Non-Climate Impact Assessment for the Transport Sector using the TRACE-tool

ICAT
Initiative for Climate Action Transparency

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Table of contents

List of Tables

List of Figures

Introduction

Transport is responsible for almost 30% of global CO_2 emissions and is one of the few industrial sectors where emissions keep growing (Chapman, 2007). Car use, road freight and aviation are the major contributors to greenhouse gas (GHS) emissions from the transport sector. These emissions would have or already having untold impacts on transport infrastructure (Atampugre et al., 2020). It also has economic and health implications (Essel et al., 2020; Andreasen et al., 2020). Ghana is one of the many countries around the world since the Paris Agreements in COP 21 to have prepared and submitted to the UNFCCC, a Nationally Determined Contribution (NDC) to reduce GHG with the first update in COP 26 (Saisirirat et al., 2022).

Recent medium-term development policy frameworks including the “Coordinated Programme of Economic and Social Development Policies (CPESD) 2017-2024 and the “National Climate Change Policy” and its related action plans and strategies show ambitious commitment from the Government of Ghana (GoG). Some of the Initiatives, such as plans for mass movement of urban dwellers on high occupancy buses, affordable and convenient public transport, and cleaner transportation, seek to the sustainability of road transport infrastructure and service and mitigate climate change variability.

Ghana has developed an “Energy Transition Framework (2020-2070)” aimed at gradually eliminating vehicles powered by fossil fuel combustion, a major contributor to emissions from the transport sector. The major policy implication for decarbonization in the transport sector as a whole and urban transport in particular is to promote active transport and electric vehicles.

The Cooperation Agreement between the United Nations Office for Project Services (UNOPS) and the Environmental Protection Agency of Ghana has been implementing the “Initiative for Climate Action Transparency (ICAT) project in Ghana. The first phase of the ICAT Project was implemented between 2017-2019. The second phase of the ICAT project was established in 2020. The ICAT Phase 2 project is designed to strengthen the results of work done in Phase 1. The current assignment, which is part of activities for Phase 2, focuses on the application of the “Transport Sector Climate Action Co-Benefits Evaluation (TRACE) tool for the quantitative evaluation of non-climate impacts of decarbonizing urban transport in Ghana.

This assignment used the TRACE tool to quantify the non-climate benefits of decarbonization strategies in the urban transport sector based on ICAT Phase 2 project activities. The TRACE tool models Ghana’s urban transport sector contributions to the NDC with respect to improving reduced travel time, air quality, and protecting human health from 2020-2040. This is despite the updated NDC covering 2020-2030.

Objective of the project

The overall objective is to quantitatively evaluate the non-climate impacts of decarbonizing urban transport in Ghana. Specifically, the assignment seeks to develop a national methodological framework for measuring these impacts from 2020 to 2040.

Project Scope

A TRACE tool is used to quantitatively evaluate the non-climate impacts of decarbonising urban transport in Ghana. This is achieved in collaboration with United Nations Environmental Protection Copenhagen Climate Centre (UNEPCCC) experts and national experts using relevant data and the TRACE tool used to analyse a selection of non-climate impacts associated with the implementation of key actions (reduced travel time, fuel savings, air quality and health benefits) to decarbonise urban transport in Ghana from 2020-2040.

Ghana is a West African Country bounded by Burkina Faso in the north, Cote Ivoire in the west, Togo in the east, and the Gulf of Guinea in the South. More than 31 million live in Ghana (GSS, 2021), making it the second most populous country in West Africa after Nigeria. Ghana is one of the fastest-growing economies in Africa, with a GDP of about 17.2 billion, which the World Bank projects to increase by 4% annually until 2030.

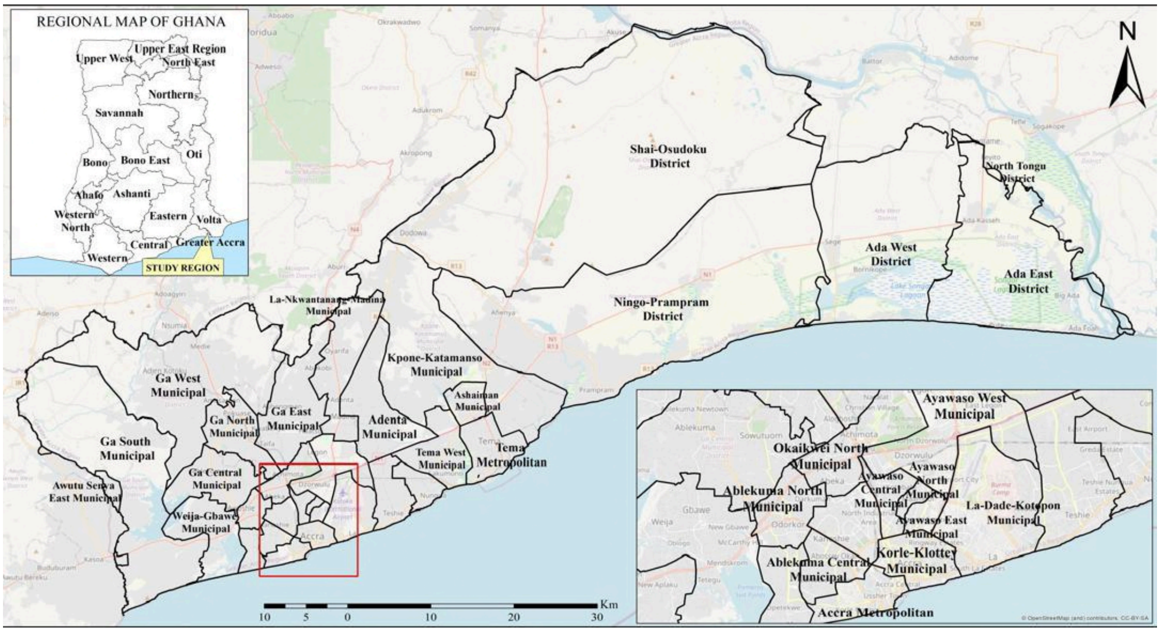

Figure 1:Map of Ghana

Technical concepts

TRACE-tool: The transport sector climate action co-benefits evaluation tool, or TRACE-tool, is an excel-based model to support quantitative evaluation of selected non-climate impacts decarbonizing the urban transport sector.

Co-benefits: Co-benefits are used to understand the multiple dimensions of a policy beyond its intended benefits. Thus, co-benefits may have numerous different definitions. In this assignment, co-benefits are simultaneous reductions of GHS, local air pollutant emissions and incidents of road crashes (fatalities).

Ministry of Transport: The Ministry is a major stakeholder when it comes to decarbonizing the urban transport sector in Ghana. Their roles are being carried out by relevant stakeholders including Driver and Vehicle Licensing Authority (DVLA), and National Road Safety Authority (NRSA).

Relevant Stakeholders: The relevant stakeholders including DVLA, BRRI, EPA, National Population Council (NPC), Ghana Statistical Service (GSS), Departments of Urban Roads, Ghana Highways Authority, National Experts on the ICAT project, UNEP officials were engaged appropriately and the views/inputs reflecting in the results.

Non-Climate impacts assessment for the transport sector using the TRACE-tool.

Impact assessment: TRACE-tool was used to assess the non-climate impacts of decarbonizing urban transport in Ghana.

Methodology for non-climate impacts assessment using TRACE-tool

The Trace Tool

The TRACE model is used to conduct the study and determine the additional benefits derived from the transport sector's goal related to the introduction of electric vehicles.

TRACE is a tool that more broadly assesses the co-benefits of decarbonisation measures/actions for the urban transport sector. It determines how the impacts of climate action are derived, i.e., it allows visualising additional benefits to reducing emissions by implementing mitigation measures in the sector.

In this way, a more comprehensive assessment can help in decision-making processes to develop policy instruments that can deliver more ambitious climate action and make important contributions to a variety of sustainable development goals.

The tool does not model ways or pathways to decarbonise the transport sector per se but rather complements existing tools for these purposes by facilitating expanded analysis of the impacts associated with the measures or actions implemented.

TRACE enables a comparison of scenarios to assess the actions' effects by determining four types of impacts: road congestion, traffic accidents, fuel savings and air pollution. In this way, the costs avoided by road congestion, the annual time lost due to said congestion, the number of traffic accidents avoided annually, the amount of fuel saved and its costs, as well as the yearly impacts avoided on health due to air pollution and the years of life lost due to this cause can be obtained.

The tool presents the results in several ways (graphs, tables) that facilitate their understanding and communication, mainly to decision-makers.

The results provided by TRACE may be relevant for decision-makers, not only regarding fuel savings but also in relation to road congestion and accidents. These can provide elements for the design and implementation of specific policies, programs, or projects in any of the transport sector branches aimed at expanding or developing the country's roads and routes, both at national and local levels.

Figure 2 shows the detailed methodology for quantitatively evaluating the co-benefits of decarbonizing urban transport in the Ghana.

Online meetings with officials of UNEP experts, Ministry of Transport and EPA: Engaged UNEP experts on the TRACE-tool for its eventual deployments to develop a methodological framework for measuring non-climate impacts from decarbonizing the urban transport in Ghana. A weekly online was initiated with MoT and EPA to consider the relevant initiatives to be captured in the TRACE-tool. A bi-monthly meeting was held with UNEP officials, MoT and EPA for progress report.

Consult the Ministry of Transport and other relevant Stakeholders: Engagement with the MoT and relevant stakeholders on TRACE scenarios, their involvement and strategies for data collection weeks. This included exchange with group of national experts working within the ICAT Phase 2 project as well as a parallel initiative to inform the NDC, support to data collection, modeling and analysis as well as handover of tools and guidance documentation for future use by the team in the EPA, Ghana. Meetings (Physical or on-line) were held bi-monthly with the MoT and EPA. Minutes were shared with those concerned a day after the conduct of sector policy and initiatives scan.

Collect and process relevant data: The relevant stakeholders were asked to provide the relevant data. The data utilization sheet included population, Gross Domestic Product (GDP), GDP/capita, transport activity by transport mode and mode type, number of vehicles, utilization rate, annual average travel distance, average occupancy, modal share, fuel efficiency, road traffic crash data (fatalities), urban road infrastructure. The data on vehicles was available from the Ghana LEAP model.

The Ministry of Roads and Highways provided information on the total lengths of different categories of roads in the Region from 2020-2023, along with information on EPA air pollution emissions. Due to the limited time available for this evaluation, the consultant also relied on secondary data from multiple sources for each category.

