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State of Urban Transport in a Nigerian Traditional City

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Abstract This study appraised the state of urban transport in a Nigerian traditional city. It examined commuters' socio-economic and transit characterization, assessed the quality of transport infrastructural facilities and services, and identified the challenges of urban transport services in Ibadan city, Nigeria. 163 copies of questionnaires were systematic randomly administered on commuters along six (6) selected traffic-corridors in Ibadan. Both descriptive and inferential (Binary Logistics Regression) statistics were used for data analysis. Major findings revealed majority (about 40%) of commuters were civil servants and earn above 90,000 naira as monthly income. Mean Weighted Value results show that taxi (3.913) and motorcycle (3.756) are dominant and most patronized means. Similarly, the availability (4.075), safety (4.000) and affordability (3.625) were most-weighted factors influencing commuting modal choice, while a trip to work (3.718) and market (3.200) are most generated trips in Ibadan. Meanwhile, most of the assessed infrastructural facilities were of poor quality, while peak/off-peak transit issues (4.050) and vehicular mechanical failure (3.487) were major challenges affecting urban commuting. Binary logistics regression results show that the condition of urban transport infrastructural facilities significantly influence overall satisfaction with urban commuting ($p < 0.000$). Cox & Snell's R-Square (36%) and Nagelkerke's R (70%) show that the model is relevant in predicting the relationship between dependent and independent variables. The study concluded that there is a need to improve urban transport system towards ensuring commuters satisfaction and urban development. Hence, recommended among others, integrated transport system with smart devices and improved conventional public transport scheme in Ibadan.

Keywords Cities, Commuters, Ibadan city, Nigeria, Traffic, Urban transport

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1. Introduction

Cities are centres of economic, social, cultural and intellectual activities which result in the drift of the population from rural to urban centres and these congregations have caused cities to expand. They rely heavily on an efficient and effective transportation system that ensures a constant supply of goods and services. It is in this sense that movement and spatial interaction of urban residents occasioned by efficient urban transport are crucial to the effective functioning of the city.

The benefits and importance of economic growth to infrastructure through continual investment have been recognized for a long time. With this, prioritizing infrastructure is part of long-term economic development for most cities. Therefore, cities that have managed to attract investments and enhance competitiveness in a highly globalized economy are those that have vastly improved the range and quality of their infrastructure. In contrast, cities that fail to provide adequate infrastructure are less likely to be competitive, prosperous and sustainable in terms of balancing economic and social development and environmental protection [1, 2].

Transport plays a key role in any given society at any given time as the interaction between the level and pattern of society as well as the average level of living standards is a crucial factor affecting their economic and social progress. The high rate of urbanization being experienced in most developing countries in general and most especially in Nigeria has created mobility challenges and ultimately impeding overall development. This mobility crisis with diverse counterproductive nature of transportation challenges posed serious challenges to spatial growth and development of cities and other urban centres [3, 4]. The success and existence of urban society largely depend upon the efficiency and availability of adequate transport facilities that can guarantee spatial interactions and seamless flows. Without an adequate and efficient supply of transport infrastructure, there can be no necessary maintenance, and well-being of the population, while the productivity of industries would be far below capacity. The provision of suitable transport services, both for inter-urban and intra-urban movement is therefore essential, of which any constraint and hindrance hamper socio-economic growth. As the transport sector makes a crucial contribution to overall economic growth and development [5], road transport plays an important role in integrating the various sectors in any given society. Transport is thus, an important component of both rural and urban development programs and also an enabling element for the achievement of global goals and ambition.

Therefore, meaningful development and functionality of urban centres are usually determined by the extent of transport system efficiency. Unfortunately, urban transport in most developing nations including Africa countries and many Nigerian cities is characterised by the inadequate and poor quality of infrastructural facilities, the mismatch between demand and supply, increased rate of accident or crashes as well as management and administrative weakness [5]. Such problems are triggered by interrelated trends such as urban population growth and unplanned and uncoordinated growth of cities, hence, the need to sustaining urban development through refocusing urban transport system in Nigerian cities. As a result, this study examined the state of urban transport in a Nigerian traditional cities with particular reference to Ibadan city, Nigeria towards understanding salient issues in urban commuting and overall development of the country. Based on this study aim, the following objectives were pursued: first, examined the socio-economic characteristics of urban commuters; second, assessed urban transit characteristics; third, examined the quality of urban infrastructural facilities and services, and finally, identified the challenges of urban transport services in Ibadan city.

In other words, this study was structured into five sections for clear and logical understanding. Following the introductory sections was the conceptual underpinning and brief literature review. The third section dealt with the research methodology that gave insight into the study area, sampling procedure, method of data collection and techniques of analysis. The last two sections, that is, section four and five presented the results and discussion of findings as well as the study conclusion and recommendations.

2. Conceptual Underpinning and Brief Literature Review

2.1. Concept of Affordability, Accessibility and Availability

This study is anchored on the concept of 3As i.e. availability, accessibility and affordability. The concept was used by Reference [6] in examining the state of public transportation services in four states universities in South-Eastern Nigeria. Accordingly, the concept of affordability deals with the extent to which financial implications of a journey to be in a position of making a sacrifice to travel on one hand or the extent to which a trip maker can afford to travel at his desired time. Affordability, therefore, is the ability of public transport users to make necessary journeys to work or school or (any urgent journeys) without curtaining other essential activities as this can force necessitate curtailment of movement.

Availability of public transport refers to route possibilities, timing, frequency and acceptable modes of travel concerning the purpose of an individual's journey which may be affected or limited by the route and travel time [6], while also, accessibility refers to the ease with which all groups of passengers can use public transport. As an illustration, it is easier to board buses with low steps than those with high steps. This is because the aged, infants/children and the physically challenged as well as those passengers with big luggage may not find public transport easily accessible. Therefore, accessibility equally contends to the ease of accessing the bus stops, acquisition of travel information and to enjoying public transport [7].

The 3As becomes vital to the system but also resolve between costs, fares, revenue, system mismanagement and operation deficiencies among others. As investments in urban transport infrastructure and its operation are paid for exclusively by the fares paid by users, while, the remaining are paid by the government through subsidies in a different form, it is thus, indispensable to integrate availability, affordability and accessibility into urban transport framework. Last, Reference [8] opined that urban mobility cannot be understood as merely the number of trips a person can make over a specific period, but also the capacity to carry out the necessary trips for achieving the basic rights of a citizen, as well as the concern for the environmental impacts that result from the choice. Hence, affordability, accessibility and availability are key ingredients for the expected performance of urban transport.

However, quality is an important competitive factor and a prerequisite of survival in the market. It is a comprehensive value judgment of the service rendered in connection with a given unit, expressed by the degree of meeting or exceeding the materials internal and external specifications relevant to the unit as perceived by the customer. Therefore, service quality is one of the most important factors for measuring the level of demand for a service or product including urban transport [9].

The concept of service quality is then, a comparison between customers' expectation and actual services performed as the extent to which expectations and service performance are similar or different influences the extent to which customers are satisfied or dissatisfied. Like in airline operations where competing organizations such as airlines provide the same types of service, urban transport service also do not provide the same quality of service as the service quality of operators is better known by the trip makers.

2.2. Literature Review

The realization of the need to harness optimum resource potentials for African development through urban transport becomes indispensable in refocusing Africa development agenda. In this regard, the Reference [1] opines that cities that want to be competitive can achieve success through the economic structure, policy levers, growth coalitions, implementation and delivery. By this, policy levers, such as institutions and regulations, infrastructure and land, skills and innovation, enterprise support and finance remained integral to city competitiveness. The extent of urban mobility

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can be examined in relation to the extent of motorization in a given society.

Also, the past few decades have seen explosive economic growth and urbanization as more than half of the world's population now lives in urban areas and by 2020, there would be over 500 cities across the world with a population over one million [10]. This rapid urbanization is already straining the infrastructure of many countries. Urban mobility as one of the attributes of urban transport has to do with mobility in an urban area and such mobility has to be planned in such a way to bring about a balance in the inter-relation between city structure and supply of transportation services [11].

Urban transport is associated with a spatial form which varies according to the models being used. In urban situations, mobility and demographic growth have been shaped by the capacity of transport infrastructure ranging from roads, bus routes and rail lines [12]. Urban form in the context of an urban transport system is the spatial imprint on an urban network, while the urban (spatial) structure is the set of relationships arising from the urban form and the underlying movements of goods and people. Thus, globally, the amount of urban land allocated to transportation is often correlated with the level of accessibility, connectivity and mobility.

In other words, the level of motorization and automobile ownership in cities is fast-growing across the world particularly in developed world due to the affluence in the socio-economic status residents [1]. Fortunately, and unfortunately, fortunately, car ownership levels although increasing but are still very low in West African cities as Reference [13] opines that automobile ownership denotes an average of 5-15 per 1000 population unlike in the cities of the developed countries with an average of 20-40 per 1000 cars per 100 inhabitants. These findings corroborated that Reference [14, 15] reported that Nigeria has the lowest level of motorization in West Africa with as low as 4 Vehicles per 1000 inhabitants, while the rate of vehicle growth is much lower than the population growth rate. And unfortunately, despite the level of motorization, the urban transport in West African cities most especially Nigerian cities is still characterized and faced with various alarming mobility and accessibility challenges with undoubtedly hinders the development of these cities in competing with their contemporaries in developed countries [16, 17]. The root of these mismatch is not unconnected to the failure of planning urban transport in line with the growing population surge, weak policy, carefree attitude of Governments, corruption, political instability among others [5]. However, the consequences have resulted in general fall in the urban mobility performance in all parts of the country (Nigeria).

appraised land-use and Ibadan traffic paralysis by analyzing the impact of land-use activities on the free flow of traffic in Ibadan where it was revealed that poor road network coverage, absence of traffic signs, effects of flooding, encroachment of carriageway, street trading and indiscriminate locations of major commercial land uses such as eateries and banks at intersections characterized the city and resulted into traffic bottleneck which invariably have negative impacts on the functionality of the city. However, the study excluded that these consequences have eaten up the growth of urban transport in the city of Ibadan.

Reference [18] observed that the lack of modern planned physical development in most Nigerian urban centres is one of the major contributors to many traffic bottlenecks and urban transport issues being experienced today. The findings of Reference [3, 19, 20] and that of Reference [17] observed that weak road management, faulty intersections, narrow carriage width, haphazard on-street parking, poor road network coverage, poor intermodal system, absence of traffic signs, lack of intelligent transport system, encroachment of carriageway, street trading and indiscriminate locations of major commercial land uses among others, obviously contribute to urban traffic crisis and paralysis, most especially congestion and unpredictable travel time and cost in the city of Ibadan. These quagmires combined, often result in traffic bottleneck which invariably has negative impacts on the functionality of the city system, such as time-wasting in travel time, environmental pollution and road accidents among others. With these backdrops, there is need to understanding the state of urban transport system towards addressing transport challenges in the city of Ibadan and achieving efficient and safe mobility means, improved traffic flow and travel time in Ibadan city, Nigeria.

3. Material and Methods

3.1. Study Area

Ibadan is located in the southern part of Oyo state of Nigeria. According to Reference [15], Ibadan has an estimated area of 3,123.32km2 (45,312.50 hectares). At Present, Ibadan had 11 local government areas namely Ibadan North, Ibadan North-East, Ibadan North-West, Ibadan South-East, Ibadan South-West, Lagelu, Oluyole, Ido, Ona-Ara and Oluyole. The city is bounded in the North by Afijio Local Government, on the East by Osun State, on the West by Ibarapa-East Local Government and in the South by Ogun-State. There are several industries in Ibadan which include the Nigeria Breweries Plc, Nigeria Bottling Company, 7up bottling company and many other companies situated in Oluyole and Olubadan Industrial Estates. The land area of Ibadan covers 463,33Km^2 hectares which are inhabited by 2,603,502 according to a projected population of 2006 [15]. Public transport services are provided mainly by the private sector, these services are however supplemented by the stale government-owned Trans City Transport Company (TCTC)/Pacesetter whose vehicles operates more intercity transportation than intra-city. Public transport is mainly by taxis, minibuses, tricycles and motorcycles within Ibadan City.

3.2 Methods

Both primary and secondary sources of data are employed for this research. The primary sources of data include questionnaire administration complemented by route familiarization and observation. This source gathered data on the trip pattern of commuters, trip generation, distribution and modal choice as well as factors influencing modal choice in urban transit and operational performance of urban transit in the study area. The secondary sources employed for this study include the use of the library, internet and maps. Data obtained through this source provided wide and in-depth views on the theme of this research. Secondary data also gives insight into the theoretical background and platform for reviewed interactions.

