Passenger Capacity and Safety: Investigating the Likelihood of COVID-19 Transmission in Public Transport Modes within Makurdi Metropolis

*Paul. T. Adeke, Kwaghgba Gbagir and Manasseh Tyogo

Department of Civil Engineering, Joseph Sarwuan Tarka University, Makurdi, Nigeria
adeke.pt@outlook.com | {gbagirkwaghgba | manassehtyogo}@gmail.com

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Abstract- Following its outbreak in the Wuhan region of China, the spread of Corona Virus (COVID-19) across the world has threatened national and local authorities or policy makers and transport experts due to its effects on human mobility. This study investigated the transmissibility of COVID-19 among passengers in transit using public transport modes in Makurdi metropolis. Analytical simulation using stochastic search method called Genetic Algorithm (GA) technique was used to simulate the transmissibility of the infectious disease within enclosed spaces of transport modes based on layouts and capacities. The sum of arithmetic sequence was used as the objective function of individual arrivals in each mode, it was minimised to obtain optimum safe capacity. Capacities of public transport modes were subdivided into; Normal, Above Normal and Below Normal (50% of Normal). Findings of the experiments indicated that optimum safe capacity of minibuses, taxis, tricycles and motorcycles used in Makurdi metropolis were at 8, 3, 2 and 1 person respectively. This occurred at 50% capacity which agreed with findings of previous studies. An efficient and sustainable public transport policy framework was designed for policy makers and transport experts to help achieve safe travel and healthier living in Makurdi metropolis during the COVID-19 era.

Keywords- COVID-19 transmission, Makurdi Metropolis, Modal Split, Mode capacity, Passenger Safety, Public Transport.

1 INTRODUCTION

The need to travel in every society can never be over emphasized. Travelling has direct impacts on the socio-cultural and economic wellbeing of citizens of every nation (Hu et al., 2013; Pan and Zuo, 2020). Mobility is essential to all facets of human existence; hence, the need for periodic evaluation of transport systems to ascertain performance efficiency and safety in order to achieve sustainability. A sustainable transport system solves today's problems in terms of environment, social and economic worth without hurting tomorrow's needs (Schiller et al., 2010; Buehler and Pucher, 2011; Gudmundsson et al., 2016; Adeke et al., 2018).

The dynamisms of the present society have made it almost impossible to forecast correctly the future societal needs for preplanning. Recent happenings in the world indicated that public transport system plays a key role in the spread of the novel Corona Virus (COVID-19) disease which broke out in faraway China to most countries of the world (Hendrickson and Rilett, 2020; Gossling et al., 2020; World Bank Group, 2020; World Health Organisation (WHO), 2020a). The trans-border movement of people justified the relevance of transport system in nation development and underdevelopment; as many countries struggled to reopen public activities after the total lockdown period experienced between March to October 2020, and thereafter.

In the 4th quarter of year 2020, there were still significant traces of threats by COVID-19 cases in some countries like China, U.S, UK, Nigeria, India and Brazil which called for caution and rethink for another lockdown season to help prevent the spread of the disease. Due to this continuous surge of the pandemic and its associated influence on mobility, it was therefore pertinent to investigate the spread of the disease through public transport systems for effective planning, design, construction and management of public facilities to achieve safe and liveable cities.

2 BACKGROUND TO THE STUDY

2.1 PUBLIC TRANSPORT SYSTEM

Public transport system is any mass transit scheme designed to provide transport services to the general public. It is an essential and the backbone of local and national economy of every society (Union Internationale des Transports Publics - UITP, 2020; Hendrickson and Rilett, 2020). In developed countries, the system uses buses, coaches, trains and taxis among others scheduled to travel on fixed routes within a given space (Ceder, 2007). The use of public transport system in every society is the only surety for efficient and sustainable mass movement of people and goods (Schiller et al., 2010; Jia et al., 2017; Zheng et al., 2020).

The disadvantages of using private cars for mass movement of people and goods include; travel cost in terms of fuel, maintenance and time lost due to delay caused by congestions, more space in the form of lane density to satisfy vehicle demand, environmental depletion caused by emission of greenhouse gases and noise (Adeke et al., 2018; Zheng et al., 2020). Many transport experts have seen the high occupancy offered by buses or coaches and trains as the major advantage over the private cars (Beirao and Cabral, 2007). Campaigners of sustainable development recommend the

*Corresponding Author

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use of mass transit for public transport system and green travel modes to curb challenges associated with private car use for commuting (Adeke et al., 2018; Zheng et al., 2020).

