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Article

Statistical approach to the diagnosis of the dynamics of urban mobility under the influence of the road congestion situation in the city of Douala, Cameroon

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Abstract: Smooth movement is an essential function and an indicator of a healthy city. Cities being engines of growth, congestion is a real cancer for the country's economy. In this sense, linking travel habits and the increase in the level of congestion in a city is very important. The objective of this work is to diagnose, using a statistical approach, the dynamics of urban mobility influenced by the traffic congestion situation in the city of Douala. For this, the study focuses on two aspects; the first aspect concerns the multivariate descriptive analysis of motorists' travel habits. The methods used involve first submitting surveys to motorists in vehicle technical inspection centers and processing the data in IBM SPSS statistical software. Follow-up of the analysis of the correlation between the congestion level and some required solutions. The second aspect focuses on the principal component analysis (PCA) that is performed. The determination of Kaiser-Meyer-Olkin (KMO) indices, the Bartlett significances, and the Pearson correlation coefficients are also done. The results show that the travel habits of motorists create a massive use of roads at certain specific time slots, in addition to extra-municipal trips mainly oriented towards the city center and the administrative district due to the monocentric situation of the city, which contributes to the increase in the level of congestion in the city. The correlation shows that there is significance between the level of congestion and the solutions considered, but this correlation is more or less moderate, which shows that the solutions considered can be used in the short term to alleviate congestion in the city.

Keywords: traffic congestion; dynamics of urban mobility; monocentrism; polycentrism

1. Introduction

Traveling in stressful conditions is a fairly widespread social problem around the world [1]. One can be faced with stressful conditions for various reasons; particular emphasis is placed on the stress coming from long journey times put on journeys and difficult travel conditions due to heavy traffic and different stop-and-go movements induced by it [2] for peak hours. Traveling in an urban area becomes an arduous task; we get depressed just thinking about a trip and imagining the time it will take on the road when it is congested. The rapid and reliable movement of people and goods is one of the key functions of arterial and sub-arterial roads in

urban areas [3]. Mobility has fundamental importance in human life: in social interactions, it has economic factors, cultural impacts, and others [4]. Convenient living in the city is a major concept in urban planning policies, and the daily functioning of the city must facilitate the lives of citizens [5]; public space and mobility are therefore two difficult subjects in many contemporary cities [6]. Particular attention must therefore be paid to sustainable mobility in urban areas because it is essential to the proper functioning of the local and national economy [7].

According to the World Bank, cities generate more than 80% of gross domestic product (GDP) [8]. The challenge of sustaining the alignment between the population, transport systems, and the road system in a city is the preservation of the existence of the city, a source of economic income. The increasingly growing population in urban centers becomes a great challenge for public authorities with regard to the adaptation between urban development and transport in the same direction as [9]. According to Patrão et al. [10], in 2018 city dwellers represented 55% of the world population. In accordance with forecasts for 2030, this indicator will have increased to 60% and in 2050 to 70%. Cities continue to sprawl alongside population growth, while our mobility systems often fail to meet the demands of social, environmental, and economic sustainability [11]. This overcrowding of cities is not without consequences for mobility; it is even one of the major causes of the phenomenon of traffic congestion. Congestion has a negative effect on cities; traffic jams lead to loss of time, serious environmental consequences through pollution (CO_2 emissions), fuel consumption, health consequences (noise, emissions of fine particles, etc.), and economic losses (time lost in traffic jams, early deterioration of infrastructure, etc.) and can even be one of the causes of car accidents [4,12,13]. One of the significant events caused by the overcrowding of cities is undoubtedly urban sprawl, which, when the city is monocentric, considerably increases the travel distances to reach the city center, increases the use of personal vehicles, and, according to [14], it causes urban environmental problems that affect the quality of life of citizens. It is more necessary than ever, even imperative, to locally contextualize the approach of synergized solutions to guarantee fluidity of travel in the context of a highly spread-out city, all while remaining within the framework of sustainable mobility, a guarantee of sustainable life for our cities.

The literature of work related to the study of mobility by survey in cities gives us a diverse overview of the fields of mechanisms considered. Residential mobility was studied in Nigeria, more precisely in Lagos; the author [15] carried out a field survey of households and subsequently used systematic random sampling methods for data collection. A study on factors affecting modal choice in urban mobility was carried out in the city of Kalamaria in Greece. The authors [7] studied the factors that explore the choice of mode to use in travel, thanks to a questionnaire survey administered to city citizens. A study on improving non-motorized urban mobility for public business travel was carried out in the city of Nanjing in China. The methodology used by the authors [16] involves a survey of official government bicycle drivers in Gulou District in Nanjing through questionnaires and interviews with officials and citizens. Another study was conducted on modeling urban residents' travel satisfaction during morning and evening rush hours. The authors [2] used surveys and used a statistical approach by cross-analysis of variables to arrive

at the expected results. Urban accessibility provided by transport services in Turin, Italy, was evaluated; the authors [17] sought the point of view of travelers through a mobility survey. The surveys in urban mobility studies are therefore more concrete, and there is a connection with the target population of the study; it is a local approach. The literature also tells us about the diversity of work carried out to contribute to the smoother flow of traffic in urban areas. Several solution approaches are proposed to improve traffic flow. It has been shown that optimizing traffic signal control at intersections can be an important method to improve traffic efficiency and reduce traffic congestion [18–23]. The use of smart cars has also been proven as a means of combating traffic jams [24]; motorists tend to overcompensate for slowing traffic in front of them with reaction time and mentality being independent variables for each driver. Promoting the use of bicycles in city centers is also proposed as an effective means of combating climate change, energy savings, and traffic jams [16,25,26]; walking is also proposed jointly [6]. Other authors [27] believe that reconfiguring the road network can reduce traffic congestion. They propose optimization techniques to alleviate traffic congestion through reconfiguration of the one-way traffic network to divert traffic from congested areas. The plurality of non-exhaustive solutions envisaged seems worthy of interest and conducive to implementation in urban areas affected by the phenomenon of congestion.

The solutions considered have limitations in terms of their applications, which must take into account the level of development intrinsic to the cities. Can all cities, depending on the resources they have, afford to implement these solutions immediately and have the expected results? For low-income cities with a relatively low level of development, would it not be more effective to find solutions specific to their situation? It is important to categorize cities according to their level of development, to estimate for each the applicability of the solutions to congestion and to predict the effectiveness of these solutions in the long or medium term. But we believe that preliminary work must be carried out upstream, that of studying local mobility models specific to each city. Some authors [7] have required an in-depth understanding of local mobility conditions and patterns as well as the key factors that dominate citizens' preferences and modal choices in urban mobility. Likewise, understanding the dynamics of residents' daily mobility patterns is essential for the planning and management of urban facilities and services [28]. Human travel behavior can strongly contribute to and justify the choice of measures taken by public authorities to alleviate road congestion.

The city of Douala is the economic capital of Cameroon cosmopolitan due to its cultural and ethnic diversity; it is one of the most populated cities in the country and stands out as the largest city in the CEMAC zone. Due to its position as a port city, through its autonomous water port, it provides a privileged maritime access route to the Atlantic Ocean, making it the economic heart of Central Africa [12]. Douala is today facing serious congestion problems on its roads, seriously hampering mobility. Studies on traffic volume and speeds were conducted in the city of Douala. The hourly traffic volume at the Deido roundabout, a very busy intersection, is where congestion caused by the concentration of traffic is the most intense in the city of Douala [29]. The study shows that traffic peaks at 7 am in the morning, and at 6 pm in the evening for a volume of nearly 8000 vehicles/hour. Traffic speeds and

congestion indices were studied in the Douala 3rd district on the Yassa-Ndokoti [12] section; the results showed that traffic speeds are very low between 7 am–11 am and 4 pm–8 pm, with speeds varying between 1 and 10 km/h. In addition, the congestion indices found are generally higher than the limit value, which shows that this section is very congested. Studies conducted in this context have focused on studying traffic volume and estimating traffic speeds and travel times. There is no work yet on studying mobility dynamics in the city. Historically, the city was formed around the estuary of the Wouri River (gateway to the Atlantic Ocean) in the colonial period, thus giving birth to the administrative district and the city center. The development of the city is being limited on the banks of the Wouri because of the river; we are witnessing massive urban sprawl that is not evenly distributed around the city center, which makes it a predominantly monocentric city. Faced with this rather special configuration in the urbanization of this city and taking into account the congestion problems it faces, it would be interesting to understand the dynamics of the daily mobility model of residents in the city and to define the level of impact of traffic congestion in this model.

This study is a preliminary work that is part of the strategic program for promoting sustainable mobility in cities with a low or medium level of development. This article aims to achieve two objectives. The first objective is to describe the mobility dynamics of motorists in the city of Douala. The congestion situation in the city forces motorists to adopt certain travel habits. The study will focus primarily on vehicle travel because two-wheeled machines do not experience congestion in the same way as vehicles. The second objective is to establish the level of correlation between the level of traffic congestion and the solutions considered in the study. We believe that by establishing the correlation between these variables, it will be more effective to visualize the local solutions that could be considered in mitigating this congestion problem. This work will contribute to the assessment and understanding of mobility dynamics for the specific case of cities whose level of development is relatively low and under the influence of significant urban sprawl. In addition, it will contribute to producing, testing local solutions and verifying their long- or short-term effectiveness.