The commuters inventory at different bus stops in the study area was taken with due regard to the number of intending passengers/commuters awaiting urban transit along the corridors as well as the condition of transit infrastructural facilities. A set of questionnaires are designed and administered on the commuters in the study area to get their views on the study objectives. However, the sample frame for this study consists of the commuters/passengers in the study area. The stratified random sampling was used to select the screening traffic corridors and the first group of respondents (commuters) in the study area. Based on this, commuters/passengers involved in urban transport along major corridors in Ibadan city were screened in as a key component of this study. It is on this premix that inventory of commuters waiting at major bus stops along six (6) stratified randomly selected corridors (Ojo- Iwo road, Iwo road – New Garage, Challenge – Dugbe, Dugbe- Ojo road, Dugbe- Molate road, Mokola – Eleyele road) were identified and enumerated resulting in 32 bus stops with 2km radius apart of spatially closed bus stops. The sample size for the study population was taken from the 544 commuters enumerated at different stratified randomly selected bus stops along the selected corridors within the delineated radius. Based on this, 30% sample size equivalent of 163 respondents was selected and sampled for data collection through the administration of the questionnaire to along the selected bus stops. Having identified and stratified the bus stops into major and minor groups based on the enumerated population of commuters found awaiting urban transit to their destinations, the final selection of respondents was made on the principle of the random sample at each bus stop.

It is important to state that data was first collected for this study in June 2017 and a follow-up/ updated data later in November 2019. The methods of data analysis used are descriptive and inferential. Descriptively, simple frequencies distributions with frequency tables, pie charts, and histograms are drawn to support illustrations on the responses of respondents based on five-point Liker scale with a relative index of variables determined through Summation of Mean Weighted Value. According to Vagias (2006) cited in Salisu et al (2020), MWV for a variable is obtained through the addition of the product of the number of responses to each aspect and the respective weight value attached to each rating. This is expressed quantitatively as thus:

$$MWV = \sum_{i=1}^{5} X_i Y_i$$

Where:

MWV = Summation of Mean Weighted Value,

Xi = number of respondents to rating i

Yi= the weight assigned a value (i = 1, 2, 3, 4, 5)

Inferentially, and Binary Logistics Regression analysis were both simultaneously used for the analysis and postulated hypothesis testing. Data presentation and analysis were both accomplished through the use of Statistical Package for Social Sciences SPSS IBM version 21.

3.3 Research Hypothesis

The postulated hypothesis was tested to establish the relationship between quality of urban transport infrastructural facilities and commuters overall satisfaction with urban commuting in the study area. The research hypothesis was tested using Binary Logistics Regression and thus, presented in the null form as:

H_0: Quality of urban transport infrastructural facilities does not influences commuters overall satisfaction with urban commuting in the study

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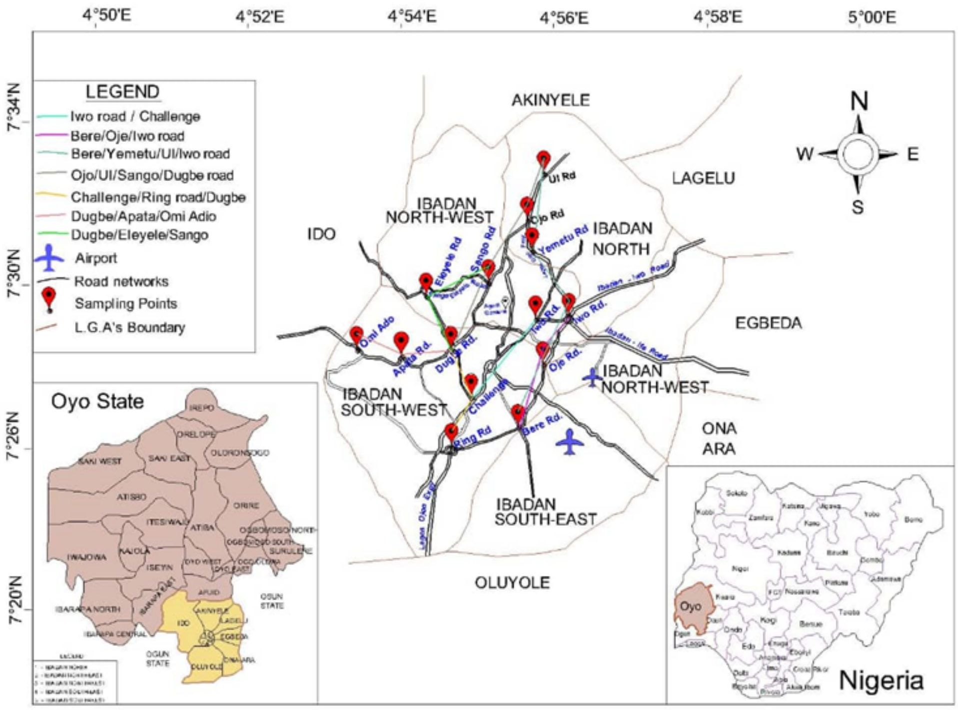

Figure 1. Map of Ibadan city in Oyo State, Nigeria showing the route corridors and sampling points

Source: Reference [17]

4. Results and Discussion

4.1 Socio-economic Characteristics of Urban Commuters

The socio-economic characteristics of commuters sampled along the selected corridors varied in components. Figure 2 shows the age classification of commuters in the study area in which commuters with age less than 24years has the lowest frequency (8.1%). Also, more than a quarter (28.8%) is 25-35years, while those with 36-45years accounted for 31.3% and only 20.6% are 46-55years. The remaining 11.3% are 56years and above. This analysis showed that respondents are adult and their view on urban transit in the study area could be relied on as a reflection of their experience.

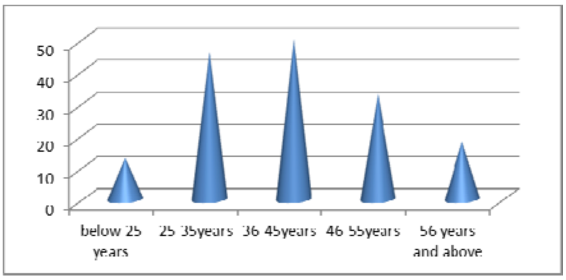

Figure 2. Age Groups of Commuters

The respondents sampled in the study area belong to various working groups in the society as shown in Table 2 where 3.1% are unemployed and 38.8% are civil servants. Also, 28.8% are private employee, 21.9% have their business and the remaining 7.5% are students. Hence, commuters in the study area are economically engaged and this makes them involve in intra-urban commuting daily to their various places of work.

Table 1 reveals that more than half of commuters (60 %) are married, slightly more than a quarter (25.6%) is single and the divorced accounted for 7.5% while the remaining 6.9% accounted for widow/widower. This shows that the married are constantly involved in urban transportation towards meeting their socio-economic obligations in the study area than the single. Also, it is observed that 2.5% of the commuters have no formal education, 16.3% has primary school education, 30% has secondary school education and 51.3% possessed higher degrees in that ascending order. It can be deduced from this analysis that commuters have various categories of academic qualifications and thus, their views could be relied on as they truly understand the context of information required from them.

Table 1. Marital Status and Education Level of Commuters

Status	Freq.	%	Education	Freq.	%
Single	41	25.6	No formal educ.	4	2.5
Married	96	60.0	Primary cert.	26	16.3
Divorced	12	7.5	Secondary cert.	48	30.0
Widow/widower	11	6.9	Higher degree	82	51.3
Total	160	100	Total	160	100

Authors' Fieldwork, 2019

Table 2. Occupation of Commuters

Occupation	Freq.	%
Unemployed	5	3.1
Civil servant	62	38.8
Private employee	46	28.8
Personal business	35	21.9
Student	12	7.5
Total	160	100.0

Authors' Fieldwork, 2019

Analyzed data on an average monthly income of commuters is presented in Figure 3 where it is observed that 2.5 % earns less than #18,000 monthly and 5% earns #18,000-30,000 on monthly basis. Also, 26.3 % of commuters sampled earns #31,000-#60,000, while 31.9% earns #61,000-#90,000 and the remaining 34.4 % earns above #90,000. This showed that the majority of respondents earn above the national minimum wage of #18000 per month in the study area.

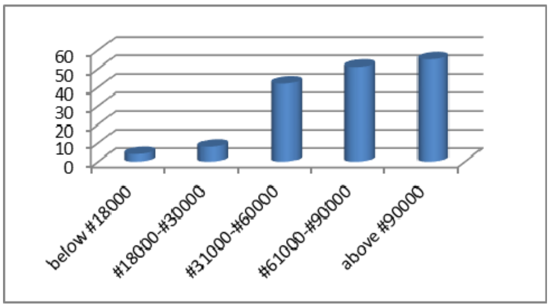

Figure 2: Average monthly Income of commuters

4.2 Urban Transit Characterization in Ibadan City

Table 4 presents the results of the relative index of the extent of patronage of urban transport by commuters in the study area on a five-point Liker's scale. The gradation of the values in ascending order consists of Not Available (NA=1), Not Patronized (NP=2), Rarely Patronized (RP=3), Patronized (P=4) and Very Patronized (VP=5). From this analysis, it was observed that Taxi is highly and very patronized by the commuters as it has the highest relative index of 3.912 which is far exceeding 2.796 estimated values for mean index value.

Also, the above is closely followed by Motorcycle with an index value of 3.756, while Minibus has a value of 3.456 and Pace-setter Transport Service Bus which is rarely patronized with 3.050 index value. However, both bicycle and tricycle are not been used by sampled respondents for their daily movement.

Table 3. Relative Index of Patronage Rate of Urban Transit Means

Means	NA	NP	RP	P	VP	TWV	MEAN	RIV	RK
Minibus	0	64	135	244	110	553	3.4563		3
Motorcycle	0	42	96	288	175	601	3.7563		2
Taxi/Cab	0	36`	75	280	235	626	3.9125		1
Unlicensed car	0	200	117	20	80	417	2.6063	2.796	5
PTS	0	152	48	208	80	488	3.0500		4
Bicycle	0	0	0	0	0	0	0		6
Tricycle	0	0	0	0	0	0	0		6

Authors' Fieldwork, 2019

Commuters were asked on the contributions of different factors in influencing their patronage of urban transportation means in the study area and the relative index of their responses is presented in Table 4. With the use of 5 points Liker's scale on the values which consist of Indifference (I=1), Not Considered (NC=2), fairly Considered (FC=3), Considered (C=4) and Highly Considered (HC=5). Of the seven factors identified, and with the mean index value of 3.347 estimated, it is observed that availability is the predominating factor influencing the patronage of urban transit in the study area. By this, availability has the highest relative index mean of 4.075 far exceeding the MIV and is closely followed by safety consideration with an index value of 4.000 and affordability which has a value of 3.625. Aside from this, accessibility (3.325), speed (2.900), reliability (2.893) and lastly comfort with an index of 2.612 are ranked in that descending order among the deciding factors influencing patronage of urban transit. Therefore, the availability of any transport means is usually given priority and preference by urban commuters in their patronage of urban transit.

Table 4. Factors Influencing Patronage Rate of Urban Transport Means

Means	I	NC	FC	C	HC	TWV	MEAN	RIV	RK
Comfort	36	56	201	80	45	418	2.612	3.347	7
Affordability	28	50	39	28	435	580	3.625		3
Accessibility	15	12	189	256	60	532	3.325		4
Availability	11	8	42	256	335	651	4.075		1
Reliability	37	74	60	152	140	463	2.893		6
Speed	19	100	69	256	20	464	2.900		5
Safety	9	0	66	320	245	640	4.000		2

Authors' Fieldwork, 2019

The relative index of the average distance of commuters from their home to various places is presented in Table 5. Using 6 point Liker's scale with values that consist of Not applicable =1, less than 5Km =2, 5-10Km =3, 11-15Km=4, 16-20Km =5 and above 21Km =6 with a mean index value of 2.9191. From this analysis, it is observed that distance to work is ranked 1st with 3.718 which has the highest relative index that is far exceeding 2.199 estimated value for mean index value. Also, distance to market is ranked second with a mean index value of 3.200 and followed by distance travel to a social gathering (2.012). The distance to the religious centre has an index value of 1.975, distance to the hospital has a value of 1.9250, and distance to friends/relative has a value of 1.687, while commuters rarely visit post office as this has least index value (0.8750) in the analysis. Hence, journey to work and journey to shopping/market are the predominant trips being made by commuters in the selected corridor.