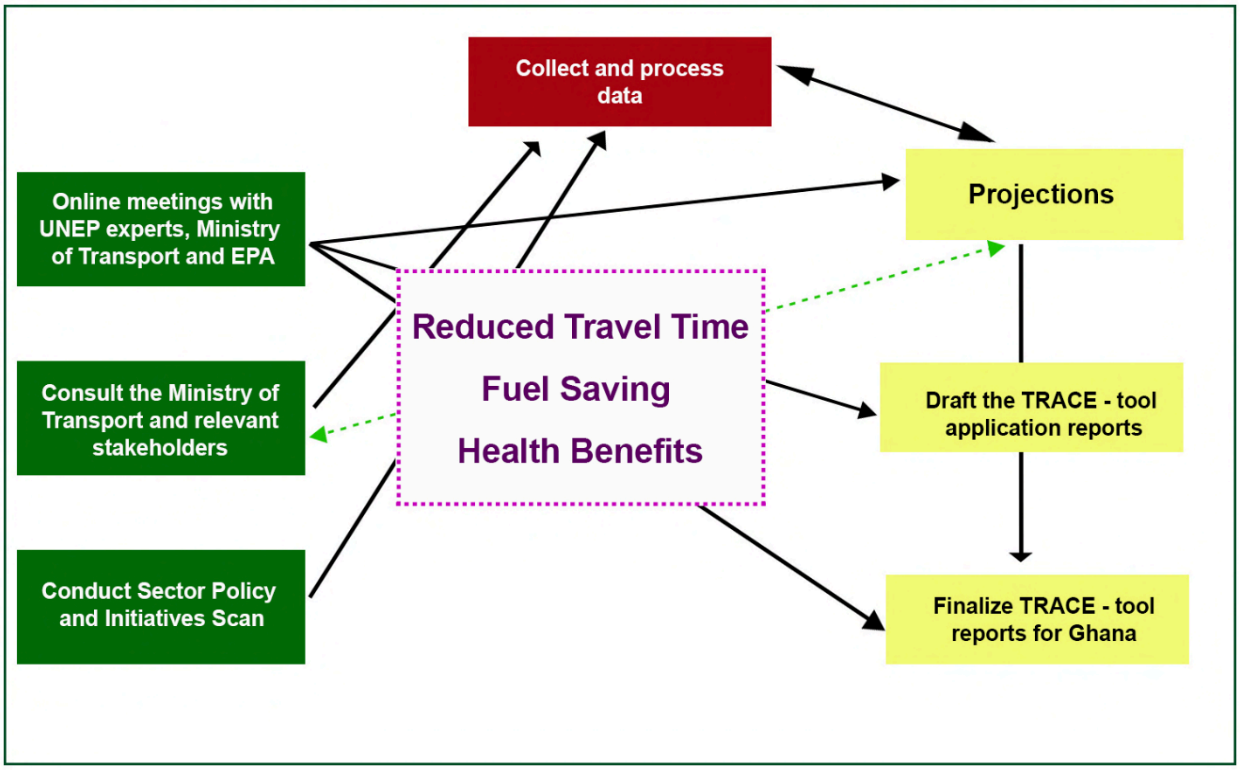

Figure 2: Methodological framework for quantitatively evaluating co-benefits of decarbonising urban transport in Ghana

Data and Projections:

In Table 1, the data on Ghana's population, GDP, and per capita GDP are presented. The data on GDP and population have been taken from World Bank data and Ghana Statistics and projected using the trend line method.

Table 1: General Input Data

	Unit	2020	2025	2030	2035	2040
Population	k people	31.585	34.672	37.985	41.298	44.611
GDP	Ghck	358535380	576120446,5	774753136,9	973385827,3	1172018518
GDP / capita	Ghc /capita	11.351	16.616	20.396	23.570	26.272

Table 2 presents data on transport activity by different modes. This data has been derived from the leap model for Ghana. The values were only available until 2019. These have been projected using the trendline projection method.

Table 2:Transport activity by mode type

Transport activity by	Unit	2020	2025	2030	2035	2040
LDV	pkm	25.540.293.600	31.850.517.600	38.160.741.600	44.470.965.600	50.781.189.600
2W	pkm	3.601.401.778	4.781.095.212	5.960.788.646	7.140.482.081	8.320.175.515
Bus	pkm	222.056.400.000	262.488.109.091	302.919.818.182	343.351.527.273	383.783.236.364
HDV large	tkm	4.984.654.133	5.961.083.345	6.937.512.558	7.913.941.770	8.890.370.982
HDV small	tkm	4.268.541.600	5.658.677.236	7.048.812.873	8.438.948.509	9.831.225.861
Small cargo	tkm	1.574.496	1.546.248	2.148.168	2.750.088	3.352.008

Table 3 shows the vehicle occupancy from different modes; these values were derived after consulting with the EPA and from the data that used the Ghana LEAP model.

Table 3: Vehicle Occupancy

Vehicle occupancy		Unit	2020
Occupancy	LDV	person/vehicle	1,8
Occupancy	2W	person/vehicle	1,0
Occupancy	Bus	person/vehicle	50,0
Occupancy	Light rail	person/vehicle	-
Occupancy	HDV large	person/vehicle	1,0
Occupancy	HDV small	person/vehicle	1,0
Occupancy	Small cargo	person/vehicle	1,0

In Table 4, the input data on distances travelled by each mode considered in this study is given, these have also been derived from the Ghana LEAP model.

Table 4: Average annual distance travelled

Average annual distance travelled		Unit	2020	2025	2030	2035	2040
Distance	LDV	vkm	51.000	51.000	51.000	51.000	51.000
Distance	2W	vkm	4.838	4.828	4.828	4.828	4.828
Distance	Bus	vkm	10.950	10.950	10.950	10.950	10.950
Distance	Light rail	vkm	-	-	-	-	-
Distance	HDV large	vkm	73.000	73.000	73.000	73.000	73.000
Distance	HDV small	vkm	36.500	36.500	36.500	36.500	36.500
Distance	Small cargo	vkm	2.372	2.372	2.372	2.372	2.372

Non-Climate impacts assessment for the transport sector using the TRACE-tool.

According to the Ministry of Roads and Highways, as of 2021, the total road network in Ghana was estimated to be approximately 80,000 kilometers (km). This includes:

1. Trunk roads: 14,500 km
2. Urban roads: 15,500 km
3. Feeder roads: 50,000 km

However, only about 23% of the total road network is paved, which equates to around 18,400 km of paved roads, so in this study on the paved road are considered. The remaining 77% (61,600 km) are unpaved roads.

Table 5: Road Length

Road length	Unit	2020
Mixed traffic roads	km	18.400

Draft the TRACE-tool application report: After input from UNEP experts, a draft of the TRACE-tool application report was submitted to the EPA, Ghana. EPA feedback was considered before the results were shared with the Ministry of Transport.

Finalize TRACE-Tool reports for Ghana: After meeting with EPA and Ministry of Transport, a final TRACE-Tool report for Ghana was submitted.

Impacts of the project in the country

The approach for the quantitative assessment of non-climate impacts of decarbonization strategies in the urban transport sector in Ghana is insightful and assisted in improving the analysis and projections behind the NDCs and strengthening capacity and awareness. The assignment used the TRACE tool to quantify the non-climate benefits of decarbonization strategies in the urban transport sector of the Ghana based on ICAT Phase 2 project activities, travel time, air quality, and health impacts.

The TRACE tool modelled Ghana's urban transport sector's contributions to recent NDC concerning air quality, reduced travel time and human health impacts. The introduction of the TRACE tool is of great help in decarbonising the urban transport sector in Ghana. For instance, the tool was used to model passenger, freight, and transport activities using fuel in Ghana. This helped estimate the congestion level in the Ghana, with the average speed travelled in the congested state being 39,41 km/h. The TRACE-tool was also used in the model LDE, litres of diesel equivalent fuel.

Nationally, more than 60% of fatalities occur in Children and persons under 35 years of age. The economic cost of these premature deaths is unquantifiable, as quite a number of the victims are breadwinners. The AIR PROLIM tool could have provided information on the number of premature deaths and years of life lost associated with health impacts such as Chronic Obstructive Pulmonary Disease (COPD), lung cancer (LC), ischemic heart disease (ISD) and Stroke among persons above 25 years of age.

Utilising the AIR-PROLIM tool could have helped in checking the revised NDC, which seeks to avoid at least 2,900 premature deaths annually from improved air quality between 2020 and 2030. The current assignment could not reveal the number of premature deaths and years of life lost in the Ghana with estimated health impact cost.

Determination of co-benefits for both scenarios

Below are the preliminary results obtained by determining the four types of impacts associated with the mitigation actions implemented in the sector. The specific results for each scenario and the total results are presented in aggregate form for each.

The BAU Scenario: Impacts without mitigation measures

Type of Impact: ROAD CONGESTION

The parameters determined associated with congestion are the time lost due to congestion, modelled for urban areas, and the cost of that congestion. Tables 6 and 7, and Figures 3 and 4 show the annual delay values for the entire period for each of the vehicle types and the delay costs.

Table 6. Annual delay by vehicle type (h). BAU scenario

Vehicle Type	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	h	80566257	84547348	88528438	92509529	96490620	100471710	104452801	108433892	112414983	116396073	120377164
2W	h	11360537	12104800	12849064	13593327	14337590	15081853	15826116	16570379	17314642	18058905	18803168
Bus	h	700471704	725979879	751488055	776996230	802504406	828012581	853520757	879028933	904537108	930045284	955553459
Light rail	h	0	0	0	0	0	0	0	0	0	0	0
HDV large	h	491374	510625	529876	549127	568377	587628	606879	626130	645380	664631	683882
HDV small	h	3168239	3374599	3580959	3743280	3947241	4151201	4355162	4559122	4763082	4967043	5171003
Small cargo	h	4967	9247	2711	3738	4498	4878	5257	5637	6017	6397	6776
Total	h	796063078	826526498	856979102	887395231	917852731	948309851	978766972	1009224092	1039681212	1070138333	1100595453

Vehicle Type	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	h	124358255	128339345	132320436	136301527	140282618	144263708	148244799	152225890	156206980	160188071
2W	h	19547431	20291694	21035957	21780220	22524483	23268746	24013009	24757272	25501535	26245798
Bus	h	981061635	1006569810	1032077986	1057586161	1083094337	1108602512	1134110688	1159618864	1185127039	1210635215
Light rail	h	0	0	0	0	0	0	0	0	0	0
HDV large	h	703133	722383	741634	760885	780136	799387	818637	837888	857139	876390
HDV small	h	5374964	5578924	5782885	5986845	6190806	6394766	6598727	6803885	7008032	7212179
Small cargo	h	7156	7536	7916	8295	8675	9055	9435	9814	10194	10574
Total	h	1131052573	1161509693	1191966814	1222423934	1252881054	1283338175	1313795295	1344253613	1374710920	1405168227

Table 7:Total cost of delay (thousand Ghc). BAU scenario

Vehicle Type	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	Ghck	246.533	258.715	270.897	283.079	295.261	307.443	319.626	331.808	343.990	356.172	368.354
2W	Ghck	28.004	29.838	31.673	33.508	35.342	37.177	39.011	40.846	42.681	44.515	46.350
Bus	Ghck	2.906.958	3.012.816	3.118.675	3.224.534	3.330.393	3.436.252	3.542.111	3.647.970	3.753.829	3.859.688	3.965.547
Light rail	Ghck	-	-	-	-	-	-	-	-	-	-	-
HDV large	Ghck	4.078	4.238	4.398	4.558	4.718	4.877	5.037	5.197	5.357	5.516	5.676
HDV small	Ghck	23.128	24.635	26.141	27.326	28.815	30.304	31.793	33.282	34.771	36.259	37.748
Small cargo	Ghck	24	46	13	18	22	24	26	28	30	32	33
Total	Ghck	3.208.725	3.330.288	3.451.798	3.573.023	3.694.551	3.816.078	3.937.604	4.059.130	4.180.656	4.302.182	4.423.709

Vehicle Type	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	Ghck	380.536	392.718	404.901	417.083	429.265	440.004	453.629	465.811	477.993	490.175
2W	Ghck	48.184	50.019	51.854	53.688	55.523	57.357	59.192	61.027	62.861	64.696
Bus	Ghck	4.071.406	4.177.265	4.283.124	4.388.983	4.494.841	4.600.700	4.706.559	4.812.418	4.918.277	5.024.136
Light rail	Ghck	-	-	-	-	-	-	-	-	-	-
HDV large	Ghck	5.836	5.996	6.156	6.315	6.475	6.635	6.795	6.954	7.114	7.274
HDV small	Ghck	39.237	40.726	42.215	43.704	45.193	46.682	48.171	49.668	51.159	52.649
Small cargo	Ghck	35	37	39	41	43	45	47	48	50	52
Total	Ghck	4.545.235	4.666.761	4.788.287	4.909.814	5.031.340	5.151.424	5.274.392	5.395.927	5.517.455	5.638.983

