*IOSR Journal Of Humanities And Social Science (IOSR-JHSS)*
*Volume 29, Issue 1, Series 9 (January, 2024) 49-55*
*e-ISSN: 2279-0837, p-ISSN: 2279-0845.*
*www.iosrjournals.org*

# A model to address from a policy perspective, the persistent road traffic congestion in Ghana.

S.A Etsibah, A.M Abane

***Abstract***
*Road traffic congestion is a global phenomenon in many cities. Researchers, planners, and policymakers have explained the causes and solutions of road traffic congestion from different perspectives. The objective of this paper is to discuss the reasons why road traffic congestion persists in cities in Ghana and to offer a policy solution to ease the challenge. A review of secondary data was done from both local and foreign literature on road traffic congestion. From it, a proposed traffic congestion solution, and a model was developed to address persistent traffic congestion. The model spells out the root causes and characteristics of road traffic congestion to explain the causes of congestion. This paper examines why road traffic congestion persists even though a lot has been written on this subject area in Ghana.*
*Policy solutions are enumerated from both foreign and local reviewed literature. This includes the classification of congestion into recurrent or non-recurrent occurrences and later categorizing the proposed solutions into demand and supply-side actions. This paper then proposes a solution to address road congestion by considering the implementation of both the supply side and demand side actions. Policy decision such as improvement in road designs and increase in the capacity of road infrastructure, actions to change human negative behaviour that cause congestion, reduction of road usage by so many private vehicles, the use of effective and smart traffic management devices or systems, the implementation and the operation of mass transit systems, and application of alternative multimodal urban transport systems are some suggested policy solutions.*

***Keywords-*** *Traffic congestion, Model, Policy decisions, Root causes, Recurrent causes, Non-recurrent causes.*

## I. INTRODUCTION

Road traffic congestion is a worldwide phenomenon, with many cities all experiencing the challenge. It is not surprising that congestion has therefore been the subject of considerable research interest in both developed and developing countries (Amoh-Gyimah & Aidoo, 2013),(Koźlak & Wach,2018), (Nyarko, 2014), (Abane, 1993), (Abane, 1992), (Agyapong & Ojo, 2018). Many of these studies have focused on the causes and consequences of road traffic congestion (Jairo et al 2021), with a few proposing solutions to the phenomenon (Jairo et al 2021). A lot of these research have always been concerned about approaches to reduce traffic congestion, pollution in cities as well as but boost energy efficiency and workforce productivity. Some have argued that rather than attempting to eliminate traffic congestion in urban areas, policymakers should formulate public policy initiatives that first minimize the levels of traffic congestion and its undesirable outcomes such as (Bull, 2004). Motivated by this argument, this paper aims to identify the root causes of traffic congestion and why it persists in Ghanaian cities and recommend policy measures to reduce road traffic congestion.

The question that needs to be answered is why road traffic congestion still persists?.

Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity, this point is commonly termed saturation ( Mahesh Babu Awari, 2013). In otherwords, road traffic congestion is experienced and simply explained as "*a situation in which demand for road spacing exceeds its supply"* (Agyapong & Ojo, 2018).

According to Hoose, (2021), traffic congestion in Accra is characterized by street vendors, the smell of motor exhaust fumes, and a chaotic situation. Interestingly, the negative effect of congestion is not only suffered by motorists and pedestrians but by all users of public transport. In his study, Abane, (1993) reported that traffic congestion is one of the most daunting problems causing delays and consequently longer travel times. This therefore needs more attention and further research from the policy perspective to find solutions, hence this paper.

## II. THEORETICAL PERSPECTIVES

Many theories are used to explain or support the issue of road traffic congestion. Some researchers have attempted to apply the rules of fluid dynamics to traffic flow and likened it to the flow of a fluid in a pipe. During congestion simulations and real-time observations, it is seen that even in heavy but free flowing situations, traffic jams can arise spontaneously. These are mainly triggered by events and interruptions by motorists, pedestrians,

or the environment. Traffic scientists liken such a situation to the sudden freezing of the super cooled fluid (Sundermier,2023).