Table 5. Factors Influencing Patronage Rate of Urban Transport Means

Distance	NA	<5	6-10	11-15	16-20	>20	TWV	MEAN	RIV	RK
to work	0	21	22	66	176	310	595	3.7188	2.919	1
to social gathering	0	55	140	60	32	35	322	2.0125		3
to relatives	0	73	142	27	28	0	270	1.6875		6
to the religious centre	0	89	94	33	16	0	277	1.9750		4
to market	0	29	36	96	216	135	512	3.2000		2
to hospital	0	56	146	63	28	15	308	1.9250		5
to post office	84	52	108	56	0	0	300	.8750		7

Authors' Fieldwork, 2019

The relative index of operational characteristics of Urban Transport means used by commuters is shown in Table 6 with the use of 5 points Liker's scale. With the values on the scale that consist of Indifference (I=1), Poor (P=2), Fair (F=3), Good (G=4), Very Good (VG=5) and relative index mean value of 3.201. From this analysis, it is observed that negotiated fair is high with 4.268 indexes which are far exceeding the MIV of 3.201. This is closely followed by unscheduled service with a value of 3.981 and fixed fare service with a value of 3.556, while schedule service has an index value of 1.000. Thus, schedule service is not in operation in the study area, unlike the other three distinguished characteristics which had a mean index value above 3.201.

Table 6. Operational Characteristics of Urban Transport Means

Characteristics	I	P	F	G	VG	TWV	MEAN	RIM	RK
Schedule	160	0	0	0	0	160	1.000	3.201	4
Unscheduled	3	0	98	159	220	480	3.981		2
Fixed fare	9	0	154	150	96	409	3.556		3
Negotiated fare	6	18	45	144	470	683	4.268		1

Authors' Fieldwork, 2019.

4.3 Quality of Urban Transport Infrastructural Facilities and Services

Table 7 shows the relative index of the functional conditions of urban transport infrastructure facilities in the study area. Using 5 point Liker's scale with values that include Not Available (NA=1), Deplorable (D=2), Fair (F=3), Good (G=4) and Very Good (VG=5) as well as a relative mean index of 1.968. It is deduced from the analysis that carriageway capacity is very good as it is ranked the highest (4.687) which is far exceeding 1.968 mean index value, while road marking has the index of 3.887, road signage and lightning has 2.993 and pedestrian crossing 1.637. Others are passengers' shield with an index value of 1.331, route information has 1.175, while layby has a value of 1.025 and road surface and pedestrian bridge have 1.000 index values each. Hence, this analysis shows that urban transit infrastructure such as signage, layby, passenger shield, lane marking, and pedestrian bridge are less pronounced in the study area.

Table 7. Quality of Urban Transport Infrastructural Facilities

Condition	NA	D	F	G	VG	TWV	MEAN	RIV	RK
Carriageway capacity	0	0	12	168	570	750	4.687	1.968	1
Road surface	160	0	0	0	0	160	1.000		8
Passenger's shield	115	74	24	0	0	213	1.331		5
Lay bye	156	8	0	0	0	164	1.025		7
Road marking	0	0	234	88	300	622	3.8875		2
Road signage & lightning	54	0	105	140	180	479	2.993		3
Vehicle/Route information	132	56	0	0	0	188	1.175		6
Pedestrian crossing	101	48	81	32	0	262	1.637		4
Pedestrian bridge	160	0	0	0	0	160	1.000		8

Authors' Fieldwork, 2019

The condition of vehicular facilities used for urban commuting was an understudy and the result was presented in Table 8 using ten indicators. The result of the analysis revealed the mean index value of 2.55. Accordingly, the lightning system of the vehicles are in good condition among other parts used as indicators with a relative index value of 4.025 and is closely followed by a braking system which has an index value of 3.6, while space capacity of the vehicles is ranked third (2.5667). However, other indicators have their index values lower than the overall mean index value for the entire analysis; hence their conditions are far below average denoting their dysfunctional or epileptic nature. As a result, most of the vehicles surveyed have a poor physical appearance, deplorable tyre, high emission rate, and poor steering rack condition. Ditto to the absence of broken mirrors and absence of restraint systems that characterized most of the vehicles observed for the study. With this, the condition of public vehicles used for urban commuting in Ibadan city appeared to be mostly not worthy of being used for passengers commuting since many of them are not in good operating condition.

Table 8. Quality of Vehicle Used

Indicators	VG	G	F	P	VP	TWV	RIM	MIV	RK
Physical appearance	3	78	216	12	15	234	2.7	2.550	5
Tyre condition	30	52	132	80	0	294	2.45		6
Space capacity	12	92	132	72	0	308	2.5667		3
Braking condition	1	8	117	296	10	432	3.6		2
Steering rack condition	29	120	87	0	10	246	2.05		8
Lighting system	24	12	99	0	285	483	4.025		1
Emission rate	22	144	47	28	0	251	2.0917		7
Restraint system condition	55	116	27	0	0	192	1.6		10
Fire safety condition	13	142	18	68	65	306	2.55		4
Side mirrors	53	74	87	4	0	218	1.8167		9

Authors' Fieldwork, 2019

The quality of service render by urban transport operators were assessed by commuters and the relative index of the results are presented in Table 9. Using 5 point Liker's Scale with a value that consists of Indifference (I=1), Poor (P=2), Fair (F=3), Good (G=4) and Very Good (VG=5) and a relative index value of 2.457. From this analysis, it is observed that adequacy is the prime quality of the service with 3.637 which is far exceeding the mean index value. This is followed by safe driving (3.618), frequency (3.406), vehicle interior (2.943), and seating arrangement (2.706). Other variables are comfort (2.625), reliability (2.625) and courtesy which accounted for 2.93 indexes.

Table 9. Quality of Service Render by Operators

Parameters	I	P	F	G	VG	TWV	MEAN	RIV	RK
Seating arrangement	7	164	90	132	40	433	2.706		5
Comfort	24	122	123	76	75	420	2.625		6
Courtesy	23	210	82	16	5	335	2.093		8
Vehicle interior	9	104	162	116	80	471	2.943	2.457	4
Reliability	27	196	123	56	0	402	2.262		7
Adequacy	4	22	93	428	35	582	3.637		1
Frequency	6	26	162	336	15	545	3.406		3
Safe driving	6	28	138	252	155	579	3.618		2

Authors' Fieldwork, 2019

Table 10 presented the result of the commuters overall satisfaction with urban transport services operation in Ibadan city. The table revealed that the highest proportion of the commuters (60.1%) were not satisfied with the urban transport service operation within the city, 20.3% accounting for 33 of the respondents attest to their satisfaction rate as strongly dissatisfied, 14.7% were satisfied while the remaining percentage of the respondents (4.9%) equivalent of 8 commuters was strongly satisfied with the operational performance of the urban transport services in the city.

Table 10. Commuters Overall Satisfaction with Urban Transport Services

Indices	Freq.	Percentage
Strongly satisfied	8	4.9
Satisfied	24	14.7
Dissatisfied	98	60.1
Strongly Dissatisfied	33	20.3
Total	163	100

Authors' Fieldwork, 2019

4.4 Challenges of Urban Transport Services in Ibadan

Table 11 shows the relative index of six challenges that influence Urban Transport Patronage in the study area in which peaking/off-peak issues ranked most with an index value of 4.050. This is followed by mechanical failure (3.487) and insecurity (3.018) while waiting time (2.587), journey time (2.512) and poor vehicle maintenance ranked least among the challenges in urban transport patronage in the study area.

Table 11. Challenges in Urban Transportation Patronage

Challenges	I	VL	L	H	VH	TWV	MEAN	RIV	RK
Peak/ off peaking issues	5	10	63	60	270	408	4.0500		1
Waiting time	6	160	183	0	65	414	2,5875		4
Journey time	21	94	246	28	10	399	2.5125	2.444	5
Insecurity	1	118	120	224	10	473	3.0188		3
Mechanical failure	5	38	150	260	105	558	3.4875		2
Vehicle maintenance	32	70	237	56	0	395	2.468		6

Authors' Fieldwork, 2019.

4.5 Hypothesis Testing

H_0: Quality of urban transport infrastructural facilities does not influences commuters overall satisfaction with urban commuting in the study

Further investigations were conducted using a binary logistic regression model to determine whether or not the condition of urban transport infrastructural facilities statistically influences commuters overall satisfaction with urban commuting in the study area. Thus, the dependent variable (that is, the variable to be predicted) which is the overall satisfaction with urban commuting is dichotomously coded as strongly satisfied/satisfied [satisfaction] = 1 and dissatisfied/ strongly dissatisfied [dissatisfaction] = 0, while the independent variables (predictors) of condition of carriageway capacity, road surface condition, passenger's shield, lay bye, road markings, road signage, vehicle/route information, pedestrian crossing/walkway and pedestrian bridge were also coded on dichotomous basis (Not Available/Deplorable/Fair =0, Good/Very Good =1) see Table 7. However, this binary logistic regression analysis is used to model and examine the relationship between a dependent variable and independent variables as it establishes the extent of the relationship between a binary outcome variable and a group of predictor variables (see Table 12).

Interestingly, the model through the Chi-square result shown in Table 12 was used to test the overall significance of predictors (independent variables) in the binary logistic regression model as used. The results show a Chi-square value of 175.681and probability of $p<0.000$. Therefore, the dependent variable is significantly predicted by the independent variables (predictors). Hence, the commuters overall satisfaction with urban commuting is statistically influenced by the condition of urban transport infrastructural facilities in the study area. More so, to understand the extent of variation, the dependent variable can be explained by the model (the equivalent of R^2 in multiple regression), the result of Cox & Snell R^2 and Nagelkerke R Square values were both presented. Hence, from Table 12, the explained variation in the dependent variable based on this study model ranges from 35.5% to 69.7% respectively indicating a strong relationship between predictor and prediction.

Furthermore, the variables in equation Table 12 shows the contribution of each independent variable to the model and its statistical significance through the Wald Test (Wald column) and statistical significance of the test in the Sig. column (Table 12). From the result, condition of carriageway capacity (p=0.019), road surface (p=0.032), and pedestrian's shield (p=0.000) added significantly to the model prediction, while road signage (p=0.326), vehicle/route information (p=0.816), pedestrian crossing (p=0.994), lay by (p=0.798), pedestrian bridge (p=0.935), and road makings (p=0.199) did not significantly add to the model. Hence, only three (3) out of nine (9) predictors best predict the model. The findings depict that a unit change or improvement in the condition of the urban transport infrastructural facilities will bring an increase in commuters satisfaction with urban commuting in the study area.

Table 12. Binary Logistics Regression Analysis Classification Table

omnibus Tests of Model Coefficients

		Chi-square	Df	Sig.
Step 1	Step	175.681	9	.000
	Block	175.681	9	.000
	Model	175.681	9	.000

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	109.793[a]	.355	.697

a. Estimation terminated at iteration number 7 because parameter estimates changed by less than .001.

Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1[a]	Road signage	-1.212	1.234	.964	1	.326	.298
	Vehicle/Route information	-.293	1.257	.054	1	.816	.746
	Carriageway capacity	1.834	.779	5.548	1	.019	6.258
	Road surface	1.470	.976	2.270	1	.032	4.348
	Pedestrian crossing	.006	.870	.000	1	.994	1.006
	Lay bye	.319	1.244	.066	1	.798	1.375
	Pedestrian bridge	-.036	.443	.007	1	.935	.965
	Road marking	.463	.360	1.651	1	.199	1.588
	Passenger's shield	4.329	.778	30.995	1	.000	75.880
	Constant	-2.725	1.461	3.479	1	.062	.066

5. Conclusion and Recommendations

This research had examined urban transport efficiency in Ibadan metropolitan area of Oyo State. The study was able to identify socio-economic attributes of commuters and residents as well as the pattern of movement and constraints to mobility in the area. Generally, the study observed a high rate of use of para-transit means of transport in form of cabs and minibuses, low use of high capacity mass transit as represented by Pacesetter Transport Service bus and non-usage of bicycles in the study corridors.

The study concluded that urban transport system in the study area is inefficient and not matured considering the poor operational characteristics of urban transport service which has been adversely influencing the level of satisfaction of urban trip makers compared to Lagos, the only city in Nigeria included in Urban Mobility ranking index [12, 16].

To have efficient urban transport system in the study area, it is recommended among others the use specified para-transit means such as taxi, motorcycles, tricycles, bus/minibus and unlicensed cab should to be thoroughly regulated. By this, the urban corridors should be judiciously used by high carrying capacity carriers with consideration for the actual and perceived volume of commuters and traffic generators. Thus, improved conventional public transport scheme along major corridors in Ibadan. This shall improve the safety and security of commuters and operators along the route. Second, considering the traffic volume and number of commuters and pedestrians along the corridor, pedestrians' facilities, most especially sidewalk and pedestrian bridge have to be adequately situated and provided at designated locations along the route for safety reasons; thus, the use of pedestrian crossing at such trunk A road should be discontinued.

Also, failed portions of the roads most especially at junction need urgent attention for fixing to ensure an efficient flow of traffic on those portions, and along the corridor. Fourth, urban transit infrastructure in the study area needs urgent improvement to make the city competes favourably with other major cities in the world. Specifically, route information, lay-bye, dedicated lane and commuter waiting shed needs to be provided at specific locations along the route. Fifth, there is a need to harmonize the existing proliferation of bus stops and waiting for bays along the route in line with international best practices. Hence, the spatial examination of locations of existing bus stops has to be carried out to have a fair interval for new ones.

