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ENHANCING TRAFFIC SAFETY ON THE YAOUNDE-BAFOUSSAM ROAD THROUGH INTELLIGENT TRANSPORTATION SYSTEMS.

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ABSTRACT

Improving road safety on the Yaounde-Bafoussam axis is a major challenge in Cameroon, where traffic accidents continue to occur frequently despite the measures implemented by transportation authorities. These accidents incur enormous human, material, and financial costs to the government. This study proposes the integration of Intelligent Transportation Systems (ITS) to reduce the risk of accidents and optimize traffic flow. Through an analysis of accident reports, road state to determine the causes of road unsafety (speeding, dangerous overtaking, poor signage), and a review of ITS solutions (monitoring sensors, dynamic signs, adaptive traffic management), we assess their potential for application on this strategic corridor. Expected results include fewer collisions, better flow management, and real-time user awareness. A pilot implementation and appropriate public policies could serve as a model for other national roads.

I. Introduction

Road unsafety refers to all accidents occurring on roads open to traffic, excluding accidents on private roads. A road accident is an unintentional collision on the road network between an automobile, truck, motorcycle, or bicycle and any other vehicle, person, or animal, whether moving or not, resulting in at least material damage (destruction of public infrastructure, automobile involved), physical damage (injuries), trauma (psychological) or the death of one or more of the people involved (Bauer, al 2014). As one of the problems undermining society on a global scale, traffic accidents are the eighth leading cause of death worldwide (WHO, 2022). According to statistics from the World Health Organization (2023), every year, around 1.19 million deaths are recorded worldwide as a result of road accidents, i.e., more than 3,000 people a day. In addition, between 20 and 50 million people are injured, many of them remaining disabled as a result of their injuries. Most (90%) of these accidents occur in low- and middle-income countries (WHO, 2023). This is precisely the case on the African continent, where the average mortality rate from road accidents is the highest in the world. It stands at 26.69 deaths per 100,000 inhabitants (World Bank 2020), compared with the global average of 17.5 deaths per 100,000 inhabitants, the European average of 9.3 deaths per 100,000 inhabitants, and the Asian average of 17 deaths per 100,000 inhabitants (UNECA 2016). Every year, the continent loses more than 300,000 people to road accidents, even though Africa has the lowest motorization rate in the world. In this appalling ranking, Cameroon unfortunately features in the top 30 countries with the most accidents, on a global scale it occupies 28th place and on the level of the African continent it occupies 11th position, with an average of 30.2 deaths per 100,000 inhabitants (World Bank 2019). Cameroon recorded 11,803 accidents in 2016, 10872 in 2017, 8150 in 2018, 9391 in 2019, 8980 in 2020, 10002 in 2021, and 13735 in 2022 (TRANSTAT 2023). As for the economic losses suffered by Cameroon, a study carried out in 2009 as part of the development of the national road safety and prevention strategy (ESNPSR)

estimated economic losses due to road accidents at nearly 100 billion CFA francs per year, or around 1% of GDP at the time. A recent WHO study (2023) estimated this at 3% of GDP in low-income countries.

In Cameroon, road transport is the most widely used mode of transport due to its flexibility and accessibility; it is the only means of travel that can reach the whole country due to the absence of railway lines and national flights in certain regions of Cameroon. It covers almost 90% of domestic passenger transport demand and around 75% of freight demand (TRANSTAT, 2015). In recent years, population growth and the resulting need for mobility have led to a considerable increase in the number of vehicles, motorcycle cabs and the proliferation of transport agencies and delivery companies in Cameroonian cities. This increase in the number of vehicles has had a significant impact on the safety of people, resources and equipment, given the number of deaths and injuries resulting from traffic accidents on Cameroon's roads every year.

Road insecurity is a crucial public health issue, not only because of the high number of victims killed, injured or disabled, but also because of the economic cost of accidents to society as a whole (Da Costa, 2007; Ram and Chand, 2016). To counter road insecurity, the authorities in charge of transport have put in place several texts and measures, such as the withdrawal of transport licenses for three months to transport agencies involved in accidents, the withdrawal of driving licenses for up to 02 years, the installation of 25-speed cameras throughout the country, traffic lights and road signs. In addition, the Ministry of Transport regularly launches road safety campaigns to monitor and track down incivism, and road criminals. During these campaigns, patrols made up of police officers, gendarmes, and Ministry of Transport agents are deployed on the roads, while other agents from the Ministry of Transport and certain non-governmental organizations visit travel agencies to sensitize drivers to road safety measures. Repressive measures have been multiplying in Cameroon for over a decade, but have failed to significantly reduce the number and severity of road accidents. On the contrary, their number and severity seem to be fluctuating over time.

Of Cameroon's ten regions, three (Centre, Littoral, and West) account for 75% of daily traffic (Rochon and Kendel, 2008). Home to the major cities of Yaoundé with a population of around 4,682,000 (Cameroon's political capital), Douala with a population of around 4,203,000 (Cameroon's economic capital) and Bafoussam with a population of over 480,000 (United Nation 2024), these regions are linked by busy national roads, often referred to as the “triangle of death”. This is due to the high number of traffic accidents. According to the TRANSTAT yearbook for 2023, the Western region recorded 516 road accidents in 2016, 380 in 2017, 427 in 2018, 145 in 2019, 182 in 2020, 772 in 2021, 678 in 2022; the Coastal region 1473 road accidents in 2016, 1159 in 2017, 1020 in 2018, 1327 in 2019, 1205 in 2020, 1210 in 2021, 5141 in 2022; and the Central region 5941 road accidents in 2016, 5994 in 2017, 4274 in 2018, 5028 in 2019, 4339 in 2020, 5852 in 2021, 5695 in 2022. Based on these data, we can see that the problem of road insecurity is palpable in Cameroon, particularly on the roads linking these regions. It is, therefore, crucial to adopt modern road safety methods to combat this scourge. It is in this context that we propose the implementation of Intelligent Transport Systems (ITS) as a measure to overcome this problem, which undermines the lives of populations and costs the State enormous resources.

The adoption of innovative transport technologies is one way of significantly reducing the number of road accidents. This concept of road safety measures has been around for over 25 years. In its early days, it went by many names: Road Transport Informatics (RTI), Advanced Telematics in Transport (ATT), and Intelligent Vehicle-Road Systems (IVRS). Today, it is universally recognized as an Intelligent Transportation System (ITS). Intelligent Transport Systems (ITS) are applications of new information and communication technologies in transport and logistics. They are described as “intelligent” because their development is based on functions often associated with artificial intelligence, such as sensory capabilities, decision-making, memory, communication, information processing and adaptive behavior. ITS can be found in a variety of sectors, including optimizing the use of transport infrastructures, improving safety (especially road safety) and security, and developing services. Already adopted by several countries to overcome road insecurity, there is a certain reluctance on the part of certain developing countries, despite the fact that they are the most affected by this scourge, which wreaks havoc on the economy through the loss of life and material damage caused by traffic accidents.

