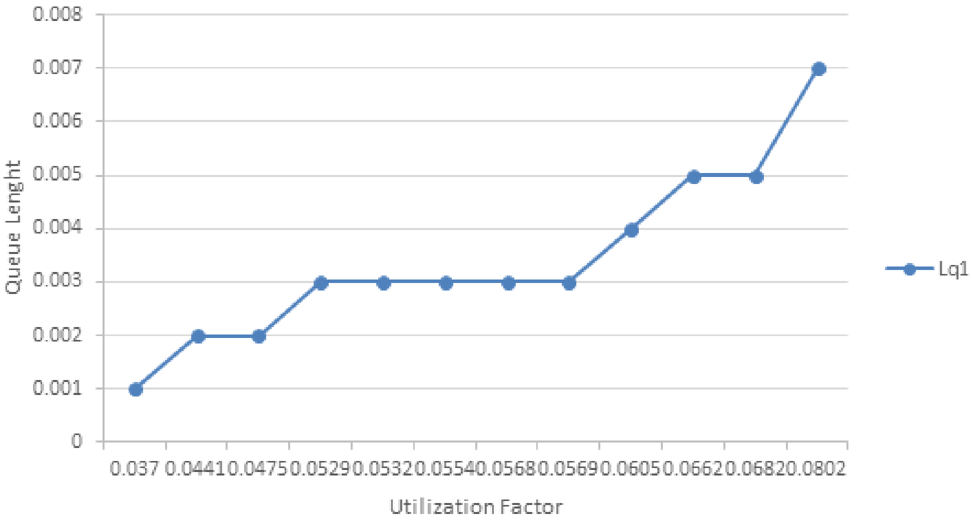

Figure 10. Plot of graph of Queue length of M/M/1 queue against Utilization factor.

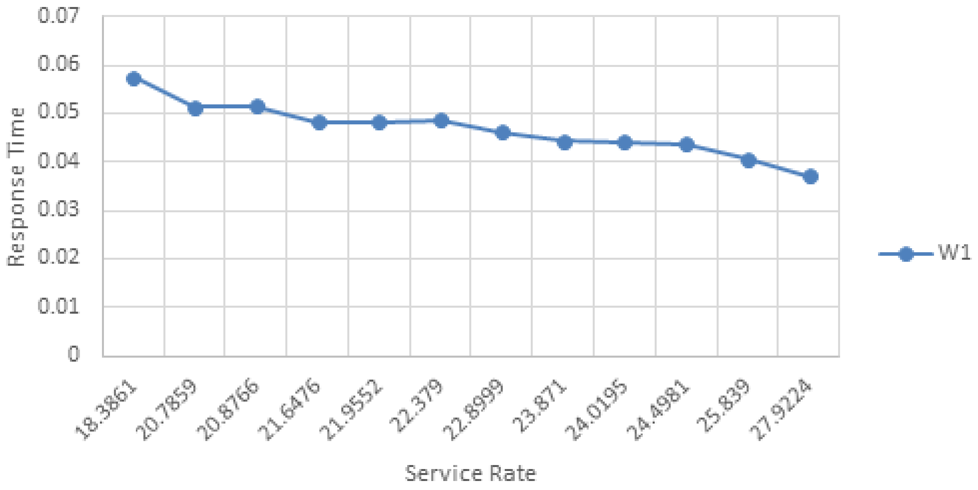

Figure 11. Response time of W_1 against service rate of m_{q1} at constant server for 2013.

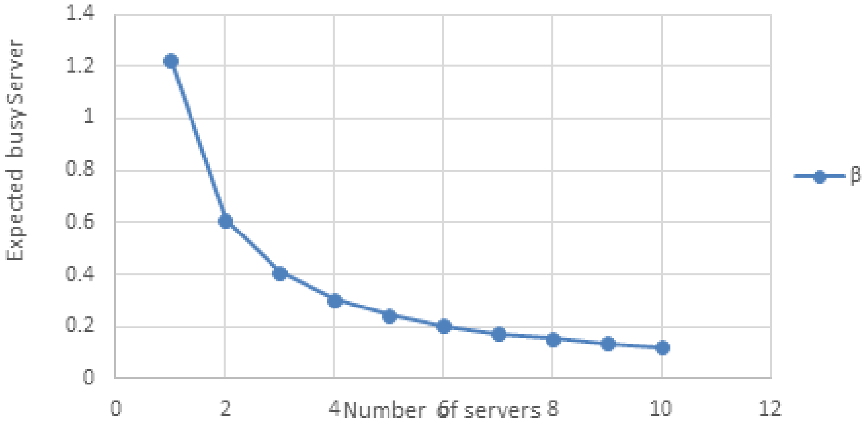

Figure 12. Expected Busy Server (β) against Number of Servers for January 2013.

queue length the server's business continued to increase.