Also, urban transport service should be properly monitored and regulated by the government, while the proliferation of transit operators and services have to be checked and harmonized like being done in other major cities of the world. The present urban transport features such as negotiated fare, vehicle maintenance, branding, unscheduled services and sole operators have to be accurately regulated and controlled to achieve enhanced performance and improved urban transit services in the city. Thus, the use of an integrated transport system with smart information devices is highly recommended and encourage for better urban mobility and accessibility efficiency towards achieving sustainable development of Nigeria cities and the nation at large.

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The Use of Matlab in Creating M/M/n/∞ Queuing Theory Model

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Abstract In our research we dealt with the creation of an algorithm designed to simulate M / M / n queuing systems with endless queues. The algorithm was created in Matlab. When creating the algorithm, we proceeded according to scientific literature, according to which we transformed the formulas into the Matlab algorithm. This process also included the optimization and creation of new outputs based on the analysis of the generated data. The research output is a Matlab algorithm suitable for creating simulations of M / M / n / ∞ systems.

Keywords simulation methods, Matlab, queueing theory, M/M/n/∞

JEL C63

1. Introduction

Through modelling it is possible to create models that simulate the behaviour of a real system. It is a powerful tool that can simulate the likely behaviour of a real system. Outputs from simulations can be used to support decision making.

In the research we dealt with the creation of a simulation model of queuing system in Matlab. In our research we have chosen Markov type of queuing theory models M/M/n/∞. Our aim is to create an algorithm that can be used to obtain statistical data when simulating a real queuing theory system.

2. Methods and materials

The aim of the research was to create a simulation model of M/M/n/∞ queue. The created model will simulate the behaviour of the real queuing system at the post office, which will provide relevant outputs based on which it will be possible to evaluate the system [1,2].

The algorithm will be created in Matlab, in the LiveScript environment. It will give us access to code, outputs, and stored variables on a single screen. This will allow us to analyse the results better and faster and determine the way forward. The code is divided into three parts - initialization, calculation and output. This will make the code clearer and make it easier to identify possible errors and fix it [3,4].

When creating the model and obtaining statistical outputs from the simulation, we followed the scripts System Modelling. They describe an algorithm for creating a simulation model with N lines and an infinite queue, along with algorithms and formulas for obtaining statistical data [5,6]

2.1. Statistics collected

2.1.1. The average number of customers in queue

$$PPC = \frac{\sum PC_i * T_i}{\sum T_i}$$

where:
PPC – The average number of customers in queue
PC_i – The number of customers in queue i
T_i – The duration of i-th time interval, expressed as:

$$T_i - T_i - T_{i-1}$$

Based on the above expression of Ti, the expression is in scripts modified as follows:

$$PPC = \frac{\sum F_i * (T - T0)}{\sum (T - T0)} = \frac{\sum F_i * (T - T0)}{Tk}$$

where:
F_i – The size of queue i
T – Status start time
T0 – Status end time
Tk – Simulation end time

2.1.1. Average server load

$$PVL = \frac{\sum VL_i * T_i}{\sum T_i}$$

where:
PVL – Average server load
VL_i – Line i utilization

Based on the above expression of Ti, the expression is in scripts modified as follows:

$$PVL = \frac{\sum L_i * (T - TO)}{\sum (T - TO)} = \frac{\sum L_i * (T - TO)}{Tk}$$

where:
L_i – Line i status

2.1.1. The average number of customers in the system

$$PPZ = \frac{\sum PZ * T_i}{\sum T_i}$$

where:
PPZ – The average number of customers in the system
PZ – The current number of customers in system

Based on the above expression of Ti, the expression is in scripts modified as follows:

$$PPZ = \frac{\sum PZ * (T - TO)}{\sum (T - TO)} = \frac{\sum PZ * (T - TO)}{Tk}$$

2.1.1. Average waiting time

$$PCC = \frac{\sum_{i=1}^{N} CC_i}{NC}$$

where:
PPC – Average waiting time
CC_i – Customer wait time in line i
NC – Number of waiting customers in line i

The relationship to PCC calculation implies that CC is the sum of the waiting times of all customers in line i. The waiting time of the customer is calculated by capturing the time of his arrival, the line of the queue to which he joined and the position in the queue. Subsequently, after finishing the customer service, the line is queued forward. Once again, we record type of event and the time it occurred. We repeat this until the customer is queued to the server, at which point we stop the waiting time measurement in the queue [5,6].

This sequence is incorporated into the algorithm as follows:

Event: Arriving in the queue

- Recording of the line the customer has accessed, position in the queue and time to variable VFj [Fj]. This variable represents the size of the queue j, where the customer's arrival time is stored. The [Fj] index indicates the customer's position in the queue.

Event: Finishing of customer service

- The difference between the current time in system T and the time spent by the first customer in the queue j VFj [1] is added to CCj. This will return the time he has spent in the queue since his arrival. At the same time, the number of customers served in line j is recorded in the variable NCj.

Event: Start of serving next customer

- After finishing the customer service, the server is ready to serve another customer from the queue. This means that the first customer from the queue will move to the server, so the waiting time was recorded in the previous step. The entire queue will move 1 customer forward.

Event: Simulation end

- After completion of the simulation, the CCj variable stores the total time all customers spent in the queue. Therefore, it is necessary to divide each variable CCj by the variable NCj in order to obtain the average queue time per customer from that line.

Within the algorithm, we used the same variable names as those used in the formulas.

3. Solution

Within the solution we created a simulation model queuing theory in Matlab. When creating the model, we decided to use data from the real system to evaluate the simulation. The data were drawn from diploma thesis: Utilization of queuing theory at a selected post office by Ing. Silvia Ďutková. Compared to the original data, we made a change at the variable Tk, which we calculated in minutes per month.

While writing the code, we first created the code exactly according to the algorithms of the System Modelling scripts. According to these algorithms, we created a flow chart of the first algorithm design. Subsequently, we modified and optimized this code for Matlab. Along with the optimization, we thought of other possibilities of using the obtained variables, which expanded the number of obtained outputs. As we wrote the code, we also found that the statistical data formulas are inaccurate and produce slightly inaccurate and distorted results. We found this error while writing the code. Subsequently, based on the analysis of the outputs and their comparison with the data measured in the real system, we proposed adjustments to the algorithms, which we included among the results of the research.

The development of the algorithm was as follows:

1. Creation of the first version of the code.
2. Code optimization.
3. Add new outputs.
4. Modifying formulas and subsequent code optimization.
5. Creation of the final version of the algorithm.

3.1. Algorithm inputs

The inputs listed in Table 1 were used during the algorithm creation.

Table 1. Algorithm inputs

Time interval	08.00 – 09.00
Hours	1
Workdays	25
Tk (min)	1500
N	6
mi0 (min)	0,84
mi1 (min)	3,23

Tk is the duration of the simulation in minutes. The simulation starts in 0 and takes Tk minutes, so 1500 minutes. N is the number of service lines, there are 6 in the simulation. The customer enters the system approximately every 0.84 minutes and the approximate length of customer service on the line is 3.23 minutes.

3.2. First algorithm version

We divided the algorithm into three logical parts: Initialization part, Simulation part and Output part. We have decided for three parts because they logically divide the program into inputs, operations and outputs. We have described these parts in their own chapters. While writing the first version, we followed algorithms and schematics from System Modelling scripts, where they were stated in Pascal programming language.

3.2.1. Initialization part

The initialization section defines the variables that are used in the algorithm. Variables are assigned their initial states, which can change during the operation of the algorithm.

There are three commands at the beginning of the algorithm: clear, tic, and rng. The clear command is used to clean up the Workspace, that is, to delete all saved variables from programs that were previously run and did not "dump" the variables. This ensures that the results of previous executions of the algorithm will not affect its current performance and will not distort the results and cause errors and bugs. Next follows the tic command, it is a paired tic-toc command. The command is used to measure the execution time of the code between the two commands. The tic code is given at the beginning of the code, toc at the end of it, to monitor the execution rate of the code and to monitor the impact of optimization measures. The rng () command is used to determine the random seed by which the program will generate pseudo-random numbers. We used it to see if editing the code affected the results, which would be undesirable in case of optimization.

At the start of initialization, the code is divided into variables declared by the user and automatically populated variables.

In the section with variables declared by the user, there are 4 variable declarations that are set by the user according to the characteristics of the system he wants to simulate. The variables have the same names as their equivalents in the queuing theory and have already been described in the previous chapter. These are the variables N, Tk, mi0 and mi1. We used data from Table 1 to populate them. These are the only variables that the user sets. Changing other variables will most likely affect the simulation results and will yield irrelevant outputs. In addition to these 4 variables, the user can change the value in the rng () function to a constant number to achieve the same results with each iteration, or set the command to rng ('shuffle') to obtain a different random seed and a series of pseudo-random numbers.

Next, there is a section with automatically populated variables that contains variables that the user should not modify. Their population is automated within the algorithm. At the beginning there is a section with the preallocation of variables. Here are preallocated some one-dimensional variables. Also, the variable N is shifted here. The N = N + 1 command is used to shift the numbering in the simulation. The problem is that the variable indexes depends on the number of servers. We have eg. 4 servers: 1., 2., 3., 4., so we will have mi1, mi2, mi3, mi4 and also the statistics will be for each server separated. The problem is the arrival of the customer, where is used variable mi with index 0 (mi [0]) and also the time variable TU uses index 0. Matlab is not able to work with index 0, all fields must start with index 1. Therefore we had to shift the customer arrival time to index mi [1] and time of arrival of the customer to TU[1], so we had to move all other indexes in the algorithm 1 higher. This means that each line and queue are represented by an index 1 greater than their actual number. Thus, line 1 has an index 2, line 2 has an index 3, and so on. Next, there are 3 declarations of one-dimensional variables cpz, ppz and pz. Cpz is a variable used to determine the total number of customers that were in the system during the simulation. The variables ppz and pz are the statistical variables described before. All variables were pre-allocated with 0.

In the next section, are multi-dimensional variables filled with initial values. Multi-dimensional variables are variables that are of the field type, and store data by indexes, with indexes according to servers in the system. At the beginning of the algorithm is a for loop that iterates from 2 to N, filling the vector variables with zeros. These vector variables include F [i] (line queue), L [i] (line state), and TU [i] event time [i]. F is set to zero because at the beginning the queue is empty. Also, the server is set to 0 because there are no customers, so the server is not serving. When the server starts serving a customer, the variable switches to state 1. TU [i] is the time of event i (arrival of the customer [1], or finishing customer service on line i [2 : N]. Initially, the TU variables are set to Tk, that is, to time of simulation end, to make sure that the first event that occurs in the system is the arrival of the customer TU [1]. The variable mi with index [2: N] stores the value mi [1] defined by the user. The variables ppc and pvl are named according to the formulas in the methods chapter. The maxf [i] variable is used to record the size of the maximum queue on server [i]. The maxft [i] variable is used to record the time when the maximum queue occurred on the line[i] for the first time. Next are declarations of 4 initial variables to start the cycle. The mi0 value stores the user-defined mi0 value. The variable T indicates the current time in the system and is initially set to 0. Next, TU [1] = 1 is assigned to determine that the first customer will enter the system within 1 minute of the start of the simulation. Next is assignment of the value T0, which is used in the formulas to obtain the statistical values.

The last command in this section performs the initial population of the variables with statistics through the for loop. Here, the ppc and pvl variables are first populated.

3.2.2. Simulation part

The simulation part of the algorithm performs the simulation and ensures the collection of statistical data. It is also divided into several parts.

The first part ensures detection and selection of the next event. This is an event model, so selecting the nearest event is crucial for the simulation to work properly. At the beginning of the code is a while loop, which encloses the entire algorithm and determines its completion. It has condition T<= Tk, that is, it will run if the current time T in system is less than or equal to the end time Tk. The cycle is followed by a temporary determination of the next TUk event. TU [1] is selected as the nearest event, and k is assigned a value of 1. This is followed by a cycle that iterates from 2 to N, which compares TU [i] with TUk. This determines whether other event occurs earlier than the TU [1] event. If the result is true, the appropriate TU [i] is stored in the TUk and the index value [i] is assigned to the index [k]. After the cycle, the next event that occurs in the system and its server index is detected. Subsequently, the value T is stored in the variable T0 and the value TUk is stored in T, which becomes the new current system time. This way, the current time of system T and the previous time in system T0 are determined.

Next, there is a decision branch that begins with an if statement to determine if the next event is the arrival of the customer or finishing of customer service. Customer arrives only in case of TU [1] where k = 1, all other indexes mean finishing of customer service on one of the lines. Therefore, the cycle determines whether k = 1. If so, it is the customer's arrival to the system. If not, it is the finishing of customer service.