The rest of this article is organized as follows. Section 2 is devoted to the presentation of the study area, here on the different district municipalities of the city of Douala. In Section 2, the study methodology from establishing the survey questionnaire is derived, and the sampling method and data collection are presented. In this section, both the processing of the survey data and the statistical approach used are presented. In section 3 the results are presented as well as relevant discussion, and finally in section 4 the conclusions of this study are presented.

2. Material and method

2.1. Presentation of the study area

The city of Douala is the capital of the coastal region in Cameroon (**Figure 1a**); it is subdivided into five (05) urban district communes and one rural district commune. Among the urban district municipalities, there is the recent municipality of Douala 1st, which mainly houses the administrative and business district, the city

center, port, industrial, and railway activities. It is limited to the South and the West by the estuary of the Wouri River, to the North by the commune of Douala 5th, and to the East by Douala 2nd. The municipality of Douala 2nd mainly brings together airport activities and a central mixed zone (housing, crafts, commerce, and small industries). It is limited to the north by the commune of Douala 5th, to the west by the commune of Douala 1st, to the east by the commune of Douala 3rd, and to the south by the Wouri River. The municipality of Douala 3rd mainly contains areas with a mainly residential and spontaneous habitat vocation. It is limited to the North by the municipality of Douala 5th and Douala 1st, to the East and South by the Dibamba River, and to the West by the communes of Douala 2nd and Douala 6th. The municipality of Douala 4th mainly houses industrial activities and areas with a mainly residential vocation. Douala 5th. It is limited to the north by the Mongo division, to the south and east by the Wouri River, and to the west by the Fako division. The study is carried out mainly in the district municipalities of Douala 3rd (**Figure 2a**), Douala 4th (**Figure 2b**) and Douala 5th (**Figure 2c**), identified as municipalities very far from the administrative zone and the city center. (see **Figures 1** and **2**)

(a) **(b)**

Figure 1. (a) Littoral region; **(b)** location of the city of Douala in the littoral region.

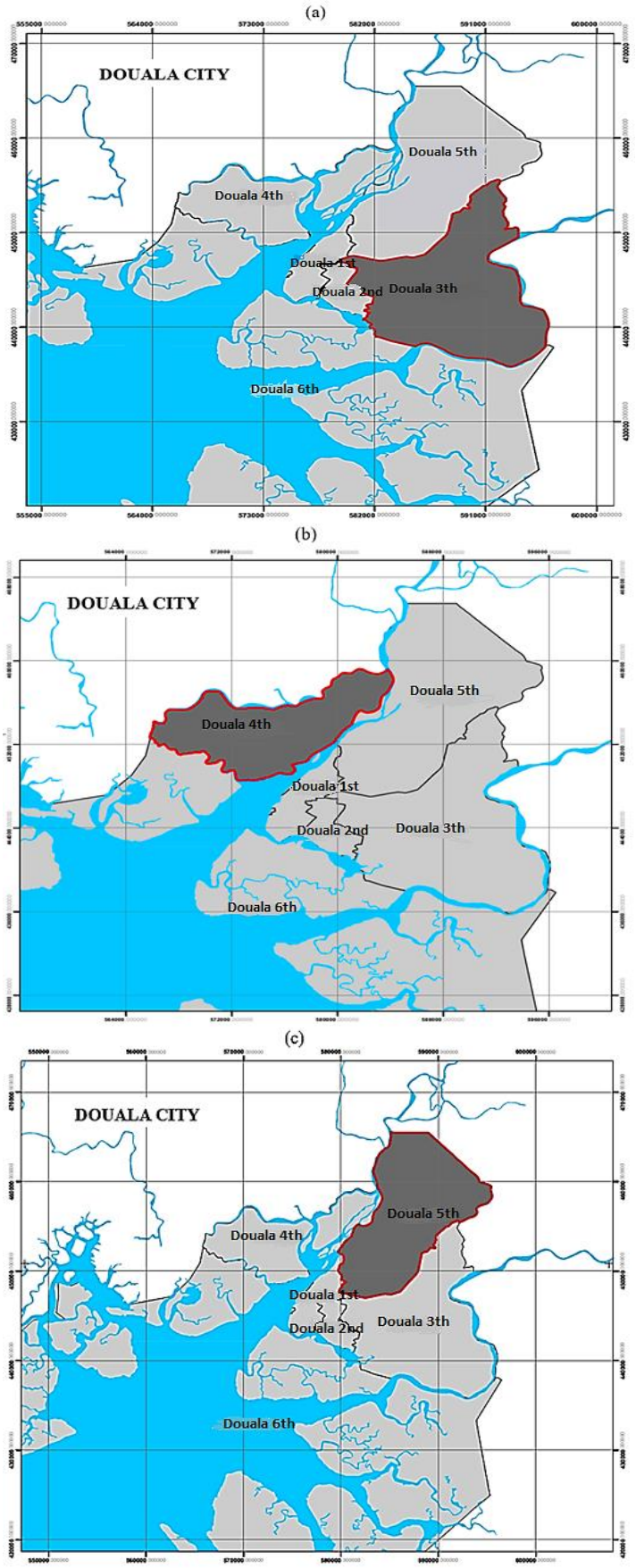


Figure 2. Location of some municipalities in the city of Douala: **(a)** Douala 3rd; **(b)** Douala 4th; **(c)** Douala 5th.

2.2. Methodology used

To carry out the present work, a working methodology is established in the form of a functional flowchart, as shown in **Figure 3**.

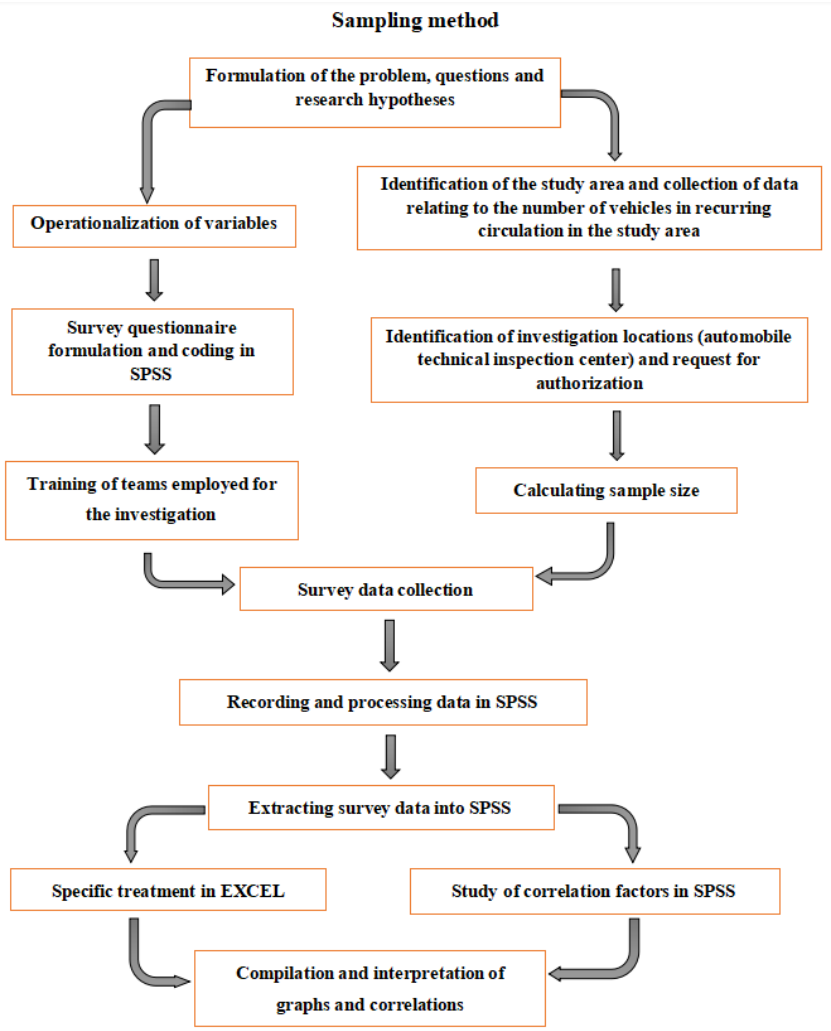


Figure 3. Flowchart summarizing the methodology used.

2.2.1. Establishment of the survey questionnaire

The variables of the questionnaire were determined according to the research questions. An operationalization was then made on the variables, and then they were coded as indicated in **Table A1** in the Appendix. The questionnaire is structured around the main axes, such as general information on the respondent, frequency of travel, reasons for travel, difficulties encountered in travel, and the proposed solution approach to ease traffic flow.

Conducting a study on the entire population of a city is very complex and very expensive. Through a representative sample, we can have an estimate of the expected responses for the entire population; the difficulty, therefore, lies in calculating a necessary sample size derived from the size of the population to deduce the results obtained for this population [30]. In the case of this study, the survey covers three distinct district municipalities assimilated to strata, and we want to evaluate the behavior of each stratum. We use here a stratified random sampling method, which

has many advantages over other sampling methods, especially when dealing with diverse populations. This method is one of the most widely used survey design methods today [31]. The accuracy is taken into account by the margin of error and the confidence interval; in general, scientists accept a margin of error of 5% in their studies and a confidence interval of 95% [32,33]. The statistical formula giving the number of motorists n to be investigated is that given in Rea and Parker [34] as follows:

$$n = \frac{t_P^2 \times P(1-P) \times N}{t_P^2 \times P(1-P) + (N-1) \times y^2} \quad (1)$$

With:

N: Number of motorists in the district municipality concerned;

P: Actual proportion (set to 0.5 by default, which allows for the largest possible sample);

t_p: Value associated with the sampling confidence interval (t_p = 1.96 for 95% confidence interval.);

y: Margin of error (5%).