The aim of this study is to find the best applications for intelligent transport systems to be implemented on the Yaounde-Bafoussam road to significantly reduce the number of traffic accidents on this route. To achieve this objective, we began by collecting data on current traffic conditions and accidents from the structures that possess them (gendarmerie, Ministry of Transport, statistics institute), analyzing these data, identifying the causes of the problem and the most accident-prone locations, and then proposing intelligent transport system applications to be adapted to this road axis.

II-Literature review

1-Overview of intelligent transportation system

Intelligent transport systems are a set of innovative applications designed to improve the management and increase the efficiency of transport networks (road, rail, air, and sea). These technologies enable users to be better informed and promote more efficient use of transport infrastructures. They offer several advantages, such as improved safety thanks to real-time alerts, efficiency gains to re-

duce congestion and fuel consumption, enhanced environmental sustainability, and improved user experience thanks to better access to information. Intelligent transportation systems bring together a wide range of information technologies and electronics focused on wired and wireless communications. Their main components are:

-Traffic management systems are a set of technologies, practices, tools, and strategies designed to ensure the safe and efficient movement of road users. These systems use a variety of methodologies and technologies, including traffic light control systems, traffic monitoring sensors and cameras, information and communication technologies and traffic management centers, to optimize traffic flow, reduce congestion, improve safety and enhance the responsiveness of the entire transportation network to changing conditions and demands. By studying real-time data, traffic management systems have the ability to change traffic lights, manage traffic incidents, implement measures to alleviate congestion and improve the longevity of transport environments (Sébastien Faye, 2014).

-Monitoring and safety systems in road transport play an essential role in ensuring the safety of infrastructure, users and goods. By integrating various technologies and control methods, these systems aim to reduce accidents, control driver behavior and protect the environment (KL Young et al. 2007). Road and infrastructure monitoring is essential to detect infringements and ensure road safety. The use of CCTV cameras, sensors and motion detection systems enables continuous assessment of traffic and user behavior (Himanshu P et al. 2023). Thanks to these systems, accidents or incidents on the roads can be quickly identified, facilitating rapid intervention by the relevant authorities.

-V2X (Vehicle-to-Everything) systems are a set of essential technologies for communication between vehicles and their environment. These systems aim to improve road safety, traffic flow and transport efficiency. They are based on wireless communication technologies that enable vehicles to exchange information in real time with their environment. This includes communication between vehicle and vehicle (V2V), vehicle and infrastructure (V2I), and vehicle and pedestrian (V2P). This type of communication enables better coordination between different road users and helps prevent accidents by providing early warnings of potential hazards (C Gschwendtner et al, 2021).

-Passenger information systems (SIP) refer to technological solutions and platforms that provide passengers with real-time information on public transport services. These systems are designed to enhance the travel experience by providing updates on vehicle location, arrival and departure times, delays, route changes and other relevant travel information (Lelitha V et al, 2010). SIPs can be found in a variety of transport modes, including buses, trains, metros and streetcars. They use a combination of hardware and software, such as digital displays, announcement systems, mobile applications and websites, to disseminate information. The aim of passenger information systems is to improve accessibility, facilitate journey planning, increase the efficiency of public transport use and improve overall passenger satisfaction.

-Geographic Information Systems (GIS) are integrated systems used to capture, store, analyze, manage and present spatial or geographic data. GIS combines cartography, statistical analysis and database technology to comprehensively analyze spatial information. This technology is used in a variety of fields, including urban planning, environmental management and transportation. It enables decisions to be made, problems to be solved and spatial patterns and relationships to be understood (C. Fouque, 2010). GIS can be used to create detailed maps, analyze the spatial distribution of features, assess environmental impacts, plan logistics and much more, making it an invaluable tool for both scientific research and practical applications.

-Electronic payment systems refer to the means and technologies used to facilitate the electronic exchange of money between parties. These systems make it possible to considerably reduce the waiting times involved in physical transactions (François Lentz, 2010). They encompass a wide range of technologies, including credit and debit cards, electronic funds transfers (EFT), digital wallets, payment gateways, online banking and mobile payment solutions. They play an essential role in the development of e-commerce, enabling consumers to purchase goods and services from the comfort of their own homes, and reducing queues at supermarket checkouts. The adoption of electronic payment systems has significantly changed the way businesses and consumers operate.

Looking ahead, trends point to increased adoption of artificial intelligence for predictive analytics in traffic management, greater emphasis on sustainable transportation options, and the expansion of smart city initiatives that integrate ITS with urban planning for holistic solutions. Overall, ITS represents a transformative approach to managing transportation networks through technology, playing a crucial role in shaping the future of mobility.

2-Previous studies on ITS implementation for traffic safety

Road unsafety is a major problem affecting all countries, whether developed or developing. According to a study by Qureshi and Abdullah (2013), the transport sector faces challenges such as high accident rates, road congestion, and carbon emissions, which compromise safe and efficient travel. To meet these challenges, Intelligent Transport Systems (ITS) have been introduced. These systems, integrating advanced communication and information technologies, help to improve traffic management, optimize infrastructure use, and enhance road safety. They are characterized by functions associated with intelligence, such as sensory capacity, communication, and information processing. In addition, ITS promotes sustainable development by supporting intermodality in transport.

a-Europe, America, and Asia

Many countries have implemented these systems to reduce accident-related deaths and economic losses. For example, with its “Vision Zero” initiative, Sweden has integrated intelligent traffic management systems, resulting in a 25% reduction in serious injuries and deaths on the roads between 2000 and 2010 (Elvik and Varre, 2013). In parallel, in the UK, technologies such as speed cameras and surveillance cameras have been introduced to control speed and detect infringements. In this way, the “Traffic Management”

program has reduced collisions by up to 20% in certain critical areas (DfT, 2017).

The integration of these systems, along with feedback from different contexts, offers valuable lessons. In Singapore, for example, the Electronic Road Pricing (ERP) system has proved effective in congestion management, reducing driving times and accidents in densely populated urban areas (Tan, 2018). Similarly, in Poland, the integration of ITS into road infrastructure has led to a significant reduction in collisions, with accidents down by 45% and fatalities down by 42%, according to Szczepanik and Besta (2018). This demonstrates the positive impact of technological solutions on road safety.

In addition, the "Smart Roads" program in Virginia, USA, has integrated sensors and communication systems to optimize traffic jams and incident management, reducing accident response time and lowering collision rates by 30% in certain targeted areas (Virginia DOT, 2020). In addition, another study by Vaitkus et al (2023) highlights the importance of ITS in reducing road accidents by targeting major risk factors, such as excessive speed and driving under the influence of alcohol, which account for over 55% of accidents in Europe. Systems such as speed control and the Alcolock system have proved effective in improving road safety in the European Union.

b- Africa

The implementation of Intelligent Transport Systems (ITS) in Africa is a promising approach to improving road safety in various countries. In South Africa, Johannesburg has adopted advanced technologies such as real-time traffic monitoring and adaptive traffic lights, helping to reduce congestion and accidents (van der Merwe et al., 2015). Similarly, in Nairobi, ITS has been integrated into the public transport system to optimize bus schedules and monitor major roads, contributing to a reduction in traffic-related risks (Mawanya et al., 2016). In Morocco, Marrakech uses electronic toll systems and intelligent transport applications to smooth traffic flow, reducing waiting times and limiting congestion (El Alami et al., 2019). In Ghana, the integration of electronic information panels in Accra has improved traffic management, providing drivers with real-time information to make better decisions, thereby enhancing road safety (Oduro et al., 2020). Finally, in Lagos, Nigeria, intelligent traffic management systems help to detect and manage incidents, facilitating rapid intervention and thus optimizing traffic flow (Ojo et al., 2021). These initiatives illustrate a growing commitment to innovative solutions to Africa's road safety challenges, making ITS a key element for safer and more efficient transport infrastructure.