If a new customer arrives, it is expected to queue, so it is initially looking for the smallest queue (the algorithm assumes that each customer prefers to queue to the shortest queue). Searching is similar to searching for the next event. Initially, it is determined that the smallest queue F [j] is queue F (2) (2 is the first-server index, because of the index shift). The index of the shortest queue j = 2 is also determined. This is followed by a for cycle from 3 to N, which compares queues on other lines with Fj. If any queue is shorter, its value is stored in Fj and its index is stored in j. In this way, the shortest queue index is determined. The following are three formulas for ppz, pz, and ppc statistics, which follow these formulas. On arrival, the number of customers (pz) increases. With these three patterns, it is important that they record events before the queue is increased. They are located before the queue is raised and lowered. Thus, they accurately record the time of occurrence and the time of event change. These are followed by an increase in the F [j] queue by one customer who has just arrived in the system. Next, after the que increases, we find out whether the current queue is the largest one that occurred on the line. The is a simple if statement. If the result is true, the current queue size is stored in maxf and the current time in the system is recorded in maxft. This is followed by an increase in cpz statistics. The last command in the branch generates the time when a new customer enters the system and it is stored to TU [1].

In the if branch of finishing customer service, ppz, pz, and pvl statistics are initially calculated. When the customer leaves, the current number of customers (pz) decreases. This is followed by a command that turns off server and sets it to L (k) = 0 because the customer has been served and left. The last command assigns Tk + 1 to TU (k), ensuring that the variable is not selected as the nearest event to occur.

Next, both if the branches are followed by a branch that checks if there are customers in the queues and if they are, it detects the status of the given server. This is done using two if statements placed in the for loop. The for loop ensures that the detection is performed for all servers. The first if determines whether there are customers in queue F[i]. If yes, then a second if follows, which detects whether the line is busy [1] or free [0]. If it is free, it means that the first customer from the queue can move to the server and the queue decreases. Otherwise, everything remains as it was. If the line is free, a series of commands follows. First, the ppc statistic is recorded according to the formula. Next, the F [i] queue will be shortened by one customer who has moved to the server. Next, pvl statistics are recorded. This is followed by a command that turns on the L [i]. The last command generates the time how long it will take to serve the customer who has just moved from queue to the server and stores the result to TU [i].

This is the last step in the while loop. After all the commands have been executed, the evaluation an performed to determine whether the cycle will continue or end.

In the simulation part, there is a collection of statistics after the while cycle. It runs through a for loop. This ensures that all recent events that occur in the system are recorded in ppc and pvl statistics.

3.2.3. Outputs part

The last part of the algorithm serves to display the simulation outputs in text form. Most statements are enclosed in a for loop to run for each server statistics. The first output is the average number of customers ppc. Before the value is outputted, it is calculated according to formula to obtain its

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final value. The output is executed by the disp () command, which ensures that the inserted string is displayed in the output window. The string to be inserted is previously declared to the vetappc variable. In it we constructed a sentence that outputs the line and its average queue per hour. Other statements work on a similar principle. Next is listing the maxf max queue along with the maxft time in which it occurred. This is followed by a listing of the average and total number of customers in the system. The last output is the average line load in%.

3.2.4. Evaluation of outputs

We obtained several outputs from the simulation using the algorithm. The results of the simulation showed statistics of the system with current input characteristics. Analysis of these results revealed several inconsistencies. There is a big difference between maximum and average queues on lines. This can be explained by, that most of the time, the queues were empty, and sometimes the system was overwhelmed by customers and the queues reached the maximum values recorded in the output. This implies that customers who entered the system went straight into the service and did not wait in line. The average number of customers in the system says that there was almost always a customer on the server. This results from ppz statistic. There were 6 servers, so if the average number of customers in system was 6.5, then each server was likely to be regularly occupied and there was approximately 1 customer in the queue. The total number of customers in the system was 1804, which is a plausible quantity due to the simulation time and does not contradict the statistics. There is a problem with average server load (pvl). Previous slight irregularities could be justified, but the pvl indicator violates these reasons. Percentage of server usage is in direct conflict with the average number of customers in the system, which says that on average, there has always been a customer in system. According to the percentual utilization of the servers, the busiest server was utilized at 13%, so approximately 87% of the time it was free. Server 6 was even free for 98% of the time of the simulation. The indicator is also very contradictory when it comes to comparing statistics within it. The first three lines have approximately the same% utilization. This results in a very strange statistic When the customer entered the system, before it was served, two other customers entered the system and they occupied lines 1, 2 and 3. For a long time, nothing happened and the situation repeated again, three customers entered the system at once and again occupied the first three lines. This is the most likely explanation. If they enter independently, gradually and not in triplets, they would in most cases go to the first line, because it was free in 87% of the time and waited for the customer. Thus, the explanation for this statistic is that customers most often entered the system in triplets. Less often in quadruples, quintuplets and sixes, but these situations must have also occurred because other lines have also been used. For fun, the worst luck had the customer who entered the system in 255.21 minutes, because then he had to queue on line 6 for the 3rd position. And according to statistics, line 6 was 98% of the time without a customer. These statistics are very unlikely. We do not claim that such situations could not have occurred, everything is possible with random generation, but it is very unlikely. Especially the part where the triplets had to go into the system at the same time, so the third customer had to come before the service of first customer was finished and when he left, there was a long pause during which the system was empty and then three customers entered the system again.

When the number of lines N = 6 was replaced by N = 2, the server usage of server 1 increased to 14% and server 2 to 16%. The average number of customers on queue was 121 on queue 1 and 125 on queue 2. The average number of customers in the system was 497.

These results seemed very unlikely, so we decided to address them in the next chapter in optimization by vectorization. This will allow us to create vectors from the variables that can be plotted and thereby check how many customers were on the servers and when they were active.

3.3. Algorithm optimization

To optimize the variables, we vectorized and preallocated them, and used GPU parallelization to speed up the rendering of outputs.

Vectorization is the transformation of commands into vectors. This is a procedure designed to get rid of unnecessary cycles in order to speed up program execution. Matlab is a vector language and it is more natural and faster for it to work with vectors than cycles. The second important change was the transformation of fields into column vectors. By default, the vector is created as a row, so it stores values in one row. However, Matlab is able to work with columns faster, so we transformed them. Another important change was the preallocation of variables. Preallocationg means pre-populating the memmory in which vector variables will be stored. This preallocation of the memmory will significantly speed up the program execution time. In the algorithm, vectors are expanded by 1 field at each iteration to obtain a complete list of variables. Matlab create vector copies by creating a copy of an vector, adding a new value to the vector, and then saving that copy as the original vector. This is a quick operation, but with many repetitions, it will start to take a lot of time. In addition, over time, the amount of data that needs to be copied increases. Preallocation will speed it up, because instead of creating a new vector on every iteration it will only create it once and then will only rewrite the preallocated values with values from the system.

We verified these statements with our own algorithm, where we tested the speed of variable population. We tried to populate a non-vectorized and vectorized, row and column variable without preallocation and with preallocation. We have generated and stored 100,000 pseudo-random numbers in these variables. The worst result was at non-vectored and not preallocated , column variable with an average time of 3.02 seconds. The fastest was a vectorized, preallocated, column variable with a time of 0.0033 seconds. Therefore, we decided to optimize the algorithm code using the procedure mentioned above.

Within the simulation algorithm, we did not find a suitable cycle that could be accelerated by parallelization without compromising its reliability. However, we managed to implement GPU parallelization in generating graphical outputs. GPU parallelization allows the use of graphics processor cores to speed up the execution of operations. The condition is that the GPU must have CUDA cores that are only in NVidia graphics cards. All changes made to the algorithm are described in the following chapters.

3.3.1. Vectorization and preallocation

We chose vectorization to column vectors, and preallocation for several reasons. The first was to optimize the code for Matlab and speed up code execution. The second was the possibility of obtaining further outputs.

At the beginning, we transformed multidimensional variables such as F [i], L [i] and mi [i]. The transformation was done by adding a second index to the variable declaration. In the first algorithm, the variables were populated by for loop by assignment operations, such as the variable F [i] = 0. The transformation was done by adding index 1 to the second position, so the new declaration has the form: F [i, 1] = 0. The second step was to get rid of the for loop. Matlab can work with vectors much faster than cycles. There are two solutions for this operation. A function or direct vector declaration. Function zeros fills the variable with zeros according to the specified range, so F = zeros (2: N, 1) creates a vector F with rows from 2 to N and with 1 column and fills it with zeros. The second option is a direct declaration F (2: N, 1) = 0, which does the same. Our experiments and the experience of other users in the Matlab forum show that the direct declaration is a little faster. The acceleration depends on the size of the vector being created. In our case, there is probably an improvement by one hundredth, or perhaps a thousandth of a second, but it is still an improvement, so we decided to declare variables directly. We transformed all variables that ranged from 2 to N depending on the line in the system as described. In this way, we eliminated several for loops, created column variables, and all variables are preallocated, which together greatly optimizes the algorithm.

3.3.2. Transformation of formulas

Given the inaccuracies in the output of the previous algorithm, we decided that we need a graphical representation of the queue, servers, and number of customers in the system to compare them with the calculated statistics. Therefore, we decided to modify the formulas so that they do not work with single values. Instead, these values are stored in variables. At the end of the algorithm, the outputs are calculated according to formulas. An example of formula for average number of customers from the algorithm:

```
ppc(j)=ppc(j)+F(j)*(T-T0);
```

The formula gradually adds to itself the multiplication of the size of the current queue and the difference between the current and the previous time. Based on this process, we transformed the formulas into the following form:

```
h(i)=h(i)+1;
FF{i,1}(h(i),1)=F(i);
TTF{i,1}(h(i),1)=T;
TT0F{i,1}(h(i),1)=T0;
ppc(i)=sum(FT{i,1}(:,1).*(TTF{i,1}(:,1)-TT0
F{i,1}(:,1)));
ppc(i)=(ppc(i)/Tk);
```

We replaced the original variables with vectors. In order to draw a custom graph of each variable for each line, we had to create a separate vector for each line. We saved them in a vector, so we created an array of vectors. To index individual values within a vector, we have created an variable h [i] that varies for each server and indexes the values in the vectors. For example, FT {i, 1} (h (i), 1) = F (i), where i = 3 and h [i] = 50. This means that an operation is in progress, e.g. customer's arrival in line 2 (3-1). 50 values are already recorded in the vector. The new value will have an index of 51 (50 + 1). Thus, the variable FF {3,1} (51,1) writes the value F (3), ie the current queue size on queue 2. The FT variable stores the size of the queue, the TTF variable stores the time T for the FT variable, and the TT0F variable to store the time T0 for the variable FT. There are also variables LT, TTL and TT0L in the algorithm, which have similar use, but for servers. The reason for separating TTF time for queues from TTL time for lines is the difference in when they are recorded. The time T for the queue is recorded in the customer arrival branch, the T part for the server in the finishing service branch. There could be a mismatch and were therefore separated. The same procedure was applied to the PZ variable, to which we added the PZT variable to store the time T.

The preallocation of these variables was problematic. The number of their elements cannot be predetermined precisely because their number depends on randomly generated values and can range from 0 to several times the time Tk, depending on the input characteristics of the system. Officially, there is no way to precisely predict the size of a variable with a variable of unknown number of elements. Therefore, we have decided to apply approximated preallocation. In this part of the algorithm, we estimate the size of the variables and based on this estimate, the size of the variables is preallocated. In the algorithm we made these estimates based on system observations. We have determined the capacity of Tk * 2 by the variables, which can be interpreted so that customer arrives or is served every half minute. This is unlikely, especially in a simulation of a real system, and the system input parameters used do not suggest this. In any case, the algorithm should be designed for other input parameters where the quantities could be higher than in our

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case. Ideally, this would be determined by analysing the relationship between the basic input characteristics N: mi0: mi1: Tk. This analysis would probably require more time to carry out, so we will carry it out as part of further research.

The approximate preallocation proceeds in 2 steps:

1. Field preallocation
2. Vector preallocation

First, there is a preallocated field in which the vector values will be stored. The field is preallocated by the cell function, in which its size is inserted. In the second part, the vectors themselves are preallocated by the zeros command to preallocate Tk * 2 positions with a value of 0.