The number of motorists in the district municipality (N) is difficult data to control. We obtained the data on the number of motorists registered in the technical inspection centers for the year 2022 from the statistics department of the Wouri Transport Department Delegation. **Table 1** shows the calculation of the number of vehicles by district for the year 2024. The transition of the number of vehicles from the year i to the year $i + 1$, is done by the following formula:

$$N_{i+1} = N_i \times \beta \times \gamma \quad (2)$$

Expression in which β is a coefficient that takes into account the annual growth rate of vehicles in the municipality. γ is a coefficient, which takes into account the rate of unregistered vehicles that escape the technical inspection. The values found in **Table 1** are in the same order as the sampling tables presented in the literature [30,32,33]. The numbers used in the study are greater than or equal to these minimum values.

Table 1. Calculation of sample size by district.

District municipality	Number of vehicles in the year 2022	β	γ	Sample calculated for the year 2024
Douala 3rd	11,221	0.3	0.2	374
Douala 4th	4351	0.3	0.2	356
Douala 5th	11,180	0.3	0.2	372

Source: Author.

2.2.2. Data collection

The usability of the data collected in the analysis is essential to have a more effective performance in the analysis. In this sense, a preliminary survey was carried out during the period from March 6 to 31, 2023. In this preliminary survey, several elements such as the survey sites, the target population, the survey period, and the budget allocated to the survey were adjusted in order to launch the final survey phase. Regarding the final survey phase, the data were collected by survey interviews with

motorists in technical inspection centers. The surveys took place from December 2023 to June 2024. **Table 2** shows the geographical location of the different technical inspection centers selected for the surveys.

Table 2. Geographic location of data collection locations.

Douala 3 municipality			
Number	**Name of the center**	**Latitude**	**Longitude**
1	DAC Technical Control Center	4.026348	9.791658
2	SAPTRANS Technical Inspection Center	4.026427	9.792094
3	CCTV-HYDRAC technical control center	4.029331	9.722245
Douala 4 municipality			
1	NGONO Technical Control Center	4.070222	9.680211
2	Joséphine Gilbert Technical Inspection Center	4.095545	9.653876
Douala 5 municipality			
1	CADCIA technical control center	4.048049	9.746109
2	SAS Technical Control Center	4.092685	9.74811
3	CEMEX Technical Control Center	4.06379	9.44575

2.3. Data processing and statistical approach used

2.3.1. Data processing

To study the travel behavior of motorists specific to each district municipality, we processed the data independently in order to highlight the results for each stratum. The data were recorded and processed in the IBM SPSS statistics software widely used in statistical surveys [35–38]; the results are presented in the form of graphics as expressed in section 5. The processing is subdivided into two phases. The first phase consists of carrying out a descriptive analysis and bringing out the summary tables as well as the graphs giving the proportions of respondents. The second phase consists of carrying out a bivariate correlation analysis, thus using the Pearson correlation coefficient and a bilateral significance test in order to identify significant correlations between the different variables; a development of the Pearson correlation is made in the paragraph following.

2.3.2. Statistical approach used

There are several methods or tests to show the correlation between two variables, including the Pearson correlation, which we will review in this article to show the level of significance that exists between the different variables taken into account to describe the mobility of motorists. The Pearson correlation coefficient indicates the level with which two or more variables are related in a study [39]. The value of the Pearson correlation coefficient can be interpreted according to **Table 3**; these comparison values are close to those used in other works [40], the Olkin (KMO) index, and the significance value of Bartlett's sphericity test. This approach allows for a more in-depth understanding of the relationships between factors and improves the depth of the study and is used in other studies [37].

Table 3. Interpretation of Pearson coefficient correlation [41].

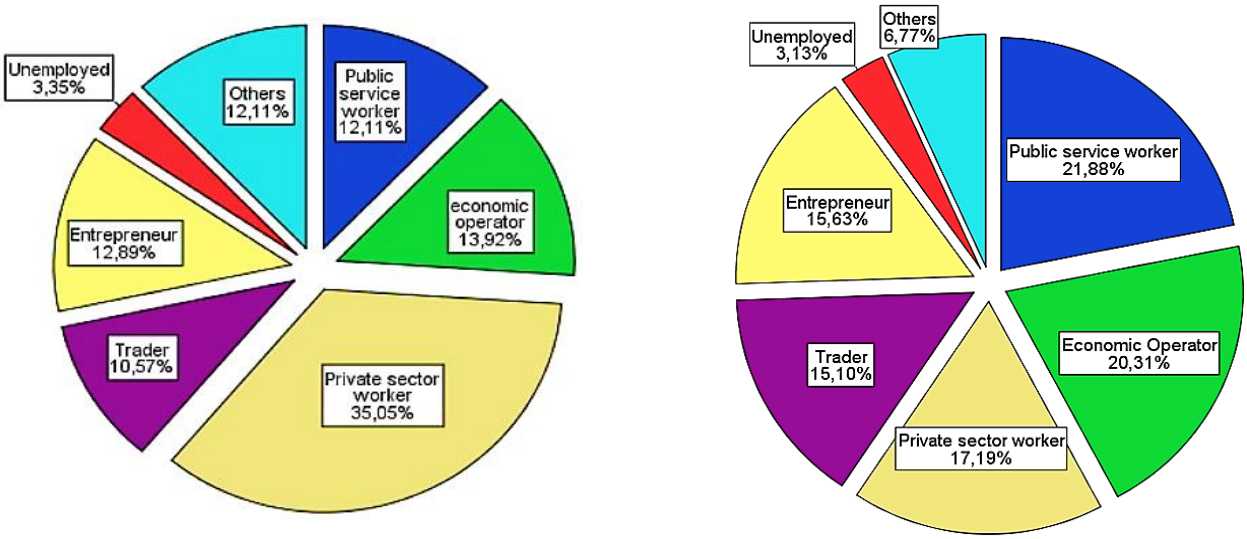
No.	Value of Pearson correlation coefficient	Interpretation of the correlation
1	0.00–0.01	Negligible
2	0.01–0.39	Weak
3	0.40–0.69	Moderate
4	0.70–0.89	Forte
5	0.90–1.00	Very strong

3. Results

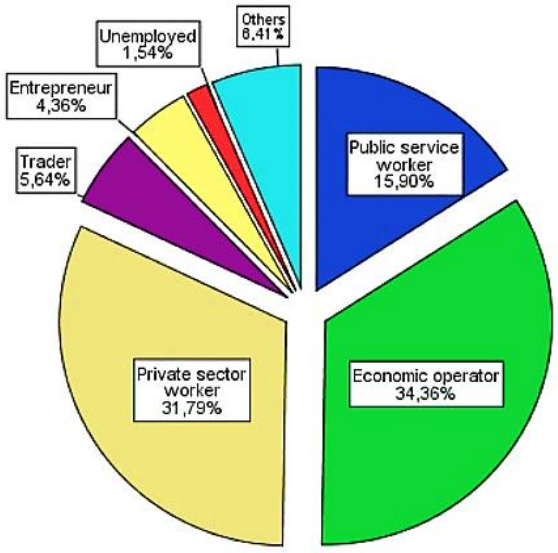
3.1. Descriptive analysis

3.1.1. Characteristics linked to predominant sectors of activity

The survey of motorists reveals that, in the district municipality of Douala 3rd, there is a dominance of private sector workers (35.05%), followed by economic operators (13.92%), entrepreneurs (12.89%), and many others (**Figure 4a**). For the district municipality of Douala of Douala 4th, there is a dominance of civil servants (21.88%), seconded by economic operators (20.31%), private sector workers (17.19%), and many others (**Figure 4b**). Economic operators (34.36%), then come private sector workers (31.79%), civil servants (15.90%), and many others dominate the district municipality of Douala 5th in the minority (**Figure 4c**). Generally, in the three municipalities, there is a predominance of private sector workers due to the multitude of companies established in the city, economic operators due to the opportunities offered by the port area, and civil servants to ensure public service in the city. (see **Figure 4**)



(a) **(b)**

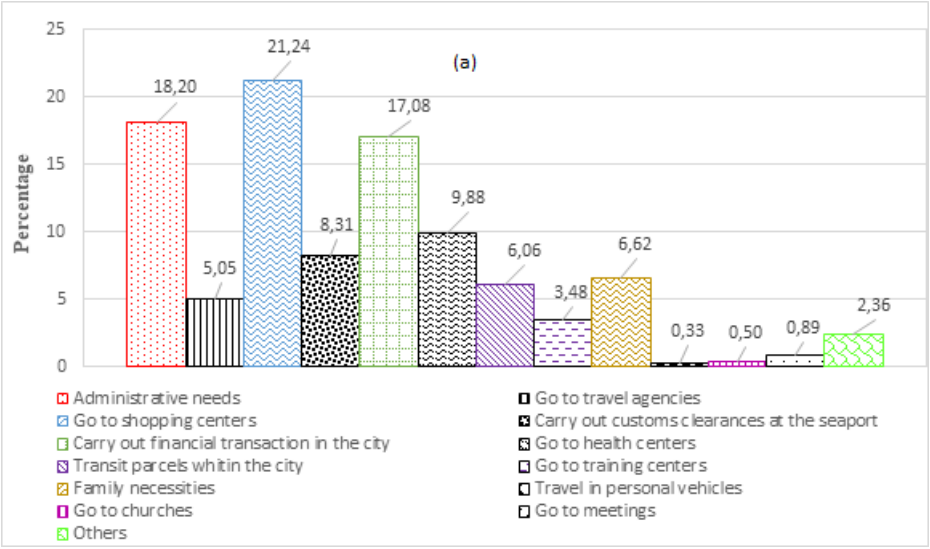


(c)

Figure 4. Predominant business sectors in the district municipalities, **(a)** Douala 3rd; **(b)** Douala 4th; **(c)** Douala 5th.

