Application of Queuing Theory in Mapping out the Potential for an Effective Coordination of Inbound Tobacco Transportation in Developing Country: Harare – Zimbabwe

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Abstract

This research explores opportunities for coordinating and integrating transportation of Tobacco from Small Mediums Farmers (SMF) to Tobacco Auction Floors (TAF) in pursuit of improving efficiency and effectiveness, which is not only beneficiary to Tobacco Auction Floors and carriers as value addition but also alleviates poverty of the farmers. It was established that Tobacco carriers and farmers spent long time of more than a week in the queue waiting to be served. High costs were incurred by both carriers/transporters and farmers as a result of uncoordinated transportation system.The Traffic intensity, denoted ρ is close to 1 indicating traffic congestion was high at the Tobacco Auction Floor.A queuing theory model of coordinating Tobacco inbound logistics was recommended to solve this problem.It includes online booking, use of electronic scheduling, tracking and CCTV at floors and electronic payment. This would also help to preserve the quality of tobacco from bad weather since there are no shades, which is vital important for further processing of it to other finished goods. Finally a private software which run on mobile networks could be ideal if it could be linked with the buying section.

Keywords: Queuing theory, inbound, efficiency, effectiveness, transportation.

1.Introduction

Traffic congestion is common in Zimbabwe particularly in Harare since it is heavily populated with a small landmass. The effects of such traffic congestion includes delay in delivery of goods and services, excessive fuel consumption, pollution, frustration and inability to estimate travel time. Agriculture is the rearing of animals, growing of crops and ornamental crops. In Zimbabwe, Tobacco and cotton are the main crops grown as cash crops. According to Zimstats,Agriculture is the backbone of the economy because more than 75% of the population rely on it. Others are employed indirectly.Agriculture supplies about 60-70% of the raw materials to other sectors of the economy. Some are practicing peri-urban farming. The roads are characterized by slower, queuing of vehicles and slower speeds.

At the three Tobacco Auction Floors, the farmers were incurring unnecessary costs due to lack of proper coordination of tobacco transportation. The costs were ranging from accommodation, food and securing bails waiting to be served. This means that the current transportation of tobacco was not good since farmers were spending more days in queue. It was also established that the transport system was in chaos due to lack of not using technology to find out predictable number of bails of tobacco prior to buying season as an input to devise a well-planned systematic way of buying tobacco. Thus the farmers spend more than one week in queues hence the need of queuing theory.

Queuing theory is the mathematical study of waiting lines, or the act of joining a line or queues.In queuing theory a model is constructed so that queue length and waiting times can be predicted (Sundarapandian, 2009).Whenever there is competition for limited or scarce resources, waiting lines and possibly, congestion will emanate.Queuing models have gained recognition as it provides useful insight towards understanding and controlling traffic flow and congestion.In almost every occasion, it is required that before being served, queue often happens when service capacity is less than the demand for service, see for example, Adedayo et al (2006).

Queuing theory is an analytical technique accepted as valuable tool for solving congestion problems and is mostly used for describing behavior at signalized and un-signalized intersections (Gross and Harris, 2008;Kim et al, 1999; Muruganananttha and Usha, 2016; Olorunsola et al,2015; Ogunlade and Okoro, 2015;Heidermann, 1997).The main characteristics in queuing models are the arrival and service patterns which are mostly described by random distributions.

Martin Anokye et al (2013) discuss the application of queuing theory to vehicle traffic at signalized intersection using a case study of Kumasi Ashanti Region Ghana.Chao et al (2009) and Quddus et al (2010) argue that the level of traffic congestion does not affect the severity of road crashes on the M25 motorway.