According to Park (2012), one traffic theory that relates to road congestion is the three-phase theory by Kerner and Rehborn (1996), which first proposes the classification of freeway traffic flow into three phases based on time series flow, occupancy, and average speed, Kerner (2004). Later revised, the three-phase traffic theory based on further work by observing that there are three traffic phases in a congested traffic, namely free flow, synchronized flow, and wide moving jams. Synchronized flow is the congested traffic state and the downstream front of this flow which is often fixed at a freeway bottleneck. Within the downstream front of synchronized flow, vehicles accelerate from lower speeds in a synchronized flow to higher speeds in free flow. However, unlike a fluid, traffic flow is often affected by signals or other events at junctions that periodically affect the smooth flow of traffic.

Owing to the poor correlation of theoretical models to actual observed traffic flows, transportation planners and highway engineers attempt to forecast traffic flow using empirical models. The working traffic models typically use a combination of macro, micro- and mesoscopic features, and may add matrix entropy effects, by platooning groups of vehicles and randomizing the flow patterns within individual segments of the network. These models are then typically calibrated by measuring actual traffic flows on the links in the network, and the baseline flows are adjusted accordingly to find the causes of congestion and suggest solutions.

Another theory that attempts to explain traffic congestion is the queuing theory. This can be used to explain the traffic congestion caused by obstructions on the road such as tollbooths or traffic lights that limits the service time, average waiting time and the flow of traffic on specific roads. The flow of customers (vehicles) from a finite or infinite population towards a service facility (route) forms queues on the account of a lack of capacity to serve all customers (vehicles) at the same time or shorter time intervals. The major element of the queuing system is the input process, which is the pattern in which vehicles arrive and use the road or system. The other elements are the size of the queue, which is the size of the input service, be it finite or infinite, and the vehicle arrival distribution, which is the pattern in which the vehicles or customers arrive at the service system being the road, tool booth or traffic light. An equally important element is the customer's behaviour (driver or operator of the vehicle behaviour). This is whether they are patient or disciplined enough to allow the service to flow in first come -first serve or otherwise.

Even though there are many benefits of the above traffic models, there are also some limitations. According to (Ni, 2020) the limitations of these models can be classified into four categories. First is the lack of model consistency among macroscopic models and between microscopic and macroscopic models. The second limitation is the lack of model flexibility to admit driver heterogeneity. Third is the lack of model capacity to look ahead into the near future and lastly the lack of model expandability beyond one dimensional traffic. Any attempt to find solutions to road traffic congestion through modelling is obliged to address these concerns.

## III. CONTEXTUAL ISSUES

Road traffic congestion in Ghana is a complex issue influenced by various contextual factors. Understanding these contextual issues is essential for devising effective strategies to alleviate congestion and improve the overall transportation system. Some key contextual issues contributing to road traffic congestion in Ghana are briefly examined here. Road traffic congestion affects almost every urban centre in Ghana. It is however most prevalent in the regional capital towns such as Accra, Sekondi- Takoradi, Kumasi, Tamale, Sunyani, and Ho.

Socio-economic issues are intricately linked to the demand and supply of transport services. Governments, policymakers, and transportation providers need to consider these factors to develop accessible, affordable, and sustainable transportation systems that meet the needs of diverse communities and promote economic and social well-being. Rapid urbanization and population growth in major cities like Accra and Kumasi have led to increased vehicle ownership and usage. This has strained the existing road infrastructure, resulting in congestion during peak hours.

Some socio-economic factors that affect the transportation system in Ghana's urban centers include inadequate road infrastructure, the dominance of informal public urban transportation, income inequality, accessibility and equity, lack of an integrated public transport system, inadequate traffic management systems, poor road maintenance, poor land use planning, and limited alternative transport options. These socio-economic issues play a significant role in shaping the demand and supply of transport services in the cities. These issues can have far-reaching implications for transportation infrastructure, accessibility, and affordability.