C-Cameroon

Since 2018, the Ministry of Transport has begun transitioning towards digitalization, adopting digital tools in the road transport sector. This digitalization is expressed in particular by installing radars for roadside control. The Ministry has acquired 25 radars, including 10 automatic ones installed on the Yaounde-Douala road and 15 semi-portable ones spread over the rest of the country to combat speeding. In September 2022, the Ym@ne driver project was officially launched by the Minister of Transport in collaboration with MTN Cameroon and CAMTRACK. This centralized solution aims to manage and track intercity buses. It aims to prevent and reduce accidents while anticipating risky driving behavior by bus and truck drivers. Several researchers have explored this theme to support the Ministry of Transport in its fight against road insecurity. A study by Kamdem and Ngole (2020) examined the challenges and opportunities of urban mobility in Douala. This research highlighted the impact of traffic jams on road safety and proposed the integration of intelligent transport systems to optimize traffic flow, recommending the installation of intelligent traffic lights and passenger information systems. Another study, by Ngandeu and Fokam (2023), analyzed Yaoundé's road infrastructure and its capacity to integrate intelligent transport systems (ITS). The authors concluded that it was necessary to significantly improve the existing infrastructure, notably by installing sensors and upgrading traffic lights. In addition, a study entitled "Risk Management in Road Transport in Cameroon: Does Digitalization Matter?" by Clarence Bea et al. (2024), identified several major risks in this sector. These include road accidents, falsification of transport documents, theft of goods, and inadequate control and monitoring. The authors highlight the transformative potential of digitalization in road transport, helping to enhance safety, improve compliance and optimize operations. They recommend the mandatory integration of digital technologies, notably by equipping vehicles with geolocation systems and other digital tools. They also encourage innovation in the sector and research into the impact of digitalization on safety and efficiency.
From this overview, it is clear that the intelligent transport systems currently present in Cameroon include radar and the Internet of Things solution, connected via Ym@ne driver. However, these systems have certain limitations. The 25 radars in service are not enough to cover the whole of the national territory, while the Ym@ne driver solution has not yet been adopted by all travel agencies, and cannot monitor vehicles for personal use. What's more, research work has focused mainly on major cities, whereas road safety is a national problem affecting the whole country, particularly the roads linking Yaounde, Douala, and Bafoussam, nicknamed the "triangle of death" due to the high number of accidents reported every day. Our study will focus on the Yaounde-Bafoussam road, the longest in this high-risk area, and will analyze traffic accidents to identify their causes. We will then propose intelligent transport systems (ITS) to be implemented on this route to reduce the recurrence of accidents.

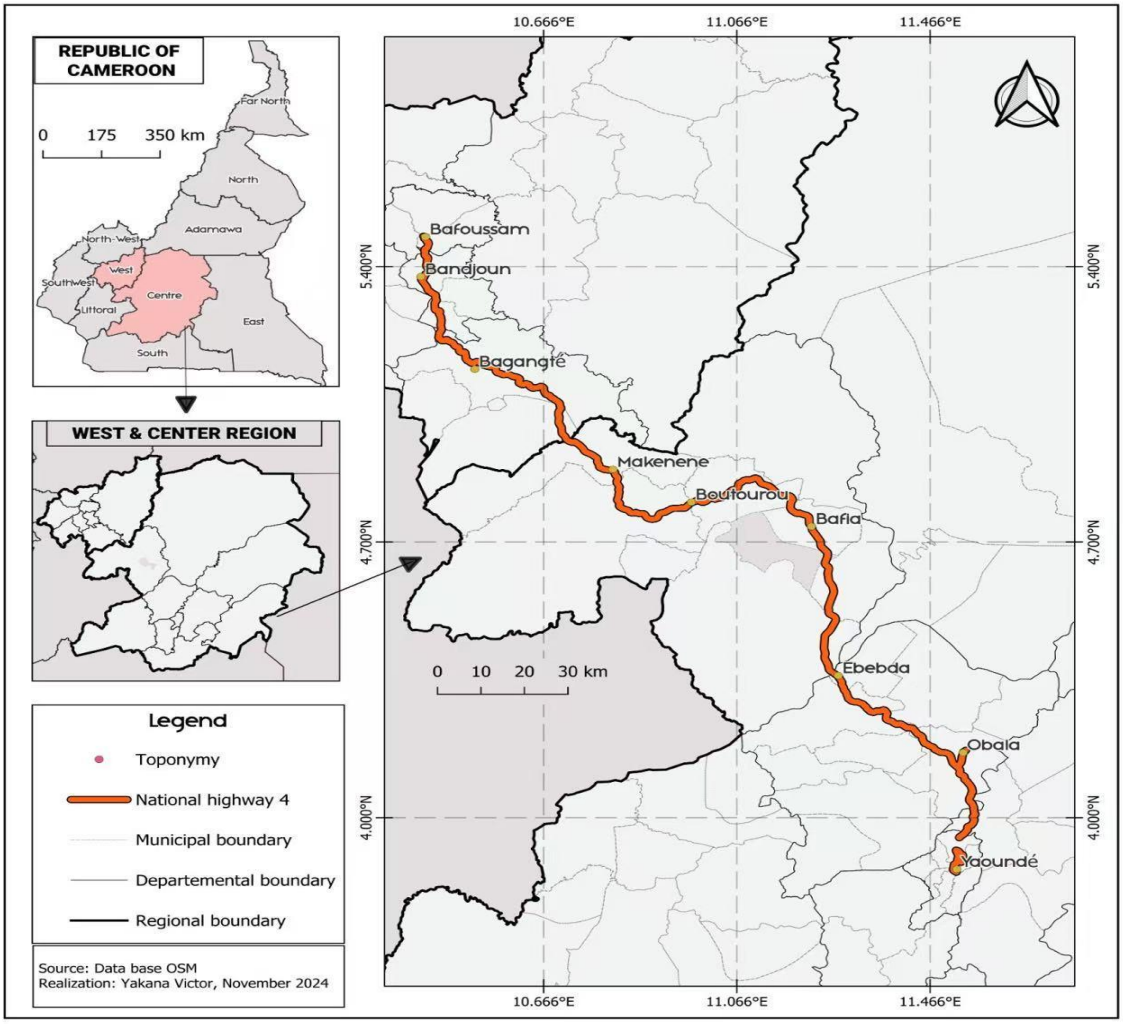
III-Methodology

1-Study area

Cameroon has been facing enormous road safety challenges for several decades. The growing number of accidents on the country's roads is very worrying. The roads most affected by this phenomenon are the national roads linking the cities of Yaounde to Douala, Yaounde to Bafoussam, and Bafoussam to Douala, known as the triangle of death. Within this triangle, our study will focus on national road number 4, which links the political capital of Cameroon, Yaounde, to the capital of the western region, Bafoussam, both of which are major centers of population. The main towns on this route are Yaounde, Obala, Ebebda, Bafia, Boutourou, Makenene, Bangante, Bandjoun, and Bafoussam (map 1). The road is 293.4 km long by car and comprises nine segments (Table 1).

