Tracking the Low Carbon Transition in the UK Road Transport Sector using Emissions Monitoring Framework

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Abstract

In this paper, the emissions monitoring framework developed by the UK committee on climate change (CCC) was used to identify and track sustainable emissions reduction in the UK road transport sector for the period 1990-2016. Various factors influencing emissions were considered (using secondary data) in drawing distinction between sustainable emissions reduction resulting from low carbon policies and projects (such as uptake of low carbon and renewable technologies, uptake of energy efficiency technologies, changes in behavioural patterns), and unsustainable emissions reduction due to exogenous factors (such as changes in gross domestic products (GDP), population, expenditure, private income and costs). The result shows that UK's effort in reducing GHG emissions existed at some points, with modest sustainability in reducing greenhouse gas (GHG) emissions, especially in the passenger road vehicle sub-sector. It was pointed out that for better emissions reduction results, there is the need for a full scale implementation of transition management cycle in this sector and beyond.

Keywords - *Climate Change; Emissions Indicators; Energy; Greenhouse Gas; Sustainability.*

I. INTRODUCTION

Decoupling environmental pressures such as greenhouse gas (GHG) emissions from economic growth is one of the main objectives of the UNFCCC andmany national and regional environmental strategies for achieving carbon reduction targets [1],[2],[3]. Decoupling is said to be successful when emissionsdecrease irrespective of increase in economic activities(e.g. GDP). The UK government has committed itself over the years to cutting emissions from its major economic sectors through energy efficiency measures and the introduction of radical low carbon technologies[4]. The transport sector which is dominated by fossil fuel internal combustion engine (ICE) technology is one of the major contributors of emissions in the UK. In 2016, theUK transport sector constitutes 25.6% of total emissions of which the road sector accounts for 92%, the highest emissions contributor in the transport sector [5].

The concern resulting fromGHG emissions in the UK and the impact of climate change results in the design of policies both at the national (UK) and regional (EU) levels. Such measures focus on improving fuel efficiency of conventional vehicles and the uptake of radically different vehicle technologies, i.e. Ultra Low Emission Vehicles – ULEV[6],[7], [8].As these strategic low carbon ambitions tend to cut emissions from the road sector in a sustainable manner, other external factors such as gross domestic product (GDP), income and emissions intensity (EI) also tend to affect changes in emissions [9],[10].Emissions reduction resulting from strategic clean energy measures is termed sustainable emissions reduction whereas thatcaused byexogenous factors are termed unsustainable emissions reduction. Therefore, the aims of this paper are:

1. To use the emissions monitoring framework developed by the committee on climate change (CCC) in the UK to assess sustainable emissions reduction in the UK road transport sector for the period 1990-2016.
2.To identify the main drivers of GHG emissions changes in the UK road transport sector and recommend the way forward.

Road sector vehicles may be divided into passenger vehicles and goods vehicles. Passenger vehicles include buses and coaches, cars and taxis, motorcycles and mopeds, while goods vehicles include light duty vehicles (LDVs) and heavy duty vehicles (HDVs).The paper is structured as follows: Chapter 1 introduces the content of the paper, highlights the aims and paper structure. Chapter 2 gives a brief on the CCC emissions monitoring framework. Chapter 3 uses the framework to assess the UK emissions reduction performance in the road sector. Chapter 4 made important observations,discussed the results,drew conclusionsand made important recommendations.

II. THE CCC INDICATOR FRAMEWORK

Changes in emissions are affected by changes in emissions intensity (EI) and/or changes in energy demand (ED). In turn, reduction in EI is influenced by the deployment of low carbon technologies whereas demand reduction can be affected by improvement in energy efficiency (EE) of appliances and machines, attitudinal change as well as changes in exogenous factors like weather, population, expenditure and costs. Among these, the sustainable mechanisms are low carbon technology deployment, energy efficiency and attitudinal change. Again, deployment of low carbon technology, energy efficiency (EE) and attitude (Att.) are influenced by the formulation and the successful implementation or actualization of proactive policies and regulations (policy milestones) and infrastructure development as shown in Fig.1 below [11].

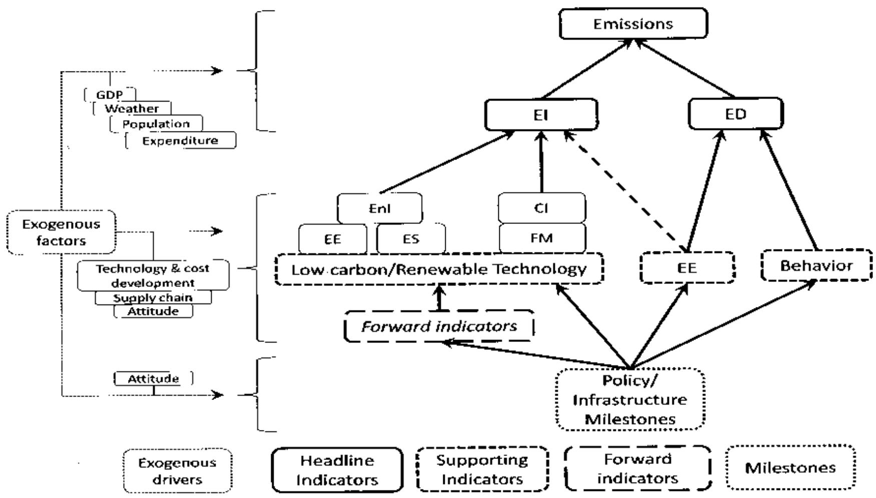

Figure 1: CCC indicator framework [11].

