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FREQUENCY AND VEHICLE CAPACITY DETERMINATION OF BOSSO AND GIDAN-KWANO CAMPUSES, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA: A LITERATURE REVIEW

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ABSTRACT

Line capacity is simply the number of passengers that can be transported within a given time interval. Growing traffic problems are a major concern for countries all over the world. The population of students in the University has increased tremendously over the last 6 years by about 525.25%. Almost every country of the world whether developing or developed are facing the problem in the management of transportation facilities. Transportation challenges experienced in most Nigerian urban centres include traffic congestion, inadequate provision of carriers for commuters in quantity and timeliness, poor traffic management, poor conditions of roads, attitudinal behaviour of drivers among others. The aim of this paper is to identify the most suitable methods or techniques in solving Transportation problem relating to bus management of the study area and also to present an overview of some selected literature that provides different techniques for solving a frequency setting (FS) problems.

Keywords: *Frequency, Model, Transportation, Vehicle Capacity*

1.0 INTRODUCTION

Transportation is the movement of people, animals and goods from one location to another (Kolo, 2018). People travelled whether to work, play, shop, business or schools. Raw materials must be conveyed from land to place of manufacture or usage; all goods must be moved from the factory to the market place and from the staffs to the consumer. Transport is the means by which these activities occur; it is the cement that binds together communities and their activities. Meeting these needs has been, and continues to be the transport task (Flaherty, 2006).

Information and communication technologies (ITS) have recently been applied in programs to support sustainable urban development. In particular, initiatives in the transportation sector aim at improving the safety, efficiency and sustainability of large cities. ITSs are generally speaking, combinations of technologies for increasing efficiency in vehicular traffic mainly focused on road transport (UNESCAP).

Cats and Gluck (2019) defined line capacity as the product of line frequency and vehicle capacity. Frequency and vehicle capacity therefore are the parameters required to determine the number of passengers transported within any given period.

Growing traffic problems are major concern for the countries all over the world. Almost every country in the world, whether developing or developed are facing the problem in the management of transportation facilities (Singh and Gupta, 2013). The population of students in the University has increased tremendously over the last 6 years by about 525.25% (FUTM Annual Report, 2020**).** Transportation challenges experienced in most Nigerian urban centres include traffic congestion, inadequate provision of carriers for commuters in quantity and timeliness, poor traffic management, poor conditions of roads, attitudinal behaviour of drivers among others. In addition, with the rapid expansion of urban population, the transportation problem in big cities becomes more and more serious (Rizzi and De La Mazza, 2017). (Suman *et al.*, 2017) sees Green and low-cost urban public transportation as the main choice of urban residents in some densely populated cities.

According to Vuchic (2002), Urban bus transit system which consists of a comprehensive route network and a reasonable departure frequency is the main component of an urban public transportation system. Overtime, there has been a setback in service demand and supply of bus transportation system in the university, the latter experiences overloading during peak period while sometimes return from a trip with little or no passengers in off-peak period, and the former faces challenge of delay in boarding buses that mostly results from a long queuing at the bus stops (Origin). However, this is a genuine problem because it is almost impossible to match the Transport Infrastructure rate with the Traffic population growth rate.

This paper therefore represents an overview of different methods or techniques for determining frequency and vehicle capacity and to identify a suitable technique for solving the Transportation problem (Frequency Settings) bedevilling the Study Area. This paper is section into three; Section 1 presents a Review of past literature, section 2 explain the nature of the study area and section 3 explain the chosen technique to solve the frequency setting problem of the case study area.

Ceder (1983), investigated frequency determination using passenger count data and presents two methods that relate frequency and headway. The study provide methods to determine bus headway for a given time period. Two of these required only maximum loads (point check data) and the other two required complete load profile (ride check) information. The result of the passenger count data was used to evaluate alternative time tables and also minimizing the required bus runs and number of buses. Equation 1 shows the relationship between the headway and bus frequency. This method has become obsolete due to the emergence of satellite surveillance and also susceptibility of the method to error.