Segment	Road segment	Length (m)
T1	Yaounde – Obala	34.4
T2	Obala – Ebebda	43.8
T3	Ebebda – Bafia	46.4
T4	Bafia – Boutourou	39.9
T5	Boutourou- Makenene	29.9
T6	Makenene – Tonga	14.8
T7	Tonga – Bangante	37,2
T8	Bangante - Bandjoun	33.3
T9	Bandjoun - Bafoussam	13.7

Table 1: road segment



Map 1: Yaounde-Bafoussam Road

2-Data collection

In Cameroon, the process of collecting, processing and analyzing accident data involves the police in urban areas, the gendarmerie in interurban areas, and the Ministry of Transport as the recipient of analysis reports. For our study, secondary data were obtained from accident reports consulted at gendarmerie stations along this route, and from registers consulted at the Ministry of Transport and the National Institute of Statistics. We collected these data using a data collection form drawn up by ourselves. Thus, at the gendarmerie stations along our study area, we consulted summaries of accident reports from 2015 to 2023. We then recorded on our data collection forms the date, time and location of the accident, the type of motor vehicle involved, information on the people involved (age, sex, blood alcohol level, seatbelt, user category), the number of people involved, the category of accident, and the possible cause of the accident (human, mechanical, environmental). At the level of the Ministry of Transport and the National Institute of Statistics, we had access to the traffic accident analysis registers, which enabled us to adjust the data we collected from the gendarmerie. Primary data refers to the data obtained during our field investigations. The collection tool here was the observation grid, which contained elements relating to road type, road condition, road signs, nature of the terrain, shoulders, etc.

3- Data treatment

The data collected was entered, coded, and stored in an Epi Info 7.0 database. They were then analyzed using the IBM-SPSS STATISTIC 27 statistical software platform. For analysis, we opted for frequency analysis, which is a method used to count and summarize the number of occurrences of different categories of a variable in a data set. In the context of our traffic accident study, this analysis enabled us to identify the most frequent causes of accidents. The results of the analyses were summarized and presented graphically.

IV- Data analysis

1-Road condition

The road linking Yaounde to Bafoussam comprises nine road segments (see Table 1), and is 293.3 km long and 10 m wide, including shoulders. It consists of two lanes separated by a white median 0.15 m wide. In the course of our fieldwork, we noted a number of observations that might explain some of the accidents.

Road segment	T1	T2	T3	T4	T5	T6	T7	T8	T9
length (km)	34.4	43.8	46.4	39.9	29.9	14.8	37.2	33.3	13.7
Road width(m)	07	07	07	07	07	07	07	07	07
Shoulder width (m)	1,5*2	1.5*2	1.5*2	1.5*2	1.5*2	1.5*2	1.5*2	1.5*2	1.5*2
No of lanes	02	02	02	02	02	02	02	02	02
Median width(m)	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0,15	0.15
Median type	White line	white line	White line	White line	white line	White line	White line	White line	white line
Presence of guardrails	No	No	No	No	No	No	No	No	No
State of guardrails	Don't exist	Don't' exist	Don't exist	Don't exist	Don't exist	Don't exist	Don't exist	Don't exist	Don't exist
State of road surface	A little good	Good	Good	Good	Good	Good	Good	Good	Good
Deterioration	Cracking, pothole	cracking	Cracking	cracking	cracking	cracking	Cracking	cracking	cracking
Presence of side drains	Yes	No	No	Yes	yes	Yes	Yes	yes	Yes
State of	Blocked	Don 't	Don't	Not	Blocked	Blocked	Not conti-	Blocked	Blocked

side drains		exist	exist	conti-nuous			nuous		
Presence of Traffic signs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
traffic sign	Speed limit, pe-destrian crossing	Speed limit	Speed limit	Speed limit, inter-section	Speed limit, in-tersection	Speed limit	Speed limit, in-tersection	Speed limit	Speed limit, in-tersection
State of traffic sign	Dirty	Hidden	Dirty	Dirty	Hidden	Hidden	Hidden	Dirty	Dirty
Rest zone	Yes	No	No	No	Yes	No	No	on	No
Rest zone equip-ment	Yes	/	/	/	no	/	/	/	/
Street vendors	Yes	Yes	yes	Yes	yes	Yes	Yes	yes	Yes

Table 2: Observations on the Yaounde-Bafoussam route

2- Interpretation

-Road surface and type of degradation: the Yaounde - Bafoussam road is generally in good condition, especially on the Ebebda - Bafoussam section. This can be attributed to the rehabilitation work carried out on this particular section. On the Ebebda – Yaounde section, however, we noted cracks, delamination and a few potholes.
-Presence of guardrail: on the Bafoussam - Yaounde road section, we noticed that guardrails were only present near the bridges. This absence of guardrails is particularly worrying, as there are houses located below the road. This situation creates a major hazard for both road users and the residents of these houses.
-Number of access points and access controls: at the Nkolguem 2 site, more specifically at the Carrefour Sa'a access point, it was observed that no access controls were in place. The absence of access controls is particularly worrying given the presence of the bypass road nearby.
-Presence and state of side drains: along the entire length of this road, we noted the presence of drains in certain places, most of them overgrown with vegetation, which prevents rainwater from being channeled properly.
-Intersection description: We identified two critical intersections on this road: Ebebda and Ndikinimeki. These intersections are controlled by priority rules and lack channelization measures. Drivers' decision-making at these intersections therefore depends solely on instinct and judgement, which can lead to an increased risk of accident.
-Presence and state of lightning: at these critical intersections, we observe that lighting is present, but its state is unsatisfactory. At intersections like Ebebda, not all lighting devices are operational. This is a cause for concern, as lighting plays a crucial role in improving visibility and helping drivers to appreciate the maneuvers of other users at intersections. Insufficient lighting can prevent drivers from correctly assessing their surroundings, recognizing road signs, and anticipating the actions of other road users. This can lead to confusion, misjudgment, and an increased risk of accident.
-Signage: As far as road signage is concerned, horizontal signage is represented by road markings and parking symbols, although these tend to disappear in places. Vertical signage is also present, with signs indicating information such as dangerous bends, speed limits, petrol stations, distances to towns and other. However, these signs are not adequately maintained, as many of them are sometimes hidden by vegetation and poorly positioned on the road, making them difficult for drivers to see, which could contribute to the occurrence of certain traffic accidents.
-Rest areas: There are two unevenly distributed rest areas on this route, one at Obala and the other at Kon Yabenta. This is often cited as a contributing factor in many accidents, given the narrowness of the road and the inadequacy of the rest areas.