3.1.2. Characteristics describing movements

The results show that in the three district municipalities, travel time is mainly used for professional activity. Secondarily, the main reasons that motivate travel in the commune of the 3rd district of Douala are purchases (21.24%), administrative needs (18.20%), and financial transactions (17.08%), as shown in **Figure 5a**. For the commune of the 4th district, we also note that purchases (19.45%), financial transactions (18.90%), and administrative needs (16.94%) are mainly the secondary causes found (**Figure 5b**). In the same convergence with the other two communes, we also find for the commune of the 5th district of Douala secondary causes, purchases (27.18%), financial transactions (18.37%), and administrative needs (12.60%) as shown in **Figure 5c**. These results show that apart from work, there are overall three major poles leading to massive travel on the roads. (see **Figure 5**)



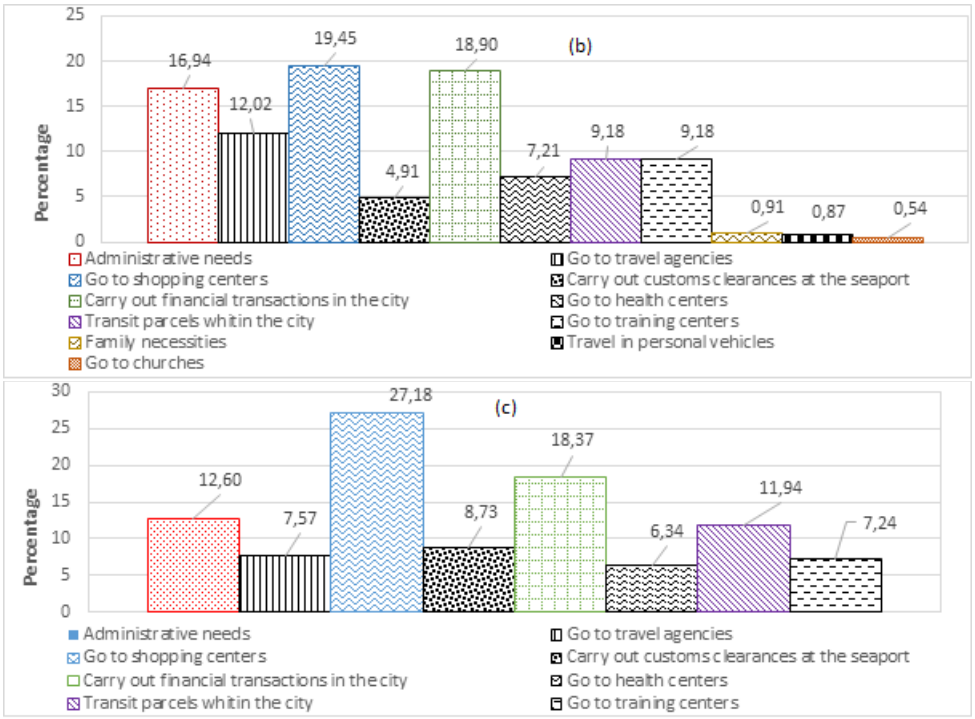
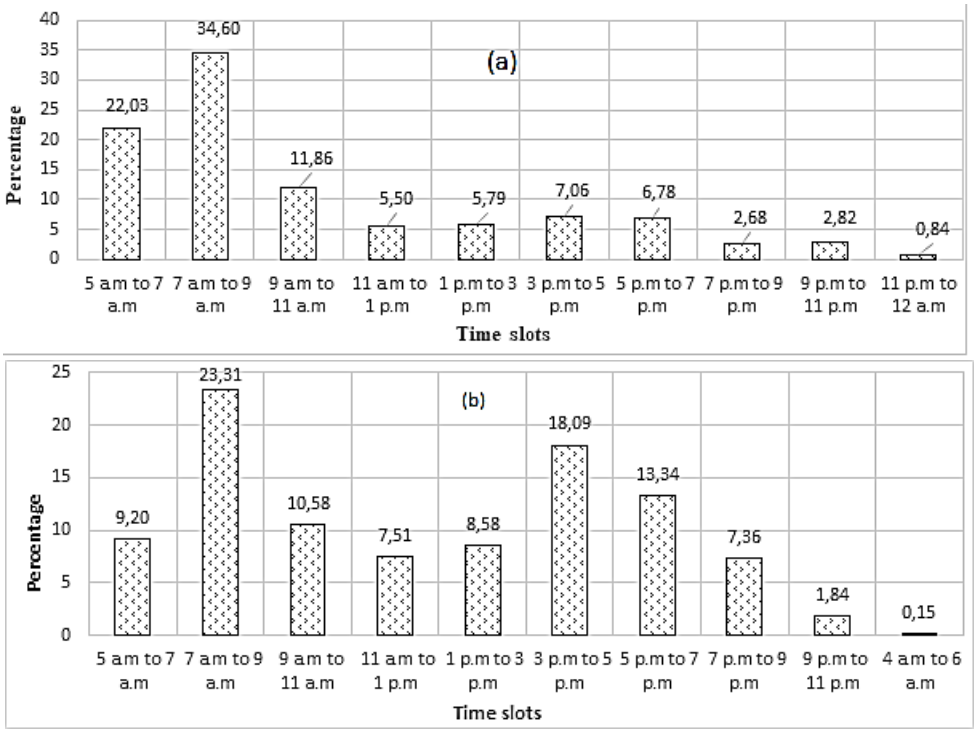


Figure 5. Secondary reasons for travel within the city, **(a)** Douala 3rd; **(b)** Douala 4th; **(c)** Douala 5th.

Mass movements occur almost every day of the week (five to six days a week). The most requested time slots for travel were also investigated, and it appears that placements are predominantly in the morning (5 a.m.–9 a.m.) and in the evening (3 p.m.–9 p.m.). It is very common to observe this form of mobility oriented towards specific time slots, very often coinciding with departure times for work and return times, as indicated by some authors [28]. **Figure 6** shows the most requested time slots for travel.



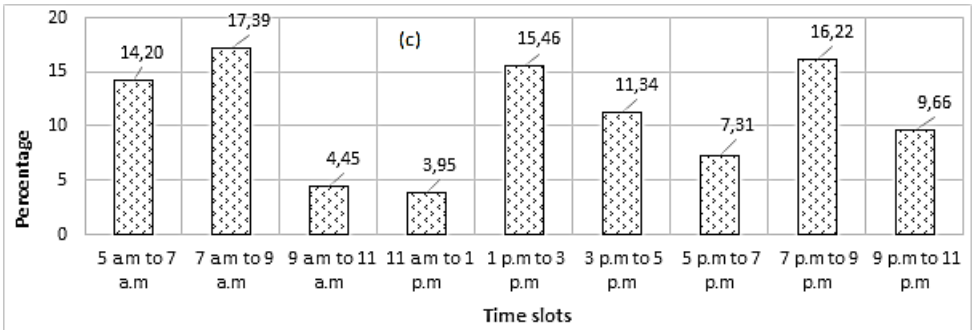
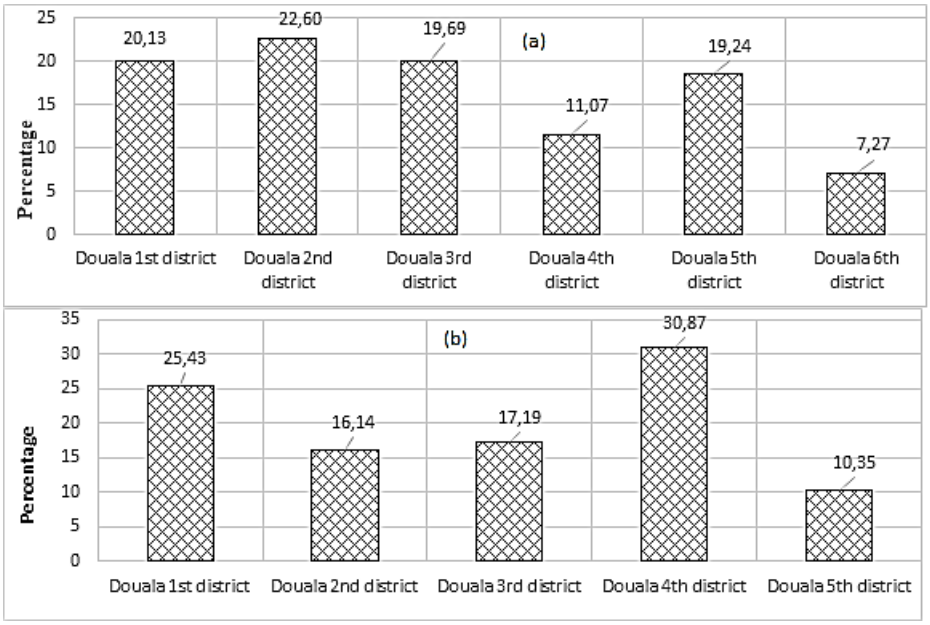


Figure 6. Most popular time slots for travel, **(a)** Douala 3rd; **(b)** Douala 4th; **(c)** Douala 5th.