Traffic congestion occurs in busy and populated environment.It can be very frustrating because of the delay it causes on vehicular movement and delivery of goods.Traffic congestion is common in Tobacco Auction Floors in Zimbabwe because it is not well structured and organized.Mala, S.P. and Varma (2016)describes traffic congestion as a situation on road network which occurs as its use increases.It is characterized by slower speeds, increased trip times and queuing of vehicles.Thus, it is necessary to apply the principle of queuing theory to find the optimal waiting time in queuing system as experienced in traffic congestion.The effects of traffic congestion includes; vehicle collision, fuel wastage and delays which leads to frustration.This can leads to late arrivals for meetings. Mala, S.P. and Varma (2016)asserts that traffic congestion occurs when a mass of traffic requires space greater than the available road capacity.Intikhat et al (2008) assert that efficient transportation system plays an important role in the provision of daily necessities in the life of citizens because it assists in the smooth running of activities for optimal performance.Meanwhile, simulation based analysis on simple network topologies showed that the local decongestion protocol can enhance road capacity and prevent congestion collapse in localized settings (Vipin et al, 2012)

Tobacco farmers were experiencing problems of transporting tobacco from their farms to Tobacco Auction Floors and worse off spending a long time at the Tobacco Auction Floors. The problems range from un-coordinated transportation system, long queues, high costs and congestion. Although in Zimbabwe we have positive advent of technology that is complimented by competent labour in various sectors, still the transportation of tobacco is a problem. This research paper seeks to find out the reason for the existence of such a transportation problem and ways of resolving transportation problem.

2.Methodology

This section introduces the data sources, discusses the M\M\1 queuing model which this paper uses to explore opportunities for coordinating and integrating transportation of Tobacco from Small Mediums Farmers to Tobacco Auction Floors.

2.1 Queuing Theory

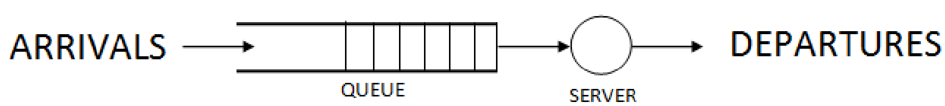

Figure 1: A general description of a Queue Model

According to Lartey (2014)queuing systems are defined by three elements; customers, servers and queues. Figure 1 depicts a general description of a queue model. Customers are the persons await service. In this study customers are farmers who brought bails of tobacco to the Tobacco Auction Floors from different provinces in Zimbabwe. The server is the source that provides the service to the customer, who is the farmer. The server refers to the Tobacco Auction Floor and its employees or representatives.

The queue is the group of customers waiting to be served, along with the place they are waiting. Queues can occur as orderly lines, but they can also be groups of customers spread out in a terminal waiting area, which is the Tobacco Auction Floor where tobacco is bought.

The performance of the queuing system is defined by the arrival process, service process and queue discipline. The arrival process represents the time pattern by which customers enter the queuing system.

Arrival processes in transportation are usually non–stationary,that is, the average arrival rate varies in some predictable way. Arrival processes also exhibit some level of stochastic variation, which is usually represented by the probability distribution for the inter-arrival time (the time separation between two successive arrivals). The service process represent the time and resources required to serve a customer. Service process, like arrival process, exhibit stochastic variation. The queue discipline is the rule of sequencing customers, typically, this is a first come first serve pattern.

Queuing system are important in transportation because of their effects on customers, and of the cost of providing the service. The dominant effect is delay, which might be measured in such ways as "time in system", "average speed", or "waiting time". Fundamentally, queuing analysis is used to determine the difference between how long it takes to complete a sale, and how long it would have taken if there were no queuing or congestion at the Tobacco Auction Floor. The following are performance measures that the researchers focus on to predict with queuing model:

Throughput: Rate at which farmers are served by the system.

Crowding or Congestion: Separation between farmers or density of farmers.

Arrival rate λ is the average number of farmers arriving per unit time.

The service pattern is the manner in which the service is rendered and is specified by the time taken to complete a service.Similar to the arrival pattern, distribution of the service time must be specified under stochastic modelling considerations (arrival is random).

The service rate μ gives the average number of farmers served per unit time.
The server utilization ρ gives the average utilization of the server(auction floors), given by:
$\lambda=\rho.\mu$.
The mean service time ϒ is the time to serve a designated customers.
The mean waiting time T is the average time spent in the queue by a customer who receives a service.
The mean queue size N is the average number of customers in the system for service.
The traffic intensity ρ is the average number of customers being served is the ratio of arrival and service rateρ given by:
$\rho=\lambda/\mu$.