3-Traffic accident trends and black spots

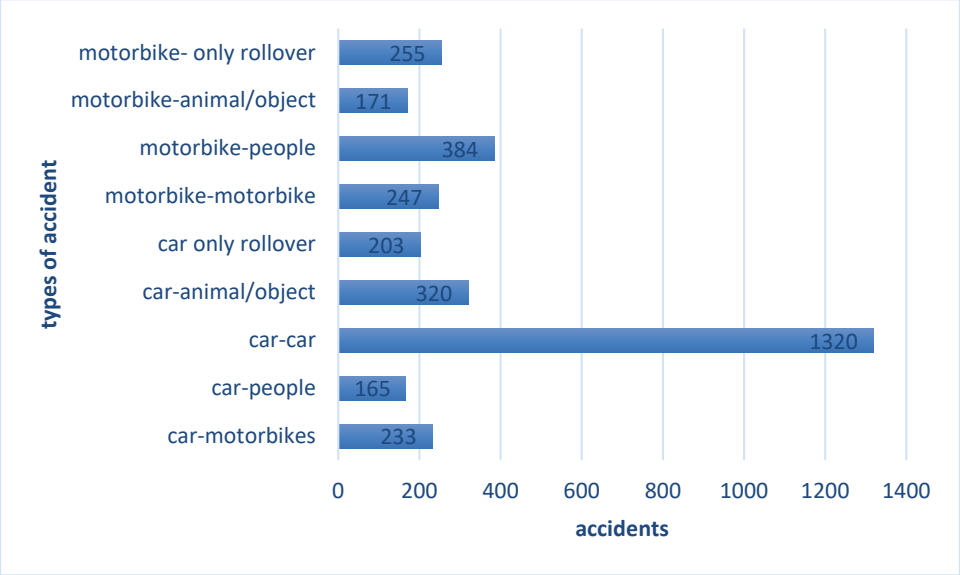
Années	Accidents matériels	Accidents corporels	Accidents mortels	Total des accidents
2015	130	215	141	486
2016	138	205	149	492
2017	116	178	97	391

2018	80	140	97	317
2019	144	125	97	366
2020	103	111	70	284
2021	108	140	104	352
2022	103	127	77	307
2023	101	125	77	303
Total	1023	1366	909	3298

Table 3: Traffic injuries

a-Types of accidents

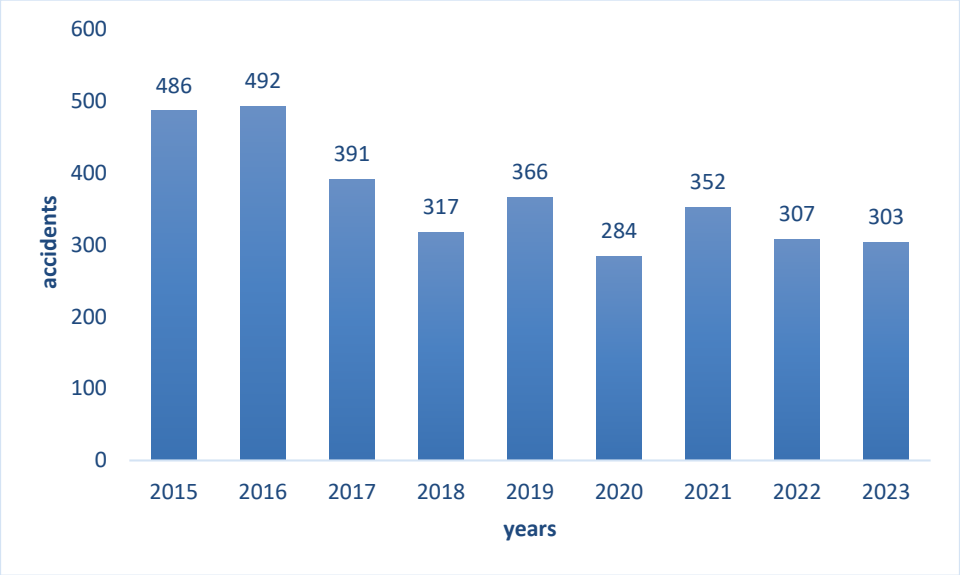
The most frequent accidents on this road are vehicle-vehicle with 1320 cases or 40% of all accidents recorded, followed by motorcycle-person collisions with 384 cases or 11.64% and vehicle-object/animal collisions with 320 cases or 9.70% (graph 1).



Graphics 1: type of accident encountered on the road Yaoundé-Bafoussam

b-Traffic accident trends by year

Figure 2 below shows the trend in traffic accidents on the Yaoundé-Bafoussam road from 2015 to 2023. An in-depth analysis of the data reveals a notable fluctuation in the number of accidents on this route over this period. Indeed, the years 2015 and 2016 stand out for their high accident figures of 486 (14.73%) and 492 (14.91%) respectively, which can be attributed to the degraded state of the road during this period, characterized by a significant presence of large holes and huge potholes, making traffic particularly difficult. Then from 2017 to 2019 we see a slight decrease in accidents on this road, a direct consequence of the maintenance work that was undertaken on a segment of this road during this period. However, in 2020, we see a considerable 8.6% drop in accidents (284 accidents recorded during this year), mainly attributable to the containment measures imposed by the government in response to the COVID-19 health crisis, which led to a significant reduction and rigorous control of travel. In 2021, however, a further increase in the number of accidents was recorded (352 accidents, equal to 10.67%). This trend is explained by the gradual return to normal of economic activities and travel, following the lifting of containment measures. Finally, in 2022 (307 accidents representing 9.30%) and 2023 (303 accidents corresponding to 9.18%), a further slight fall in the number of accidents was recorded, as a result of the renovation work carried out on the entire road in preparation for the African Cup of Nations, which was held in 2022.