Response time against Service rate

In Figure 11, it is expected that increase in service rate will result to a decrease in the response time. This is because, when the rate at which customers are being attended to is high, the time a customer spends on the queue and in service reduce. In some cases, the nature of a case may cause a constant response time at an increase of service rate, for instance, some cases may take a long time to finish while some take little time to be handled.

Expected busy server /Number of servers

Result from Figure 12 shows that as the number of servers increase, expected busy server decreases at constant arrival and service rate. This is because the available cases are going to be shared at constant arrival rate and service rate. The expected busy server is a percentage of time servers that are busy. The smooth nature of the curve emphasizes that the server are parallel, meaning that they all have the same processing power (any of them can handle any case with the same capacity).

Number of customers in the entire system (L) against number of servers

Figure 13 shows that increase in the number of servers significantly reduces the number of customers at constant arrival rate and service rate. Note that the increase in the number of servers only affects the M/M/m model (Lq_2)

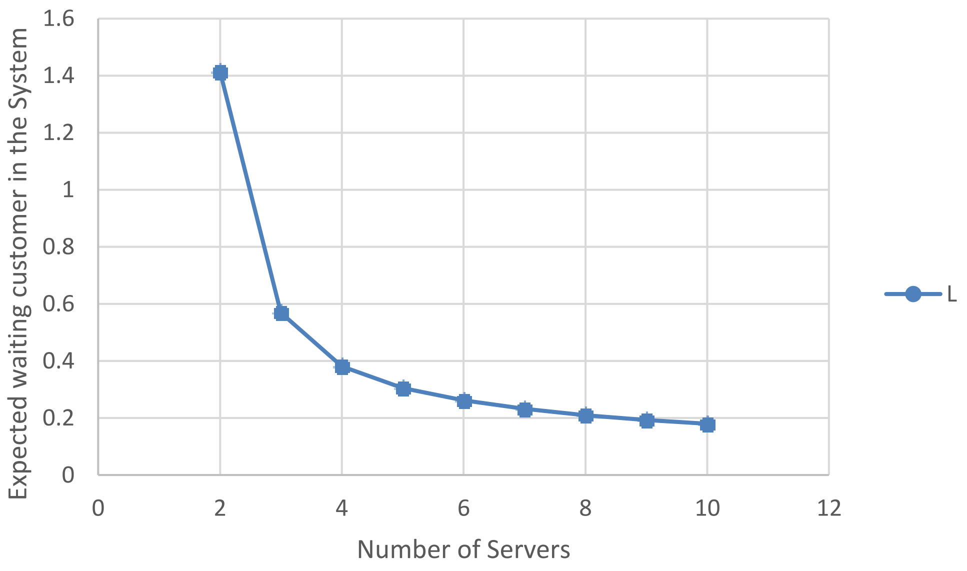

Figure 13. Total customer in the entire System (L) against Number of Servers for Jan 2013.

because M/M/1 has nothing to do with more than one server.

The time captured for these individual cases helps to know how long a case has stayed in any agency level before leaving the agency. The model can also be used to know the detailed mode of operation such as the number of cases that arrived in a specified period of time, the efficiency of the system in terms of workers utilization capacity. Result from this queueing model enables LEA administrators to have an estimate on the number of workers needed in their offices for effective operation based on the crime case arrival at a particular period of time. The data analysis on the queueing network model shows the following values: at 2 servers, W (total time spent in the entire system) is 2.07097115; at 3 servers, W is 1.41746454; at 3 servers, W is 1.32997128 up to 10 servers. The result shows that beyond 5 servers, W remains constant meaning that the system needed maximum of 5 persons for an effective operation. The results of the system helps managers of organization to make effective decision on a way forward of the organization. Finally, result from these models also shows that it also helps in crime control. This means that when crime cases are handled instantly as it comes without much delay and prejudice, and the suspect or culprit is punished appropriately, others who are developing criminal intention may be discouraged because of the fear of severe punishment emanating from disobeying the law by committing crime.

Conclusion

In this work, the queuing network model has been implemented to evaluate the performance of LEA on crime information management. Since parameters such as time cases spent on both queues (W_{q1} or W_{q2}) and servers (W_1 or W_2), total time taken by each case to be handled were calculated as shown on the algorithm above; this enables LEA's administrators to know the capacity of their staff members and the entire office i.e. how efficient the workers are in terms of how many cases handled in a specified time. This system also enables the admin to predict the number of workers expected in his or her office based on the rate of arrival of case in a specified time.

This work shows that queueing theory provides an effective and powerful modeling technique that helps LEAs in a more effective decision making to achieve their statutory goals. When results from the model are implemented, it leads to improvement on public security measure and more productivity of the LEAs.

Appropriate application of this system, solves the problems of staff redundancy, resource waste by government due to over staffing, under staffing due to miscalculation by the management and finally enhances the visibility of operations of the LEAs to government and the public at large.

It is recommended that in fuure priority queuing discipline may be used instead of first come first served applied in this work to accommodate cases that may be handled urgently. Further research may also include multiple queues, multiple servers in order to observe area of specialization of staff if need be.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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