***Causes of road traffic congestion***

The US Federal Highway Administration, (FHWA), (Karner,2018), has observed that congestion is the result of seven main root causes, often interacting with one another. These seven sources are traffic incidents and events, event working zones, bad or severe weather conditions, fluctuations in normal traffic conditions, occasional organization of special events along route, ineffective traffic control measures and devices, physical

bottlenecks that affect road capacity and human movement. Other influencing factors are indiscipline of pedestrains, motorist and transport operations along a route, and inappropriate citing of traffic lights or traffic management devices, equipment and infrastructure.

***Traffic influencing factors:***

Traffic incidents and events disrupt the normal flow of traffic, by physical impedance in the travel lanes. Events such as vehicular crashes, breakdowns, and debris left from road construction along travel lanes are the most common form of incidents. In addition to blocking travel lanes physically, these events that occur on the shoulder or along the roadside can influence traffic flow by distracting drivers, leading to changes in driver behavior such as slow driving and affecting the quality of traffic flow. Even incidents off the roadway can be considered traffic incidents if they affect travel flow directly or indirectly.

Other traffic influencing factors such as construction activities on the roadway and usage of the road for transport operation such as unofficial bus stops or business activities can result in physical changes to the highway environment. These changes may include a reduction in the number or width of travel lanes, lane shifts or lane diversions, elimination of shoulders, and even temporary roadway closures. Delays caused by work have been cited by travelers as one of the most frustrating conditions they encounter on trips (Afrin & Yodo, 2020).

Bad or severe weather conditions also cause changes in the traffic environment and in driver behavior which affects traffic flow. Due to reduced visibility, drivers will usually lower their speeds and increase their headways when precipitation, fog, or smoke are present. Wet road condition, snowy, or icy roadway surface conditions also lead to the same effect even after precipitation has ended(Afrin & Yodo, 2020).

**Transport demand factors:**

Demand side factors are actions, tactics or strategies that are designed to reduce the number of persons or vehicles that travel or use the roads with the aim to reduce congestion. These may include road pricing with tolls, prohibiting certain classes of vehicle license numbers from using public roads on specific days or periods. It is known that fluctuations in normal transport demand causes congestion in the long run. This is due to variations in daily, or weekly activities such as times of beginning and close of work, daily or weekly activities at specific locations cause variations in normal demand and these lead to higher traffic volumes. Varying vehicular demand volumes that are superimposed on the road infrastructure or system, with a fixed designed traffic capacity affects traffic flow. At certain times of the day as a result of variable demand (i.e., unreliable) travel times and low vehicular movement frequency, even without any of the Category 1 events occurring, could cause serious traffic congestion (Afrin & Yodo, 2020). Occasional organization of special events along the streets may also cause major congestion as they lead deviation in traffic flow. These changes cause surges in traffic demand that overwhelm the transport system or road network and slows down vehicular flow.

Physical highway features: Traffic control devices, either wrongly installed or not functional could cause traffic congestion. The intermittent disruption of traffic flow by control devices such as railroad grade crossings and poorly timed signals also contribute to congestion and travel time variability. Physical bottlenecks that negatively influence the capacity of roads also cause congestion. Transportation engineers have long studied and addressed the physical capacity of roadways which is the maximum amount of traffic capable of being handled by a given highway section. It is worth noting that capacity is determined by several factors including the number and width of lanes and shoulders, merged areas at interchanges, roadway alignment such as grades and curves. Toll booths may also be thought of as a special case of a bottleneck because they restrict the physical flow of traffic. There is also a wild card in the mix of what determines capacity which is driver behavior. Research has shown that drivers familiar with routinely congested roadways space themselves closer together and drive more inconsiderately than drivers on less congested roadways. This leads to road crashes and an increase in traffic congestion.