There are different public transport schemes for different countries and states over the world to suit their peculiar characteristics and transport policies. While some developed countries in Europe, America and Asia use buses, coaches, trains and taxis as public transport modes, the system in most developing countries encompasses any means used for conveying trip makers individually or enmass from one location to the other. Common modes used for such transportation system include, bicycles, bikes, tricycles, taxis, buses, minibuses, coaches and trains whose services are usually provided by non-governmental service providers, mostly private companies or individuals. These para transit modes provide individualised rides without defined routes or timetable, stop for boarding and passengers disembark on request to the nooks and crannies of the metropolis. Though such para transit modes provide relatively high level of comfort sometimes - usually when not overloaded, there is high risk of accident and the fare is somewhat higher compare to buses, coaches and trains. (Gbagir et al., 2018; Oyewole et al., 2020).

2.2 CORONA VIRUS (COVID-19) PANDEMIC

The outbreak of Corona Virus (COVID-19) in December 2019 at the Wuhan region of China and its wide spread across countries have claimed many lives (WHO, 2020a). It is a contagious disease that could be contracted by a susceptible individual through touching the mouth and nose fluids (droplets) of an infected person or touching exposed surfaces in public places where such droplets may have fallen from coughing, sneezing and talking, then linking to one's respiratory system through the mouth or nose (WHO, 2020a; Anchordoqui and Chudnovsky, 2020; Okunlola et al., 2020; Tipaldi et al., 2020; Yezli and Khan, 2020; Xu and Chraibi, 2020).

According to World Bank Group (2020), the disease was declared a pandemic on 11th March, 2020 following its wide spread and deadly effect in countries like China, Italy, U.S, France, Spain and Brazil (Orro et al., 2020; Wilbur et al., 2020). Thereafter, preventive guidelines for controlling the spread of COVID-19 were published (World Bank Group, 2020; WHO, 2020b, c; UITP, 2020). The rules include; continues use of face mask, avoid touching exposed surfaces, washing hands regularly using disinfectants, avoid hand shake with friends using palms and minimise travelling – stay at home when not necessary (for teleworking) (WHO, 2020a, b; Federal Medical Centre Makurdi – FMCM, 2020). Also, in order to contain the pandemic, new policies were set by local and international authorities to help contain its spread ranging from social distancing, travel ban, stoppage of social, commercial and administrative activities. The persistent deadly effect of the pandemic posed significant threats to city planners, transport experts, engineers and policy makers on the safety of using public transport

system (De Vos, 2020; Chinazzi et al., 2020). The COVID-19 era experienced drastic change in travel behaviour which affected the transport sector from water, air and land transport system. The air travel especially contributed most in spreading the COVID-19 disease across the globe (Gossling et al. 2020).

2.3 IMPACT OF COVID-19 ON PUBLIC TRANSPORT SYSTEM

The COVID-19 era is characterised with changes in travel behaviour in terms of mode choice and the need to travel, as well as the dynamics of the entire transport systems (Hong et al., 2020). Countries in Europe, Asia and America have made conscious efforts to introduce new transport policies that would help reduce the spread of the deadly disease among commuters, as their modal split witnessed significant variation with mode choice shifted to less capacity or active mode such as cycling and walking (Hong et al., 2020; Tokey, 2020). The new public transport policy stipulates that optimum occupancy of public transport modes such as; buses, trains and coaches, be reduced to 50% since public transport system is a key player in the spread of COVID-19 disease (Hendrickson and Rilett, 2020; UITP, 2020; Chinazzi et al., 2020; WHO, 2020b; NCDC, 2020; Arnaud, 2020). On the other hand, the situation in developing countries where para transit modes strive most (Gbagir et al., 2018; Zava, 2021) is the most favoured since its occupancy is usually between 1 – 3 persons only. Though insufficient layout space is the major disadvantage of para transit modes of transportation, it is the recommended system for the COVID-19 era. Tokey (2020) reported variations in bike-share between March - April and May 2020 upward to decrease, then increase respectively. This was attributed to the stay-at-home rule at the peak of the lockdown policy, then the period of adopting preventive measures and reopening of public places for social activities. Arnaud (2020) encouraged the use of micro-mobility modes such as walking, bicycles, e-bikes, scooters and skateboards. which have single occupancy (or require less capacity) as the best mode choice that suits the COVID-19 era. The major advantage of para transit mode in this era is the insufficient layout space to accommodate less passengers.

