PREDICTION OF PARKING LOT AVAILABILITY USING ELANG’S LOSS MODEL

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Abstract

Parking is one of the most crucial needs in the developing and developed nations. Urban population growth and business activities in Lagos State have contributed to the frenzied location of facilities. Often facilities are located without adhering to the set standards and regulations. Noncompliance to standards particularly in busy business districts usually contributes to traffic congestions in those areas. Similarly, the unavailability of enough parking spaces is another setback to free flow of movement. The negative effects of these misdemeanors cannot be overemphasized. High commercial areas with adequate planned parking spaces and total compliance will enhance easy traffic flow but in areas where there is no adequate planning and compliance will create bottlenecks for the road users, then parking becomes one of the most disruptive elements within the locality.

This study was based on the use of Geographic Information Systems (GIS) technology in analyzing the compliant rate of facilities along some specific roads in Ikeja. To all the facilities studied, results showed that over 33% did not comply with the rule set out by the Lagos State Government. Elang’s Loss Model was used to determine the probability that a customer that is unable to park due to inadequate parking lots leaves the system/facility.

Keywords: Geographic Information Systems (GIS), of Surveying & Geoinformatics

1.0 INTRODUCTION

The rapid growth in urban population and business activities has drastically affected facility locations in many Nigerian cities particularly in Lagos State. Facilities that are improperly located disrupt urban activities especially urban transport system. Road usage being the most popular mode of transportation in Lagos is easily affected when facilities are located in manners that hinder free flow of traffic. Arguably, it can be stated that more than half of the population of Lagos State depend on this mode of transportation. This is evidenced by the traffic congestion observed in major business districts of the State particularly in Ikeja. Another activity that leads to heavy traffic along urban business region is the average available parking spaces and the distance of these facilities from the road (Karimi, Toosi and Toosi, 2014).

Public and private parking space which is one of the important parts of a modern urban transport system plays an important role in decreasing the load of heavy traffic. Lack of enough accessible parking spaces can hurt local business and decrease the quality of life of residents. Suitable site selection for parking spaces increases parking efficiency and indirectly results in increase of traffic fluency. City managers must study and analyze parking pattern to ensure proper parking (Wither, Kligman and McDevitt, 2002).

Due to the increasing nature of population growth in Lagos, the Central Business Districts (CBDs) such as Victoria Island, Lagos Island, Ikeja, Oshodi, etc. are overcrowded and the infrastructure to handle the parking facilities is
inadequate, leaving these areas overwhelmed by huge traffic congestion (Olusina, 2013). As a result, these CBDs are faced with problems of parking management. In spite government’s efforts at tackling these challenges not much seem to have been achieved as serious traffic congestion are still observed all across Lagos, particularly in Ikeja Local Government Area.

This research examines the compliance of the existing facilities located along some major commercial streets (along Maryland, Opebi, Allen, Awolowo Road and Oba Akran) in Ikeja Local Government Area with the Lagos State physical planning and development regulations 2005. The facilities include: banks, eateries, markets, shopping plazas and bus stops. Spatial data on these facilities were collected: queries and analysis of compliance rate were carried in a Geographic Information Systems (GIS) environment; for facilities with inadequate parking lots, Elang’s Loss Model was applied; and recommendations on solving these parking locations problems were proffered.

1.2 Study Area

The study focused on some selected areas in Ikeja Local Government Area (i.e. Maryland, Opebi, Allen, Awolowo Road and Oba-Akran). Ikeja is part of the Lagos Metropolitan Area and the capital of Lagos State with a population of 313,196 as at 2006 population census. It has a very strong commercial base and a large number of businesses which are mostly retail and service based. It has the largest shopping mall in the Lagos Mainland “Ikeja City Mall”, a large computer market “Computer Village” and Murtala Mohammed International Airport. (Wikipedia, 2014).