But there is a problem. By approximating the size of an element, it is likely that we will not preallocate the right amount of memory. This could cause problems when calculating statistics, where the formula would count with zero values. This would not affect the result, n + 0 = n. A problem would arise when plotting graphs where even zero points would be plotted. In addition, in terms of optimization, zero points would take up memory space. Therefore, after completing the simulation part and before the output part, it is necessary to insert another part that will modify the preallocated vectors and remove unnecessary zero elements from them. For this we used the property of the variable TT, which records the time T. T is the current time and at the end of the simulation it equals or is greater than the maximum value and the simulation ends. So, we can assume with certainty that if we find the maximum of TT, we find its last non-zero value within the vector. Any subsequent value must be zero. Based on this assumption, we created a for loop that iterates from 2 to N. The use of the loop was necessary in this case because we could not find a way to vectorize vector variables stored in cell fields. The maximum value position within the vector is searched for in the cycle. When found, all three vectors associated with it are cut off based on its value. So, if we are looking for the maximum for TTF {2,1} - i. the second vector in the TTF field. The result is stored as a coordinate in the variable Yft (i, 1) by the command [~, Yft (i, 1)]. The result is stored as a coordinate in two variables specified by square brackets. The maximum value is stored in the first place and its coordinate in the second. The maximum value is not needed, so its saving is denied using the ~ character and only its coordinate is stored. Subsequently, this coordinate is used to determine the point at which the vector is to be cut.

In this way, a sufficient amount of memory is preallocated for the variables. This may not seem efficient at first glance, but it is, and the result is optimizing code speed, even though we've added a few extra lines to the code. This is because when Matlab expands a vector with a new variable - it must always copy the vector, paste the variable to the copy, delete the old one, and replace it with the new one. These are 4 operations that execute as many times as many variables are written to the vector. On the other hand, the preallocation takes place once, then the preallocated values are only overwritten with new ones and, in the end, the excess space is cut off. So if it were generated 500 values, so without preallocation, about 4 * 500 = 2000 operations would take place, while with approximate preallocation only 1 + 500 + 1 = 502 operations. The efficiency of this method was verified in tests where we tested the speed of the algorithm with and without pre-location. As a result, the implementation of the preallocation algorithm was accelerated by an average of 2.5 seconds, which we rate as an improvement.

In the ways outlined in this chapter, we have modified and optimized all multidimensional variables

3.3.3. Command vectorization and other optimizations

In statement vectorization, we tried to replace cycles in the algorithm. We have described the vectorization of cycles from the initialization part in the previous section. There were also several cycles that could be vectorized within the computational part. Here we have optimized the search for the closest event and the search for the smallest queue. We replaced the for loops with the min function, which looks for the minimum and stores its size and position. We have done the same for the smallest queue, but we only saved the index.

Other optimization activities include the use of short-circuit operator. We used it when deciding whether someone is in the queue and whether the line is serving. Originally it was solved through two if statements. For example, the short-circuit operator is && (logical and). In this context, it is used to determine whether both terms are true. The difference between using & and && is that && evaluates the second expression only if the first is true. So, if the first expression is false, the second does not even evaluate and saves time. Using this command, we merged both if statements into one with optimized evaluation.

3.3.4. GPU parallelization

Vector variables obtained by vectorization allow us to create graphical outputs from the simulation. Creating graphical outputs is hardware-intensive in the case of a large number of plots. This process is parallel by default but is limited by the number of CPU cores. Therefore, Matlab makes it possible to speed up this process by using graphical cores. CPUs usually have from 2 to 8 cores, the number of threads can be doubled. GPUs have several hundreds or thousands of cores depending on the type of card. However, parallelization also copies and creates temporary variables, which slows down the process. Therefore, it should always be considered whether parallelization pays off. Usually, small and unpretentious amounts of operations are not worthwhile, while larger ones are.

In the outputs are plotted many coordinates on the graph area, so we decided to use GPU parallelization. We have added graphical outputs to the end of the algorithm. Initially, it checks to see if a compatible graphics card is available on your computer. This is done by attempting to create gpuArray, and if successful, true is returned. If this field cannot be created, an exception occurs, and a catch branch returns false. Based on the result of this attempt, values are assigned to variables in cycles. We made the assignment through for loops because we could not find a way to vectorize cell fields. We made these assignments so only one variable i sused in the graphical outputs.

3.4. New simulation outputs

Using new variables, it was possible to create new outputs in graphical form. The graphs were outputted through for loops, in which we enclosed all the properties and parameters that should be plotted for the graph. First is the figure function. It is used to separate the plotted graphs from each other, because when plotting from the cycle, an error occurs, in which only the last plotted graph is displayed, and the others are discarded. The graphs are displayed using the painters function, which is suitable for 2D graphs. The position parameter is also set, in which the resolution of the graph is determined. This is followed by the plot command, where the x and y axis parameters are inserted, and the hexadecimal colour is set to blue. This is followed by a hold command with the off parameter, which is used to determine whether the graphs will be drawn into each other and overlap, or each graph will have its own space. The off parameter specifies that each graph will be separate. Next is the title statement, which creates the title of the graph based on the inserted string. The number of the server for which the graph is displayed is inserted in the algorithm. The following are the xlabel and ylabel commands, which create descriptions of the x and y axes based on the entered text.

The graphical outputs are created for the queue size, server state and number of customers in the system. The queue size and server status are plotted separately for each line, the number of customers in the system is total for the system. From the obtained outputs, the queue size output on server 1 in Figure 1 and the status of server 1 in Figure 2 are displayed.

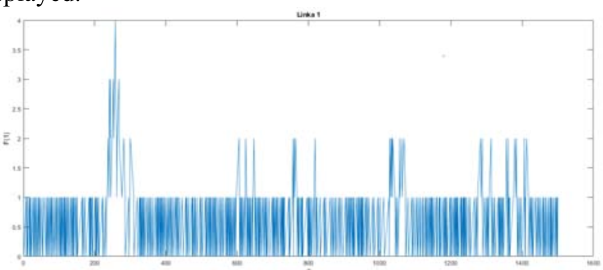

Figure 1. The queue size of queue 1 in time

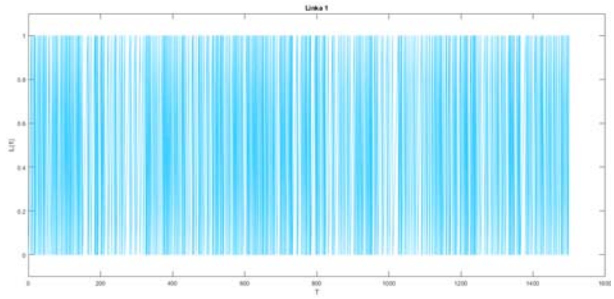

Figure 2. Utilization of server 1

As it can be seen from Figures 1 and 2, the server 1 was almost fully utilized. However, this differ with the statistics obtained, which is strange because they are drawn from the same data from which the statistics are calculated.

To check the results, we placed three more vectors in the algorithm to record the values of the queue and lines at each point in the system. For comparison, server 1 has been plotted from approximately 900 intercepts in Figures 1 and 2. In the new algorithm, approximately 4500 points were captured for Line 1, from which the graph was drawn. It is likely that some of them are duplicates. Nevertheless, it is a much more accurate graph. Given the simulation time, which is 1500 minutes, it can be argued that for line 1 its state was captured approximately every 1/3 minute, that is every 20 seconds. There is no difference between the data in the graphs, both showing the same values. We chose to keep the new vectors values because it plotted the data more accurately and without the oblique edges in the chart, from which it is unclear what they mean. We have also changed the function of plotting a plot from a plot to a stairs function, which creates "staircase" graphs that are more legible and without oblique edges. We also tested its use on data from previous vectors to avoid unnecessarily creating new, larger vectors, but there were inaccuracies in the graphs due to fewer points captured over time. Therefore, we decided to use the new vectors for plotting graphs.

3.5. Algorithm modification based on output analysis

Based on the outputs, we have determined that the formulas used to calculate the statistics are incorrect. By analysing the original formulas, we concluded that the formulas used in the algorithms were incorrectly derived from the original formulas. The problem was at time T0, which symbolizes the previous time in the system. The original formula assumes Tj-T (j-1). T (j-1) has been expressed as T0 and we think that there is a mistake. In the original formula, time T was a two-dimensional vector with times Tj and T (j-1) separately for each link. The reason for it is the connection to the TU time, which is separated for each server. Each server has its own service duration. Initially, T is stored in T0 and TU is stored in T. Thus, T0 is the time of the previous event and T is the time of the next closest event. However, these events may not be performed by the same server. The formula clearly works with one queue, that is, the utilization of just one server. Therefore, in our opinion, it is also necessary to work with the time for the line and not with the general system time. For example, let's say that a finishing customer service event is on server 5 at time T = 20. The event executes and finishes, and the next event selection begins again. The algorithm evaluates the finishing customer service event on server 1 at T = 21 as closest, so it stores the value 20 in T0 and the value 21 in T0. In the formula: ppc (j) = ppc (j) + F (j) * (T- T0), the queue size of server 1 is used, the time T that corresponds to the server 1, but it uses the time T0 that corresponds to the server 5. This greatly shortens the real service time that was different from the time used in the formula. Therefore, we propose to use indexed times T and T0 to record for each line separately and to avoid mixing times between lines.

In the algorithm we solved it directly without having to record the time T0. Matlab has the diff function, which is designed to subtract vector elements in a [i] -a [i-1] way, so we only recorded the time T [i]. So, the difference time T [i] -T [i-1] was calculated using the diff function. We added 0 to the resulting field, because this is the first value of the unmodified vector T and throws it off in the calculation because it is the first value bound to T [i-1] and there is nothing to subtract from it. Therefore, it is added to the beginning of the vector. The new formula in the code:

```
ppc(i)=(sum(FT{i,1}(:,1).*([0 ;diff(TTF{i,1}(:,1))]))/sum(([0  ;diff(TTF{i,1}(:,1))]))
);
```

Despite the difficult looking code, this is the same formula as in the methodology, only with the correction of the time T.

After this adjustment, the graphs matched the text output, but we noticed another drawback. If we set the number of lines to 16, then lines 10 - 15 have 0% utilization and the first lines create a queue with a waiting time of 0.5 to 2 minutes. It does not make sense. In a real system, if the customer enters a system, he would go to the line where he would be immediately served. We focused on the part where the queue is selected by the customer. The logic of the algorithm is that the customer selects the smallest queue when he arrives at the system. That is correct but let us consider the following situation. Lines 1, 2 and 3 are serving a customer and line 4 is empty. Customers are in queue on lines 1 and 2. There are no customers on lines 3 and 4. If we choose only the nearest minimum queue, the first option is line 3, because its queue is empty. But the algorithm does not take into account that there is a customer on the server and so the customer who entered the queue must wait. While line 4 is completely empty and unused. This is nonsense in terms of a real system. If I have to choose a cash register in the store, I will choose the one that is empty. Therefore, we propose to modify the algorithm so that when selecting a queue, it takes into account not only the queue, but also the state of the line. The server has 2 states. State 0 if empty and 1 if serving. This can be used to determine the total number of customers on the server. Therefore, we calculate the minimum of the sum of the queue and server occupancy to get the total number of customers on the line. In the previous example, the customer will be moved to line 4 because it is empty and will go straight from the queue to the operator without the need for waiting. Now that we have adjusted the algorithm to the number of lines 16, the simulation showed that there was no queue anywhere and the waiting time on the line was 0, so there was an immediate service. We consider this adjustment to be a key one from the point of simulation feasibility, because it brings simulated customers' behaviour closer to reality.

3.6. Final algorithm version

All previous chapters led to the final version of the algorithm, which is the result of the research. To compare the versions of the algorithms, we measured the speed and memory that the algorithms occupied with the same input parameters set out in Table 1. The measurement results are shown in Table 2.

Table 2. Algorithm version comparison

	First run (s)	Subsenquential runs (s)	Memory requirement (byte)	Used memory to process speed ratio (MB/s)
First version	0,48	0,30	982	3,2
Final version without graphs	0,84	0,7	786 578	1097,35
Final version with graphs	3,11	1,23	1 451 497	1152,42

The values were measured on a computer with 4 core i5-7500 processor, 16GB DDR4 2400 MHz RAM in dual channel, NVidia GTX 1050 Ti graphics card and M2 SSD with 900 MB / s write, 1500 MB / s read speed.

Despite an approximately 800-fold increase in memory requirements, there was only an approximately 2-fold increase in the time required to execute the algorithm on the first and final version without graphs. In graph ploting, the first run time is considerably longer, and the space requirement has also increased. The used memory to process speed ratio is how fast the data in the algorithm was processed in MB / s (larger is better). Here can be seen the effect of code optimization on execution speed. It could be interesting to have the final version in the unoptimized version with the same amount of data or running the algorithm on a more powerful computer.

Two statistics were added to the final version of the algorithm, the average queuing time (pcc) and the total number of customers served (NC). Both statistics are output only in text form. Together with other outputs, they provide comprehensive information about the behaviour of the created system model. The algorithm produces both text and graph outputs. These are created on the basis of collected statistics. The simulation model collects two types of statistics, statistics integrated over time and statistics not integrated over time. For statistics integrated over time, the time they occurred is stored. Based on it, it is possible to create graph outputs that show the time sequence of events of a given variable. Non-time-integrated statistics record the average or total values of selected variables. They are mostly used to create text outputs.