Furthermore, the International Association of Public Transport (2020) and WHO, (2020a) highlighted precautionary measures to curb transmission of COVID-19 disease in public transport system to include; the use of disinfectants and proper sanitation, inauguration of monitoring workforce, access control, business continuity plan and, internal and external communication. The report and many other documents around the world recommended 50% capacity usage of transport modes in the COVID-19 era (NCDC, 2020; Wilbur et al., 2020). Due to almost unchecked operational policies of public transport systems in most developing countries where public transport service providers fail to adhere to safety guidelines, there is high risk of transmitting the contagious disease when in transit in the COVID-19 era. Also, the significant shift of mode choice from bus transport to other mode choices such as walking and

cycling was attributed to the fear of violating the social distancing rule since it was impossible to maintain at least 2 meters distance apart when in public transit (Orro et al., 2020; Nian et al., 2020; Wilbur et al., 2020).

Unfortunately, transport modellers never saw the pandemic coming hence failed to develop packages and policies that will address issues concerning social distancing as the major safety rule guiding the spread of the pandemic (Moslem et al., 2020). Some developing countries like Nigeria have not witnessed conscious efforts by local authorities to create transport policies and enforcement that could help reduce the spread of COVID-19 disease. While in developed countries, emphasis of new transport policies is on isolating commuters to achieve social distancing using micro-mobility modes and teleworking policies (Arnaud, 2020; Shergold et al., 2015; Mogaji, 2020; Bhuiyan et al., 2020; Zalite and Zvirbule, 2020). These policies partly promote green travel behaviour and guarantee cleaner air and healthy environment, hence more sustainable.

2.4 LIKELIHOOD OF TRANSMISSION

Medical experts have established high transmissibility of COVID-19 disease among persons sitting near each other at distances less than 2 meters within confined and unconfined spaces when one is infected (Illesanmi and Afolabi, 2020; Okunlola et al., 2020; Gossling et al., 2020; Hotle et al., 2020). The use of mathematical models in epidemiology – for modelling spread of infectious disease in a given population has been reported in several researches (Sattenspiel, 1990; Grassly and Fraser, 2008; Abusam et al., 2020; Buchwald et al., 2020; Yan and Lan, 2020). Yan and Lan (2020) used stochastic approach to investigate the transmissibility of COVID-19 within a confined space with emphasis on the spreading virus and movement of individuals, the study employed logistic models like those used in Abusam et al. (2020). Xu and Chraibi (2020) used microscopic numerical models to simulate pedestrian dynamic which influences the transmissibility of COVID-19 among customer in a supermarket (a confined space). Essential parameters of the sub-model included, speed of movement, time spent in the space and direction of movement. A publication by Federal Medical Centre Makurdi (FMCM) (2020) indicated that the probability of COVID-19 transmission between a carrier without face mask and a healthy person without face mask is relatively high (90%) compare to that of one or both parties wearing face masks at 70% and 1.5% respectively.

In this study, most commuters ignored the face mask, the measure of transmissibility of COVID-19 among passengers in transit is examined using a probabilistic technique which depends on the frequency of occurrence of an event. The likelihood of transmission is estimated using stochastic search method known as Genetic Algorithm (GA). It is an evolutionary technique based on ideals from biological evolution characterised by natural genetic and selection. GA is an optimisation and Artificial Intelligent (AI) technique used for computational modelling based on genetics and evolution (Mitchell,

1999; Haupt and Haupt, 2004). It was developed based on Charles Darwin's evolutionary principle termed survival of the fittest. According to Munakata (2008), the fundamental principles of GA include; selection of solutions based on their fitness, reproduction for crossover of genes, and mutation for random change of genes. The GA finds optimum solution to problems just as species evolve to better adapt to their environments. It is a heuristic and numerical simulation approach which has numerous applications in sciences and engineering for selecting optimum solution among many options.