It is also interesting to look at the scope of travel by looking for the district municipalities to which travel is more oriented. The results show that in the district municipality of Douala 3rd, travel is mainly extra-municipal and oriented towards the municipalities of Douala 2nd and Douala 1st, secondarily intra-municipal (**Figure 7a**). In the district municipality of Douala 4th, travel is mainly intra-municipal and secondarily extra-municipal, oriented towards the municipalities of Douala 1st and Douala 3rd (**Figure 7b**). For the district municipality of Douala 5th, travel is also mainly intra-municipal and secondarily extra-municipal and oriented towards the municipalities of Douala 1st and Douala 3rd (**Figure 7c**). It is noted that when the movements are not oriented in the municipality of residence, they converge in the city center (Douala 2nd) and the administrative district (Douala 1st), which explains the very dense traffic on the main roads of these municipalities. This result also indicates the roads with heavy traffic, so it is very urgent to increase the capacity to further smooth the traffic flow. (see **Figure 7**)



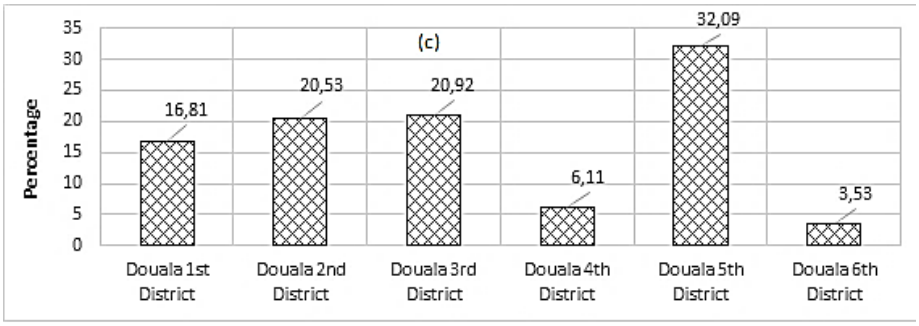


Figure 7. District municipalities most frequently used for travel, **(a)** Douala 3rd; **(b)** Douala 4th; **(c)** Douala 5th.

3.1.3. Difficulties encountered in travel

Motorists are faced with a variety of constraining elements that significantly affect mobility in the city. In the Douala 3rd district municipality, the main constraints are traffic jams (28.50%), poor road conditions (27.88%), and the glaring inadequacy of parking lots (16.20%), as shown in **Figure 8a**. (see **Figure 8**)

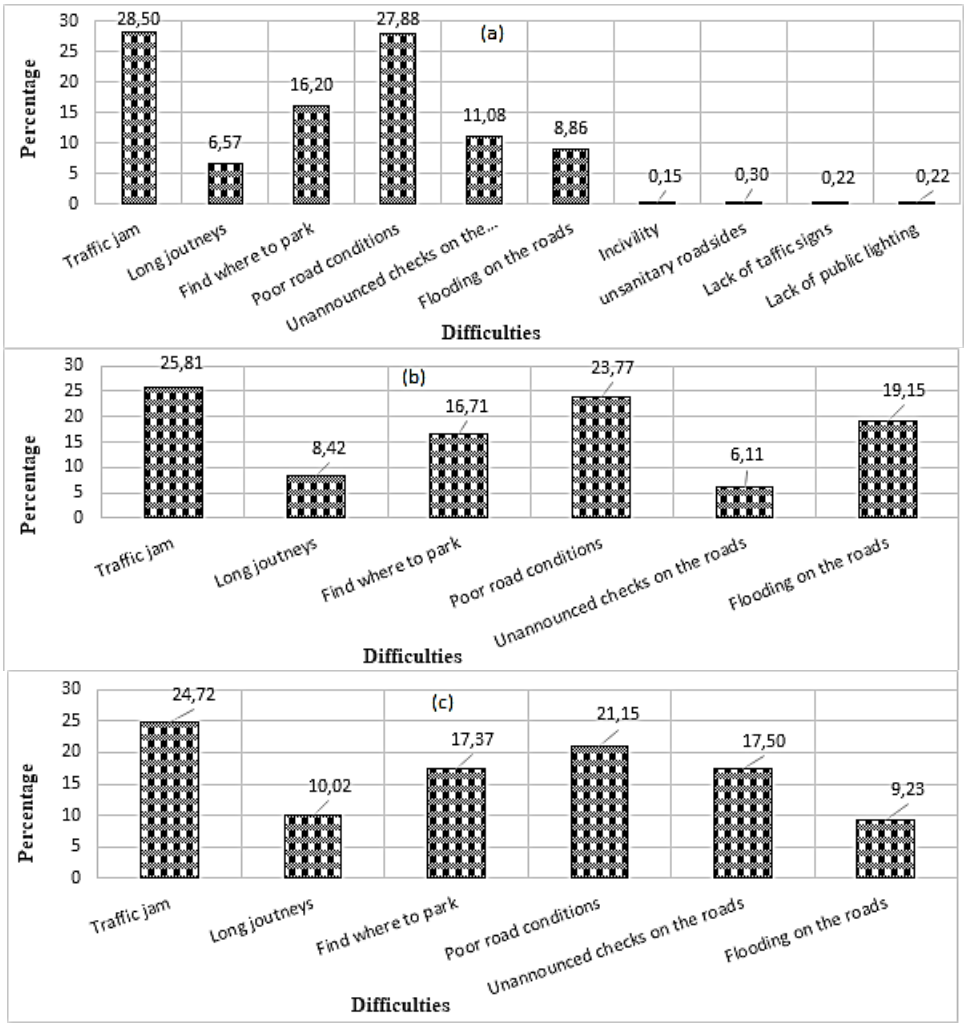


Figure 8. Nature of difficulties encountered during travel, **(a)** Douala 3rd; **(b)** Douala 4th; **(c)** Douala 5th.

For the district municipality of Douala 4th, the main reasons cited are traffic jams (25.81%), poor road conditions (23.77%), and flooding of roads during the rainy season (19.15%), as illustrated in **Figure 8b**. As for the district commune of Douala 5th, [a] similarity is observed with those of the district municipality of Douala 3rd. Traffic jams (24.72%), poor road conditions (21.15%) and the glaring inadequacy of parking lots (17.37%) are mainly observed, but there is also an influence of random checks on the roads (17.50%) observable in **Figure 8c**. Generally speaking, in the background, there are also difficulties such as very long journeys to travel each day and the incivility of citizens leading to unsanitary roads.

3.2. Correlation between mobility variables

The main factors likely to influence mobility were correlated. These include daily travel frequency (E1), weekly travel frequency (E2), traffic jam severity level (E3), mobility difficulties (E4), and solutions considered (E5). **Table 4** gives motorists' responses on this subject.

Table 4. Responses from motorists in the three district municipalities.

Douala 3rd district municipality							
No.	**Questions**	**Answers**					
4	Daily travel frequency (E1) in %	1 to 2 times/day	3 to 4 times/day	5 to 6 times/day	7 to 8 times/day	Others	
		58.25	26.55	10.31	3.86	1.03	
5	Weekly travel frequency (E2) in %	1 day	2 days	3 days	4 days	5 days	6 days	7 days
		3.60	2.83	3.35	6.70	28.87	34.54	20.10
16	Traffic jam severity level (E3) in %	Very strong	Strong	Average	Weak			
		42.01	34.28	20.88	2.83			
	Mobility difficulties (E4)	Rarely	Most often	Always				
13	Frequency of confrontation to congestion (%)	7.29	35.42	57.29				
14	Frequency of encountering difficulties when traveling (%)	2.64	30.08	67.28				
	Solutions considered (E5)	excellent	Alright	Good	fair	weak		
17a	Polycentrism (%)	9.09	15.06	30.39	36.88	8.58		
17b	Limitation of temporary occupation + road maintenance (%)	7.53	16.62	26.49	26.41	22.95		
17c	Collaboration of periodic parts control services (%)	4.67	9.09	16.62	31.69	37.93		
17d	Increase in parking spaces (%)	10.65	21.30	22.34	27.01	18.70		

Table 4. (*Continued*).