Graphic 2: breakdown of accidents by year on Yaounde-Bafoussam Road

c- Traffic accidents by month

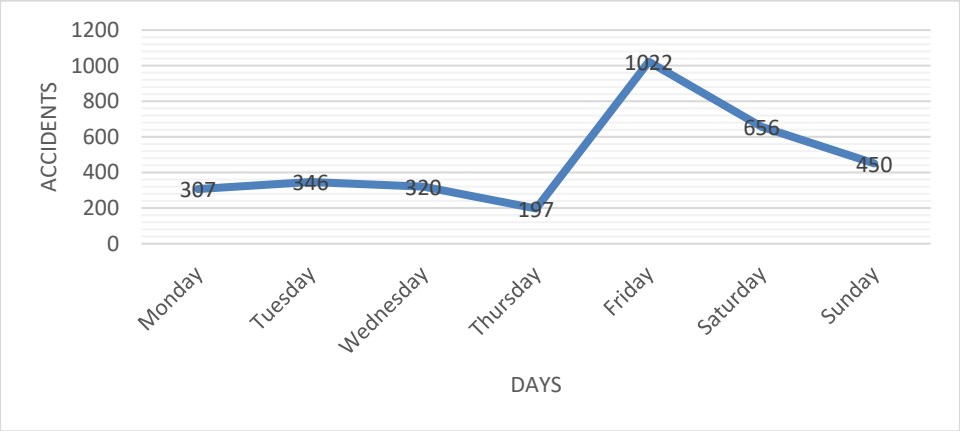
After studying our data, we analyzed traffic accidents according to the months in which they occurred (graph 3). July and August were the most accident-prone months, with 520 and 480 accidents respectively. This can be explained by the fact that these months coincide with the major school vacations, a period during which there is an intensification of travel in the country, due to vacation camps, soccer championships, music competitions, and other. The months of December and January follow closely, as they are also marked by the end-of-year festivities, a period when many people travel to join their families. April, the month of Easter, also sees a large number of travelers, not least because of the festivities linked to the various Christian sacraments celebrated in some families. By contrast, the months of February, March, May, June, September, October and November, while also recording accidents, show a slightly lower rate. This lower rate is mainly due to business travel and other less intensive activities during these periods.

Graphics 3: breakdown of accidents by month on the Yaounde–Bafoussam road

d- Road accident trends by day of the week

The graph below shows an analysis of accidents by day of the week. We can see that Friday is the day with the highest number of accidents, totaling 1,022 cases, followed by Saturday with 656 accidents and Sunday with 450. Friday, which marks the start of the weekend, is particularly popular for travel. Many people travel on this day: some want to join their families for the weekend, others are attending weddings or funerals, often scheduled for Saturday. Still others simply want to enjoy themselves over the weekend. Saturday is marked by travel for those who couldn't get away on Friday, while Sunday is usually the day when people return to their

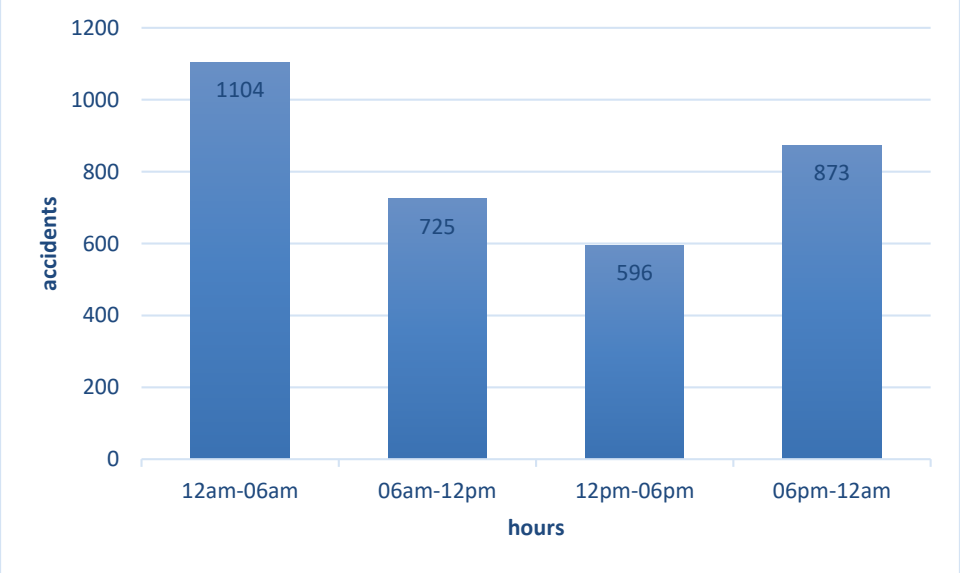
home town. On the other hand, Monday, Tuesday, Wednesday and Thursday are also travel days, but these are less intense than the last three days of the week



Graphic 4: breakdown of accidents by day on the Yaounde-Bafoussam road

e-Frequency of road accidents by time of day

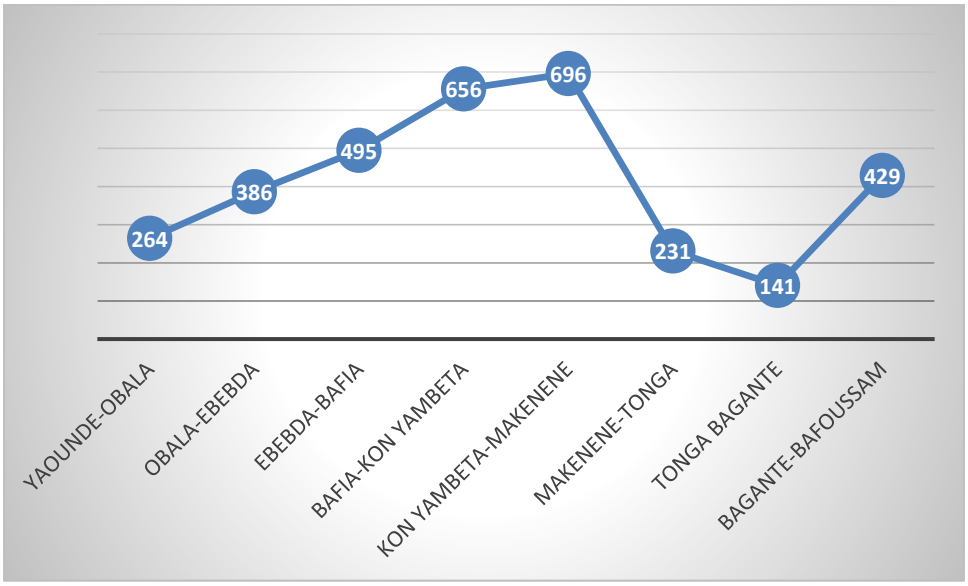
The temporal frequency of accidents was classified into four groups. As shown in the graph below, it was noted that of the 3298 accidents recorded in our descriptive analyses, 873 accidents were recorded from 6pm to 12am and 1104 from 12am to 06am, representing 26.47% and 33.47% respectively. This indicates that the most accident-prone period on the road between Yaounde and Bafoussam in Cameroon is between 06pm and 06am, with around 60% of accident cases.