Compared to the original version of the algorithm, we consider the modified, final version as a step forward. It provides multiple outputs, allows to view the development of statistics over time, and all the variables obtained are still available at the end of the program and can be processed into other outputs. Due to the highier amount of data to be recorded, the new version requires nearly 800 times more memory than the first version. However, its execution time is only about 4 times longer in subsequential runs. If ploting graphs is turned off, the execution time is only 2.5 times greater. The execution speed is reduced by code optimization, i.e., vectorization, prealocation, and parallelization. This way, the final version was successfully optimized, which is also confirmed by the column of the ratio of used memory to the speed of execution of the algorithm that has the highest data processing speed in the final version.

4. Conclusions

The aim of our research was to create a simulation algorithm that will simulate a queue theory system in Matlab. The aim was to create a model that will simulate the M/M/n/∞ system. When creating the algorithm, we first made a flowchart according to the algorithms from the literature. Then we have written the first version of the algorithm according to the diagram. Next, the algorithm was optimized for Matlab. While optimizing the algorithm, we encountered errors in the algorithms from the literature that caused incorrect outputs. We analysed the errors and suggested some corrections. By analysing the available vectors, we designed new outputs in the form of graphs showing system changes over time.

The research output is an algorithm enabling simulation of M / M / n / ∞ system. The algorithm provides the user with both textual and graphical outputs. Using the created algorithm, it is possible to perform simulations of real systems with N service lines and with infinite queue. Outputs from the algorithm can be used in solving queuing theory problems and research activities.

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An Assessment of Solid Waste Transportation in Ado-Odo/Ota Local Government Area, Ogun State, Nigeria

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Abstract This paper examines solid waste transportation in Ado-Odo/Ota Local Government Area of Ogun State. Adequate transportation of solid waste is one of the major challenges of waste managers in Nigeria because of inherent factors ranging from dearth of transport infrastructure to poor attitude of residents. Data were collected through the aid of questionnaires, personal observations, visitations to some villages and towns as well as dumpsites. The questionnaires were divided into two parts: household respondents and solid waste management staff. The data obtained were analyzed using Descriptive Statistics, Factor Analysis and Item Analysis. From the analysis of the data obtained from household and waste management respondents the mean and standard deviation reflect high degree of correlation and concurrence. From the principal component analysis of both the household respondents and waste management staff, there are two principal factors respectively that should be given higher consideration in solid waste management in Ado-Odo/Ota Local Government Area. These factors include waste collection and disposal method, frequency of collection and reliability of waste vehicles. Based on these findings, the study concluded that attitudinal change on the part of the household, government intervention on road maintenances, and adequate maintenance of PSP vehicles will go a long way in reducing the heaps of refuse and indiscriminate dumping of solid wastes in the entire vicinity of Ado-Odo/Ota Local Government Area in Ogun State, Nigeria.

Keywords Solid Waste, Transportation, Disposal, Waste Management

JEL L91

1. Introduction

Transportation is the movement of people or goods from a place of origin to a place of destination. It is an essential human activity having a major impact on their social and economic well-being. Transportation of solid waste is the act or process of conveying waste from its place of generation or temporary storage to final disposal site.

Inadequate transportation and disposal of solid waste causes nuisance and hazard to the teeming populace and lead to environmental problems. Over the last decade, the amount of municipal solid waste has been increasing steadily; it is obviously due to the impact of rapidly increasing urbanization and economic development. The effectiveness of handling waste in terms of collection and disposal through proper means of transportation remains undesirably low. The large population of people in cities and communities gave rise to indiscriminate littering and open dumps. These dumps in turn formed breeding grounds for rats and other vermin, posing significant risks to public health [9].

Solid waste management in Ogun State is characterized by insufficient coverage of the disposal coupled with inefficient method of collection of waste in which co-disposal of both municipal and hazardous waste takes place in open space, drainages and other unauthorized places that promotes indiscriminate disposal [3].

The estimated generated waste according to [11] is between 0.7 and 1.8kg per capita of waste and these are produced every day in developed cities' urban areas and approximately 0.4 to 0.9kg are produced in developing cities.

Reference [10] is of the view that solid waste in developing countries is given very low priority. Reference [8] also stated that solid waste management is given very low priority in the budget due to limited finance.

Reference [5] is of the view that there is a lack of human resources, at both the national and local levels, having the technical expertise necessary for solid waste management, planning, and operations. Furthermore, according to [1], the social status of solid waste management workers is generally low as a result of the negative perception of the society regarding the work which involves the handling of solid waste. Such societal perception leads to low grades for the work, low self-esteem for the workers especially the garbage men and in turn produces low working ethics and poor quality of the work they carry out [5].

The collection and transportation of municipal solid waste (MSW) are those public services that have an important impact on public health and the appearance of towns and cities. Most municipalities lack efficient collection techniques and as a result, not all waste generated is collected. This further led to increasing dumpsites and abandoned waste deposits on the streets, major roads and open places in residential areas across the Local Government Area. The uncollected waste turns a breeding ground for diseases carrying organisms leading to diseases such as malaria.

Reference [7] carried out a study on a review of local factors affecting solid waste collection in Nigeria. It was discovered that the method of waste collection adopted, and equipment used are faced with many challenges in Nigeria. Unfortunately, most of the urban areas' disposal sites are usually located outside the urban areas due to the scarcity of land. There is no fixed route map for transportation and operators; therefore, there is lack of adequate capacity to transport it. The current waste collection and transport operators are already overloaded arising from the lack of facilities and insufficient resources. To compound this problem further is the inadequate awareness of the importance of proper waste disposal, a major factor that has led waste producers to adopt bad practices, such as indiscriminate dumping of waste in water bodies, littering, burning of waste. There is a lot to be done in this regard; waste management agencies can better improve their waste management techniques to encourage citizens to adopt better waste disposal practices.

Due to increasing problem in the management of solid waste generated in most cities in the developing countries private sector participation arrangement started as a response to the failure of service delivery by the public sector. Not all generated waste is collected in the developing countries. Waste collection in developing countries ranges between 20-80%. This is because only few areas in the municipalities can easily be reached when trailers and trucks are to be used. This is because most of the streets are not designed to allow such waste collection vehicles to pass. Some streets are unpaved, narrow, sloping and slippery during the rainy seasons. In such areas the volume of waste increases and is rarely collected [4].

Reference [6], identified a lack of adequate funds as one major problem faced by waste collection agencies that result in inefficiencies in carrying out their duties. It limits their ability to purchase necessary equipment, including waste containers and collection vehicles. In Nigeria today, there are two systems of handling the waste. The first is a formal system that is managed by the government. It comprises the cities' municipalities or waste management agencies whereby they are responsible to ensure safe, reliable and cost-effective collection, transportation and final disposal of solid waste. It often requires large financial resources than in most cases allocated on the public budget, therefore, making it almost impractical to deal with based on the complexity, technicality and the problem associated with waste management.

Reference [2], stated that this type of system is frequently characterized as inefficient and expensive. The second is the informal system which engages private dealers only such as communities of scavengers and private associations. In some areas, this operation includes charging some amount of money from residents for picking up their garbage. The two systems are however seen as having very little interference and cooperation in all aspects of waste handling, making the problem of solid waste transport and management even worse and persistent.

2. The Methods

2.1. The Study Area

The area of study is Ado-Odo/Ota Local Government Area in Ogun State. Ado-Odo/Ota is one of the most populated out of 20 Local Government Area in Ogun State in the South –West region of Nigeria. Its Latitude is 6.6887 Lat (DMS) 60 41'19N and Longitude 3.2320 Long (DMS) 30 13'55E, with the estimated 2006 census population of 669,886. It was created on May 19, 1989. The Local Government Area is also on the industrial hubs with the highest concentrations of industries in Nigeria. Ado-Odo/Ota being the largest industrial area tends to have the highest number of industries in the state, with this fact, the Local Government generates the highest IGR for Ogun State. They are primarily agrarian; they produce cash crops, food crops, mineral resources, and vegetables.

Ado-Odo/Ota is one of the industrial heartlands of Ogun State located in Nigeria. The Local Government is populated mainly by the Awori people, a subset of the Yorubas and the original inhabitants of the region. It has shared a boundary with Lagos State in east and south, Yewa South and Ifo Local Government Area in the north and Ipokia LGA in the west. The other towns and cities located in Ado-Odo/Ota LGA include Ado-Odo, Agbara, Igbesa, Iju, Itele, Kooko Ebiye Town, Owode-Ijako, Ilogbo, Ijoko, Atan, Ketu-adieowe, Alapoti, Ere, Sango, Ota.

2.2 Data Collection

The study was based on primary data. The primary data that were used in the study was collected from household and waste management staff through a well-structured questionnaire.

2.3 Study Population

The population of this study consist of selected household in eight (8) towns which include: Ota, Agbara, Igbesa, Iju, Atan, Ilogbo, Ijoko, Sango and solid waste management staff

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in Ado-Odo/Ota Local Government Area in Ogun State, Nigeria.

2.4 Sampling Techniques and Sample Size

A multistage sample technique was used to select 370 household respondents and 30 waste management staff in Ado-Odo/Ota Local Government Area for the study. In the first stage, a purposive sampling technique was used to select eight towns in which the study was carried out. In the second stage, purposive sampling technique was used to select one dumpsite out of three in the study area. In the third stage, 30 waste management staff were purposively selected among waste collectors, drivers, managers, PSP operators and Ogun State Environmental Protection Agency office. Lastly, a purposive sampling technique was used to select 370 household respondents in the study area.

2.5 Analytical Techniques

Descriptive statistics was adopted in the study to analyze the socio-demographic data for the household and waste management staff. Factor analysis statistical technique was used to carry out the systematic reduction of the extracted variables that are highly correlated while item analysis was used for the Likert scale.

3. Results and Discussion

3.1 Socio-demographic Characteristics of Household Respondents

The socio-demographic of the households and waste management staff such as the age, sex, educational qualification, marital status, average monthly income, household size, employment status, and size of accommodation amongst others are being assessed to determine their effect on solid waste transportation in the study area and are shown in Fig.1.

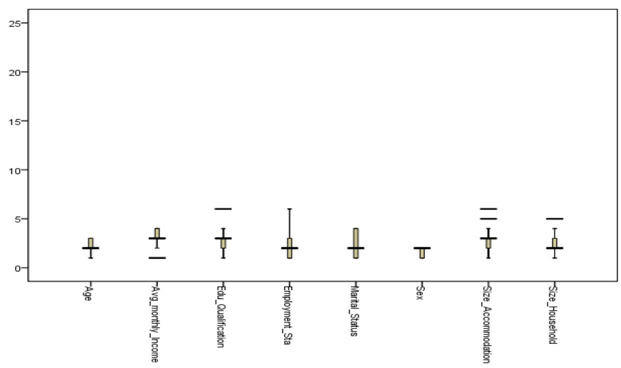


Figure 1. Boxplot Demographic representation of Household Respondents

3.2 Descriptive Statistic for waste collection disposal for household respondents

The descriptive statistics shows that the mean, standard deviation and the number of respondent's data analyzed are 304. The mean of the obtained data shown in Table 1 shows a high degree of correlation among respondents on various matter, while the standard deviation values reflects a high degree of concurrence of the data obtained.

Table 1. Descriptive Statistic

	N	Mean	Std. Deviation
Location of the Administration of questionnaires	304	3.4507	2.43954
Container type	304	2.6776	1.02511
Waste Collector	304	2.3783	0.81952
Frequency of Waste Collection	304	3.1382	1.46488
Method of Waste Disposal	304	2.7895	1.11178
Method of Waste Transportation	304	1.7730	1.13355
Attitude of Waste Collector	304	2.1283	0.63971
Perception of Waste Management	304	2.4836	0.61852
Valid N (listwise)	304		

Author's Computation, 2019

Table 2. Communalities

Variable	Initial	Extraction
Location of Administration of questionnaire	1.000	0.552
Container type	1.000	0.473
Waste Collector	1.000	0.774
Frequency of waste collection	1.000	0.672
Method of waste Disposal	1.000	0.769
Method of waste Transportation	1.000	0.721
Attitude of waste Collector	1.000	0.579
Perception of waste Management	1.000	0.461

Author's Computation, 2019

Table 2 shows the random values for extraction. This extraction values implies, the proportion of variance variables that can be explained by the factors, the data reveal that location, waste collectors, frequency of collection of waste, method of waste disposal, and attitude of waste collector has significant effect on waste collection and disposal.