For a stable system, the service rate λ and thus ρ should always be less than unity.Thus it is also known as utilization factor of the server.The average number of customers in the system is equivalent to the average number of customers in the queue together with those being serviced:

$$L_s = \frac{\lambda}{\mu - \lambda} \qquad (2.1)$$

The average number of customer in queue is equivalent to the number of customers who are waiting in the queue.It is defined as follows:

$$L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} \qquad (2.2)$$

The average time spent in the system is equal to the total time that a customer spends in a system, that is, waiting time plus the service time. It is given by:

$$W_s = \frac{1}{(\mu - \lambda)} \qquad (2.3)$$

The average waiting time in queue is the average time a customer waits in queue for getting service.It is given by:

$$W_q = \frac{1}{\mu(\mu - \lambda)} \quad (2.4)$$

3. Analysis and Results

Traffic congestion is observed at the three major Tobacco Auction Floors during the peak hours of morning (7 to 10 am), afternoon (12 to 3pm) and evening (5 to 8pm) sessions.Table 1and Figure 3depictsTraffic data at the 3 major Tobacco Auction Floors showing traffic intensity recorded for different times of the day.That is, the number of arrivals, time spent in minutes, number of farmers or trucks served, time spent in minutes by farmers.The arrival and service rates are derived from these quantities.The traffic intensity is derived from the arrival and service rates.

Table 1: Traffic data at the 3 major Tobacco Auction Floors showing traffic intensity recorded for different times of the day.

Location	**Session**	**Arrival average number of trucks (rate)**	**Arrival time**	**Service average number of trucks(rate)**	**Service time**	**Traffic intensity**
Auction floor 1	morning	30	1.34minutes	45	1.29minutes	0.666
Auction floor 2	morning	50	1.36minutes	60	1.56minutes	0.833
Auction floor 3	morning	15	2.30 minutes	23	1.27 minutes	0.652
Auction floor 1	afternoon	31	1.38minutes	42	1.17minutes	0.738
Auction floor 2	afternoon	28	1.43minutes	45	1.37minutes	0.622
Auction floor 3	Afternoon	13	2.33minutes	10	1.45minutes	0.722
Auction floor 1	Evening	52	1.41minutes	65	1.25minutes	0.8
Auction floor 2	Evening	47	1.52minutes	63	1.38minutes	0.74
Auction floor 3	Evening	15	2.32hours	21	1.32hours	0.714

Table 2presents mean number of farmers in a system waiting Ls, mean number of farmers waiting in the Queue Lq, mean time spent in the system and mean time spent in the queue at the 3 major Tobacco Auction Floors.The values are derived by application of the respective formulas Equation (2.1) to Equation (2.4). The general objective of this study is to build a basic model of coordinating tobacco transportation based on queuing theory and use it to determine best times for integrating transportation of tobacco from the farm to the auction floor. This is done in order to reduce congestion and delays at auction floors.

Table 2: Mean number of farmers in a system waiting Ls,, mean number of farmers waiting in the Queue Lq, mean time spent in the System and mean time spent in the queue at the 3 major auction floors.

Location	session	Arrival rate λ	Service rate μ	Traffic intensity P	Mean number of farmers waiting in the system per minute L_s	Mean number of farmers waiting in the queue per minute L_q	Mean time spent in the system W_s	Mean time spent in the queue W_q
Auction 1	morning	30	45	0.666	2	2	0.06	0.044
Auction 2	morning	50	60	0.833	5	4	0.1	0.083
Auction 3	morning	15	23	0.652	2	2	0.125	0.08
Auction 1	Afternoon	31	42	0.738	3	2	0.09	0.067
Auction 2	Afternoon	28	45	0.622	2	1	0.06	0.037
Auction 3	Afternoon	13	18	0.722	3	2	0.2	0.144
Auction 1	Evening	52	65	0.8	4	3	0.076	0.062
Auction 2	Evening	47	63	0.74	3	2	0.0625	0.047
Auction 3	Evening	15	21	0.714	3	2	0.143	0.12