Douala 3rd district municipality								
No.	**Questions**	**Answers**						
Douala 4th district municipality								
No.	**Questions**	**Answers**						
4	Daily travel frequency (E1) in %	1 to 2 times/day	3 to 4 times/day	5 to 6 times/day	7 to 8 times/day	Others		
		17.98	25.92	44.97	11.11	0		
5	Weekly travel frequency (E2) in %	1 day	2 days	3 days	4 days	5 days	6 days	7 days
		0.53	2.13	1.06	13.36	36.36	33.69	12.83
16	Traffic jam severity level (E3) in %	Very strong	Strong	Average	Weak			
		6.25	76.56	15.10	2.08			
	Mobility difficulties (E4)	Rarely	Most often	Always				
13	Frequency of confrontation to congestion (%)	3.13	90.57	6.25				
14	Frequency of encountering difficulties when traveling (%)	3.63	82.90	13.47				
	Solutions considered (E5)	excellent	Alright	Good	fair	weak		
17a	Polycentrism (%)	10.88	18.13	41.45	26.42	3.11		
17b	Limitation of temporary occupation + road maintenance (%)	16.06	25.91	39.38	15.03	3.62		
17c	Collaboration of periodic parts control services	13.98	30.05	37.31	12.95	5.71		
17d	Increase in parking spaces (%)	48.71	23.32	14.51	12.95	0.51		
Douala 5th district municipality								
No.	**Questions**	**Answers**						
4	Daily travel frequency (E1) in %	1 to 2 times/day	3 to 4 times/day	5 to 6 times/day	7 to 8 times/day	Others		
		20.92	25.51	23.47	29.59	0.51		
5	Weekly travel frequency (E2) in %	1 day	2 days	3 days	4 days	5 days	6 days	7 days
		0.51	2.04	3.57	1.78	19.13	54.08	18.88
16	Traffic jam severity level (E3) in %	Very strong	Strong	Average	Weak			
		19.90	68.88	10.20	0.98			
	Mobility difficulties (E4)	Rarely	Most often	Always				
13	Frequency of confrontation to congestion (%)	3.57	65.05	31.38				
14	Frequency of encountering difficulties when traveling (%)	4.85	53.57	41.58				
	Solutions considered (E5)	excellent	Alright	Good	fair	weak		
17a	Polycentrism (%)	25.76	28.32	22.70	16.84	6.37		
17b	Limitation of temporary occupation + road maintenance (%)	25.76	33.16	20.66	15.05	5.36		
17c	Collaboration of periodic parts control services (%)	18.36	25.77	25.77	18.10	11.99		
17d	Increase in parking spaces (%)	43.62	19.36	20.41	13.51	3.09		

The principal components analysis (PCA) was carried out on the one hand on the mobility difficulties in the three municipalities. In Douala 3rd, a variance factor of 76.53 was retained for a Kaiser-Meyer-Olkin index of 0.5 and a Bartlett

significance of 0.000. In Douala 4th, a variance factor of 68.64 was retained for a Kaiser-Meyer-Olkin index of 0.5 and a Bartlett significance of 0.000. In Douala 5th, a variance factor of 72.56 was retained for a Kaiser-Meyer-Olkin index of 0.5 and a Bartlett significance of 0.000. On the other hand, the PCA focused on the solutions envisaged in the three municipalities. In Douala 3rd, a variance factor of 47.92 was retained for a Kaiser-Meyer-Olkin index of 0.64 and a Bartlett significance of 0.000. In Douala 4th, a variance factor of 58.61 was retained for a Kaiser-Meyer-Olkin index of 0.73 and a Bartlett significance of 0.000. In Douala 5th, a variance factor of 53.93 was retained for a Kaiser-Meyer-Olkin index of 0.73 and a Bartlett significance of 0.000. The KMO values are between 0.5 and 0.73, which shows that the data are moderately suited to the PCA. The Bartlett significance sphericity test index is 0.000, which means that the mobility variables are not independent. The components retained in the principal components analysis (PCA), the eigenvalues and the percentage contribution of the variance rate for the principal components are reported in **Table 5**.

Table 5. Factor analysis of components.

Douala 3rd district municipality						
Factor analysis (E4)						
Component	**Initial eigenvalues**			**Extraction Sums of squares of retained factors**		
	Total	**% of variance**	**% cumulative**	**Total**	**% of variance**	**% cumulative**
1	1531	76,534	76,534	1531	76,534	76,534
2	0.469	23,466	100,000			
Factor analysis (E5)						
Component	**Initial eigenvalues**			**Extraction Sums of squares of retained factors**		
	Total	**% of variance**	**% cumulative**	**Total**	**% of variance**	**% cumulative**
1	1299	32,464	32,464	1299	32,464	32,464
2	1109	27,718	60,182	1109	27,718	60,182
3	0.831	20,775	80,957			
4	0.762	19,043	100,000			
Douala 4th district municipality						
Factor analysis (E4)						
Component	**Initial eigenvalues**			**Extraction Sums of squares of retained factors**		
	Total	**% of variance**	**% cumulative**	**Total**	**% of variance**	**% cumulative**
1	1373	68,647	68,647	1373	68,647	68,647
2	0.627	31,353	100,000			
Factor analysis (E5)						
Component	**Initial eigenvalues**			**Extraction Sums of squares of retained factors**		
	Total	**% of variance**	**% cumulative**	**Total**	**% of variance**	**% cumulative**
1	1356	33,909	33,909	1356	33,909	33,909
2	1070	26,756	60,666	1070	26,756	60,666
3	0.892	22,310	82,975			
4	0.681	17,025	100,000			

Table 5. (*Continued*).

Douala 5th district municipality						
Factor analysis (E4)						
Component	**Initial eigenvalues**			**Extraction Sums of squares of retained factors**		
	Total	**% of variance**	**% cumulative**	**Total**	**% of variance**	**% cumulative**
1	1451	72,562	72,562	1451	72,562	72,562
2	0.549	27,438	100,000			
Factor analysis (E5)						
Component	**Initial eigenvalues**			**Extraction Sums of squares of retained factors**		
	Total	**% of variance**	**% cumulative**	**Total**	**% of variance**	**% cumulative**
1	1321	33,034	33,034	1321	33,034	33,034
2	0.995	24,885	57,919			
3	0.961	24,022	81,940			
4	0.722	18,060	100,000			

The study of the Pearson correlation presented in **Table 6** shows that in the three district municipalities, the P value between the variables E3 and E4, then E3 and E5, is 0.000, which shows the correlation between these variables is statistically significant and is not the effect of chance. The correlation between variables E3 and E4, then E3 and E5, is between 0.201 and 0.512 in the three district municipalities, which means that it varies from low to moderate. It can be said that the expansion in the level of severity of traffic jams increases to a more or less moderate extent the frequency of encountering difficulties during travel. It also increases to a more or less moderate extent the level of effectiveness of the solutions envisaged. The more or less moderate correlation of the solutions envisaged shows that these solutions can be used in the short term to alleviate congestion in the city. In the long term, the reconfiguration of the road network seems to be an optimal solution [27]. The urban master plan (PDU) of the city of Douala proposes a restructuring of the city through the development of a "Central Business District," the development of an exceptional site at the contact of the port, the airport, and the city center; the development of major intersections; the expansion of major roads; and the development of secondary roads.

Table 6. Correlation between groups of variables affecting mobility.

Douala 3rd district municipality						
		E1	**E2**	**E3**	**E4**	**E5**
E1	Pearson correlation	1	0.282 **	−0.095	0.056	−0.106 *
	Sig (bilateral)		0.000	0.060	0.275	0.040
	Number of people (*N*)	388	388	388	385	375
E2	Pearson correlation	0.282 **	1	−0.018	−0.034	−0.126 *
	Sig (bilateral)	0.000		0.720	0.509	0.015
	Number of people (*N*)	388	388	388	385	375

Table 6. (*Continued*).

Douala 3rd district municipality						
		E1	**E2**	**E3**	**E4**	**E5**
E3	Pearson correlation	−0.095	−0.018	1	0.264 **	0.201 **
	Sig (bilateral)	0.060	0.720		0.000	0.000
	Number of people (*N*)	388	388	388	385	375
E4	Pearson correlation	0.056	−0.034	0.264 **	1	0.167 **
	Sig (bilateral)	0.275	0.509	0.000		0.001
	Number of people (*N*)	385	385	385	385	372
E5	Pearson correlation	−0.106 *	−0.126 *	0.201 **	0.167 **	1
	Sig (bilateral)	0.040	0.015	0.000	0.001	
	Number of people (*N*)	375	375	375	372	375
Douala 4th district municipality						
E1	Pearson correlation	1	0.531 **	−0.174 **	−0.130 *	−0.142**
	Sig (bilateral)		0.000	0.001	0.011	0.006
	Number of people (*N*)	378	374	378	378	374
E2	Pearson correlation	0.531 **	1	−0.143 **	−0.079	−0.189 **
	Sig (bilateral)	0.000		0.006	0.126	0.000
	Number of people (*N*)	374	374	374	374	372
E3	Pearson correlation	−0.174 **	−0.143 **	1	0.473 **	0.512**
	Sig (bilateral)	0.001	0.006		0.000	0.000
	Number of people (*N*)	378	374	384	384	380
E4	Pearson correlation	−0.130 *	−0.079	0.473 **	1	0.232**
	Sig (bilateral)	0.011	0.126	0.000		0.000
	Number of people (*N*)	378	374	384	386	382
E5	Pearson correlation	−0.142 **	−0.189 **	0.512 **	0.232 **	1
	Sig (bilateral)	0.006	0.000	0.000	0.000	
	Number of people (*N*)	374	372	380	382	382
Douala 5th district municipality						
E1	Pearson correlation	1	0.167**	−0.102*	−0.374**	0.073
	Sig (bilateral)		0.001	0.043	0.000	0.148
	Number of people (*N*)	392	392	392	392	392
E2	Pearson correlation	0.167**	1	−0.142**	0.078	−0.191**
	Sig (bilateral)	0.001		0.005	0.121	0.000
	Number of people (*N*)	392	392	392	392	392
E3	Pearson correlation	−0.102*	−0.142**	1	0.204**	0.232**
	Sig (bilateral)	0.043	0.005		0.000	0.000
	Number of people (*N*)	392	392	392	392	392
E4	Pearson correlation	−0.374**	0.078	0.204**	1	−0.009
	Sig (bilateral)	0.000	0.121	0.000		0.863
	Number of people (*N*)	392	392	392	392	392

Table 6. (*Continued*).