2.0 SECTION 1: REVIEW OF LITERATURE

Cats and Gluck (2019) classified frequency setting problem or line capacity to Strategic and Tactical level. At strategic level, frequency settings is affected by the passengers route choices and the vehicle capacity depends on the choice of public means of transportation (light rail, bus, train, metro), while at tactical level, both service frequency and vehicle capacity can be altered on a seasonal basis and vary by day and time of the week.

$$F = \frac{P_j}{\gamma_{jc}} = \frac{P_{*j}}{d_j}, j = 1,2,3..,q \tag{1}$$

P_j Is the load in period j associated with daily maximum load point.

$$\max i \in S \sum_{j=1}^{q} P_{ij} = \sum_{j=1}^{q} P_{*j} ,$$

$$\text{And } P_{j=} \max i \in S(P_{ij})$$

More recent development involved the use of additional decision variable and metaheuristics Yu *et al.,* (2010) or Jointly computed Dell' olio *et al.,* (2012).

Early works on Frequency Setting assumed a fixed demand-line assignment to be based on analytic models (Newell, 1971; Salzborn, 1972; Scheele, 1980; Han and Wilson, 1982) or heuristic solution methods Furth and Wilson (1981). These seminal approaches were later extended including uncertainty in the demand observed in each line or other considerations. Hadas and Shnaiderman (2012) address the minimization of a total cost based on empty seats and not-served demand. Thanks to GPS, APC, and AVL tools, the authors defined probability distributions for travel times and passenger demand. Based on this information, they defined an analytical optimization approach that determines frequencies and vehicle sizes.

Nurit and Shlomo (2020) defined Transit assignment as the mapping of passenger demand over a given transit network; this procedure yields the estimated distribution of passengers in a network and enables its assessment. Therefore, transit assignment plays a key role in both planning and management of transit networks. Transit Models are broadly divided to schedule and frequency based transit assignment. Schedule based assignment modify passenger flow in time, and frequency based assignment estimate the average distribution of passengers over time. Therefore, schedule based models are commonly used for management purposes, enabling detailed flow simulation, while frequency based models are commonly used for planning purposes, enabling to efficiently model large scale networks Kepaptsoglou and Karlaftis (2009).

Li *et al.,* (2013) consider stochastic parameters such as demand, arrival times, boarding/alighting times, and travel times. A stochastic optimization approach was used to find the optimal frequency that minimizes the sum of the expected value of the company profit and the waiting time costs for passengers. A Generic Algorithm (GA) was developed to solve the problem and compare their approach with traditional Frequency Setting models of Newell (1971) and Ceder (1984). It was observed that the headways obtained are usually larger than those using the approach by Newell (1971) and shorter than those using Ceder (1984). The authors revealed that these moderate headways provide a better balance between the bus operational costs and the passengers' satisfaction.

Canca *et al.,* (2016) proposed a Mixed Integer Non-Linear Programming (MINLP) model to determine optimal line frequencies and capacities in dense railway rapid transit (RRT) networks in which typically several lines can run over the same open tracks. Given a certain demand matrix, the model determines the most appropriate frequency and train capacity for each line taking into account infrastructure capacity constraints, allocating lines to tracks while assigning passengers to lines. The service providers and the user's stances are simultaneously taking into consideration. The first is considered by selecting the most convenient set of frequencies and capacities and routing passengers from their origins to their destinations while minimizing the average trip time. The second one by minimizing operation, maintenance and fleet acquisition cost. Due to the huge number of variables and constraints appearing in real size instances, a pre processing phase determining the best k-paths linking origin and destination stations is followed.

Recently, Nassir et al., (2019) used smart-card database to develop a link based recursive model that estimates the links' attractiveness. One of the aspects in traffic assignment is the prioritization of passengers. Bar-Gera *et al.,* (2012) termed the "proportionality" property for private car assignment, suggesting that for any link in the network, the same proportion can be applied to all passengers, regardless of their origin or destination.