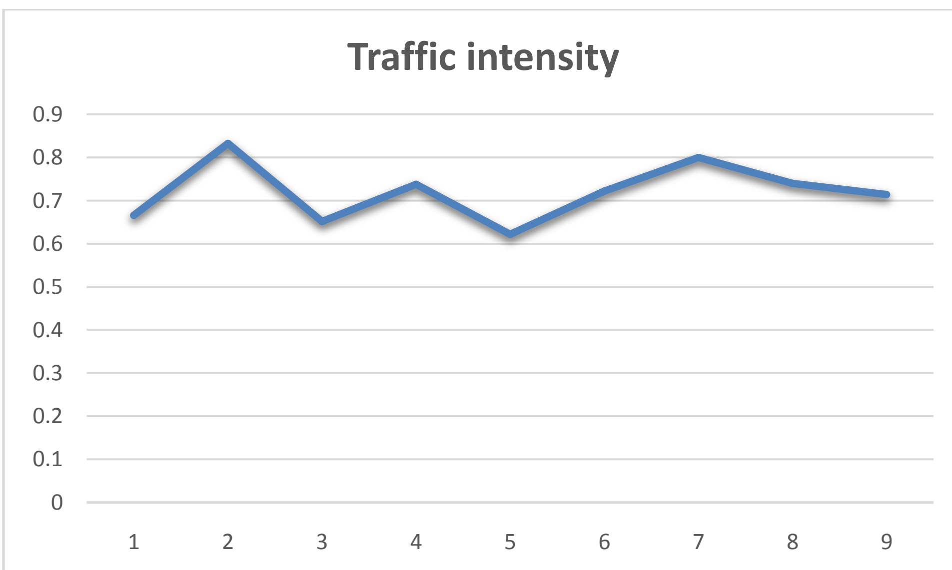

Figure 3: Graphical presentation of the traffic intensity at the three auction floors

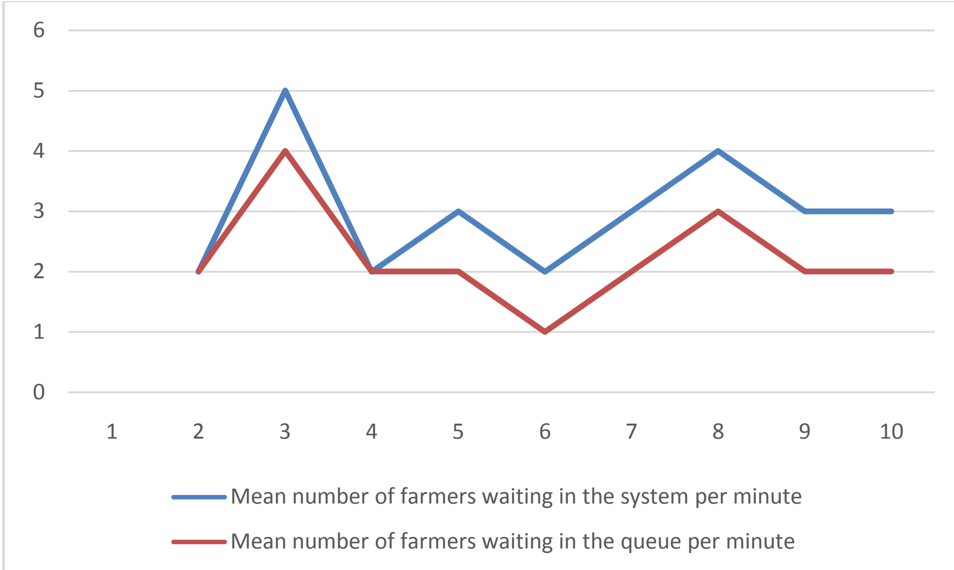

Figure 4: Graphical presentation of mean number of farmers waiting in the system per minute(Ls) and the mean number of farmers in the queue per minute(Lq)