2.5 PUBLIC TRANSPORT POLICIES FOR COVID-19 ERA

Generally, the formulation of transport policy requires setting a transport strategy which could be evaluated using strategy elements and policy instruments (Schiller et al., 2010; Adeke et al., 2018). These tools are essential for performance assessment of the policy strategy. Unlike policies associated with COVID-19 pandemic, the outbreak of the disease was an impromptu challenge which required urgent attention (Moslem et al., 2020), hence policies set by many local authorities were not properly evaluated before adoption (Arnaud, 2020; UITP, 2020; Chinazzi et al., 2020; Orro et al., 2020; Nian et al., 2020). A critical review of such policies based on case studies around the world led to substantial decision elements for the use of public transport systems. These analyses vary among locations and are somewhat contradictory. Some transport experts have argued that public transport system is actually COVID-19 safe if all safety measures specified by medical authorities while travelling such as social distancing by using 50% capacity, use of face mask, frequent washing of hands using disinfectants, proper ventilation of modes, avoidance of unnecessary talks and movement when in transit are maintained (UITP, 2020; Orro et al., 2020). Therefore, the uniqueness of cities in terms of travel behaviour and public transport systems necessitate developing transport policies that conform to individual city characteristics.

The aim of this study is to develop a safe and sustainable operational policy framework for public transport system in the COVID-19 era for Makurdi metropolis. Objectives of the study include to; assess the layout and occupancy of public transport modes in Makurdi metropolis, evaluate using numerical simulation the likelihood of contracting or transmitting COVID-19 disease among passengers and drivers of public transport system and propose optimum occupancy for safe and sustainable travel by commuters and drivers in Makurdi metropolis.

3 METHODOLOGY

3.1 DESCRIPTION OF STUDY AREA

Makurdi metropolis is the capital city of Benue state, in the North-Central Geopolitical Zone of Nigeria. It is the centre of socio-cultural, administrative, educational and commercial activities in Benue state. The city lays within 16 km radius area of Benue state. The present human population residing in the metropolis is estimated at 500,797 persons (NPC, 2006). Available transport modes in the metropolis include; minibuses, taxis, private cars,

tricycles, motorcycles, bicycles and walking. According to NCDC (2020), as at 11th November, 2020, Benue state had recorded 493 confirmed cases of COVID-19 carriers with 11 deaths, among which Makurdi metropolis being the centre of activities bears over 80% of the reports. The location of Makurdi metropolis is as shown in Figure 1.

Fig. 1: Location of Study Area

3.2 DATA COLLECTION AND ANALYSIS

The physical inspection of available mode choices in Makurdi metropolis to ascertain layouts and capacities was carried out. The mode occupancy was divided into three major scenarios namely, Normal which was the ideal capacity of the mode, Above Normal was the nonstandard capacity which in most cases accommodated higher than the ideal situation and Below Normal which was half (50%) the ideal capacity recommended by authorities and the COVID-19 guidelines for public transport systems (UITP, 2020; Chinazzi et al., 2020; NCDC, 2020).

Data analysis involved the use of GA technique to evaluate the likelihood of COVID-19 transmission when on transit among passengers and the driver. The fitness function which expresses the sum of arithmetic sequence of arrivals in the mode was used. In formulating this problem, the fitness function which defined the susceptibility of contraction by any passenger and driver in a mode where there was at least a carrier is the sum of the arithmetic series $f(x_i)$ in the order of entry for the i th occupant expressed as Equations 1;

$$f(x_i) = 0.5x_i^2 + 0.5x_i \quad (1)$$

where x is the serial number of the last occupant within the confined space such that the boundary condition $x \geq 1$ is satisfied. In contrast, a null situation was assumed whenever there was no carrier in the experiment. The procedure for numerical simulation method of GA is as presented in Figure 2.

1. SELECTION

- Population Initialization:* Generate random set of passengers identified as chromosomes using binary codes
- Reproduction:*
 - Evaluate fitness function and corresponding probability of each chromosome which represents passenger x_i in the set.
 - Create mating pool of randomly selected solutions weighed by the fitness for expected count.
 - Select solutions with higher fitness at least approximately 1 as actual count that can survive to the next generation.