Human activities and indiscipline attitude: The final factor is human activities and in-disciplined attitude**.** In Ghana and many parts of the world, too many fierce business and commercial activities occur close to major roads. This automatically induces a high volume of human and vehicular traffic in these areas. In a highly competitive environment, each business and transport operator try to gain competitive advantage and therefore operate in a manner that causes a lot of human and vehicular interactions, interferences, and sometimes a loss in control of basic traffic regulations or controls causing serious congestion.

**Supply Side factors**

Supply side factors are actions and strategies that are aimed to explain how travellers and users of the road can commute from one place to the other to reduce or eliminate road traffic congestion. These may include the building of more roads, expansion of the lanes of existing roads or design and building of bridges, terminals, interchanges, and other road infrastructure along specific roads to increase the road capacity. They also include building more transit facilities, increasing services and amenities in exiting transit systems, introduction of better traffic management centers.

***Why road traffic congestion persists in major Ghanaian cities.***

Regardless of the numerous evidence-based policy implementations aimed at dealing with the phenomenon, road traffic congestion persists in Ghana. This may be because there is a gap between research findings, and its practical and policy application. It also appears there is a focus on resolving the challenge of traffic characteristics from either the supply side action only or the demand side action only, instead of a combination of the two (Litman, 2020). Therefore, in many traffic prone communities, one can identify so many challenges including:

- Too many vehicles competing for road space at a certain time of the week or the day.
- The lack of implementation of a road traffic congestion policy plan or guide
- Inefficient, inadequate public transport system and poor use of mass transit systems such as trains and coaches, use of BRT Bus systems and multimodal urbans transportation.
- Poor traffic regulatory arrangements to monitor, synchronize, divert, restrict, and control vehicular movement in certain areas such as the central business districts (CBD) at certain times of the day.
- Inadequate road network and infrastructure to absorb the ever-growing demand and high capacity.
- Lack of innovative and smart road designs to redistribute traffic and ease flow but heavy reliance on traffic lights, junctions, police check points or barriers.
- No innovation to adjust working hours in cities and other social activities in urban areas.
- No effective vehicle pooling arrangement such as "park and ride" in specific traffic prong areas.
- High indiscipline and adherence to traffic regulations of road users and pedestrians.

From horizontal causes of traffic congestion, a lot of human activities and vehicle activities still contributes to the persistence of road traffic congestion. A lot of pedestrian obstruction persist in many urban areas in Ghana, such as interferences with traffic flow by activities around major roads, such as markets, lorry stations or terminals, shopping malls, churches, and entertainment spots. There is also indiscriminate crossing of the roads and selling along roads, deliberate blocking of some major roads as police check points, tolling booths and installation of speed rumps, bumps, humps, and tables that reduce the speed of vehicular flow.

***Identification of recurrent and noncurrent traffic congestion.***

According to Skabardonis & Varaiya (2003), traffic congestion may be recurrent meaning the congestion occurs more frequently at specific times of the day or week and or non- recurrent, where the congestion occurs during specific events or seasons. Users of roads get used to recurrent congestion and may make adjustment in travel time and patterns; however non-recurrent congestion can be very frustrating to commuters because they are often unexpected. In the words of (Afrin & Yodo, 2020), since the recurring congestion is a cyclical scenario, the analysis of how quickly traffic congestion can return to its normal operating state without congestion will be beneficial in developing a resilient transportation management system (Wan, Yang, et al,2018), (Afrin & Yodo, 2020). Additionally, a resilience-based traffic congestion measure for both recurring and nonrecurring congestions is an area that has a potential research scope. Several resilience-oriented congestion measures have been proposed for recurring congestion but few for non-recurrent congestion (Tang, Heinemann,2018), (Yodo, Wang,2016).

Implemented mitigation approaches such as effective transportation management plans, are often successful in reducing the rate of congestion for a while. However, some of the most applied congestion mitigation approaches for both recurring and nonrecurring congestion such as adding more road base capacity, haves often not eliminated congestion permanenantly. It has been observed that the capacity of road infrastructure can be improved by increasing the number and size of highways, adding additional lanes, and building new highways (Triantis, et al,.2011). However, this approach obviously demands a substantial amount of capital and implementation costs and may not be the solution to traffic congestion in the long run.