Cats and Gluck (2019) determined frequency and vehicle capacity at the network level while accounting for the impact of service variations on users and operator costs. To this end, the authors proposed a simulation-based optimization approach. The model unlike the aforementioned techniques allows for simultaneous determination of frequencies and vehicle capacities based on iterative assessment of candidate solution using a dynamic and stochastic transit assignment model termed "Busmezzo". However, the proposed model has limitation to integrate vehicle scheduling constraints into frequency and vehicle capacity determination problem. In addition, under special event, the use of the model extends beyond tactical level and includes strategic network design and supply settings. The performance of the model was checked by minimizing the total cost function in terms of operator and user cost as shown in equation 2. See (Cats and Gluck, 2019) for details on the equations.

$$z = minC_u + C_o \tag{2}$$

Where; $$C^u = \beta^{VOT} . \sum_{j\epsilon J}\left[\beta^{initial\_wait} t^{initial\_wait} + \beta^{extra\_wait} t_j^{extra\_wait} + \beta^{ivt} t_j^{ivt} + \beta^{walk} t_j^{walk} + \beta^{trans} x_j\right] \tag{3}$$

And $$C^o = C^f + C^d + C^t + C^s \tag{4}$$

The passenger arrival process depends on service frequency Ceder (2007). The Poisson distribution is an appropriate assumption for high frequency services in which passengers' arrival at stops is a random process. In the case of low-frequency service or an intensive transfer stop such as train station. Passenger arrivals cannot be regarded as a Poisson process, and an alternative distribution such as lognormal should be used. The passenger alighting process is assumed to follow a binomial distribution Morgan (2002).

The Frequency Setting problem (FS) determines the number of trips for a given set of lines L to provide a high level of service in a planning period. Since frequency changes influence the passengers' perception of the level of service it may lead to an increment or decrement of the system usage. A simple version of the problem is to determine the frequency f' (buses/hour) for each line l ϵLsuch that travel times are minimized and the fleet size is bounded.

$$[p] = f(x) = \begin{cases} \min \sum_{i \in v} \sum_{j \epsilon v} D_{ij} \; T_{ij}^{l} : \sum_{l \in L} [t^{l} . f^{l}] \leq F \end{cases} \tag{5}$$

3.0 SECTION 2: DESCRIPTION OF STUDY AREA

The university has two campuses namely; Bosso and Gidan-Kwanu Campus otherwise known as University main campus. Niger state is located between latitude 8^0 10' N and 100 30'N and between longitude 3^0 30'E and 7^0 30'E. Niger State covers an area of 96,363 square kilometres. Students traverse daily between the two campuses for lectures and other academic purposes. The route connecting these campuses was digitized with temporal intermediary bus stops where passengers (students) highlighted or enter the bus from/to any of the campuses.