Graphic 5: breakdown of accidents by hour on the road Yaounde-Bafoussam road

f-Black spots

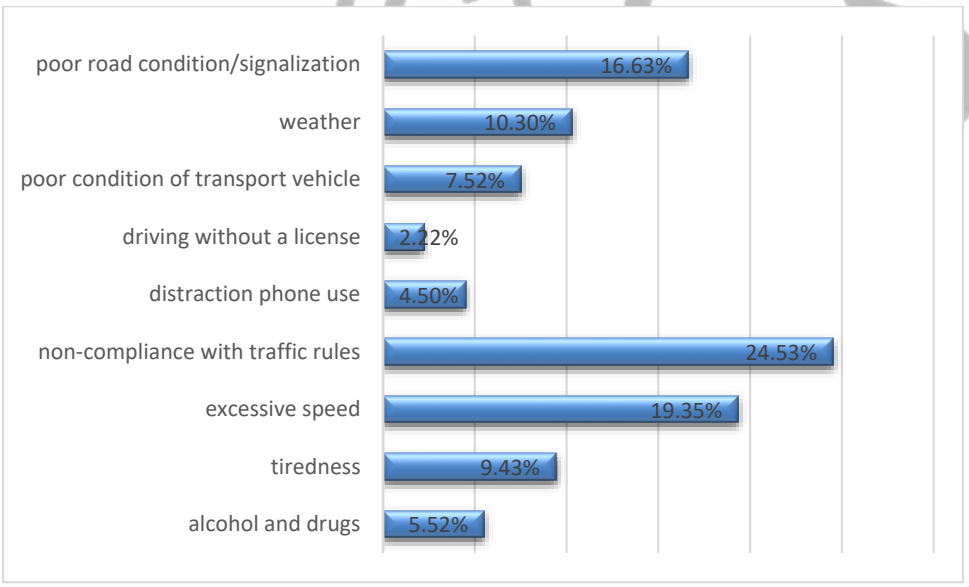
The identification of accident “black spots” (an accident black spot is a location with a higher number of accidents than other locations on the same road) and potential safety problems illustrates road sections with a high accident risk. In our study, the identification of accident “black spots” was categorized into eight accident-prone sections. Graph 6 shows that the highest black spot on the Yaoundé-Bafoussam axis, with 21.1% of accidents, is the kon yambeta - Makenene segment (696 accidents), closely followed by the bafia - kon yambeta segment with 656 accidents or 19.9%.



Graphic 6: black Spots of accidents on the Yaounde-Bafoussam road

4. Causes of accidents

After analysis of the accident reports, the main causes of accidents on this road were failure to comply with traffic regulations (809 accidents or 24.53%), excessive speed (638 accidents or 19.35%), road conditions (549 accidents), weather (340 accidents), driver fatigue (311 accidents), vehicle condition (248 accidents), alcohol (182 accidents), distracted driving (148 accidents) and driving without a driver's license (73 accidents).



Graphic 7: Causes of accidents on the Yaounde-Bafoussam road

V-Propose ITS solutions tailored to address traffic safety issues in this highway

Integrating intelligent transport systems into traffic management and driver behavior monitoring can considerably improve road safety. In the table below, we propose intelligent transport systems to be implemented on the Yaounde-Bafoussam road, based on the causes of accidents encountered on this route. Each system is accompanied by an example already in operation in a country around the world.

Causes of accidents	ITS solutions	Examples

Noncompliance with traffic rules	-Traffic Surveillance and Camera Systems -Warning Applications	-Redflex -RoboCop Traffic App
Excessive speed	-Speed Control Systems -Navigation Applications with Speed Alerts	-Siemens Sitraffic -TomTom GO Navigation
Poor Road conditions and signalization	-Traffic Management Systems (TMS) -Real-Time Mapping Applications -Alert and Notification Systems -Road Condition Monitoring Systems -Signage Optimization Applications -User Feedback	-City of Los Angeles Traffic Management Center -Waze -Smart Traffic Signs in Michigan -Road Weather Information Systems (RWIS) -Dynamic Message Signs (DMS) -SeeClickFix
Weather	-Real-Time Weather Forecasting Applications -Automatic Alert Systems	-Weather Underground -Waze
Tiredness	-Fatigue Detection Systems -Driver Assistance Applications	-Seeing Machines -Rest Area Finder
Poor condition of transport vehicle	-Fleet Management Systems -Predictive Maintenance Applications	-Teletrac Navman -Geotab
Alcohol and drugs	Alcohol Detection Systems	BACtrack coprocessor
Distraction	-Distraction Detection Technology -Safe Driving Applications	- SmartDrive - LifeSaver
Driving without a license	-Automatic License Plate Recognition (ALPR) Systems -Driver Registration Applications	- PlateSmart -DriveSafe

VI-Discussion

1-Traffic management center (TMC)

For a better implementation of ITS, the Cameroonian government needs to create a traffic management center. This center will play a fundamental role in organizing, regulating, and optimizing vehicle movements on road networks, notably through the use of intelligent transport systems (ITS). The center will be responsible for

-Real-time monitoring and data collection: TMCs, equipped with ITS, provide permanent traffic monitoring, collecting real-time information on traffic flow, vehicle speed, and traffic density at different points on the road network, thanks to the sensor and camera systems installed on the roads. The data collected is processed to identify traffic problems, such as congestion or accidents, with a view to triggering appropriate measures.

-Traffic Management and Incident Response: TMCs play a crucial role in incident management and traffic regulation. Thanks to ITS, centers can quickly detect abnormal situations (accidents, congestion) and alert emergency services as well as drivers via display panels or navigation applications. Thanks to real-time data, they can also adjust traffic lights to meet the needs of their customers. Signaling to optimize traffic flow and reduce waiting times at intersections (Rahul Patel. T al, 2020)

-Information and Communication: TMCs provide valuable information to road users. They disseminate information on traffic conditions, incidents, and roadworks via a variety of channels, including mobile apps, websites, and variable message signs placed along roads, they can also provide real-time route recommendations to drivers, directing them towards less congested routes to avoid delays.

Planning and strategy: The data collected by TMCs is also used for long-term planning. By analyzing historical and current data, TMCs can identify trends, helping to plan future infrastructure projects and improve traffic management on the road network (J. Tipaldo, 2003).

2-Implementation challenges

The implementation of Intelligent Transport Systems (ITS) in Cameroon presents a number of challenges that may hinder their adoption and effectiveness. The main challenges relate to infrastructure, financing and users.

-Infrastructure: Many of Cameroon's roads require significant improvements before ITS solutions can be integrated. Roads in poor condition limit the effectiveness of traffic monitoring and management systems. In the case of the Yaounde - Bafoussam road, it has been renovated, but this renovation alone is not enough, as the road was built over fifty years ago, and over time the population and the number of vehicles have increased. This road needs to be rebuilt to meet current and future transport expectations.

-High technology costs: The acquisition and installation of ITS equipment, such as monitoring systems, sensors and traffic management software, requires a significant investment, which can be a deterrent for governments and local authorities. But given the loss of human life (manpower) and economic losses (3% of GDP) suffered by Cameroon as a result of traffic accidents, the high cost of these technologies should not be a brake on the implementation of intelligent transport systems in the country.

-Users: here, the concern lies in the lack of ITS skills and resistance to change. The lack of qualified personnel to install, maintain and manage ITS represents a major brake on their installation. We also have a possible reluctance to change on the part of road users, urban planners and political decision-makers, for fear that they will disrupt established practices or behavior, even though these behaviors may fail to solve road safety problems.