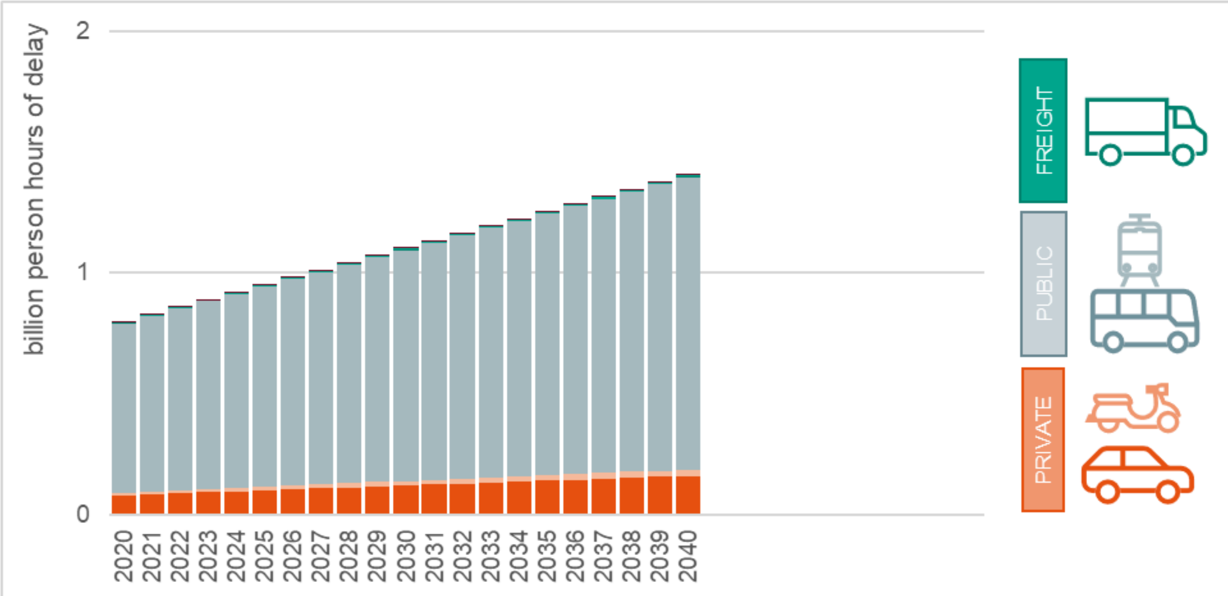

Figure 3 : Time lost due to congestion in hours

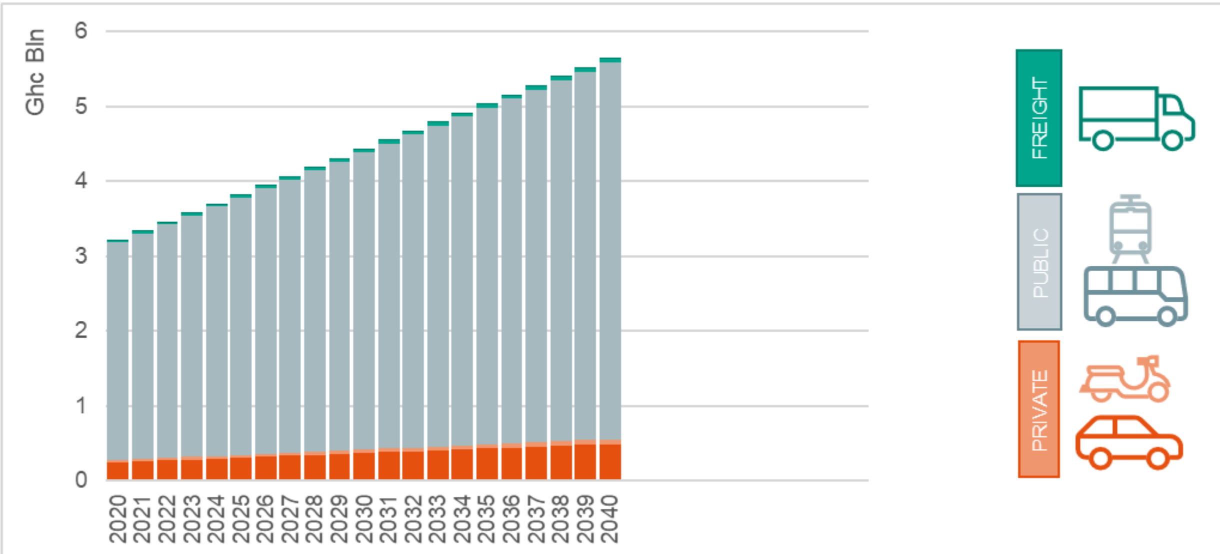

Figure 4: Cost of congestion

Type of Impact: TRAFFIC ACCIDENTS

Table 8 shows the average annual cost of traffic accidents from 2018 to 2030, expressed in monetary values. This includes the impact of deaths from this cause and non-fatal injuries, which are a significant and considerable number in this cost, property damage, and medical costs associated with accidents.

Table 8. Table Average annual cost of traffic accidents (thousand GhC). BAU scenario

	Unit	2020 - 2040
Fatalities	Ghck	303.790
Nonfatal injuries	Ghck	168.985
Property damage c	Ghck	56.032
Medical costs	Ghck	15.695
Total	Ghck	544.503

The behaviour of traffic accidents and each of its elements show a slightly increasing trend throughout the entire period, as can be seen in Figure 5 and in the values presented in Table 9.

Figure 5: Cost of traffic accidents by type of impact (thousand GhC). BAU scenario

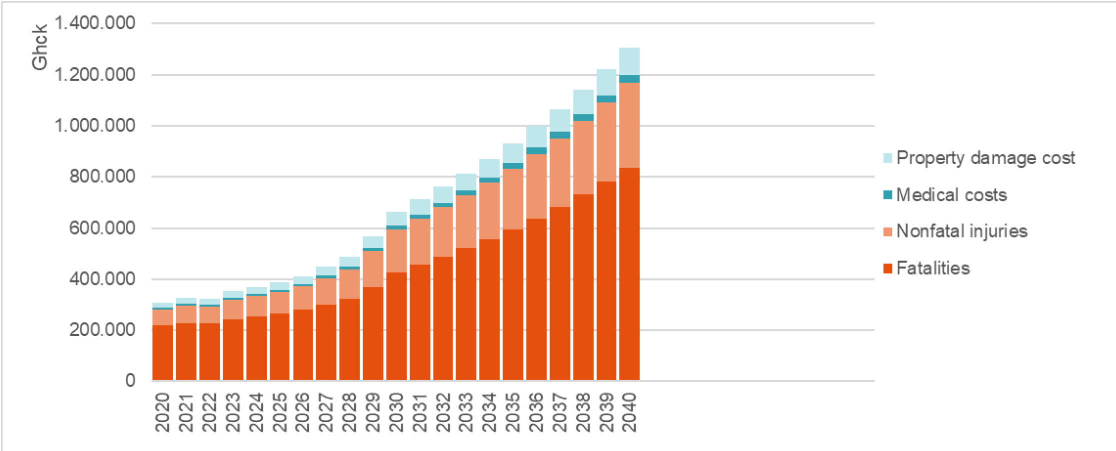

Table 9: Traffic accident costs (thousand Ghc). BAU scenario

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Fatalities	Ghck	221.000	225.500	226.000	243.500	254.500	266.000	280.000	301.000	324.000	367.000	425.500
Nonfatal injuries	Ghck	61.117	70.118	67.197	75.836	79.101	84.610	92.352	103.640	114.848	142.021	168.144
Property damage c	Ghck	20.265	23.250	22.281	25.146	26.228	28.055	30.622	34.365	38.081	47.091	55.753
Medical costs	Ghck	5.676	6.513	6.241	7.044	7.347	7.858	8.578	9.626	10.667	13.191	15.617

	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Fatalities	Ghck	455.500	487.500	520.500	557.000	596.000	638.000	681.000	730.500	781.500	836.000
Nonfatal injuries	Ghck	180.744	193.329	206.186	220.829	235.872	252.844	270.087	289.372	309.344	331.101
Property damage c	Ghck	59.931	64.104	68.367	73.222	78.210	83.838	89.555	95.950	102.572	109.786
Medical costs	Ghck	16.787	17.956	19.150	20.510	21.908	23.484	25.085	26.877	28.732	30.752

Impact Type: FUEL SAVINGS

Figures 6 and 7 show the annual fuel consumption for each of the years of the study and its costs, whose linear behaviour is because the number of vehicles in each category or group remains constant throughout the entire period.

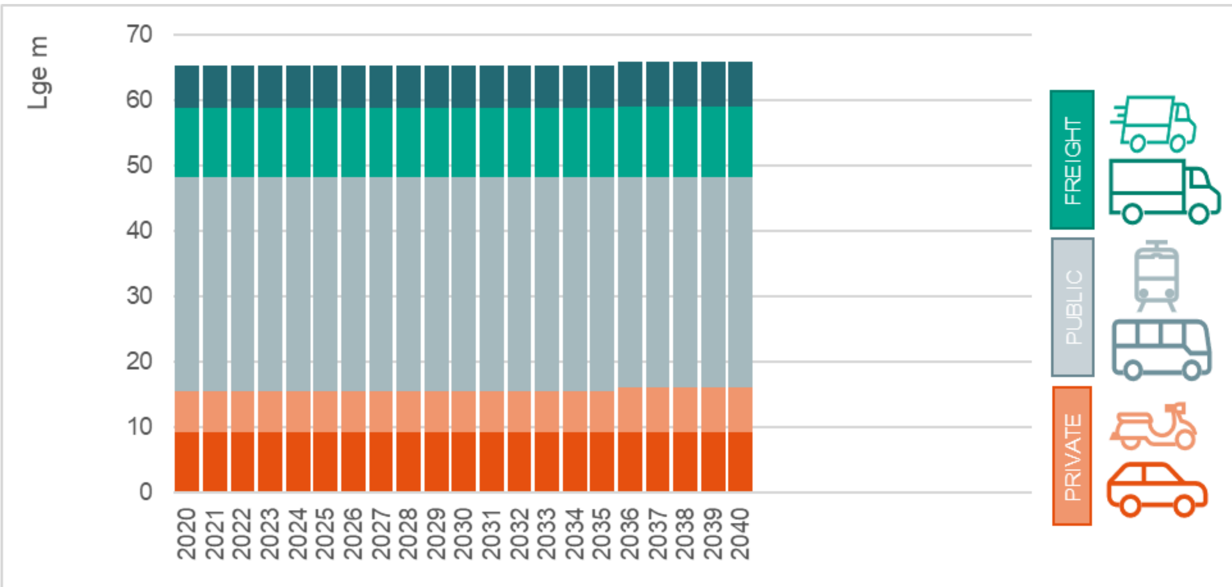

Figure 6: Annual fuel consumption (thousands of litres of diesel) eq). BAU scenario