Table 3. Rotated Component Matrix

	Component		
	1	2	3
Collector	0.846	0.238	0.043
Method of Transportation	-0.836	-0.148	0.009
Container type	0.639	0.123	0.223
Frequency of Waste Collection	-0.529	0.370	0.505
Attitude of Collector	0.063	0.755	0.064
Location	0.358	0.638	-0.129
Method of Disposal	0.084	-0.212	0.847
Perception of Waste Management	0.209	0.394	0.512

Author's Computation, 2019

Table 3 shows the various loading factor for the extracted components based on the data analyzed. The data below 0.5 were suppressed and the result shows that component 1 and 3 has more loading factor, this implies that they have direct impact on the analyzed data. The data were sorted by size and significant level and the Rotation converged in 6 iterations. The varimax seeks for the rotation of the original factors such that the variance of the loading is maximized.

The scree plot in Fig. 2 shows the three values that are above the Eigenvalue of 1while others are below the Eigenvalue of 1 and are not extracted.

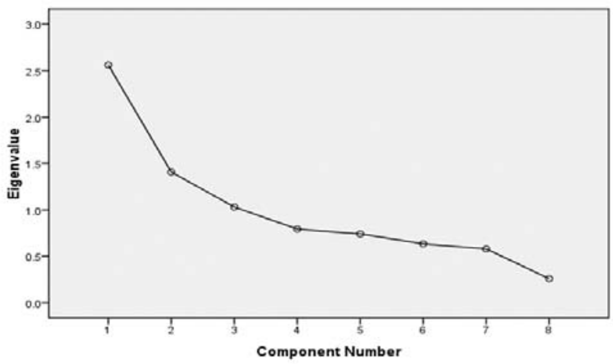


Figure 2. Scree Plot for Household Respondents

The principal component analysis of the variables gives 3 factors based on the eigenvalue of greater than one and the loading factor is greater than 0.5. Table 4 reveals the influence of the variables on solid waste transportation in Ado-Odo/Ota local government of Ogun state. From the result in table 4, the two factors labelled as waste collection method and method of waste disposal have highest number of variables among other factors and are considered to be principal factors. Their factor loading ranges from –0.529 to 0.847 which implies that clusters are sturdy.

Table 4. Summary of results with the clusters for household respondents

Creative label	Factor code	Variable	Factor loading
Waste Collection Method	Factor 1	Waste Collector Method of Transportation Container type Frequency of Waste Collection	0.846 -0.836 0.639 -0.529
Attitude of Collector/Location	Factor 2	Attitude of Collector Location	0.755 0.638
Method of waste Disposal	Factor 3	Frequency of Waste Collection Method of Disposal Perception of Management	0.505 0.847 0.512

Author's Computation, 2019

Therefore, those variables are considered very important. The clusters raised concerns about Waste Collection Method, Attitude of collector/location and method of waste disposals which generally speak to solid waste transportation.

Table 5. Factor 1 (Waste Collection Method) Household Respondents

Variable Description	Factor Loading
Waste Collector	0.846
Method of transportation	-0.836
Container type	0.639
Frequency of waste collection	-0.529

Author's Computation, 2019

In table 5 it can be seen that Waste collector have a high loading factor of 0.846 which implies that they have high impact factor on extraction of waste from the local government likewise the container type utilized in extraction of the waste is also important. Although, it can be seen from table 5 that the container type has the highest frequency which implies that it is the most utilized type of waste container but due to the health disadvantage that it poses, open container is not the most suitable type of waste container to be utilized.

Table 6. Respondents Assessment of PSP Transportation from Household

ITEM	SD		D		U		A		SA	
	F	%	F	%	F	%	F	%	F	%
Introduction of PSP has brought environmental improvement in the area	54	17.8	68	22.4	11	3.6	136	44.7	35	11.5
Cost of waste disposal charged by the PSP is too high	21	6.9	70	23.0	95	31.3	92	30.3	26	8.6
Are your street easily accessible for solid waste collection vehicle	40	13.2	103	33.9	7	2.3	99	32.6	55	17.9
PSP vehicle are too old and breakdown constantly	14	4.6	18	5.9	10	3.3	55	18.1	207	68.1
PSP operators use environmentally friendly vehicle	142	46.7	106	34.9	25	8.2	17	5.6	14	4.6
Quality of service provided is excellent	94	30.9	148	48.7	29	9.5	30	9.9	3	1.0
Number of time refuse is collected is adequate	112	36.8	134	44.1	30	9.9	24	7.9	4	1.3
Attitude of PSP worker is cordial	20	6.6	60	19.7	117	38.5	92	30.3	15	4.9
Refuse heaps all over the LGA have now disappeared	189	62.2	73	24.0	17	5.6	19	6.3	6	2.0

Author's Computation, 2019

Table 6 shows the item analysis of the assessment of PSP transportation from household respondents.

3.3. Data Presentation of Factor Analysis on Waste Management Staff

Table 7. Descriptive Statistics of Waste Management Staff

	N	Max.	Mean	Std. Deviation
Number of Vehicle	30	3.00	1.7000	0.79438
Types of Vehicle	30	3.00	2.8667	0.34575
Ages of Fleets	30	5.00	4.6000	0.49827
Point of Collection Waste	30	7.00	3.7000	2.27657
Frequency of Waste Collection	30	5.00	4.7000	0.46609
Distance to Dump Site	30	4.00	2.4000	1.06997
Problem Evaluation of Waste Mgt	30	2.00	1.2000	0.40684
Valid N (listwise)	30			

Author's Computation, 2019

The descriptive statistics of waste management staff shows that the mean, standard deviation and the number of respondent's data analyzed are 30. The mean of the obtained data shown in Table 7 shows a high degree of correlation among respondents on various matter, while the standard deviation values reflects a high degree of concurrence of the data obtained.

Table 8. Communalities for waste management staff

	Initial	Extraction
Number of Waste Vehicle	1.000	0.467
Types of Waste Vehicle	1.000	0.757
Ages of Waste Vehicles	1.000	0.546
Point of Waste Collection	1.000	0.813
Frequency of Waste Collection	1.000	0.725
Distance to Dumpsite	1.000	0.791
Problem Evaluation of Waste Management	1.000	0.593

Author's Computation, 2019

The random values for extraction were shown in Table 8. This extraction values implies that the proportion of variance variables that can be explained by the factors, the data reveal that type of vehicle, age of vehicle, point of collection of waste, frequency of collection of waste, dumpsite distance and evaluation of problem posed by municipal solid waste evacuation has significant effect on waste collection and disposal.

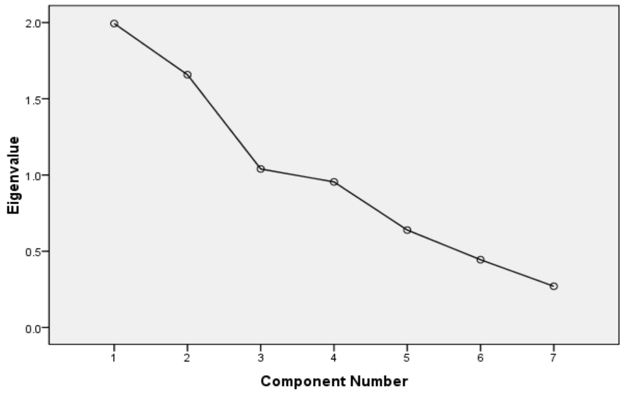
Table 9. Rotated Component Matrix for waste management

	Component		
	1	2	3
Frequency of Waste Collection	-0.848	-0.039	0.065
Point of Waste Collection	0.810	0.392	-0.051
Distance to Dumpsite	0.646	-0.604	0.095
Problem Evaluation of Waste Mgt.	0.030	0.766	0.079
Ages of Waste Vehicles	0.175	0.710	0.108
Type of Waste Vehicle	0.156	0.068	0.853
Number of Waste Vehicle	-0.349	0.086	0.582

Author's Computation, 2019

Table 9 shows the various loading factor for the extracted components based on the data analyzed. The data below 0.5 were suppressed and the result shows that component 1 and 2 have more loading factor, this implies that they have direct impact on the analyzed data. The data were sorted by size and significant level and the Rotation converged in 5 iterations. The varimax seeks for the rotation of the original factors such that the variance of the loading is maximized.

Figure 3. Scree Plot for waste management staff



The screen plot in Fig. 3 shows the three values that are above the Eigenvalue of 1 while others are below the Eigenvalue of 1 and are not extracted.

Table 10. Summary of Results with the Clusters for waste management staff

Creative label	Factor code	Variable	Factor loading
Environmental and frequency of collection	Factor 1	Frequency of Waste Collection Point of Waste Collection Distance to Dumpsite	-0.848 0.810 0.646
Environmental/Vehicle Challenges	Factor 2	Distance to Dumpsite Problem Evaluation of Waste Mgt. Ages of Waste Vehicles	-0.604 0.766 0.710
Vehicle specification	Factor 3	Type of Waste Vehicle Number of Waste Vehicle	0.853 0.582

Author's Computation, 2019

Table 10 reveals the influence of the variables on solid waste transportation in Ado-Odo/Ota local government of Ogun state. From the result in table 10, the two factors labelled as Environmental /Frequency of Collection and Environmental/Vehicle Challenges have highest number of variables among other factors and are considered to be principal factors. Their factors loading ranges from -0.848 to 0.810 which implies that clusters are down the line. Therefore, those variables are considered very important. The clusters raised concerns about Environmental/Frequency of Collection and Environmental/Vehicle Challenges which generally speak to solid waste transportation.

Table 11. Factor 1 (Environmental and Frequency of Collection)

Variable Description	Factor Loading
Frequency of Waste Collection	-0.848
Point of Waste Collection	0.810
Distance to Dumpsite	0.646

Author's Computation, 2019

In table 11, it can be seen that Point of Collection have a high loading factor of 0.810 which implies that it has high impact factor on extraction of waste from the local government likewise the distance of refuse dumpsite in extraction of the waste is also important. The negative loading factor of frequency of waste collection does not have positive influence on waste collection method although it has significant effect.

Table 12. Factor 2 (Environmental/Vehicle Challenges)

Variable Description	Factor Loading
Distance to Dumpsite	-0.604
Problem Evaluation of Waste Management	0.766
Ages of Waste Vehicles	0.710

Author's Computation, 2019

Both Problem evaluation and Ages of Vehicles in Table 12 have high impact factor and this implies that both factors have significant effect on transportation of waste in Ado Odo/Ota local government. While the negative loading factor of Distance opposed the other two variables because of the opposite sign -0.604.

Table 13. Factor 3 (Vehicle specification)

Variable Description	Factor Loading
Type of Waste Vehicle	0.853
Number of Waste Vehicle	0.582

Author's Computation, 2019

Both Type of Vehicle and Number of Waste Vehicle in Table 13 have high impact factor and this implies that both factors contribute to transportation of waste in Ado Odo/Ota local government.

Table 14. Respondents Assessment of Solid Waste Transportation from Waste Management Staff

ITEM	SD		D		U		A		SA	
	F	%	F	%	F	%	F	%	F	%
Designated refuse dumpsite is too far	9	30.0	12	40.0	-	-	5	16.7	4	13.3
Poor road network	1	3.3	-	-	-	-	-	-	29	96.7
Awareness of the program is adequate	7	23.3	3	10.0	-	-	5	16.7	15	50.0
Irregular payment by the people	-	-	2	6.7	-	-	12	40.0	16	53.3
Lack of adequate facilities/equipment	-	-	-	-	-	-	2	6.7	28	93.3
Lack of capability to maintain and repair vehicle	-	-	-	-	-	-	1	3.3	29	96.7
Lack of cooperation from waste generators	-	-	-	-	-	-	9	30.0	21	70.0
Cooperation on the part of government official					1	3.3	13	43.3	16	53.3
Lack of qualified/trained personnel	-	-	-	-	1	3.3	6	20.0	23	76.7
Lack of financial resources	-	-	-	-	-	-	4	13.3	26	86.7

Author's Computation, 2019

Table 14 shows the item analysis of the assessment of PSP transportation from household respondents.

4. Conclusion and Recommendations

This study was conducted with the objectives of identifying the most important risk factors associated with solid waste transportation and also to reduce indiscriminate dumping of waste along the highway and the entire environment.

The outcome of the analysis shows that waste collection method, method of waste disposal, frequency of collection and environmental/vehicle challenges are considered to be the major problem with solid waste transportation in this study.

The following recommendations are made based on the findings of this study.

- The Ogun State Government Environmental Protection Agency (OGEPA), should partner with Private Sector Participant (PSP) to monitor the attitude of the waste collectors, the method of waste transportation, enforce a standard container to enable effective collection of waste and also to facilitate frequency of waste collection.
- OGEPA should empower the PSP Operators and ensure that they use environmental-friendly vehicles.
- Government should acquire new solid waste standard trucks because the existing ones are of age and frequently breakdown.
- OGEPA should take it as a point of duty to make sure that the PSP vehicles are properly and mechanically maintained before they are allowed to ply the roads.
- Government should legalize and empower the cart pushers to be able to cover the areas which the PSP operators cannot cover or reach.
- Government should help in the repair of the roads to enable the PSP operators to be effective because the bad road also contributes to the poor conditions of the vehicles.

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