Conclusion

Road safety is an issue that concerns every country in the world, especially developing countries like Cameroon. Cameroon's roads are the scene of numerous traffic accidents. To find a solution to this problem, which causes enormous losses in material and human resources for the government, we studied traffic accidents on the Yaounde-Bafoussam road, one of the country's deadliest. Our analysis revealed that the causes of accidents on this road are linked to non-compliance with traffic regulations, excessive speed, road conditions, weather conditions, driver fatigue, vehicle conditions, alcohol, distracted driving, and driving without a license. To combat this problem, we propose the implementation of Intelligent Transport Systems (ITS) on the Yaounde-Bafoussam road, which would represent a significant step forward in improving road safety in Cameroon. By integrating advanced technologies such as traffic management systems, distraction detection, alcohol detection systems, speed control systems, fatigue detection systems, as well as traffic monitoring and automatic license plate recognition (ALPR) systems, and using real-time data, these systems would not only reduce the number of accidents but also optimize traffic flow. The results observed in many countries show significant potential for transforming our traffic management and our ability to respond to emergencies. By fostering a proactive road safety culture, this approach could also serve as a model for other road corridors seeking to improve. However, the commitment of local authorities and stakeholders is essential to ensure the success and sustainability of this project, which could make the Yaounde-Bafoussam road an inspiring example of road safety innovation in Cameroon. However, although the implementation of intelligent transport systems offers many advantages, challenges remain, including: how to adapt driver behavior to these new technologies.

References

[1] Al-Marafi, M. N., Alhadidi, T. I., Alhawamdeh, M., & Jaber, A. (2024). Enhancing road safety strategies through applying combined treatments for different crash severity. Urban Science. https://www.semanticscholar.org/paper/9edb8a1fdf8c2d05f3ed341a689df384cbd40cd7
[2] Al-Hattab, M., Elassy, M., Takruri, M., & Badawi, S. (2024). Intelligent transportation systems for sustainable smart cities. Transportation Engineering, 16, 100252. https://doi.org/10.1016/j.treng.2024.100252
[3] Banque Mondiale. (2019). Road safety facts and figures: Africa region. https://www.worldbank.org/en/news/feature/2019/03/15/road-safety-in-africa
[4] Banque Mondiale. (2020). GRSF and Total Foundation announce partnership to advance data-related capacity building through the African Road Safety Observatory. https://www.banquemondiale.org/fr/news/press-release/2020/01/16/grsf-and-total-foundation-announce-partnership-to-advance-data-related-capacity-building-through-the-african-road-safety-observatory
[5] Bauer, R., Steiner, M., Kisser, R., Macey, S. M., & Thayer, D. (2014). Accidents and injuries in the EU: Results of the EuroSafe Reports. Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz, 673-680.
[6] C.E.A. (2016). Road safety in Africa: A regional overview. https://www.uneca.org/publications/road-safety-africa
[7] Department for Transport. (2017). Traffic management: The impact of technology on road safety. https://www.gov.uk/government/publications/traffic-management-and-road-safety
[8] El Alami, M., Bouhaya, A., & Sebastian, J. (2019). The use of electronic toll collection and smart transport applications in Marrakech, Morocco: Enhancing traffic flow and reducing congestion. Journal of Transport and Health.
[9] Elvik, R., & Varre, J. (2013). The effects of the Vision Zero initiative on road safety in Sweden. Accident Analysis & Prevention, 124-130.
10-Faye, S. (2014). Contrôle et gestion du trafic routier urbain par un réseau de capteurs sans fil. [Control and management of urban traffic by a wireless sensor network]. https://www.semanticscholar.org/paper/e640fbf2da30001a7d89adcc53fcc42b69241cdd
[11] Gschwendtner, C., Sinsel, S. R., & Stephan, A. (2021). Vehicle-to-X (V2X) implementation: An overview of predominate trial configurations and

technical, social and regulatory challenges. https://www.sciencedirect.com/science/article/pii/S1364032121002690
[12] Hanai, T. (2023). Advancements in Intelligent Transport Systems in Japan: Enhancing safety and efficiency.
[13] Himanshu Pahadia, Lu, D., Chakravarthi, B., & Yang, Y. (2023). SKoPe3D: A synthetic dataset for vehicle keypoint perception in 3D from traffic monitoring cameras. In 2023 IEEE 26th International Conference on Intelligent Transportation Systems (ITSC). https://arxiv.org/abs/2309.01324
[14] KL Young & Regan, M.A. (2007). Intelligent transport systems to support police enforcement of road safety laws. In ATSB Research and Analysis Report.https://www.researchgate.net/profile/Michael-Regan-4/publication/252923780_Intelligent_Transport_Systems_to_Support_Police_Enforcement_of_Road_Safety_Laws/links/0f3175328c5b746fc9000000/Intelligent-Transport-Systems-to-Support-Police-Enforcement-of-Road-Safety-Laws.pdf
[15] Lentz, F. (2010). Acceptation et usage des systèmes de paiement électronique de détail par les consommateurs. https://www.semanticscholar.org/paper/0f228c50df3c945cfa7da5084b304d7acb042cff
[16] Mawanya, T., Mungai, R., & Mwangi, J. (2016). Integrating intelligent transport systems in public transport in Nairobi: Enhancing bus schedules and monitoring major routes.
[17] Mumdouh, A., Al-Sharif, A., & Al-Saleh, K. (2019). Behavioral adaptation to Intelligent Transport Systems: Risks and opportunities. Transportation Research Part F: Traffic Psychology and Behaviour.
[18] Oduro, F., Mensah, S., & Ayim, I. (2020). Improving traffic management in Accra through the integration of electronic information panels: A case study. African Journal of Transportation Research, 12-25.
[19] Ojo, A., Ayeni, O., & Ezeanya, E. (2021). Intelligent traffic management systems in Lagos: Incident detection and traffic optimization for better road safety. International Journal of Transportation Science and Technology, 284-295.
[20] OMS. (2022). Global Status Report on Road Safety: Summary. World Health Organization, Geneva. http://apps.who.int/iris
[21] OMS. (2023). Accidents de la route. https://www.who.int/fr/news-room/fact-sheets/detail/road-traffic-injuries
[22] Patel, R., Venkatraman, P., Boyles, S., & Boyles, V. (2020). Data-driven, real-time traffic signal optimization: A distributed approach. https://www.semanticscholar.org/paper/47558f8181774cae546cb8434a314bcb3fb3a6a5
[23] Qureshi, A., & Abdullah, M. (2013). Challenges in the transport sector: A study on road safety, congestion, and emissions.
[24] Rochon, C., & Kendel, A. (2008). Traffic safety indicators and their implications in urban settings: The case of Cameroon. Urban Transport Journal.
[25] Szczepanik, M., & Besta, T. (2018). The impact of Intelligent Transport Systems on road safety in Poland.
[26] Tan, D. (2018). The effectiveness of Electronic Road Pricing in Singapore: A case study on congestion management.
[27] TRANSTAT. (2023). Transport statistic Cameroon.
[28] United Nations. (2024). World urbanization prospects 2024: Population and growth trends. https://population.un.org/wup/
[29] van der Merwe, S., Meyer, J., & Mosiana, A. (2015). The impact of real-time traffic monitoring and adaptive traffic signals on road safety in Johannesburg. South African Journal of Civil Engineering.