Douala 5th district municipality						
	Pearson correlation	0.073	−0.191**	0.232**	−0.009	1
E5	Sig (bilateral)	0.148	0.000	0.000	0.863	
	Number of people (*N*)	392	392	392	392	392

**. The correlation is significant at the 0.01 level (two-tailed). *. The correlation is significant at the 0.05 level (two-tailed).

The solutions envisaged by this urban master plan are part of a long-term program. In the medium term, the city hall has opted for road maintenance, although the frequency of maintenance is very low. It also proceeds less recurrently to the release of mobility areas occupied by street traders; this task is very difficult because of the incivility of citizens due somewhat to the difficult economic situation currently. Some of these solutions, applied as well as they are, are among the solutions proposed in this study, but they require more frequent application.

This restructuring of the city always aims to maintain the city in its state of monocentrism. The polycentric aspect of the city (which is better adapted in view of the strong urban sprawl) should be taken into account in the restructuring programs by creating urban sub-centers in the different district municipalities studied. The frequency of motorized travel, which was approximately one trip per day according to the 2011 urban master plan, varies mainly from 2 to 6 trips per day according to the results of this study; a migration to several sub-centers could therefore reduce the heavy congestion on the main arteries leading to the city center and the administrative district.

In this study, the methodology used was developed based on the characteristics of the city studied. Indeed, the city on which the study focuses is a city whose level of development is relatively low, the updating of population data is not frequent, which required the use of a statistical approach to the study of mobility dynamics. Taking into account the adjustment coefficients made it possible to limit the margin of error. More effective methodologies can be used in the case of more developed countries for the analysis of mobility dynamics; this is the case of the direct and instantaneous analysis of GPS data from all vehicles in traffic data collection stations on the roads. This method has the advantage of directly collecting data provided by the vehicles, which are more precise compared to those given by the driver.

4. Conclusion

In this paper, the dynamics of urban mobility influenced by the traffic congestion situation in the city of Douala, Cameroon, were diagnosed. This study was about relating, on one hand, the mobility dynamics and the difficulties encountered in traveling through the city and, on the other hand, the effectiveness of the solutions envisaged and the level of road congestion. This study provided a multivariate descriptive analysis of mobility in the city and a correlation between congestion factors and the solutions envisaged.

The results of the descriptive analysis show a predominance of motorists linked to the economic activity strongly established in the city, to the central administrative

services, and to the public service. This requires frequent travel on the roads to reach the service structures. Travel is mainly oriented towards professional activity, and secondarily towards essential needs such as purchases and administrative necessities. The habits of motorists in travel create a massive use of roads at certain specific time slots. Extra-municipal travel is mainly oriented towards the city center and the administrative district due to the monocentric situation of the city, combined with travel habits that considerably affect traffic in the city, thereby contributing to the increase in the level of congestion in the city. The study of the correlation shows that there is a significance between the level of congestion and the solutions envisaged, but this correlation is more or less moderate, which shows that the solutions envisaged can be used in the short term to alleviate congestion in the city. Despite the low rate of implementation of the PDU in the city of Douala, we believe that if a polycentric vision of the city is associated with the battery of measures taken by the public authorities, this could greatly contribute to drastically reducing congestion in the city.

Some of the proposed solutions may have a positive effect on traffic-related factors. Increasing the mobility area and the good condition of the roads will have a positive impact on reducing congestion on the roads. The polycentrism of the city will strongly influence the dynamics of mobility in the city, like the frequency and reasons for travel. The creation of suburban centers will allow a reorientation of travel towards the nearest suburban centers, which must mainly integrate the functionalities that were taken as reasons for travel. Despite the low implementation rate in the execution of the PDU of the city of Douala, we believe that if a polycentric vision of the city is combined with the battery of measures taken by the public authorities, this could greatly contribute to drastically reducing the frequency and reasons for travel in the city.

As strong points, the results found here can be used and valued by the public authorities as a decision-making tool in the planning policies of the city of Douala. It is possible to make a conjecture of the results of this paper and apply it to cities configured similarly to Douala. This study also has limitations; it is noted that as a preliminary study on the diagnosis of urban mobility, this article studies in a general sense the applicability of certain solutions to the common problems encountered by the three district municipalities. The phenomenon of congestion may have similarities in its manifestation, but there is a specific aspect specific to each district that has not been the subject of in-depth development. In addition, difficulties are indicated on the approach used, which is quite expensive at the level of field surveys. In perspective, the specific aspect in terms of solutions specific to each district will be addressed, and an additional study will be conducted with the aim of establishing a map of highly congested areas at the most busy travel times.

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References

1. Jang J, Ko J. Factors associated with commuter satisfaction across travel time ranges. Transportation Research Part F: Traffic Psychology and Behaviour. 2019; 66: 393-405. doi: 10.1016/j.trf.2019.09.019
2. Jin Z, Yang X, Li C, et al. Modeling urban resident travel satisfaction during the morning and the evening peak hours: A case study in Beijing. International Journal of Transportation Science and Technology; 2024.
3. Yang JS. A study of travel time modeling via time series analysis. In: Proceedings of 2005 IEEE Conference on Control Applications, 2005. CCA 2005; August 2005. pp. 855-860.
4. Almeida A, Brás S, Sargento S, et al. Exploring bus tracking data to characterize urban traffic congestion. Journal of Urban Mobility. 2023; 4: 100065. doi: 10.1016/j.urbmob.2023.100065
5. Lindov O, Omerhodžić A, Mujić A, et al. Sustainable Urban Mobility Living Lab: Case study Sarajevo. Transportation Research Procedia. 2022; 64: 25-33. doi: 10.1016/j.trpro.2022.09.004
6. Ravazzoli E, Torricelli GP. Urban mobility and public space. A challenge for the sustainable liveable city of the future. The Journal of Public Space. 2017; 2(2): 37. doi: 10.5204/jps.v2i2.91
7. Tyrinopoulos Y, Antoniou C. Factors affecting modal choice in urban mobility. European Transport Research Review. 2012; 5(1): 27-39. doi: 10.1007/s12544-012-0088-3
8. Organisation des Nations Unies. World urbanization prospects: the 2003 revision population database. Organisation des Nations Unies (ONU); 2007.
9. Costa PB, Neto GCM, Bertolde AI. Urban Mobility Indexes: A Brief Review of the Literature. Transportation Research Procedia. 2017; 25: 3645-3655. doi: 10.1016/j.trpro.2017.05.330
10. Patrão C, Moura P, Almeida AT de. Review of Smart City Assessment Tools. Smart Cities. 2020; 3(4): 1117-1132. doi: 10.3390/smartcities3040055
11. Papadakis DM, Savvides A, Michael A, et al. Advancing sustainable urban mobility: insights from best practices and case studies. Fuel Communications. 2024; 20: 100125. doi: 10.1016/j.jfueco.2024.100125
12. Esse FLE, Cyrille MA, Kenmogne F, et al. Estimation of Measurement Parameters of Urban Traffic Congestion: Case of a Road Section of the Douala 3rd District Commune in Cameroon. ResearchGate; 2024.
13. Ali MS, Adnan M, Noman SM, et al. Estimation of Traffic Congestion Cost-A Case Study of a Major Arterial in Karachi. Procedia Engineering. 2014; 77: 37-44. doi: 10.1016/j.proeng.2014.07.030
14. Galiano G, Forestieri G, Moretti L. Urban sprawl and mobility. Urban and Maritime Transport XXVII. 2021; 1: 245-255. doi: 10.2495/ut210201
15. Aliu IR. Unpacking the dynamics of intra-urban residential mobility in Nigerian cities: Analysis of low-income families in Ojo Lagos. Cities. 2019; 85: 63-71. doi: 10.1016/j.cities.2018.12.005
16. Shi F. Improving urban non-motorized mobility for public affairs trips: A survey and analysis of innovative official bicycles in Nanjing city, China. Journal of Urban Management. 2019; 8(3): 396-407. doi: 10.1016/j.jum.2019.03.005
17. Ceccato R, Deflorio F, Diana M, et al. Measure of urban accessibility provided by transport services in Turin: a traveller perspective through a mobility survey. Transportation Research Procedia. 2020; 45: 301-308. doi: 10.1016/j.trpro.2020.03.020
18. Wei J, Ju Y. Research on optimization method for traffic signal control at intersections in smart cities based on adaptive artificial fish swarm algorithm. Heliyon. 2024; 10(10): e30657. doi: 10.1016/j.heliyon.2024.e30657
19. Wang H, Liu R, Wang P, et al. Intelligent optimization of dynamic traffic light control via diverse optimization priorities. International Journal of Intelligent Systems. 2021; 36(11): 6748-6762. doi: 10.1002/int.22567
20. Li Z, Xu C, Zhang G. A deep reinforcement learning approach for traffic signal control optimization. arXiv; 2021.
21. Wang P. Traffic signal optimization control in five-road intersection based on artificial fish swarm algorithm. Control Engineering of China. 2019; 26(7): 1284.
22. Ma C, He R. Green wave traffic control system optimization based on adaptive genetic-artificial fish swarm algorithm. Neural Computing and Applications. 2015; 31(7): 2073-2083. doi: 10.1007/s00521-015-1931-y
23. Lu B, Wang Q, Wang Y. An improved artificial fish swarm algorithm for traffic signal control. International Journal of Simulation and Process Modelling. 2019; 14(6): 488. doi: 10.1504/ijspm.2019.106158