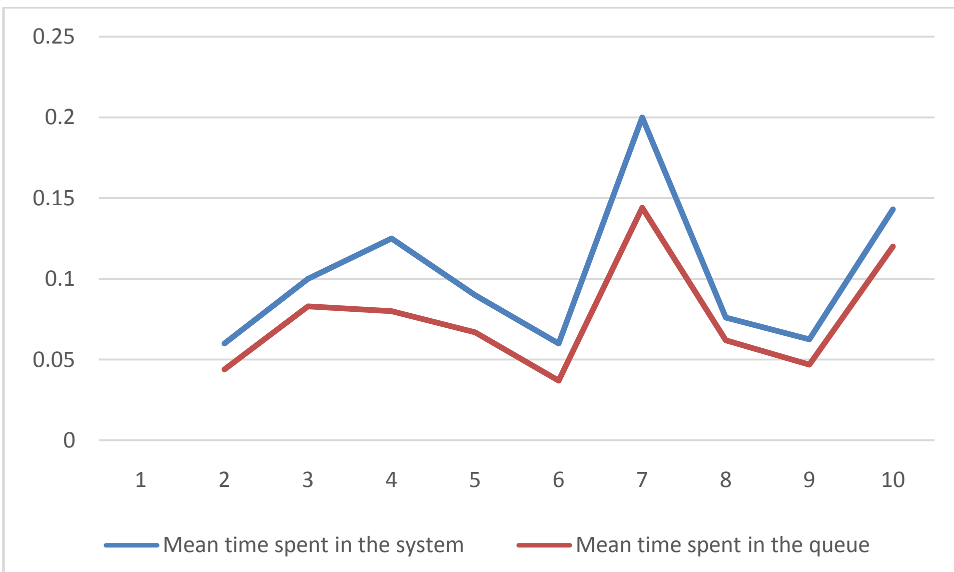

Figure 5: Graphical presentation of mean time spent in the system (Ws) and the mean time spent in the queue (Wq)

3.1 Morning Sessions of the Three Major Tobacco Auction Floors

The arrival and service rate are 30 and 45, respectively, at Tobacco Auction Floor 1 and the traffic intensity is 0.66.This indicates a stable traffic congestion situation at the floors.The mean number of farmers waiting in the system (Ls=2), mean number of farmers waiting in the queue (Lq=2), mean time spent in the system (Ws=0.06), the mean number of time spent in the queue (Wq=0.044) tend to confirm the traffic congestion situation at the floors.

The arrival and service rate are 50 and 60, respectively at Tobacco Auction Floor 2 and the traffic intensity is 0.833.This indicates a high traffic congestion situation at the floors as the value is closer to 1.The mean number of farmers waiting in the system (Ls=5), mean number of farmers waiting in the queue (Lq=4), mean time spent in the system (Ws=0.1), the mean number of time spent in the queue (Wq=0.083) tend to confirm the traffic congestion situation at the floors.

The arrival and service rate are 15 and 23 respectively at Tobacco Auction Floor 3 and the traffic intensity is 0.652.This indicates a stable traffic congestion situation at the floors.The mean number of farmers waiting in the system (Ls=2), mean number of farmers waiting in the queue (Lq=2), mean time spent in the system (Ws=0.125), the mean number of time spent in the queue (Wq=0.08) tend to confirm the traffic congestion situation at the floors.

3.2 Afternoon Sessions of the Three Major Tobacco Auction Floors

The arrival and service rate are 31 and 42 respectively at Tobacco Auction Floor 1 and the traffic intensity is 0.738.This indicates a high traffic congestion situation at the floors as the value is closer to 1.Thus the derived parameters validate the traffic congestion at the floors.

The arrival and service rate are 28 and 45 respectively at Tobacco Auction Floor 2 and the traffic intensity is 0.622.This indicates a high traffic congestion situation at the floors as the value is closer to 1.The mean number of farmers waiting in the system (Ls=3), mean number of farmers waiting in the queue (Lq=2), mean time spent in the system (Ws=0.09), the mean number of time spent in the queue (Wq=0.067) tend to support the traffic congestion situation at the floors.

The arrival and service rate are 13 and 18 respectively at Tobacco Auction Floor 3 and the traffic intensity is 0.722.This indicates a high traffic congestion situation at the floors. The mean number of farmers waiting in the system (Ls=3), mean number of farmers waiting in the queue (Lq=2), mean time spent in the system (Ws=0.2), the mean number of time spent in the queue (Wq=0.144) tend to validate the traffic congestion situation at the floors.

3.3 Evening Sessions of the Three Major Tobacco Auction Floors

The arrival and service rate are 52 and 65 respectively at Tobacco Auction Floor 1 and the traffic intensity is 0.8.This indicates a high traffic congestion situation at the floors as the value is closer to 1. The mean number of farmers waiting in the system (Ls=4), mean number of farmers waiting in the queue (Lq=3), mean time spent in the system (Ws=0.076), the mean number of time spent in the queue (Wq=0.062).Thus the derived parameters validate the traffic congestion at the floors.