2. CROSSOVER

- Take two solutions randomly at a time from the mating pool based on actual counts.
- Select randomly internal points of the solutions, then swap the parts to obtain new offsprings.
- Perform Step 2(ii) for all the solutions until a new population is formed for the actual counts by randomly selecting a pair at a time.

3. MUTATION

- Randomly select a portion of each solution and artificially swap with flipping chromosomes to obtain mutated offspring.
- Iterate Step 3(i) to obtain a new breed which would not be possible from mere reproduction and crossover processes.
- Examine the outcomes to see that most solutions in the population become alike so that no further significant changes can be achieve with further iterations.

Fig. 2: Steps of Simulation using GA Technique

4 ANALYSES OF RESULTS AND DISCUSSION

The assessment of mode layouts and capacities within the metropolis at *Normal*, *Above Normal* and *Below Normal* (50%) occupancies revealed that, normal occupancy level of every mode provided 100% capacity, which though does not provide sufficient space, its allowed passengers to sit based on the design standard of the mode. The *Above Normal* scenario is an occupancy greater than 100% capacity of the designed standard. The occupancy is compacted such that passengers get in contact with each other at high pressure. The *Below Normal* occupancy is the 50% of *Normal* capacity. It provides spaces within seats to allow for free movement and hinder transmission of the COVID-19 disease.

4.1 MINIMIZATION OF LIKELIHOOD OF TRANSMISSION

Results of the GA analysis for optimum transmission and contraction of COVID-19 when in transit using public transport modes with at least a carrier in the confined space is as presented in Table 1.

Table 1. Optimum Safe Capacity of Modes

Modes	Max. Capacity (persons)	Optimum Capacity (persons)	Category of Capacity
Minibus	15	8	Below Normal
Taxi	7	3	Below Normal
Keke	5	2	Below Normal
Napep			
Okada	3	*1	Below Normal

*Obtained conversely

Table 2. Public Transport Policy Framework for COVID-19 Era

Aim of Strategy	Strategy Elements	Policy Instruments
To minimise transmissibility of COVID-19 among passengers using public transport modes in Makurdi metropolis	Maintain social distance	Adopt micro mobility or active modes
		Avoid frequent travel when unnecessary
		Ensure public transport mode capacity is 50% or less full
	Practice enhanced hygiene standards	Adopt teleworking system
		Use disinfectant, gloves and face masks frequently
		Wash hands and disinfect vehicle frequently
		Talk less when on transit
		Avoid high touch surface areas in public transport such as hand rails, doors and window knobs
		Isolate clothes and other wears when returned from journeys
	Infrastructural development	Create lanes for micro mobility modes on carriageways
		Improve pedestrian road facilities (Zebra crossing and walkways)
		Ensure public transport mode capacity is 50% full only
	Law enforcement agents	Checkmate the use of facemasks, hand gloves and hand washing
		Monitor Lane and junction usage by commuters

Table 1 showed that the optimum safe capacity of modes occurs when occupancy was *Below Normal*. This analysis reveals that public transport modes operated at safe condition when all modes carry capacities *Below Normal* at 50% full. Given that, all precautionary measures such as; use face mask, talk less, avoid touching exposed surfaces with bare hands (always use hand gloves) and maintain at least 1m distance apart with other commuters. This conforms to findings of previous studies (Wilbur *et al.*, 2020; NCDC, 2020; Chinazzi *et al.*, 2020; UITP, 2020). Based on the above analysis, there is urgent need to review public transport policies in Makurdi in order to achieve this level of safety. The enforcement and compliance of the COVID-19 guidelines should be imposed on passengers and drivers by law enforcement agents. Succinctly, the proposed operational policy framework for public transport operators and council authorities in the COVID-19 era is presented in Table 2.

4 CONCLUSION AND RECOMMENDATION

This study investigated the layouts and capacities of public transport modes used in Makurdi metropolis by commuters. Analytical simulation method using a stochastic search method called GA technique was used to simulate the likelihood of transmission of the infectious COVID-19 disease within enclosed space of the public transport mode. The objective function of the system to be minimised depended on the sum of arithmetic series of individual arrivals in the system. Capacities of public transport system used for the experiment were divided into *Normal*, *Above Normal* and *Below Normal* (50% of *Normal*). Findings of the experiments indicated that optimum safe capacity of transport modes used in Makurdi occurred at 50% capacity, which agreed with findings of previous studies. An efficient and sustainable public transport policy framework was designed and recommended for use by policy makers and transport

experts for achieving safe travel and healthier living in Makurdi metropolis in the COVID-19 era.