***Efficient operation and adjustments in existing arrangements, infrastructure, and capacity***

One of the best approaches to solving and sustaining the solution of traffic congestion is to make proactive or reactive adjustments to traffic arrangements when urgently needed and operate the existing infrastructure more efficiently. The existing infrastructure can be utilized more efficiently by redesigning mitigation routes for specific congestion bottlenecks, such as constructing interchanges instead of depending on only traffic lights to increase the road function or baseline capacity (Systematic, 2005.)

Another is to effectively apply various sector traffic management systems, such as traffic incident management, which requires identifying congested areas and lanes and making the necessary adjustments such us re-setting direction priority or dedicated lanes to ease traffic flow. Identifying and acting swiftly at accident scenes, improving response times, and managing accident scenes or other incident scenes helps in reducing the event induced congestions (Haselkorn, Yancey, Savelli, 2018).

It is also possible to reduce traffic congestion by adjusting work zones and work times. It is not necessary for every organization to start work at 8:00am and close at 5:00pm. Adjustments can be made to ease congestion

at peak times (Pesti, Wiles, et al 2008). Organizing certain special events at specific areas such as within the CBD, around shopping malls, by major roads, near to marketplaces or major public areas also causes serious traffic congestion. In Ghana it is normal to find people block certain roads in some cities or towns and use the road for funerals and other activities. Planning for such special events ahead of time, developing alternative routes and coordinating with the traffic control plans may ease congestion**.**

Efficient use of traffic controlling devices and travel demand management helps to mitigate against heavy traffic congestion. It is normally thought that controlling traffic signals, ramp meters, and managing lane usage with a computerized system are often found to be a practical approach in reducing congestion during peak hours (Systematics,2005).

However, these traffic control systems may also largely contribute to traffic congestion if not well managed or synchronized with demand and traffic flow. Different management protocols, such as travel demand management (TDM), non-automotive travel modes, and land use management, can be followed (Luten, K., 2004). In the words of Abane (1993), *"measures to address traffic congestion is becoming increasingly evident that a lot more has to be done to make them effective".*

## IV. SUGGESTED POLICY SOLUTIONS

Currently, a variety of traffic congestion measures are available depending on various performance criteria, such as speed, travel time delay, level of services, or other indices. However, there is no fixed universal method of measuring traffic conditions at present (Rao &Rao, 2012). Policymakers, researchers, and transportation experts have been working for many years to develop different measurement approaches to estimate traffic congestion accurately. One main measure is using the Roadway Congestion Index (RCI) (Mahama et al., 2013).

It has been suggested that to prevent congestion and to improve efficiency on our roads, vehicular traffic should somehow be forced or allowed to move at a density corresponding to maximum traffic flow (Adjei-Boateng, 2013). According to Armah et al., (2010), policy proposals to reducing traffic congestions may be categorized into three broad categories, being Government policy and planning, travel demand management, and supply management. However, policy approaches usually attempt to provide either strategic alternatives, which encourage greater usage of existing alternatives through promotion, subsidies, or restrictions.

In the words of Bull, (2004), while local conditions must always be considered in addressing road traffic congestion, it is prudent to note that instead of always adding to the base capacity of roads as the only solution, it would seem advisable to give priority to traffic management actions and initiatives such as, rectification and improvement in the design and use of intersections in major cities, rationalization of on-street parking to prevent blockage to traffic flow, staggering of working hours to ease the traffic congestion during daily peak hours, synchronization of traffic lights to suit traffic needs and ease vehicular flow, developing signals that literally stops traffic and then also permits it to move in intervals yielding the traffic density corresponding to the maximum flow of vehicles would result in an increased flow of vehicles on the road (Adjei-Boateng, 2013). There is also the need to reverse traffic flow direction on some main streets during peak hours.