24. Sharke P. Smart Cars. Mechanical Engineering. 2003; 125(03): 50-52. doi: 10.1115/1.2003-mar-2
25. Bachand-Marleau J, Larsen J, El-Geneidy AM. Much-Anticipated Marriage of Cycling and Transit. Transportation Research Record: Journal of the Transportation Research Board. 2011; 2247(1): 109-117. doi: 10.3141/2247-13
26. Krizek KJ, Stonebraker EW. Assessing Options to Enhance Bicycle and Transit Integration. Transportation Research Record: Journal of the Transportation Research Board. 2011; 2217(1): 162-167. doi: 10.3141/2217-20
27. Karimi H, Ghadirifaraz B, Shetab Boushehri SN, et al. Reducing traffic congestion and increasing sustainability in special urban areas through one-way traffic reconfiguration. Transportation. 2021; 49(1): 37-60. doi: 10.1007/s11116-020-10162-4
28. Liu L, Biderman A, Ratti C. Urban mobility landscape: Real time monitoring of urban mobility patterns. In: Proceedings of the 11th international conference on computers in urban planning and urban management, Citeseer; 2009. pp. 1-16.
29. République du Cameroun. Information gathering/verification study for the development of the transport network in Douala in the Republic of Cameroon (French). Japan International Cooperation Agency (JICA); 2017.
30. Kotrlik J, Higgins C. Organizational research: Determining appropriate sample size in survey research appropriate sample size in survey research. Information technology, learning, and performance journal. 2001; 19(1): 43.
31. Reddy KG, Khan MGM. Constructing efficient strata boundaries in stratified sampling using survey cost. Heliyon. 2023; 9(11): e21407. doi: 10.1016/j.heliyon.2023.e21407
32. Taherdoost H. Determining sample size; how to calculate survey sample size. International Journal of Economics and Management Systems. 2017; 2.
33. Ali SA. Sample size calculation and sampling techniques. Journal of the Pakistan Medical Association. 2012; 62(6): 624.
34. Rea LM, Parker RA. Designing and conducting survey research: A comprehensive guide. John Wiley & Sons; 2014.
35. Singh AS, Masuku MB. Sampling techniques & determination of sample size in applied statistics research: An overview. International Journal of economics, commerce and management. 2014; 2(11):1-22.
36. Mustafa A, Basha E. Survey data show the correlation between school attachment dimensions and internet addiction among secondary school students in Kosovo. Data in Brief. 2023; 51: 109638. doi: 10.1016/j.dib.2023.109638
37. Islam MA, Bhuiyan MAF. Factors affecting citizen safety of urban transportation service in Bangladesh: The case of Pabna municipality. Heliyon. 2024; 10(2): e24697. doi: 10.1016/j.heliyon.2024.e24697
38. Li W, Feng W, Yuan H. Multimode Traffic Travel Behavior Characteristics Analysis and Congestion Governance Research. Feng Z, ed. Journal of Advanced Transportation. 2020; 2020: 1-8. doi: 10.1155/2020/6678158
39. Lalinde JDH, Castro JFE, Tarazona MEP, et al. On the proper use of Pearson's correlation coefficient: definition, properties and assumptions (Spanish). AVFT – Archivos Venezolanos de Farmacología y Terapéutica. 2018; 37(5).
40. Santiago K, Yanes A, Mercado-Caruso N. Analyzing Correlations in Sustainable Tourism Perception: Statistical Insights from Diverse Caribbean Colombian Tourist Sites. Procedia Computer Science. 2024; 231: 490-495. doi: 10.1016/j.procs.2023.12.239
41. Rahadian H, Bandong S, Widyotriatmo A, et al. Image encoding selection based on Pearson correlation coefficient for time series anomaly detection. Alexandria Engineering Journal. 2023; 82: 304-322. doi: 10.1016/j.aej.2023.09.070

Appendix

Table A1. Operationalization and coding of variables.

No.	Variable	Code
A → General information about respondent		
1	Age group	1 = 21 to 30 years; 2 = 31 to 40 years; 3 = 41 to 50 years; 4 = 51 to 60 years; 5 = 61 to 70 years; 6 = 71 to 80 years; 7 = 81 to 90 years; 8 = Others
2	District municipality of residence	1 = Douala 1st; 2 = Douala 2nd; 3 = Douala 3rd; 4 = Douala 4th; 5 = Douala 5th
3	Professional sector	1 = Civil servant; 2 = Operator Economic; 3 = Private sector worker; 4 = Trader; 5 = Entrepreneur; 6 = Unemployed; 7 = Others
B → Frequency of movement		
4	Daily frequency of travel for professional activity	1 = 1 to 2 times; 2 = 3 to 4 times; 3 = 5 to 6 times; 4 = 7 to 8 times; 5 = Others
5	Weekly number of days of travel for professional activity	1 = 1 day; 2 = 2 days; 3 = 3 days; 4 = 4 days; 5 = 5 days; 6 = 6 days; 7 = 7 days
6	Most popular time slots for travel	1 = 5 a.m.–7 a.m.; 2 = 7 a.m. –9 a.m.; 3 = 9 a.m.–11 a.m.; 4 = 11 a.m.–1 p.m.; 5 = 1 p.m.–3 p.m.; 6 = 3 p.m.–5 p.m.; 7 = 5 p.m.–7 p.m.; 8 = 7 p.m.–9 p.m.; 9 = 9 p.m. and 11 p.m.
C → Reasons for travel		
7	Percentage of travel allocated to professional activity	1 = 1 to 20%; 2 =21 to 40%; 3 = 41 to 60%; 4 = 61 to 80%; 5 = 81 to 100%
8	Other reasons for travel outside of professional activity	1 = Administrative necessity; 2 = Go to travel agencies; 3 = Make purchases; 4 = Go to the port area; 5 = Make financial transactions; 6 = Go to hospitals; 7 = Others (to be indicated); 8 = Carry out parcel transit; 9 = Go to training institutions
9	Travel range	1 = Always outside my municipality; 2 = Most often outside my municipality; 3 = Rarely outside my municipality; 4 = Always in my municipality
10	District municipalities most in demand for travel	1 = Douala 1st; 2 = Douala 2nd; 3 = Douala 3rd; 4 = Douala 4th; 5 = Douala 5th; 6 = Douala 6th
D → Difficulties encountered in travel		
11	Frequency of encountering difficulties during travel	1 = Always; 2 = Most often; 3 = Rarely; 4 = Never
12	Nature of difficulties encountered during travel	1 = Traffic congestion; 2 = Very long journeys; 3 = Finding somewhere to park; 4 = Poor road conditions; 5= Random checks on the roads; 6 = Flooding of the roads; 7 = Others
13	Frequency of encountering traffic congestion	1 = Always; 2 = Most often; 3 = Rarely; 4 = Never
14	Average time spent traveling to work when traffic is flowing smoothly	1 = 1 to 5 min; 2 = 6 to 10 min; 3 = 11 to 15 min; 4 = 16 to 20 min; 5 = 21 to 30 min; 6 = 31 to 60 min; 7 = 61 to 80 min; 8 = Others (to be indicated)
15	Average time spent traveling to work when traffic is congested	1 = 1 to 5 min; 2 = 6 to 10 min; 3 = 11 to 15 min; 4 = 16 to 20 min; 5 = 21 to 30 min; 6 = 31 to 60 min; 7 = 61 to 80 min; 8 = 81 to 120 min; 9 = Others (to be indicated)
16	Severity level of traffic congestion during travel	1 = Very strong; 2 = Strong; 3 = Medium; 4 = Weak
E → proposed solution approach to smooth traffic flow		
17	Validation of proposed solutions is likely to contribute to the smoothing of traffic in the city	• Polycentrism: 1 = Yes, 2 = No; • Limitation of temporary occupation and congestion of public roads combined with permanent road maintenance: 1 = Yes, 2 = No; • Creation of a joint inspection service (municipality and Ministry of Transport, etc.) for periodic parts for vehicles: 1 =

		Yes, 2 = No; • Creation of private car parks and the multiplication of parking areas: 1 = Yes, 2 = No; • Others (to be specified).
18	Services to be found in sub-centers of district municipalities after polycentralization	• Administrative services: 1 = Yes, 2 = No; • Port services: 1 = Yes, 2 = No; • Shopping centers: 1 = Yes, 2 = No.

Source: Author.