REFERENCES

- Abusam, A., Abusam, R. and Al-Anzi, B. (2020). Adequacy of Logistic Models for Describing the dynamics of COVID-19 pandemic, *Infectious Disease Modelling*, 5, (2020), 536 – 542.
- Adeke P. T., Ato A. A. and Joel E. (2018) A Policy Framework for Efficient and Sustainable Road Transport System to Boost Synergy between Urban and Rural Settlements in Developing Countries: A Case of Nigeria, *1st International Civil Eng. Conf. (ICEC 2018)*, Department of Civil Engineering, Federal University of Technology, Minna, Nigeria, 1(1), 22 - 30.
- Anchordoqui, L. A. and Chudnovsky, E. M. (2020). A Physicist view of COVID-19 Airborne Infection through Convective Airflow in Indoor Spaces, *SciMedicine Journal*, 2 (Special Issue COVID-19), 68 – 72.
- Arnaud, K. (2020). Urban Transport and COVID-19: Challenges and Prospects in Low- and Middle-income Countries, *Cities and Health*. <https://doi.org/10.1080/23748834.2020.1791410>
- Beirao, G and Cabral, J.A.S. (2007). Understanding attitudes towards public transport and Private Car: a quantitative study, *Transport Policy*, 14, 478 – 489.
- Bhuiyan, M. A. A., Rifaat, S. M., Tay, R. and De Barros, A. (2020). Influence of Community Design and Socio-demographic characteristics on Teleworking, *Sustainability*, 12 (5781), 1 – 11, doi:10.3390/su12145781.
- Buchwald, A. G., Adams, J., Bortz, D. M. and Carlton, E. J. (2020). Infectious Disease Transmissions Models to Predict, Evaluate and Improve Understanding of COVID-19 Trajectory and Interventions, *Perspectives*, 17(10), 1204 – 1206.
- Buehler, R. and Pucher, J. (2011). Making Public Transport Financially sustainable, *Transport Policy*, 18, 126 -138.
- Ceder, A. (2007). *Public Transit Planning and Operation; Theory, Modelling and Practice*, Elsevier, Amsterdam. Netherlands.
- Chen, J. and Li, S. (2017). Mode Choice Model for Public Transport with Categorized Latent Variables, *Mathematical Problems in Engineering*, 2017, ID 7861945, DOI: <https://doi.org/10.1155/2017/7861945>
- Chinazzi, M., Davis, J. T., Ajelli, M., Gioannini, C., Litvinova, M., Merler, S., Piontti, A. P., Mu, K., Rossi, L., Sun, K., Viboud, C., Xiong, X., Yu, H., Halloran, M. E., Longini, J. M. Jr., Vespignani, A. (2020). The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) Outbreak, *Science*, DOI: 10.1126/science.aba9757 (2020).