2.0 CONSTRUCTING PARKING LOTS

Some of the conditions for constructing parking lots are discussed below:

(1) Parking Design- The design of functional parking should be governed by the characteristics of the vehicles that will use it. This will influence the turning radii, lane width, maneuvering space and vertical clearance will always be determined by the largest vehicles that require access to the space. Parking space designs are classified by the angle between the curb and the parking stalls, common parking angles are 90°, 60°, 45° and 30°. The type of angle used will depend on the available and shape of space. (Oduwaye, 1998).

No matter the parking layout (width and length of stalls, the width of aisles, etc.) and parking angle adopted: (i) the layout of the parking facility must be flexible enough to adapt future changes in vehicle dimensions, and (ii) the stall and aisle dimensions must be compatible with the type of operation planned for the facility (Litman, 2014).

(2) Types of Parking Lots- There are two types of parking lots identified: (i) Angle Parking and (ii) Parallel parking. Angle parking is more convenient for motorist than parallel parking, but it invariably produces a much higher accident rate than parallel parking at some location. Angle parking is more adaptable to trucks and other types of commercial vehicles, it encourages extension to streets at certain width, and the large overhang of front fenders and bumpers on many types of motor and pedestrian movement are heavy. However, for Parallel parking, it is often difficult to establish on downtown retail streets where angle parking has prevailed. Spaces for potential customers are reduced and motorist frequently complain that parallel parking is too difficult particularly for women drivers (Withee, Kligman and McDevitt, 2002).

For the various parking interlock modules and their angle efficiency: (i) the most preferable type of parking is the bumper to bumper arrangement; (ii) the herringbone interlock can be used at 45° and is produced by adjacent sides having one-way movement in the same direction. The arrangement requires the bumper of one car to face the fender of another car; (iii) One-way Aisles- with parking angles less than 90°, drivers can be restricted to certain
direction. However, the angle should usually be no greater than 75° (Oduwaye, 1998).

**Shared Parking**- two or more land users that are controlled by one or more owners can use the same parking area over the course of a day. In many cases, parking may be shared because the land users operate at totally different times. In other cases, the land users operate at the same times, but the peak usages are at different times (Fitzgerald and Halliday, 2007; Olusina, 2013)

**Off Street Parking**- Most parkers are reluctant to walk even short distances from their ultimate destination. The maximum walking distance a parker will tolerate depends on trip purpose, city size and cost of parking. Parkers prefer parking facilities near their destination (office workers maximum distance of 5 or 6 blocks with low rate, while short term parkers like shoppers maximum of 1 or 2 blocks). Preferably, parking lots should be located on or near major arterials (Radnor , 2001).

(3) **Site Location**- Site selection is a very long process because the choice of a poor location can be very costly. Once a region or community is identified as a potential location, specific sites must be identified and evaluated, and these include: customer base, construction/leasing cost, land cost, site size, transportation, utilities, zoning restrictions, traffic, safety/security, competition, area business climate, income level and other demographic characteristics.

A business has several options for locating any facility, but service-related businesses often rent or purchase existing facilities in shopping malls or office buildings (Karimi, Toosi and Toosi, 2014)

**2.1 Lagos State Physical Planning and Development Regulations**

According to Lagos State physical planning and development regulations 2005, any person intending to carry out any development must: apply to the authority, submit architectural drawings, a location plan, physical planning technical report and survey plan.

**Parking Requirements**- apart from Residential and Industrial, other commercial uses must: (a) **hotels and guest houses**- 2 car parking spaces for every three hotel/guest rooms in residential zones, and 1 car parking space for every three hotel/guest rooms in other residential zones and other land use zones; (b) **restaurant, eatery and fast foods outlets**- 1 car parking space for every ten (10)m² of eating area in the case of; (c) hospital and private clinics- 1 car parking space for every three (3) bed spaces in the case of: Car Park Standard- a car parking space shall not be less than 2.5meters in size, and must not obstruct free movement of vehicles and persons; **Bus-Stops Standard**- Location of bus-stops should be coordinated with the local transit agency. Bus-stops shall not be located closer than 300ft apart nor nearer than 200ft to the nearest intersection. The design shall conform to the highway manual. When parking frequency exceeds 10 buses a day for period longer than 5 minutes, motor parks shall be provided. (Federal Highway Manual, 2005).