Also, there is the need to reduce the installation of too many traffic lights, speed ramps, bus stops and toll booths along busy urban streets. In as much as some of these are helpful in ensuring safety on the roads, they all have the potential of creating traffic queues. The alternative infrastructure to numerous traffic lights in certain parts of the city is the building of flyovers and bridges along busy interchanges.

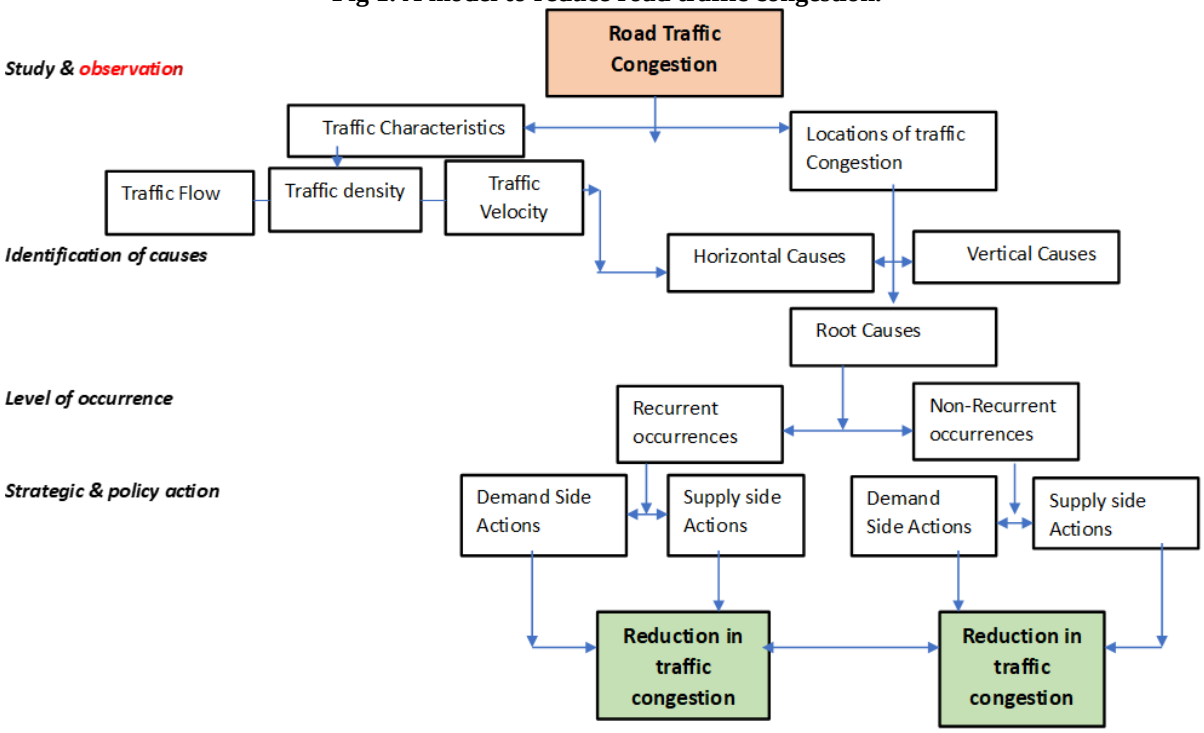
Even though policy solutions have often been viewed from the Supply side actions which are efforts to increase road capacity, the issue of congestion may be solved by considering three main issues being, traffic management, smart mobility solution issues and implementation of intermodal and multimodal transport policy solutions.

The implementation of effective intermodal and multimodal transport systems as an urban transport policy will help in solving many of the congestion challenges. These include the deliberate use of alternative transport modes such as rail, inland water, the sea, and other mass transit transportation vehicles such as big buses and coaches and the effective implementation of BRT systems. There is the need to encourage from the policy perspective cordial operational relationship and cooperation between public and private transport operators as intermodal and multimodal systems are implemented in cities and between cities.