- De Vos, J. (2020). The effect of COVID-19 and subsequent social distancing on travel behaviour, *Transportation Research – Interdisciplinary Perspectives*, 100121, 1 – 8. DOI: <https://doi.org/10.1016/j.trip.2020.100121>.
- Gbagir, K., Etu, J. E. and Oyedepo, O. J. (2018) Motorcycle Ownership Assessment and Estimation in Makurdi, North Central, Nigeria: A Multinomial Logit Model Approach, *Journal of Civil Engineering, Science and Technology*, 9(2), 87 – 97.
- Gossling, S., Scott, D. and Hall, C. M. (2020) Pandemics, Tourism and Global Change: A Rapid Assessment of COVID-19, *Journal of Sustainable Tourism*, 1 – 20. DOI: <https://doi.org/10.1080/09669582.2020.1758708>
- Grassly, N. C. and Fraser, C. (2008). Mathematical Models of Infectious disease transmission, *Nature Reviews – Microbiology*, 6, (2008), 477 – 487.
- Gudmundsson, H. Hall, P. R., Marsden, G. and Zietsman, J. (2016). Sustainable Transportation; Indicators, Frameworks, and Performance Management, *Springer*, London.
- Haupt, R. L. and Haupt, S. E. (2004). *Practical Genetic Algorithms*. 2nd Edition, John Wiley and Sons, Inc., Publications, Canada.
- Hendrickson, C. and Rilett, L. R. (2020). The COVID-19 Pandemic and Transportation Engineering, *Journal of Transport Engineering, Part A: Systems*, 146 (7), 1 – 2, DOI: <https://doi.org/10.1061/JTEPBS.0000418>
- Hong, J., McArthur, D. and Raturi, V. (2020). Did Safe Cycling infrastructure still matter during a COVID-19 Lockdown? *Sustainability*, 12, 8672, DOI: 10.3390/su1220867
- Hotle, S., Murray-Tuite, P. and Singh, K. (2020) Influenza Risk Perception and Travel-Related Health Protection Behaviour in the US: Insights for the Aftermath of the COVID-19 Outbreak, *Transportation Research Interdisciplinary Perspectives*, 5 (2020), 1 – 8, DOI: 10.1016/j.trip.2020.100127.
- Hu, X., Wang, J. and Wang, L. (2013) Understanding the Travel Behaviour of Elderly People in the Developing Country: A Case Study of Changchun, China, 13th COTA International Conference of Transportation Professionals (CICTP 2013), *Procedia – Social and Behavioural Sciences* 96, 873 – 880.
- Illesanmi, O. and Afolabi, A. (2020). Time to Move from Vertical to Horizontal Approach in Our COVID-19 Response in Nigeria, *SciMedicine Journal*, 2 (Special Issue “COVID-19”), 28 – 29.
- International Association of Public Transport (2020), Public Transport Authorities and COVID-19 Response from the Frontline, Austria/New Zealand.
- Jia, H.; Appolloni, A.; Wang, Y.Q. (2017) Green travel: Exploring the characteristics and behavior transformation of urban residents in China. *Sustainability*, 9, 1043.
- Mitchell, M. (1999). *An Introduction to Genetic Algorithms*. A Bradford Book, MIT Press, Massachusetts, USA.
- Mogaji, E. (2020). Impact of COVID-19 on Transportation in Lagos, Nigeria, *Transportation Research Interdisciplinary Perspectives*, 6(2020), 1–8, DOI: 10.1016/j.trip.2020.100154.
- Moslem, S., Campisi, T., Szmelter-Jarosz, A., Duleba, S., Md Nahiduzzaman, K. and Tesoriere, G. (2020). Best-Worst Method for Modelling Mobility Choice after COVID-19: Evidence from Italy, *Sustainability*, 12, 6824, 1 - 19.
- Munakata, T. (2008). *Fundamentals of New Artificial Intelligence, Neural Evolutionary, Fuzzy and More*. 2nd Edition, Computer and Information Science Department Cleveland State University, USA.
- Nian, G., Peng, B., Sun, D., Ma, W, Peng, B. Huang T. (2020). Impact of COVID-19 on Urban Mobility during Post-epidemic Period in Megacities: From the perspectives of Taxi Travel and Societal Vitality, *Sustainability*, 12, 7954, DOI:10.3390/su12197954
- Nigeria Centre for Disease Control (NCDC) (2020). *Report on COVID-19*, Retrieved from www.covid19.ncdc.gov.ng, Date: 31st March, 2020.
- NPC (2006). *National Population Commission, Federal Republic of Nigeria Official Gazette*, 94, No. 24, Nigeria.
- Okunola, M. A., Lamptey, E., Senkyire, E. K., Serwaa, D. and Aki, B. D. (2020) Perceived Myths and Misconceptions about the Novel COVID-19 Outbreak. *SciMedicine Journal*, 2(3), 108 – 117.