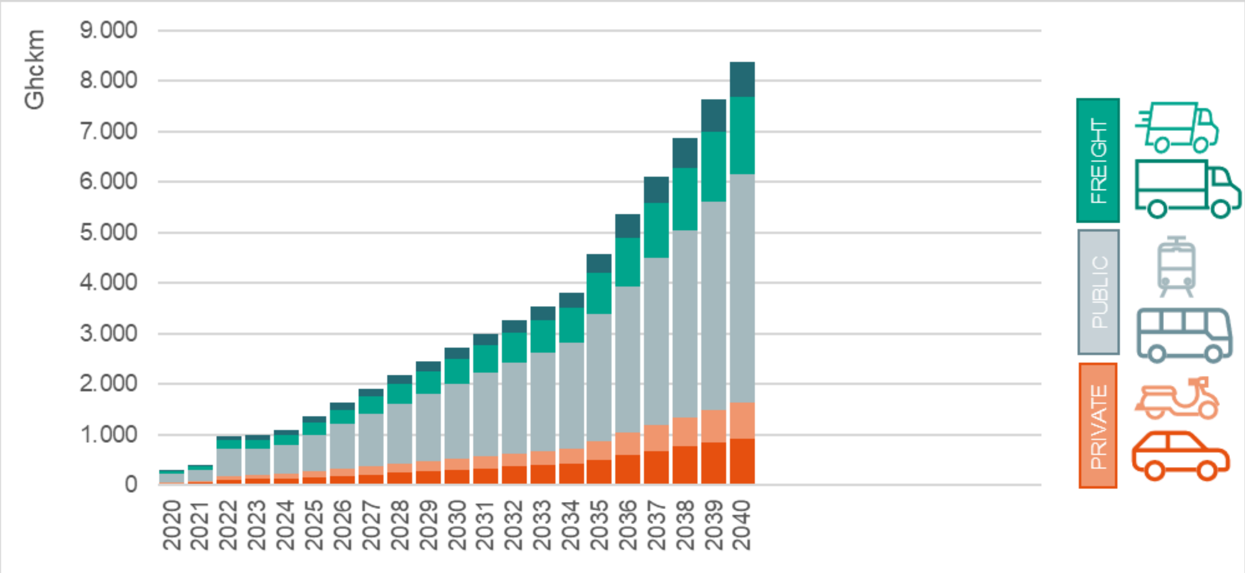

Figure 7 : Fuel costs (Million Ghc). BAU scenario

Figure 8 shows the structure of fuel consumption over the period. It concentrates on the consumption of diesel, mainly gasoline, which corresponds to the types of vehicles considered in this scenario.

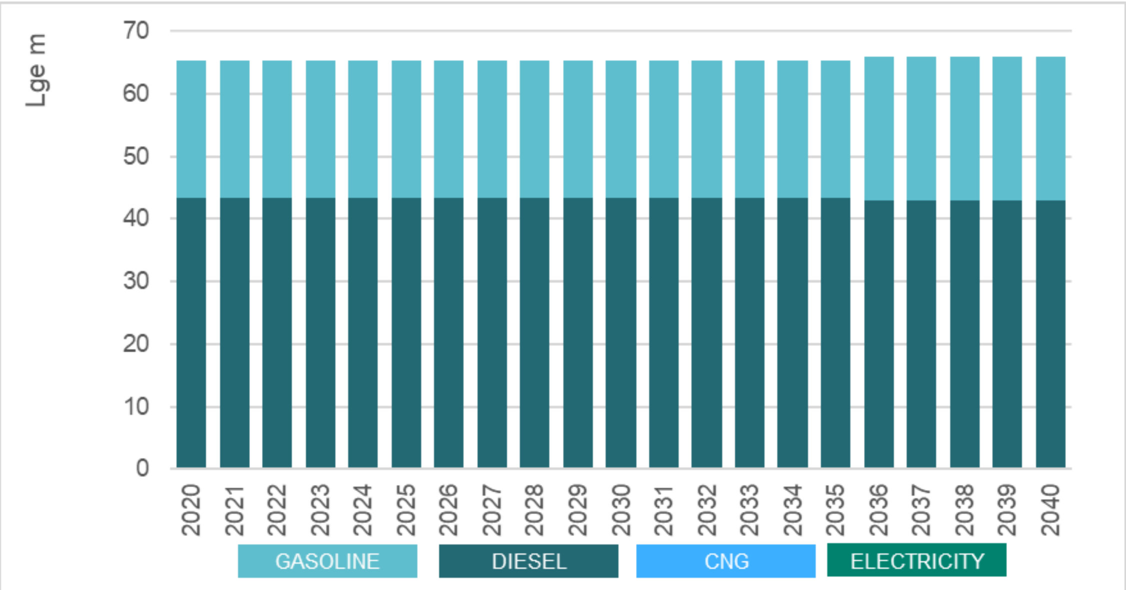

Figure 8: Fuel consumption structure (thousands of liters of diesel) eq). BAU scenario

Tables 10 and 11 present the numerical values throughout the period, showing the aggregate consumption and costs by type of vehicle and fuel and the total values.

Table 10. Fuel consumption (millions of litres of diesel) eq). BAU scenario

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	Lge m	9	9	9	9	9	9	9	9	9	9	9
2W	Lge m	6	6	6	6	6	6	6	6	6	6	6
Bus	Lge m	33	33	33	33	33	33	33	33	33	33	33
HDV small	Lge m	11	11	11	11	11	11	11	11	11	11	11
Small cargo	Lge m	6	6	6	6	6	6	6	6	6	6	6
LDV	Lge m	9	9	9	9	9	9	9	9	9	9	9
2W	Lge m	6	6	6	6	6	6	6	6	6	6	6
Bus	Lge m	33	33	33	33	33	33	33	33	33	33	33
Light rail	Lge m	-	-	-	-	-	-	-	-	-	-	-
HDV large	Lge m	-	-	-	-	-	-	-	-	-	-	-
HDV small	Lge m	11	11	11	11	11	11	11	11	11	11	11
Small cargo	Lge m	6	6	6	6	6	6	6	6	6	6	6
Total	Lge m	65	65	65	65	65	65	65	65	65	65	65
Diesel	Lge m	43	43	43	43	43	43	43	43	43	43	43
Gasoline	Lge m	22	22	22	22	22	22	22	22	22	22	22

	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	Lge m	9	9	9	9	9	9	9	9	9	9
2W	Lge m	6	6	6	6	6	7	7	7	7	7
Bus	Lge m	33	33	33	33	33	32	32	32	32	32
HDV small	Lge m	11	11	11	11	11	11	11	11	11	11
Small cargo	Lge m	6	6	6	6	6	7	7	7	7	7
LDV	Lge m	9	9	9	9	9	9	9	9	9	9
2W	Lge m	6	6	6	6	6	7	7	7	7	7
Bus	Lge m	33	33	33	33	33	32	32	32	32	32
Light rail	Lge m	-	-	-	-	-	-	-	-	-	-
HDV large	Lge m	-	-	-	-	-	-	-	-	-	-
HDV small	Lge m	11	11	11	11	11	11	11	11	11	11
Small cargo	Lge m	6	6	6	6	6	7	7	7	7	7
Total	Lge m	65	65	65	65	65	66	66	66	66	66
Diesel	Lge m	43	43	43	43	43	43	43	43	43	43
Gasoline	Lge m	22	22	22	22	22	23	23	23	23	23

Table 11: Fuel costs (million Ghc). BAU scenario

		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	Ghcm	40	52	105	123	131	161	191	221	251	281	311
2W	Ghcm	28	36	74	86	91	112	133	154	175	196	217
Bus	Ghcm	164	216	545	523	586	737	889	1.040	1.191	1.342	1.493
HDV small	Ghcm	54	71	179	172	192	242	292	341	391	440	490
Small cargo	Ghcm	28	36	74	86	91	112	133	154	175	196	217
LDV	Ghcm	40	52	105	123	131	161	191	221	251	281	311
2W	Ghcm	28	36	74	86	91	112	133	154	175	196	217
Bus	Ghcm	164	216	545	523	586	737	889	1.040	1.191	1.342	1.493
HDV small	Ghcm	54	71	179	172	192	242	292	341	391	440	490
Small cargo	Ghcm	28	36	74	86	91	112	133	154	175	196	217
Total	Ghcm	313	411	977	989	1.092	1.365	1.638	1.911	2.184	2.456	2.729

		2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	Ghcm	341	371	402	432	514	602	686	769	852	936
2W	Ghcm	238	259	281	302	359	452	514	577	639	702
Bus	Ghcm	1.644	1.795	1.947	2.098	2.516	2.887	3.298	3.709	4.121	4.532
HDV small	Ghcm	540	589	639	688	826	963	1.100	1.237	1.375	1.512
Small cargo	Ghcm	238	259	281	302	359	452	514	577	639	702
LDV	Ghcm	341	371	402	432	514	602	686	769	852	936
2W	Ghcm	238	259	281	302	359	452	514	577	639	702
Bus	Ghcm	1.644	1.795	1.947	2.098	2.516	2.887	3.298	3.709	4.121	4.532
HDV small	Ghcm	540	589	639	688	826	963	1.100	1.237	1.375	1.512
Small cargo	Ghcm	238	259	281	302	359	452	514	577	639	702
Total	Ghcm	3.002	3.275	3.548	3.821	4.574	5.355	6.112	6.869	7.626	8.383

Benefits with mitigation measures (MIT scenario: Modal shift to Buses)

Similar to the BAU scenario, the results of the MIT scenario are presented.

Type of Impact: ROAD CONGESTION

Figures 9 and 10 show the results regarding time lost due to congested traffic and the cost of delay in urban areas.