Traffic management solution issues include the implementation of the five E's being Engineering, Education, Enforcement, Encouragement and Evaluation of transport and traffic issues to reduce congestion on our roads. Then adaption of Smart mobility solution such as the use of artificial intelligent systems, synchronized and dynamic traffic lights, the use of smart ICT applications to improve and manage traffic flow, access to traffic data and smooth infrastructure connections are a few examples.

**THE MODEL**

**Fig 1. A model to reduce road traffic congestion.**




A model to address road traffic congestion, 2023

***Road traffic congestion reduction model***

From the above observations, a model is proposed (Fig.1) to help minimize road traffic congestion in Ghanaian cities. The model is original in its construction and was developed from data through review of literature. It is designed in four stages, being the observation and study stage, identification of traffic congestion stage, the stage of noting the level of occurrence, and finally the identification and implementing of strategies and policies action stage.

The model commences on a study and observation of the traffic congestion situation in the area, identification of highly prone traffic locations and the traffic characteristics. The traffic characteristics is important because it forms the basis of identifying the problem. Traffic characteristics may include the traffic flow, the traffic density and velocity. Then the cause of the traffic congestion needs to be clearly identified and these causes need to be further classified into the horizontal and vertical causes of congestion. Then the root causes of these traffic congestion are then identified and noted and then categorized into either non-recurrent or recurrent occurrences. These root causes of congestion may be because of inadequate introduction of demand side actions, which are actions to reduce road usage or the lack of adequate supply side actions which are policy actions to reduce urban sprawl. The solution to each type of traffic congestion may be resolved by finding and introducing solutions through either supply side actions or demand side actions or initiatives.

The operationalization of this model will help in the planning, operations, and the design of road infrastructure. Traffic congestion may be because of either uninterrupted flow, where the flow is regulated by vehicle-to-vehicle interaction and interaction between the vehicle and the road or the environment, or an interrupted flow, where the flow is regulated by external factors such as traffic signals or smart traffic systems and devices. The congestion on roads may occur either consistently or occur seasonally or occasionally. The advantage of this model is that it considers both the vertical and horizontal causes of traffic congestion as well as the demand side and supply side actions to solve road traffic congestion.

In summary, the proposed model can be used to solve road traffic congestion through the four main levels of planning. These are firstly the observation of traffic conditions and study in specific urban areas. From the observation and study, one is likely to identify the root causes and other causes of the traffic congestion being vertical or horizontal. Then the level of the traffic occurrence needs to be measured and recorded as either recurrent or non-recurrent traffic. With this information short term interventions may be employed to solve the traffic situation immediately and long term strategic and policy actions and initiatives may have to be adapted to permanently reduce or eliminated the traffic congestion in the area.

## V. CONCLUSION

Traffic congestion still persists in Ghana and many part of the world even though a lot of interventions or proposed solutions have been suggested in the past from literature. These proposed solutions have been identified and partly implemented in many ways. The solutions include designing,construction and increasing the capacity of roads, eliminating traffic incidents or events, improving the ineffective traffic control measures and devices, removal of bottleneck that prevent the flow of traffic, reducing the indiscipline of road users or pedestrains, adjustment in the hours of official work times, inappropriate citing of road instrastcture and devices and installation of smart traffic management devices.

These proposed solutions to traffic congestion have been done in the past by implementing them from either the demand side action factors or the supply side action factors, where the demand side action factors are actions that are actions or initiatives designed to reduce the number of people, vehicles or users of the roads with the aim of reducing traffic congestion. Alternatively, the supply side actions being actions and initiatives aimed at explaining and expanding how travellers and road users ease to commute from one location to the other also with the aim of reducing traffic congestion.

The proposed traffic congestion reduction model in this paper details a systematic policy process or solution flow to address the challenge. The process begins with a detailed obervation and study of traffic characteristics and trafic location in the country or area of concern. The causes of traffic congestion need to be identified from either the vertical or horizontal causes. Then the root causes of these traffic congestion needs to be identified and classified by its level of occurances being recurrent occurances or non-recurrent occurances. Appropriate policy interventions and solution activities need to be implemented from both the demand and supply side actions where appropriopraite to resolve or reduce road traffic congestion in urban areas.