**3.0 METHODOLOGY**

**Data Sources**- Data were sourced from both primary and secondary sources. Primary data included: the Global Positioning System (GPS) coordinates of the facilities, types and size of parking lots, flow of traffic at the parking lots, photographs of the facilities, to minimize bias, simple random sampling technique was adopted to determine which facility to select and a one-on-one oral interview was also conducted to collect information from the staff and customers of these facilities; while the Secondary data included: facility location required standards and demography (Lagos State Official Gazette and the Federal Republic of Nigeria Official Gazettes respectively); an already preprocessed and sampled Landsat satellite imageries of 0.6m spatial resolution, and an existing map of Ikeja LGA (Lagos State Surveyor General’s Office, Survey division, Alausa).

**Data Processing**- The image was rectified and georeferenced to World Geodetic System 1984 (WGS84) datum, and projected to the Universal Traverse Mercator (UTM) map projection system Zone 31.

The raster satellite imagery was digitized in the ArcGIS 9.0 environment and shape files were created. Integration of both spatial and aspatial data were carried out. Queries and analysis based on Lagos State Physical Planning and Development Regulations compliant rate were carried out and the probability that a customer drives away from a facilities due to inadequate parking lots was determined using Erlang’s Loss Model. (Section 4.2.2)
4.0 RESULT AND ANALYSIS

The results and analysis on the location of facilities, their parking spaces, their compliance with the Lagos State Physical Planning and Development Regulations setback standard of 9m from access roads and the number of cars (customers) driving off as a result of no parking space were calculated using Erlang’s Loss Model are discussed below.

4.1 Locations of All the Facilities

Routes (Maryland, Opebi, Allen, Awolowo Road and Oba – Akran) and facilities covered are shown in Figure 4.1a; while Figure 4.1b shows Euclidean pixel variations i.e. the degree by which the areas are affected by the events caused by the facilities. The areas within the yellow region are highly affected than the areas in blue.

4.2 Spatial Distribution of All the Facilities

4.2.1 Financial Houses & Eateries

These includes 70 Banks and insurance companies (Fig. 4.2), and 13 Eateries (Fig. 4.3).

4.2.2 Shopping Plaza & Markets

These includes 9 Shopping Plazas (Fig. 4.4) and 2 Built and Open Space Markets (Fig. 4.5).
4.2.3 BUS-STOPS

These includes 17 Bus Stops (Figure, 4.6).

4.1.1 Compliant Facilities

Financial Houses & Eateries

Figures 4.7 and 4.8 show some of the Financial Houses and Eateries that met the 9m Lagos State Physical Planning and Development Regulations on setback requirement.

4.1.2 Non-Compliant Facilities

Financial Houses & Eateries

Figures 4.9 and 4.10 showed some of the Financial Houses and Eateries that did not meet the 9m setback standard respectively.
The compliant and non-compliant queries for other facilities were also carried out.

4.2.2 Parking Space Availability

Parking space availability for the Eateries are shown in Figure 4.11.

4.8 RESULTS ANALYSIS

The results on facilities compliance with the Lagos State Physical Planning and Development Regulations on road setback requirement and on the number of parking spaces available, are analyzed below:

(i) On Availability of Parking Space- From Figure 4.11 on Parking Space Availability for the Eateries, the highest available parking space in all the eateries is Mr. Biggs, Maryland, with 24 car spaces, while Mama Cass, Allen Avenue, has the least (7 car spaces). It did not meet the required number of parking spaces for the type of eateries. Similarly, from Figure 4.12, out of all the facilities, Adebowale House (a plaza) has the highest number of parking space (128).

(ii) On Compliance- The Financial Houses had over 60%, Shopping Plazas over 29% while the Eateries less than 11% (Fig. 4.13a). On Non-compliance rate Financial Houses also had over 47%, Shopping Plazas over 27% while the Eateries also has less than 25% (Fig. 4.13b).
The Compliance and Non-Compliance of the other Facilities were also determined and plotted. Similarly, the Total/Overall Compliance and Non-Compliance of all the Facilities were also computed and there was over 66% Total Compliance and over 33% Non-Compliance of all the Facilities (Fig. 14).