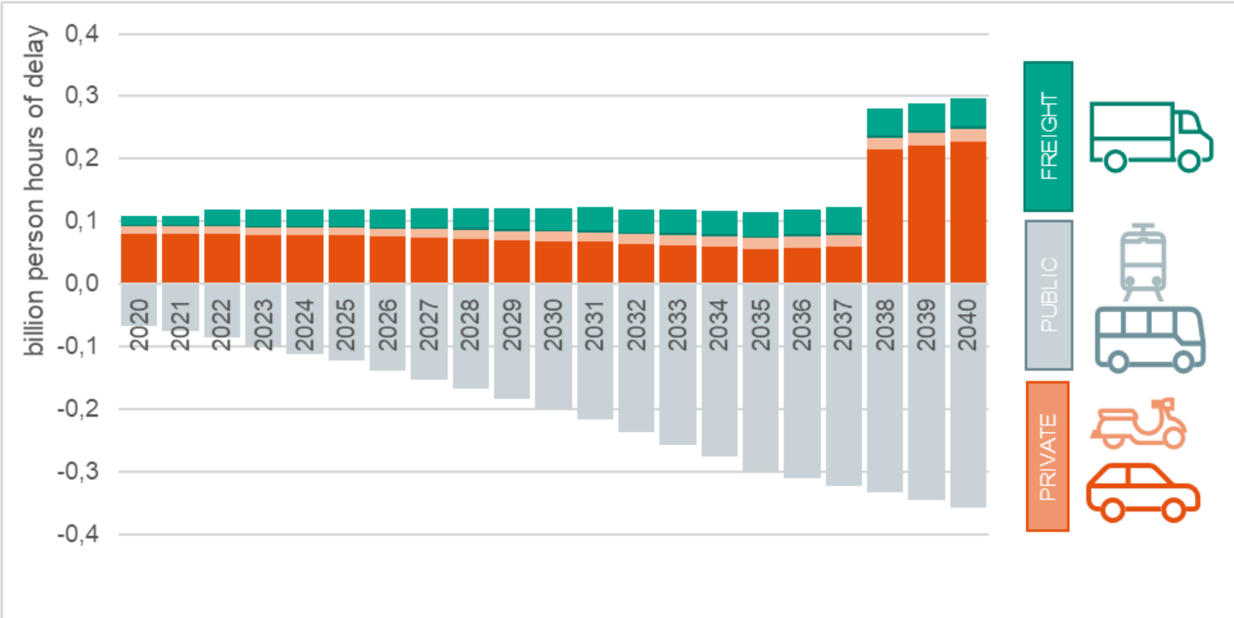

Figure 9: Time lost due to congestion : Mit scenario

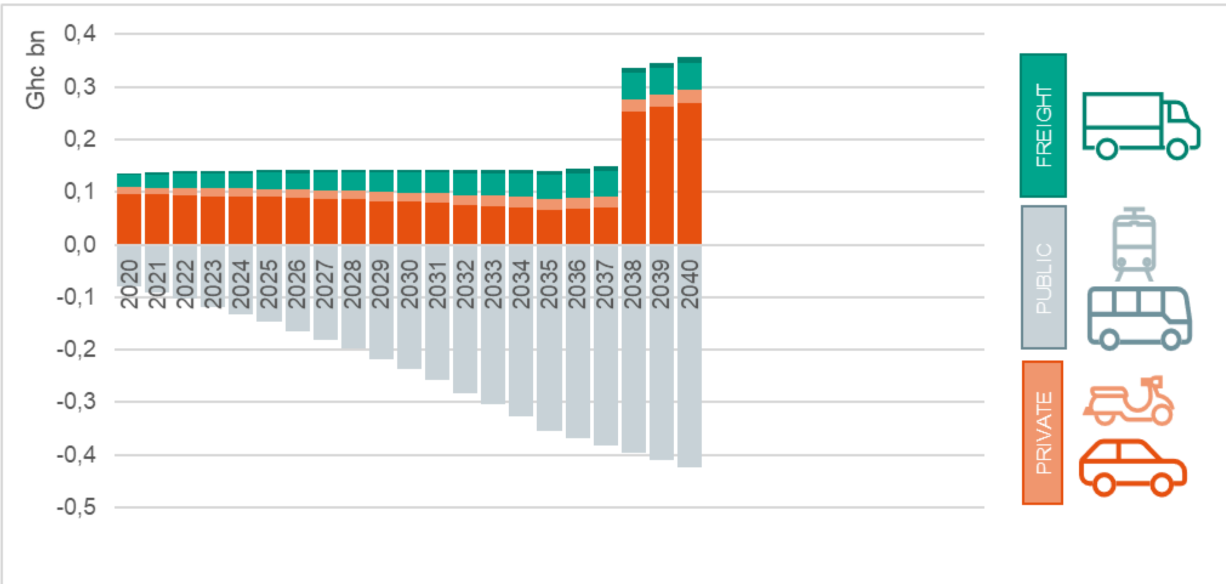

Figure 10. Cost of delay: MIT scenario

In turn, tables 12 and 13 show the annual delay values for the entire period for each of the vehicle types and the total delay costs for this scenario.

Table 12: Annual delay by vehicle type (h). MIT scenario

Vehicle Type	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	h	80.566.257	80.217.136	79.774.559	78.255.044	77.580.094	76.794.218	74.822.474	73.764.271	72.575.235	70.080.461	68.573.731
2W	h	11.360.537	11.701.354	12.052.394	12.413.966	12.786.385	13.169.976	13.565.076	13.972.028	14.391.189	14.822.925	15.267.612
Bus	h	0	0	0	0	0	0	0	0	0	0	0
Light rail	h	-66666667	-76422222	-86720889	-100015644	-111548506	-123703905	-139163293	-152728547	-167006293	-184927759	-200813993
HDV large	h	1.572.397	1.651.017	1.733.568	1.820.247	1.911.259	2.006.822	2.107.163	2.212.521	2.323.147	2.439.305	2.561.270
HDV small	h	14.961.127	15.709.183	25.226.574	25.811.038	26.598.641	27.501.739	28.574.504	29.833.646	31.299.287	32.995.478	34.950.855
Small cargo	h	0	0	0	0	0	0	0	0	0	0	0
Total	h	41.793.652	32.856.468	32.066.207	18.284.650	7.327.873	-4.231.149	-20.094.076	-32.946.080	-46.417.435	-64.589.591	-79.460.525

Vehicle Type	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	h	66.913.525	63.815.677	61.786.338	59.577.805	55.786.490	57.460.085	59.183.888	214.811.406	221.255.748	227.893.421
2W	h	15.725.641	16.197.410	16.683.332	17.183.832	17.699.347	18.230.328	18.777.237	19.340.554	19.920.771	20.518.394
Bus	h	0	0	0	0	0	0	0	0	0	0
Light rail	h	-217514545	-238233713	-256767266	-276230348	-300125797	-310977507	-322247165	-333951930	-346109705	-358739174
HDV large	h	2.689.333	2.823.800	2.964.990	3.113.239	3.268.901	3.432.346	3.603.964	3.784.162	3.973.370	4.172.039
HDV small	h	36.698.398	35.214.388	36.417.449	37.620.510	38.823.571	40.026.631	41.229.692	42.432.753	43.635.813	44.838.874
Small cargo	h	0	0	0	0	0	0	0	0	0	0
Total	h	-95.487.648	-120.182.438	-138.915.157	-158.734.961	-184.547.488	-191.828.117	-199.452.384	-53.583.055	-57.324.002	-61.316.446

Table 13: Total cost of delay (thousand Chc). MIT scenario

Vehicle Type	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	Ghck	95.367	94.954	94.430	92.631	91.832	90.902	88.568	87.316	85.908	82.955	81.172
2W	Ghck	13.448	13.851	14.267	14.695	15.135	15.589	16.057	16.539	17.035	17.546	18.072
Bus	Ghck	-	-	-	-	-	-	-	-	-	-	-
Light rail	Ghck	- 78.914	- 90.462	- 102.653	- 118.390	- 132.041	- 146.430	- 164.729	- 180.787	- 197.687	- 218.901	- 237.706
HDV large	Ghck	3.723	3.909	4.104	4.309	4.525	4.751	4.989	5.238	5.500	5.775	6.064
HDV small	Ghck	35.419	37.190	59.722	61.106	62.970	65.108	67.648	70.629	74.099	78.114	82.744
Small cargo	Ghck	-	-	-	-	-	-	-	-	-	-	-
Total	Ghck	69.043	59.442	69.870	54.351	42.422	29.921	12.533	- 1.065	- 15.146	- 34.511	- 49.655

Vehicle Type	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	Ghck	79.206	75.539	73.137	70.523	66.035	68.016	70.057	254.275	261.903	269.760
2W	Ghck	18.615	19.173	19.748	20.341	20.951	21.579	22.227	22.894	23.580	24.288
Bus	Ghck	-	-	-	-	-	-	-	-	-	-
Light rail	Ghck	- 257.475	- 282.000	- 303.939	- 326.977	- 355.263	- 368.108	- 381.448	- 395.303	- 409.694	- 424.644
HDV large	Ghck	6.367	6.685	7.019	7.370	7.739	8.126	8.532	8.959	9.407	9.877
HDV small	Ghck	86.881	83.367	86.216	89.064	91.912	94.760	97.608	100.456	103.304	106.153
Small cargo	Ghck	-	-	-	-	-	-	-	-	-	-
Total	Ghck	- 66.406	- 97.235	- 117.818	- 139.679	- 168.626	- 175.626	- 183.024	- 8.719	- 11.500	- 14.566

Type of Impact: TRAFFIC ACCIDENTS

This type of impact shows the same behaviour as in the BAS scenario, with a slight growth trend throughout the entire period, but presents a significant decrease in the average annual cost of accidents and each of their elements, as shown in Table 14 and Figure 11.

Table 14 : Average annual cost of traffic accidents (thousands Ghc). MIT scenario

	Unit	2020 - 2040
Fatalities	Ghck	244.565
Nonfatal injuries	Ghck	67.634
Property damage cost	Ghck	10.150
Medical costs	Ghck	6.282
Total	Ghck	328.630

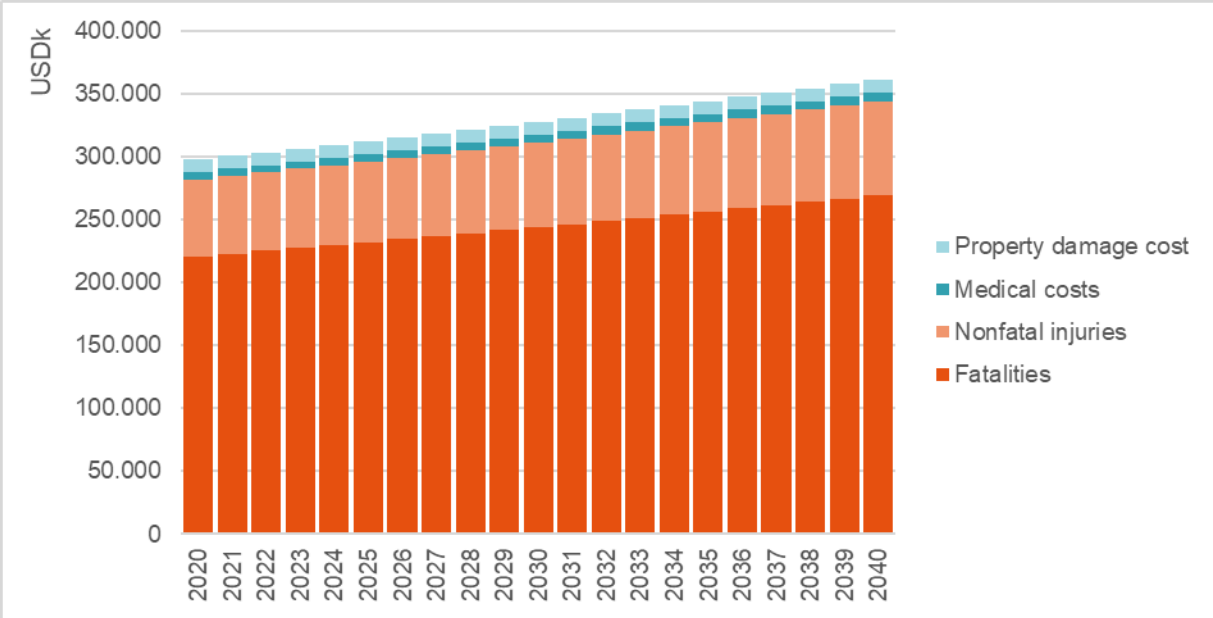

Figure 11:_Cost of road accidents by type of impact

Impact Type: FUEL SAVINGS

Similarly, in this MIT scenario, Figures 12 and 13 show the annual fuel consumption for each study year and their costs. In this scenario, the predominance of mass transportation modes is observed, in accordance with the country's policies for introducing electric vehicles as a majority mode of transportation.