- Orro, A., Novales, M., Monteagudo, A., Perez-Lopez, J. and Bugarin, M. R. (2020). Impact of City Bus Transit Services of the COVID-19 Lockdown and Return to the New Normal: The Case of a Coruna (Spain), *Sustainability*, 12, 7206. DOI: 10.3390/su12177206.
- Oyewole, K. A., Akinpelu, O. P. and Akinola, A. O. (2020). Assessing Correlates of Motorcycle Patronage in Abeokuta Metropolis, Ogun State, Nigeria, 2nd International Conference on Sustainable Infrastructural Development (ICSID)2020, Department of Civil Engineering, College of Engineering, Covenant University, Ota, Nigeria.
- Pan, X and Zuo, Z. (2020). Exploring the Role of Utility-difference Threshold in Choice Behaviour: An Empirical Case Study of Bus Services Choice, *International Journal of Transportation Science and Technology*, 9 (2020), 128- 136.
- Sattenspiel, L. (1990). Modelling the spread of infectious disease in Human Population, *Year Book of Physical Anthropology*, 33, 245 – 276.
- Schiller, P. L., Bruun, E. C. and Kenworthy, J. R. (2010). *An Introduction to Sustainable Transportation – Policy Planning and Implementation*. Earthscan, New York, USA.
- Shergold, I., Lyons, G. and Hubers, C. (2015). Future Mobility in an Ageing Society – Where are we heading? *Journal of Transport and Health*, 2 (2015), 86 – 94.
- Tipaldi, M. A., Lucertini, E., Orgera, G., Zolovkins, A., Laurino, F., Ronconi, E., Pisano, A., La Salandra, P. C., Laghi, A. and Rossi, M. (2020). How to Manage the COVID-19 Diffusion in the Angiography Suite: Experiences and Results of Italian Interventional Radiology Unit, *SciMedicine Journal*, 2 (Special Issue COVID-19), 1 – 8.
- Tokey, A. I. (2020). Changes of Bike-share usage in Five Cities of United States during COVID-19. *Transport Findings*,
- Union Internationale des Transports Publics (UITP) (2020). Management of COVID-19 – Guidelines for Public Transport Operators, Brussels, Belgium.
- Wilbur, M., Ayman, A., Ouyang, A., Poon, V., Kabir, R. Vadali, A., Pugliese, P., Freudberg, D., Laszka, A., Dubey, A. (2020). Impact of COVID-19 on Public Transit Accessibility and Ridership. Available on: <https://arxiv.org/abs/2008.02413>
- World Bank Group (2020). *Assessing the economic Impact of COVID-19 and Policy responses in Sub-Saharan Africa – An Analysis of Issues shaping Africa's Economic Future*, Volume 21, 2020, Washington DC, USA, DOI: DOI: 10.1596/978-1-4648-1568-3.
- World Health Organization (WHO) (2020a). Novel Coronavirus (2019-nCoV) Advice for the Public. Retrieved from: <https://web.archive.org/web/20200126025750/https://www.who.int/emergencies/diseases/novelcoronavirus-2019/advice-for-public>. Accessed on 6th August, 2020).
- World Health Organization (WHO) (2020b). Q&A on Coronaviruses (COVID-19). Retrieved from: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/q-a-coronaviruses>. Accessed on 17th June 2020.
- Xu, Q. and Chraibi, M. (2020). On the effectiveness of the measures in supermarkets for reducing contact among customers during COVID-19 Period, *sustainability*, 12, 9385, DOI: 10.3390/su12229385
- Yan, Z. and Lan, Y. (2020). Modeling COVID-19 infection in a confined space, *Nonlinear Dynamic*, 101, (2020), 1643 – 1615.
- Yezli, S. and Khan, A. (2020). COVID-19 Social Distancing in the Kingdom of Saudi Arabia: Bold Measures in the Face of Political, Economic, Social and Religious Challenges, *Travel Medicine and Infectious Diseases*, 101692, <https://doi.org/10.1016/j.tmaid.2020.101692>.
- Zalite, G. G. and Zvirbule, A. (2020) Digital Readiness and Competitiveness of the EU High Education Institutions: The COVID-19 Pandemic Impact, *Emerging Science Journal*, 4(4), 297 – 304.
- Zava, A. E. (2021). Recommendations for Making Okada Safer and Better for Urban Mobility, *Usak University, Journal of Engineering Science*, 4(1), 1–14, DOI: 10.47137/uujes.832806
- Zheng, J., Cheng, Y., Ma, G., Han, X. and Yu, L. (2020). Feasibility Analysis of Green Travel in Public Transportation: A case study of Wuhan, *Sustainability*, 12, 6531. DOI: 10.3390/su12166531