**Acknowledgements**

The author is grateful to all who have contributed in many ways towards the completion of this draft. Special thanks go to Professor Albert Machistey Abane, Geography and Regional Planning Department University of Cape Coast, and Dr. Edward Danso Ansong a senior lecturer at the Department of Computer Science, from University of Ghana for their immense support and comments.

**Declaration of Interest**

The author declares that he has no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

## References

[1]. Abane, A. M. (1994). Driver Behaviour and City Traffic! Empirical Observations From Accra, Ghana. Research Review, 10(1&2), 1–11.https://journals.co.za/docserver/fulltext/inafstud/15/1-2/177.pdf?expires=1553685545&id=id&accname=guest&checksum=21AA1B6EEC2888637DDDFD53483C418B

[2]. Adjei-Boateng, F. (2013). MODELING VEHICLE TRAFFIC FLOW BETWEEN TRAFFIC LIGHT. Masters Thesis , KNUST, Kumasi, 1(1).

[3]. Afrin, T., & Yodo, N. (2020a). A survey of road traffic congestion measures towards a sustainable and resilient transportation system. In Sustainability (Switzerland) (Vol. 12, Issue 11). MDPI. https://doi.org/10.3390/su12114660

[4]. Afrin, T., & Yodo, N. (2020b). A survey of road traffic congestion measures towards a sustainable and resilient transportation system. Sustainability (Switzerland), 12(11), 1–23. https://doi.org/10.3390/su12114660

[5]. Agyapong, F., & Ojo, T. K. (2018). Managing traffic congestion in the Accra Central Market, Ghana. Journal of Urban Management, 7(2), 85–96. https://doi.org/10.1016/j.jum.2018.04.002

[6]. Amoh-Gyimah, R., & Aidoo, E. N. (2013). Mode of transport to work by government employees in the Kumasi metropolis, Ghana. Journal of Transport Geography, 31, 35–43. https://doi.org/10.1016/j.jtrangeo.2013.05.008

[7]. Armah, F. A., Yawson, D. O., & Pappoe, A. A. N. M. (2010). A systems dynamics approach to explore traffic congestion and air pollution link in the city of Accra, Ghana. In Sustainability (Vol. 2, Issue 1, pp. 252–265). MDPI. https://doi.org/10.3390/su2010252

[8]. Bull, A. (2004). Traffic Congestion - The Problem and How to Deal with it? In United nations: Economic Commission for latin America and the Caribbean, Deutsche gesellschaft für Technische Zusammenarbelt (GTZ) GmbH. www.cepal.org/es/suscripciones

[9]. Koźlak, A., & Wach, D. (2018). Causes of traffic congestion in urban areas. Case of Poland. SHS Web of Conferences, 57, 01019. https://doi.org/10.1051/shsconf/20185701019

[10]. Litman, T. (2020). Introduction to Multi-Modal Transportation Planning: Principles and Practices. Victoria Transport Policy Institute, September, 1–21. http://www.vtpi.org/multimodal_planning.pdf

[11]. Mahama, F., Annan, J., Amponsah, S. K., & Sebil, C. (2013). STUDY OF VEHICULAR TRAFFIC CONGESTION IN THE SEKONDI-TAKORADI METROPOLIS.

[12]. Ni, D. (2020). Simulation Modelling Practice and Theory Limitations of current traffic models and strategies to address them. Simulation Modelling Practice and Theory, 104(October 2019), 102137. https://doi.org/10.1016/j.simpat.2020.102137

[13]. Nyarko, R. A. (2014). The Causes and Effects of Traffic Jam on Commercial Transport Operations (Issue 10507117). http://ugspace.ug.edu.gh

[14]. Sundermier,A.(2023).Unlocking the mysteries of freezing in supercooled water droplets. SLAC National Accelertor laboratory.Phys.org. DOI: 10.1038/s41586-023-06283-2.