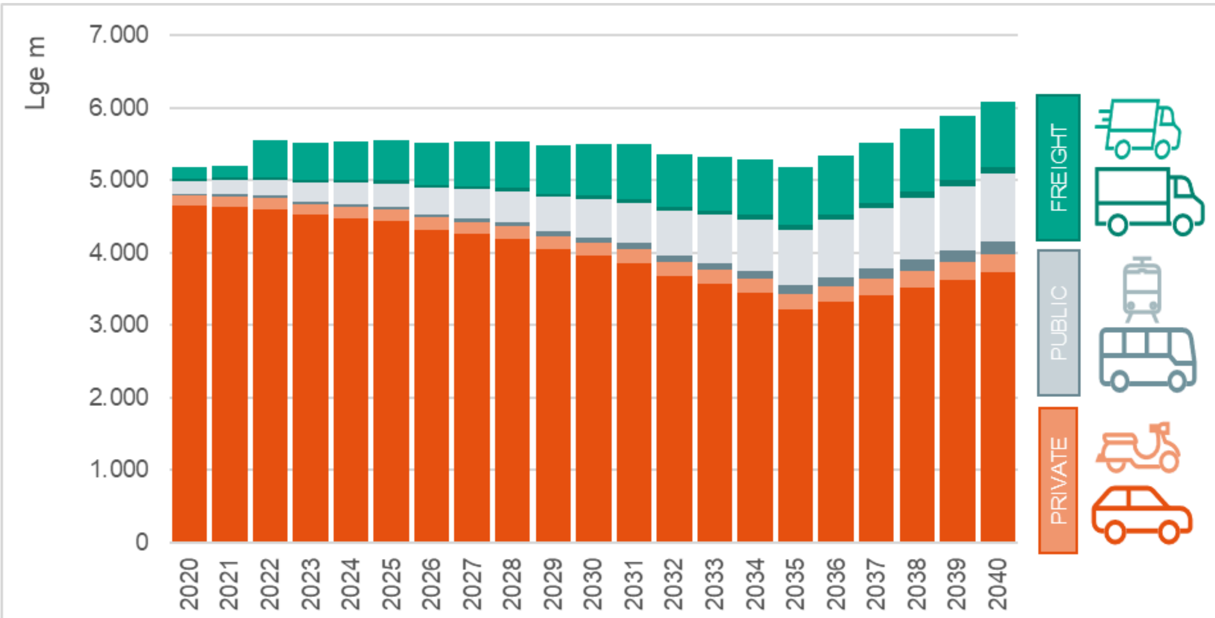

Figure 12: Annual fuel consumption (thousands of litres of diesel) eq). MIT Scenario

The behaviours shown for consumption and costs tend to increase over time associated with the gradual incorporation of new electric vehicles in each category or group until the end of the period.

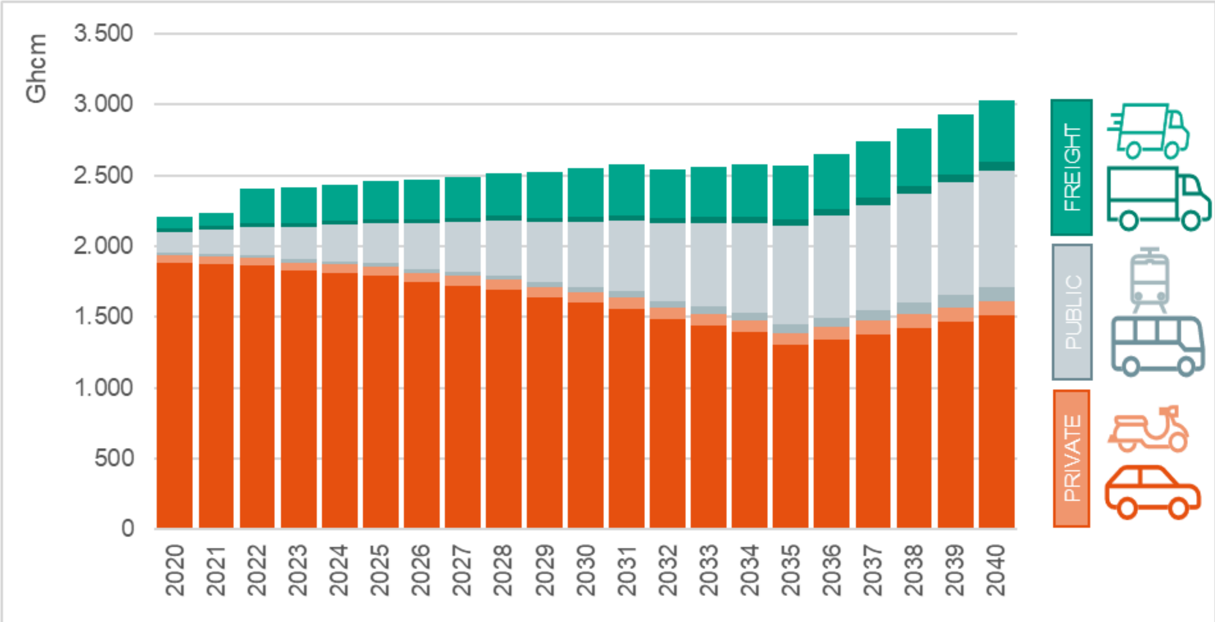

Figure 13: Fuel costs : MIT scenario

The structure for fuels shows the introduction and use of electricity, a fundamental characteristic of this mitigation scenario in the sector, until completely replacing the rest of the fuels towards the end of the study period, figure 14.

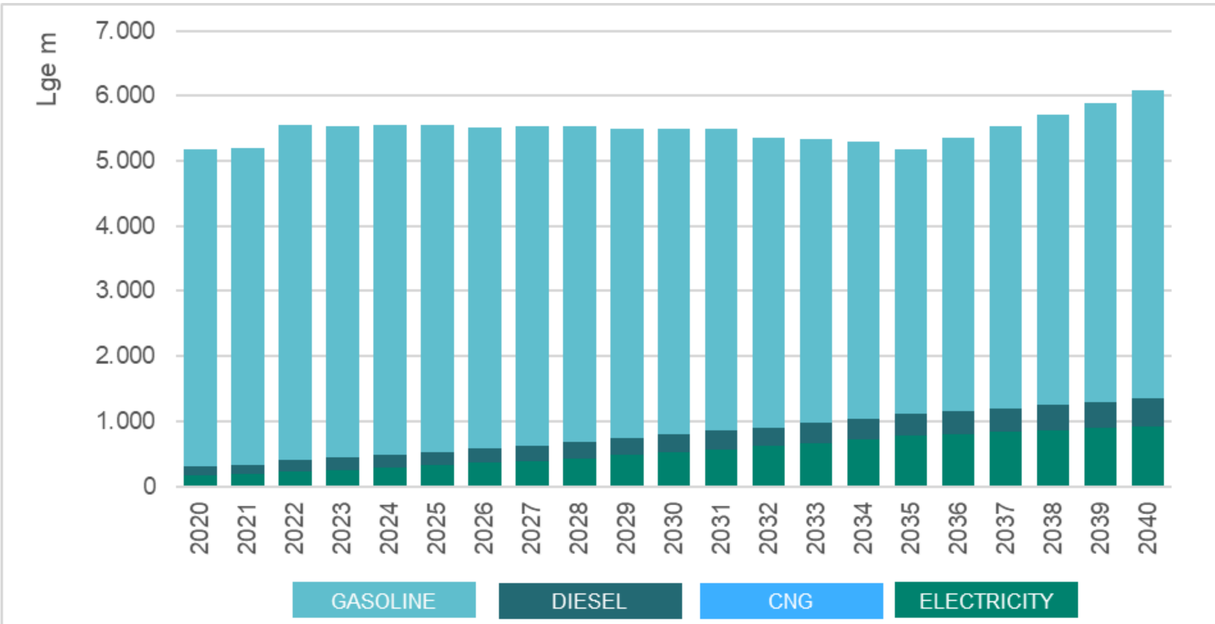

Figure 14: Fuel consumption structure (thousands of liters of diesel) eq). MIT Scenario

Tables 15 and 16 show the aggregate consumption and costs by type of vehicle and fuel and the total values for each, throughout all the years of the period.

Table 15. Fuel consumption (thousands liters of diesel) eq). MIT Scenario

	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	Lge m	4.655	4.635	4.609	4.522	4.483	4.437	4.323	4.262	4.193	4.049	3.962
2W	Lge m	138	142	146	151	155	160	165	170	175	180	185
Bus	Lge m	26	29	32	35	39	43	47	52	57	62	69
Light rail	Lge m	172	198	224	259	288	320	360	395	432	478	519
HDV large	Lge m	32	34	35	37	39	41	43	45	48	50	52
HDV small	Lge m	155	163	514	525	542	560	582	607	637	672	712
Small cargo	Lge m	-	-	-	-	-	-	-	-	-	-	-
Total	Lge m	5.179	5.201	5.561	5.529	5.546	5.561	5.520	5.531	5.542	5.492	5.500
Electricity	Lge m	172	198	224	259	288	320	360	395	432	478	519
Diesel	Lge m	127	134	188	195	203	212	222	233	246	260	277
Gasoline	Lge m	4.880	4.869	5.149	5.076	5.055	5.029	4.938	4.903	4.864	4.753	4.703
CNG-LPG	Lge m	-	-	-	-	-	-	-	-	-	-	-

	Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	Lge m	3.866	3.687	3.570	3.442	3.223	3.320	3.420	3.522	3.628	3.737
2W	Lge m	191	197	203	209	215	221	228	235	242	249
Bus	Lge m	75	83	91	100	110	121	134	147	162	178
Light rail	Lge m	563	616	664	714	776	804	833	864	895	928
HDV large	Lge m	55	58	61	64	67	70	74	77	81	85
HDV small	Lge m	747	717	741	766	790	815	839	864	888	913
Small cargo	Lge m	-	-	-	-	-	-	-	-	-	-
Total	Lge m	5.497	5.358	5.330	5.296	5.182	5.352	5.528	5.709	5.896	6.090
Electricity	Lge m	563	616	664	714	776	804	833	864	895	928
Diesel	Lge m	292	291	305	319	334	350	366	384	402	421
Gasoline	Lge m	4.642	4.450	4.361	4.262	4.072	4.198	4.328	4.462	4.599	4.741
CNG-LPG	Lge m	-	-	-	-	-	-	-	-	-	-

Table 16: Fuel costs (Million Ghc). MIT scenario

		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LDV	Ghcm	1.881	1.873	1.862	1.827	1.811	1.793	1.747	1.722	1.694	1.636	1.601
2W	Ghcm	56	57	59	61	63	65	67	69	71	73	75
Bus	Ghcm	15	16	18	20	22	24	26	29	31	35	38
Light rail	Ghcm	153	176	200	230	257	285	320	352	384	426	462
HDV large	Ghcm	22	23	24	26	27	28	30	31	33	34	36
HDV small	Ghcm	86	90	246	252	260	268	279	291	306	322	341
Small cargo	Ghcm	-	-	-	-	-	-	-	-	-	-	-
Total	Ghcm	2.212	2.235	2.409	2.415	2.439	2.462	2.468	2.493	2.519	2.525	2.553

		2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
LDV	Ghcm	1.562	1.490	1.442	1.391	1.302	1.341	1.382	1.423	1.466	1.510
2W	Ghcm	77	79	82	84	87	89	92	95	98	101
Bus	Ghcm	42	46	51	56	61	67	74	82	90	99
Light rail	Ghcm	501	548	591	636	691	716	742	769	797	826
HDV large	Ghcm	38	40	42	44	46	48	51	53	56	59
HDV small	Ghcm	358	344	355	367	379	391	402	414	426	438
Small cargo	Ghcm	-	-	-	-	-	-	-	-	-	-
Total	Ghcm	2.578	2.547	2.563	2.578	2.566	2.653	2.743	2.836	2.932	3.031
HDV large	Lge m	55	58	61	64	67	70	74	77	81	85
HDV small	Lge m	747	717	741	766	790	815	839	864	888	913
Small cargo	Lge m	-	-	-	-	-	-	-	-	-	-
Total	Lge m	5.497	5.358	5.330	5.296	5.182	5.352	5.528	5.709	5.896	6.090

Impact Type: AIR POLLUTION

As has occurred in the previous impacts, in the MIT scenario, lower values of atmospheric pollution on health are obtained in relation to the BAS scenario, with the number of premature deaths being twice as low. This has a decisive influence on reducing associated costs, as can be seen in Table 17.