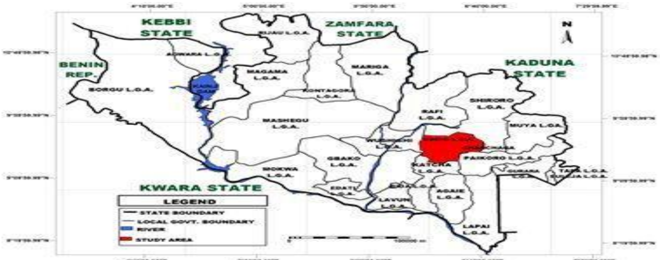

Figure 1: Map Showing Bosso, Minna Niger State

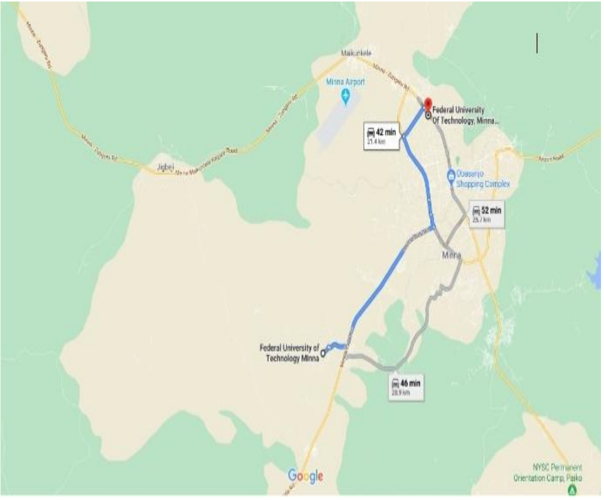

Figure 2: Route Map connecting Gidan-kwano and Bosso Campus Minna

3.0 SECTION 3: SELECTED MODEL

3.1 DYNAMIC TRANSIT ASSIGNMENT MODEL (BusMezzo)

BusMezzo is a dynamic public transport operation and assignment model used for supporting analysis and evaluation of public transport planning, operations and control. Cats and Gluck (2010) sees that BusMezzo captures three passengers congestions effect by: 1) deteriorating comfort on board a crowded vehicle. 2) denied boarding in case of insufficient bus capacity. 3) Service fluctuation as a result of flow-dependent dwell time variation.

Mezzo is an object-oriented, event-based simulator that models vehicles individually but does not represent lanes explicitly. Links in Mezzo are divided into two parts: a running part, which contains vehicles that are not delayed by the downstream capacity limit, and a queuing part, which extends upstream from the end of the link when capacity is exceeded. The boundaries between the running and queuing parts are dynamic and depend on the extent of the queue. Data to be used for the model are collected using a CCTV camera for capturing passenger boarding, alighting, and walking periods. A field survey is also carry out to determine the topography and other properties of the route network.

3.2 TRANSIT OBJECT FRAMEWORK

The Mezzo transit oriented classes includes; Bus type, bus vehicle, bus trip, bus line, bus route and bus stops.

1 **Bus Types:** This defined the features of different types of vehicle such as length, number of seats and passenger capacity as presented in Table 1.

2 **Bus Vehicle:** This has a specific bus type and maintains a list of their scheduled trip.

3 **Bus Line:** It is defined by its origin and destination terminals and intermediate stops it serves in between.

4 **Bus Route:** is a unique route in terms of a sequence of links travelled.

5 **Bus Trip:**This maintains a list of schedule arrival times at each stop for specific trip.

6 **Bus Stops:** It is characterized by the link on which it is located and it position on that link, it also stores information on the physical characteristic such as length and types of stops (in-lane or bay stops) and a list of bus line that serves this stops. Cats *et al.,* (2010)

Table 1: Bus types available to the Students for Transport Simulation

Variables	**Mini bus**	**Normal Bus**	**Articulated**
Seats Capacity			
Total Capacity			
Length (meters)			
Number of front/rear door			
Boarding time per passenger (seconds)			
Alighting time per passenger (seconds)			
Time dependent cost, β^t (N/vehicle-hour)			
Additional time-dependent cost when vehicle stand idle			
Fixed cost, β^f_k(N/vehicle-hour)			

Distance-dependent cost, β^f_d (N/vehicle-km)	

3.3 MODELLING FRAMEWORK

This model consists of three sub-modules performed in iterative process. The search process generates new solutions as well as upper and lower bound of frequency. In each of iteration of optimization algorithms, a potential setting on frequencies and vehicle capacities are generated and used as input to the dynamic transit assignment model. The three sub-modules include:

1 Search Algorithm

2 Feasibility Constraints

3 Performance Evaluations

4.0 CONCLUSSION

Frequency setting problem have been a well known transportation problem especially with the high rate of population in some countries or settings. Summarily, four (4) different approaches of frequency and vehicle capacity determination were reviewed. The obsolete mathematical analysis to determine the frequency and headway which involve manual passenger count data, Mixed Integer Non-Linear Programming (MINLP) model to determine optimal line frequencies and capacities in dense railway rapid transit (RRT) networks, and The use of Analytical models or heuristics solution methods. At the end of the reviewed methods, Simulation, Analytical and mathematical methods, a dynamic transit Assignment model otherwise known as BusMezzo was chosen to be used in this paper due to its simplicity to use, ease and accuracy in data collection method and efficiency in the generated output.

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