With reference to all the facilities studied in Figure 14 over 33% did not comply with the rule set out by Lagos State Government, therefore, customers that cannot park as a result of lack of adequate parking spaces will leave the system/facility.

(iii) On Customers’ Loss - As mentioned above (i and ii), for facilities that have no enough parking space for their customers to park, e.g. Mama Cass, Erlang’s Loss Model (in queueing theory) was used to determine the probability that a customers will leave the system. This becomes a loss to such facility/system.

**Erlang’s Loss Model:** From survey, Customers’ vehicles arrived at Mama Cass at random during the evening period at a rate of 6 vehicles per hour. Customers’ stay at the eatery’s park was exponentially distributed, with a mean duration of 0.5 hr. (μ = 2). The eatery has 7 spaces (N = 7) in the park set aside for the vehicles. The probability that a customer who is unable to park go away is calculated as follows:

\[ \lambda = 6 \text{ arrivals/hr, } \mu = 2 \text{ services/hr, } \rho = \frac{\lambda}{\mu} = \frac{6}{2} = 3, \text{ and the utilization factor } = \rho/\lambda = 3/7 = 0.429 \]

From Gupta and Hira (2008), the probability that \( n \) vehicles will be parked (\( P_n \)):

\[ P_n = \frac{\rho^n \mu}{n!} \frac{1}{\sum_{i=0}^{n} \frac{\rho^i \mu}{i!}} \quad \text{for} \ n = 0, 1, 2, ..., N \quad (1) \]

The probability of an empty space:

\[ P_0 = \frac{1}{\sum_{i=0}^{N} \frac{\rho^i \mu}{i!}} \quad (2) \]

The probability that a vehicle cannot park is the probability that all the \( N \) spaces are occupied (Erlang’s Loss Model):

\[ P_n = \frac{\rho^n \mu}{N!} \sum_{i=0}^{N} \frac{\rho^i \mu}{i!} \quad \text{for} \ n = 0, 1, 2, ......., N \quad (3) \]

Using Equation 2, the probability of an empty slot (\( n = 0 \)) = 0.076979 and Table 1 shows the probabilities for the different arrivals of vehicles until all the slots are occupied.

Table 1 shows the probabilities of the different arrivals of vehicles.

<table>
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<tr>
<th>Probability of ( n ) vehicles parking</th>
<th>Probability Values</th>
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<tbody>
<tr>
<td>P0</td>
<td>0.076979</td>
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<tr>
<td>P1</td>
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<td>P2</td>
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</table>
The Probability that a customer cannot park (Equation 3 i.e. \( n > N \)) = 0.033403.

5.0 CONCLUSIONS

This research was based on determining the compliant rate of facilities located along some major roads in Ikeja with the Lagos State physical planning and development regulations 2005 on 0.9m road setback and the required number of parking lots per type of facility. Arrival and service rate of vehicles at the parks were determined, database was created and analysis carried out in a GIS environment. For the facilities that did not comply with the regulations, the probability of their customers driving off as a result of lack of adequate parking lots was determined using Elang’s Loss Model.

The study revealed critical factors that contributed to traffic congestion in Ikeja: unavailability of adequate parking spaces, closeness of facilities to major roads and attitude of motorists. It is also revealed that the ability of the State Government alongside its traffic management agencies to enforce policy standards are essential for effective traffic management. While the provision of convenient parking facilities is essential, appropriate site planning and design treatments can be used to minimize their negative visual impact. Multi-storey, underground and shared parking methods should be widely embraced.

Finally, the study revealed that an optimal facility location, in a GIS environment, is a panacea for traffic management. The GIS will assist in creating a comprehensive parking management database with coding scheme that uniquely identifies each parking lot, location, type (ground, multi-storey, shared, etc.), ownership (private or public), number of lots/spaces, price, time of higher patronage, and so on.

REFERENCES