The arrival and service rate are 47 and 63 respectively at Tobacco Auction Floor 2 and the traffic intensity is 0.74.This indicates a high traffic congestion situation at the floors as the value is closer to 1.The mean number of farmers waiting in the system (Ls=3), mean number of farmers waiting in the queue (Lq=2), mean time spent in the system (Ws=0.0625), the mean number of time spent in the queue (Wq=0.047) tend to support the traffic congestion situation at the floors.

The arrival and service rate are 15 and 21 respectively at Tobacco Auction Floor 3 and the traffic intensity is 0.714.This indicates a high traffic congestion situation at the floors. The mean number of farmers waiting in the system (Ls=3), mean number of farmers waiting in the queue (Lq=2), mean time spent in the system (Ws=0.143), the mean number of time spent in the queue (Wq=0.12) tend to validate the traffic congestion situation at the floors.

4. Discussions

This paper focused on the application of queuing theory in mapping out the potential for an effective coordination of inbound Tobacco transportation in Zimbabwe. It assumed that the time interval between successive arrival and service time is independent and shows a normal distribution.For all the 3 Tobacco Auction Floor the study adopts FCFS (First Come First Serve) approach where the farmers are made to line up or queue according to their arrival time as they wait to be served in order to,minimize congestion.The number of farmers in each Tobacco Auction Floor is counted and the time in minutes noted when waiting to be served after being served.These values are used to derive the arrival and service rates of the farmers.The data was observed over a period of 9 days in peak hours of morning, afternoon and evening (7 – 10am , 12 – 3pm and 5-8pm respectively)

Generally, the traffic intensity is closer to 1 for all the 3 Tobacco Auction Floors during all the three sessions (Morning, Afternoon and Evening). Moreover from the calculations in Table 2, the mean number of farmers waiting in the system per minute ranges from 2 to 5 and the mean number of farmers waiting in the queue per minute ranges from 1 to 4 showing presence of a queue at any given time of the day at the 3 Tobacco Auction Floors.

This shows existence of a queue and evidence that farmers spend more than one week at the queues waiting to be served.Figure 3, Figure 4 and Figure 5 shows the existence of queue at the three Tobacco Auction floors.

5.Conclusions

Critical analysis of the data collected at three Tobacco Auction Floors reveals a smooth flow of traffic and perfect system since the server at each channel was able to serve more than the trucks in waiting queue when servers resume work. Moreover, there seems to be high traffic volumes in the evening. It was observed that in the evening there are few road blocks and the farmers take advantages of the situation to move their tobacco. This situation is less or non-existent in the morning or afternoon. Farmers are spending more than a week in a queue waiting to be served.The winter season stretches from May to early August in Zimbabwe.Thusfarmers were exposed to face spells of the winter weather on which they spent mostly boarding vehicles, this left them vulnerable to flue and related diseases. In light of vendors who mushroom the areas did not just congest the area and pollute the area but then compromise security of farmers and their tobacco or cash. Over and above the research concluded that the farmers endured long queues due delays in servicing, hence, more costs were incurred than could have been saved if there was a structured and coordinated transportation of tobacco. The effective coordinated transportation of tobacco, if it could allow farmers to book bails at their farms before transportation would allow Just In Time Delivery (JITD), farmers would save more time and have hassle free, which was not the case.

A model of coordinating Tobacco Inbound Logistics was recommended to solve this problem. It includes online booking, use of electronic scheduling, tracking and CCTV at floors, and electronic payment. This would also help to preserve the quality of tobacco, which is vital important for further processing to other finished goods.

With the advent of telecommunication in Zimbabwe, Tobacco Auction Floors must make use of social media such as WhatsApp to allow farmers to book bails for sale and get approval to ship and deliver at definite set time.

A private software which run on mobile networks could as well be ideal if it could be linked with buying section. This could be done if each auction determines first its service time and number of bails they can serve per day. This is of great importance as it will maximizeutilization of carriers which are kept idle for a week and reduce costs of artificially congestion from the neglected and uncoordinated transport system.

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