Table 17: Premature deaths and years of life lost. MIT scenario

	Unit	2020 - 2040
Premature deaths	number of deaths	10.785
Years of life lost	total years	150.990
Health impact costs	thousand USD	5.392.500

Figure 15 shows slightly lower values of the annual impacts of air pollution on health for the MIT scenario compared to the BAS scenario, with both premature deaths and years of life lost being lower. The numerical values are detailed in Table 18.

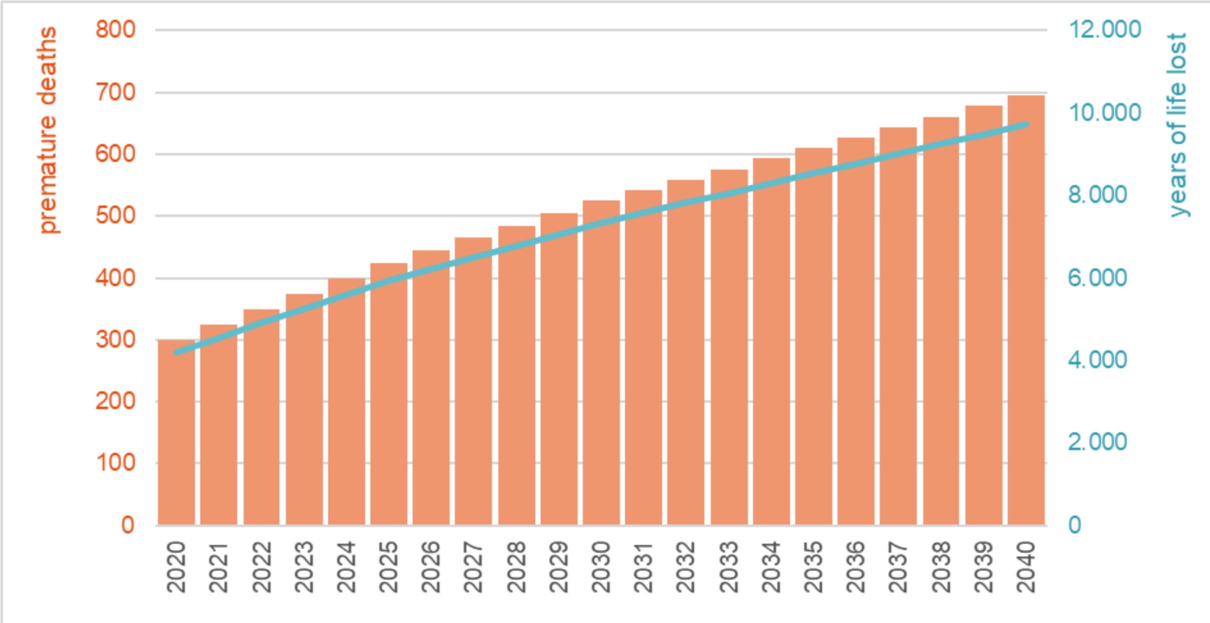

Figure 15: Annual health impact of air pollution. MIT scenario

Table 18: Air pollution results. MIT scenario

		Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Premature deaths	aths	number of deaths	300	325	350	375	400	425	445	465	485	505	525
Years of life lost	lost	total years	4.200	4.550	4.900	5.250	5.600	5.950	6.230	6.510	6.790	7.070	7.350
Health impact costs	osts	thousand USD	150.000	162.500	175.000	187.500	200.000	212.500	222.500	232.500	242.500	252.500	262.500

		Unit	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Premature deaths	aths	number of deaths	542	559	576	593	610	627	644	661	678	695
Years of life lost	lost	total years	7.588	7.826	8.064	8.302	8.540	8.778	9.016	9.254	9.492	9.730
Health impact costs	osts	thousand USD	271.000	279.500	288.000	296.500	305.000	313.500	322.000	330.500	339.000	347.500

The annual costs of annual air pollution impacts are shown in Figure 13.

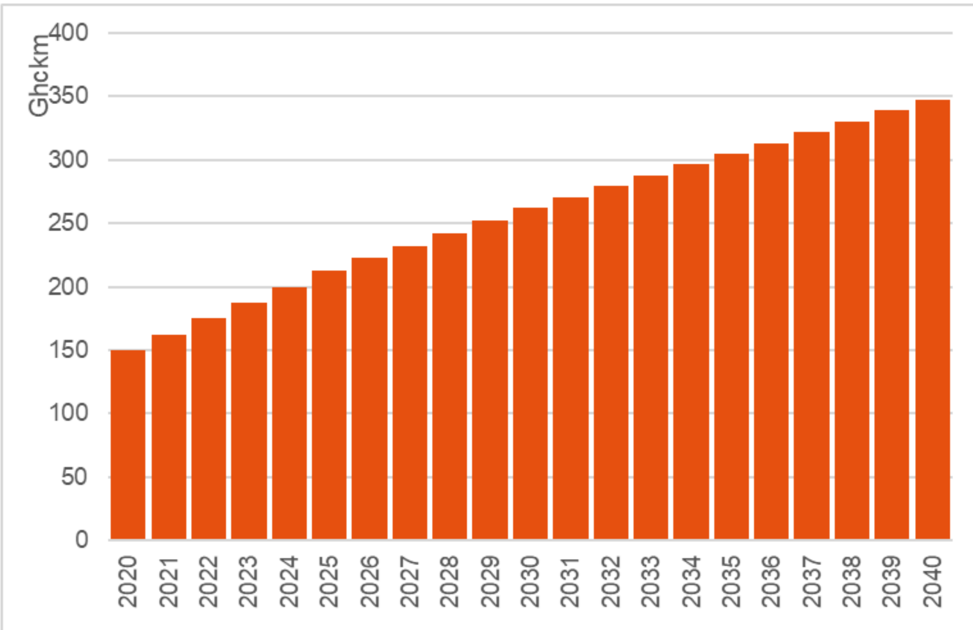

Figure 16Annual cost of air pollution impacts on health (million Ghc). MIT scenario

Total additional benefits for both scenarios

This section shows the results in aggregate form for the entire period from 2018 to 2040, considering both scenarios evaluated for each type of impact.

In summary, Figure 17 graphically presents the totals for the impacts showing significant values. In the case of the impact related to accidents, no significant values were reported to allow grouping, so the analysis must be done separately from the scenarios.

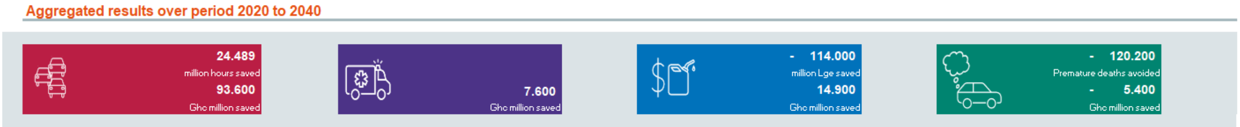

Figure 17: Aggregate results for the period 2018 to 2040 for Congestion, Fuel Economy and Air Pollution.

Figures 18 and 19 show the values of the annual costs avoided by congestion and the annual lost time avoided in congestion in relation to the impact produced by congestion, respectively.

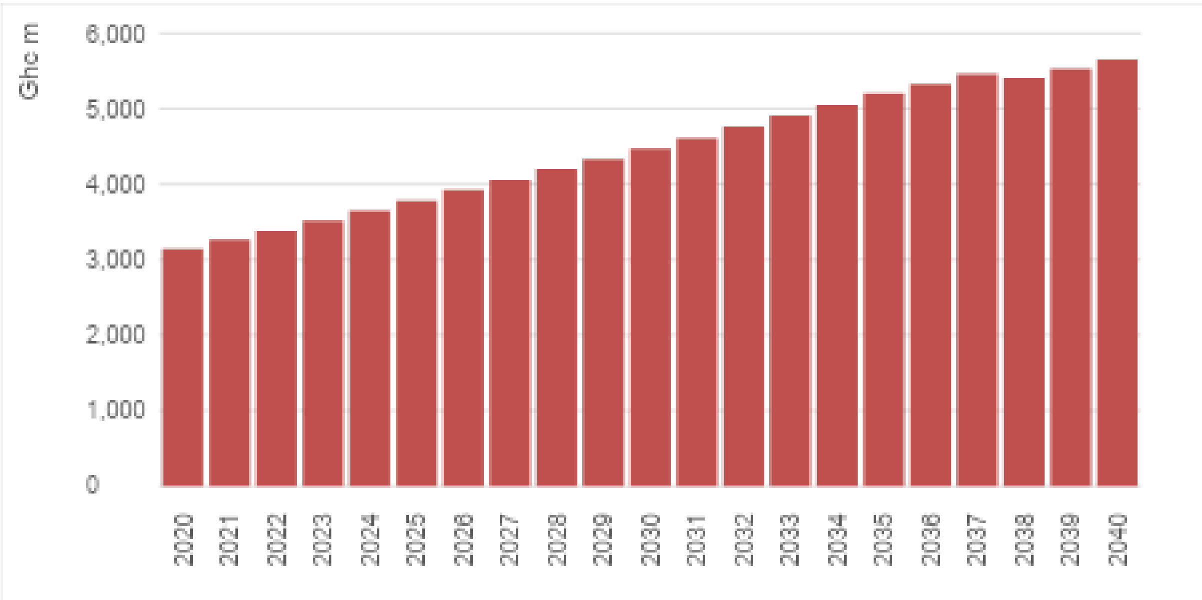

Figure 18: Annual avoided costs due to congestion

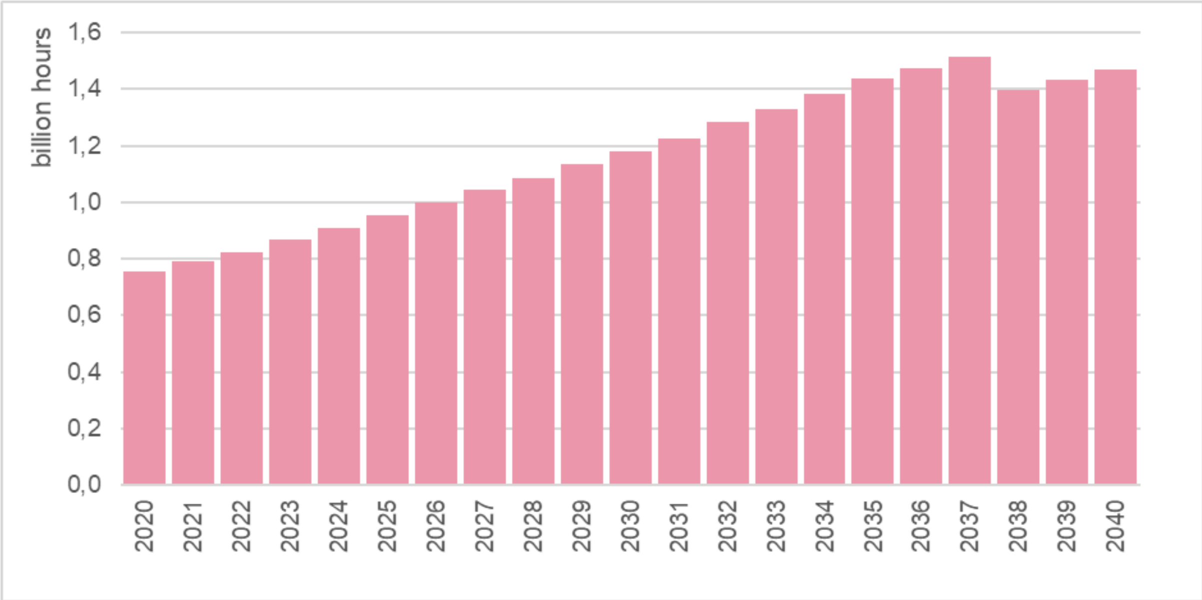

Figure 19: Annual time lost in congestion (billion hours)

Regarding the impact associated with fuel savings, Figure 20 shows the annual savings values in fuel costs during the study period.

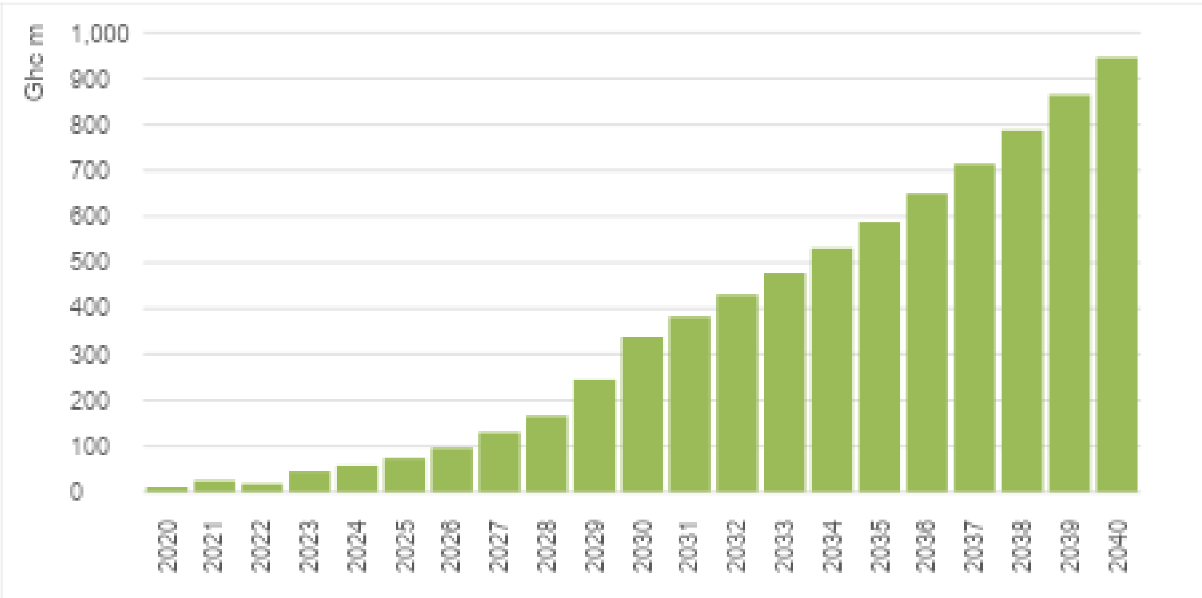

Figure 20 : Annual savings in fuel costs .

Finally, the total values of the annual costs avoided due to implementing the mitigation actions evaluated for the sector are shown, throughout the entire period (Figure 21) and the Annual Costs Avoided for each of the types of impacts (Figure 22).

Non-Climate impacts assessment for the transport sector using the TRACE-tool.

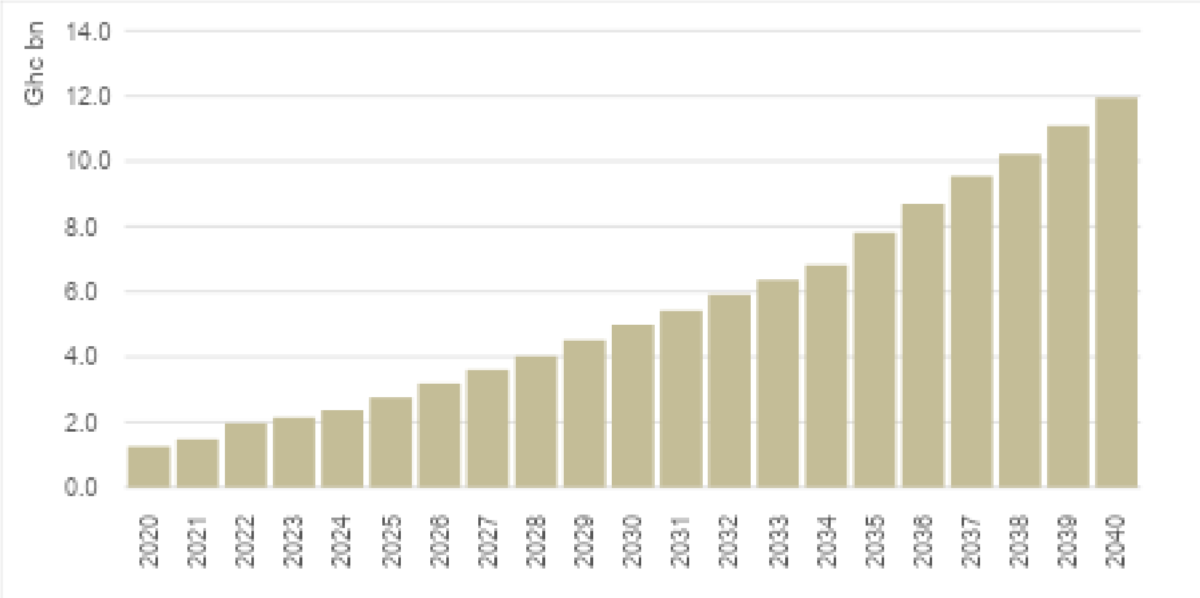

Figure 21:Total annual avoided costs

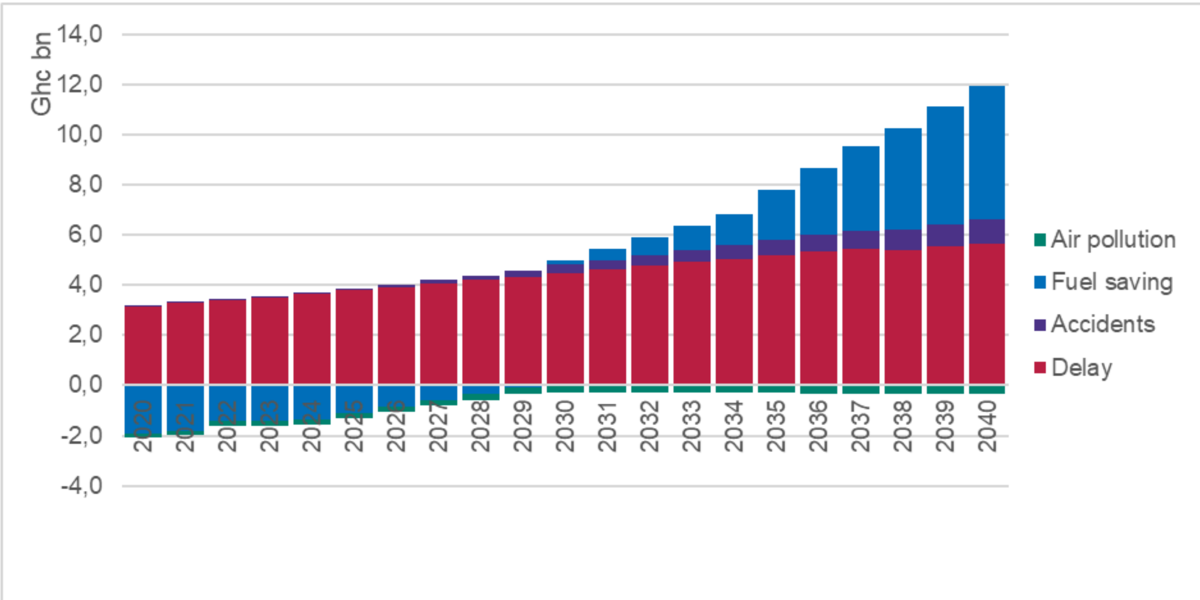

Figure 22:Total annual avoided costs by type of impact.

Lessons learned and recommendations

Access to relevant data was the main challenge associated with the deployment of TRACE-tool to model for Ghana. This was even noted as a challenge in ICAT Phase 1 which was to be looked at under ICAT Phase 2. The data champions from the nine ministries, as used in the ICAT 1 reports, are to be retooled to provide and update the relevant data for future purposes. For instance, there was no information on the number of different types of electric vehicles registered in the Ghana Region to be used in the TRACE tool. Further, the types of registered vehicles were recalibrated to meet the criteria of the TRACE tool

Non-Climate impacts assessment for the transport sector using the TRACE-tool.

Another lesson is the inability to organize a workshop on the TRACE tool. The relevant stakeholders would have been introduced to the Tool and given feedback on the Ghana model. The workshop could have also given the opportunity to train the relevant stakeholders on how to use the tool and the associated expectations from them in the future.

The use of AIRPOLIM-T results to feed the TRACE-tool to estimate the health impacts type (Chronic Obstructive Pulmonary Disease (COPD), lung cancer (LC), ischemic heart disease (ISD) and Stroke, from urban transport ambient air pollution was challenging. This was noticeable using health impact type including COPD, LC, IHD and ST against different age categories such as 25-29, 30-34, 35-39, 40-44, 45-49,50-54. The LEAP data on premature deaths and years of life lost was not readily available. Hence there was no computation for economic costs as indicated in the TRACE-tool.

According to the statistics from DVLA, there was a 54.37 per cent increase in the number of registered BEV vehicles in Ghana from 2022-to 2023. According to the National Electric Vehicle Policy 2023, there are 17,660 PEVs in Ghana, of which 55 per cent are BEVs and 45 percent are PHEVs. Almost 96 per cent of the BEVs are two-and three-wheelers. All are assumed to be used in Greater Accra region because of the available charging points. However, they were not factored into the TRACE tool. Its inclusion would have presented an interesting scenario about the inroads of electric vehicles in Ghana . The Government recently launched the use of electric buses by Aayalolo (pseudo-BRT).

Ghana has an ambitious plan for higher occupancy vehicles to reduce the number of cars on the road without a functional BRT. Most of the higher occupancy vehicles in Ghana offer inter-city bus transport service, largely originating from the Greater Accra Region. Aayalolo offers the solution to reducing traffic congestion on the roads in the Greater Accra Region. The recent introduction of electric buses to be used by the Greater Accra Passenger Transport Executive (GAPTE), the operators of Aayalolo, is in the right order.

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Annex 1

Table 1: Number of registered vehicles in Greater Accra Region used for the transport activity (Ghana Leap Model)

Vehicle Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Heavy Duty Vehicles	110	121	132	143	150	156	169	172	174	176
Motorcycles	240	290	350	407	446	483	516	571	626	681
Urban Buses	155	162	174	188	197	205	211	219	227	235
Light Commercial Vehicles	127	142	166	196	219	241	264	287	309	331
Passenger Cars	598	657	715	773	832	890	949	1007	1066	1124

Year	Motorcycle	Tricycle	LDV	HDV Small	Buses	HDV large	Total
2023	19,785	4,489	19,412	13,926	2079	3757	63,448
2022	23,272	7,043	44,764	21,457	4342	4431	105,309
2021	31,355	11,104	53,614	23,825	4731	5742	130,371
2020	25,441	5,964	44,740	18,467	4568	4058	103,238

Source: DVLA 2024* Recalibrated with the data excludes tipper trucks, equipment, harvester and agricultural equipment. *motorcycle=2w, tricycle=small cargo, Pmv up to 2000 cc and cmv up to 2000 cc= Heavy duty vehicles (HDV) small, *HDV-vehicles up to 16 to >32

Table 2: Ghana GDP and projections (Source: World Bank Data)

Year	GDP (GH₵ millions)
2010	46042,56
2011	59816,01
2012	75315,32
2013	93415,91
2014	113343,01
2015	136957,39
2016	167315,9
2017	205914,92
2018	257667,75
2019	302988,19
2020	358535,38
2021	459129,81
2022	565118,7