The framework is in line with emission expressions in literature for factors controlling the aggregate societal carbon emissions. The aggregate emissions (CO2) can be identified under three influencing factors; carbon intensity of GDP, income per capita, andpopulation size [9], [10].

$$CO_2 = \frac{CO_2}{GDP} \times \frac{GDP}{Pop} \times Pop \quad \text{...............(1)}$$

The carbon intensity of the GDP in the expression is a representation of the emission intensity (EI) on the framework and similarly, GDP per capita and population represent activity levels and thus, energy demand (ED) on the framework. The carbon or emission intensity of GDP (CO2/GDP) is further a function of two variables; the energy intensity (EnI) of GDP (En/GDP) and the carbon intensity (CI) of the energy source, i.e. fuel (CO2/En).

$$\frac{CO_2}{GDP} = \frac{En}{GDP} \times \frac{CO_2}{Eng} \quad \text{......................(2)}$$

Energy intensity reflects both energy efficiency and economic structure – ES, (the extent of domestic manufacturing/service activities), while carbon intensity of fuel reflects the fuel mix (FM) of the energy source of an economy [12],[10]. Reductions in EnI and CI of fuel are the result of investment in low carbon and renewable energy technology as indicated on the framework. However, energy efficiency (which is an item of energy intensity and subsequently, of emissions intensity on the expression) can also reflect energy demand as it is an indicator of energy consumption rate, as shown on the framework. Here, energy demand is considered a function of energy efficiency (and behaviour). The overall expression is given in equation (3) below.

$$CO_2 = \frac{En}{GDP} \times \frac{CO_2}{En} \times \frac{GDP}{Pop} \times Pop \quad \text{.... (3)}$$

III. CARBON PERFORMANCE IN THE UK ROAD SECTOR FOR 1990-2016

To assess the low carbon performance of the UKin the road sector, some basic data (BD) from literature are necessary to serve as input for the CCC framework. These data include GDP representatives of vehicle kilometres (veh-km), passenger kilometres (pass-km), tonne kilometres (ton-km) and the resulting energy consumption rates (mtoe) in the road sector. These parameters were used as instruments in analysing the headline and supporting indicators to reveal changes in emission intensity, energy intensity or efficiency, energy demand and attitudinal change in the transition to a low carbon road sector. The UNFCCC [5] in its road transport emissions data joined emissions from HDVs and buses together.But going by economic activities in the road sector, historical trends have shown that around 80% of GHG emissionsfromHDVs/busescan be attributed to HDVs[14]. Moreover, emissions from LPG (liquefied petroleum gas) and CNG (compressed natural gas) fuels in the road sector are negligible [17].

A. *Headline Indicators (HI)*

Over the last two decades or so of UK transition to low carbon energy, carbon emissions from the road sectorcontinued to rise from 1990 until 2005, where it began to decline until 2012 but went up againuntil 2016[5]. These historical changes were shared roughly equally among both passenger vehicles and goods vehicles as they are indicating a corresponding emissions change. The next emissionsHIs are the emission intensityEI (CO2/load-km, the amount of emissions per unit road activity) and energy demand ED (in toe, the gross amount of energy consumed over a period).It can be seen from Table I that theEIfor passenger vehicles were continuously decreasing throughout the transition period right from 1990 (except between 2010 to 2012 where it remained constant) until 2016.For goods vehicles, the EI assumes an irregular pattern for the period 1990-2016, showing no response to the transition process. To check for sustainability in the process, the EI dynamics can be explained under energy intensity EnI (toe/load-km, the amount of energy consumed per unit road activity) and carbon intensity CI of fuel (CO2/toe, the amount of emissions released per unit volume of fuel burnt). The EnIof passenger vehicles was continuously decreasing from 1990 until 2016 (except between 2010 to 2014 where it remained constant). For goods vehicles, there is an irregular pattern of EnI changes similar to the pattern underthe corresponding EI, indicating inadequate low carbon intervention in the subsector. The CI of fuel also shows a continuous reductionbetween 1990 and 2010, with an irregular pattern thereafter until 2016.

B. *Supporting Indicators*

Supporting indicators are those that measure the planned structural changes (due to the transition) that lead to reductions in the headline indicators (energy intensity, carbon intensity of fuel and energy demand). Reduction in energy intensity and carbon intensity of fuel is a function of the extent or percentage of low carbon energy sources or renewables introduced for use in the road transport sector in the course of the transition process. It can be seen from Table I that the percentage of biofuel in road transport rose from 0% in year 1990 to over 3% towards 2016[18]. In a similar development, percentage of electric vehicles rose from 0.01% in 2005 to 0.6% in 2014followed bya sudden upsurge to 1.4% in 2016; the fastest rate in the history of electric vehicle penetration.

For energy demand analysis, two drivers were considered; energy efficiency (EE) of road vehicle technologies and behavioural patterns or attitude(Att.) of road vehicle users. The EE factor is a form of energy intensity observed from a different angle; it is the amount of energy per unit of activity that can be saved in comparison to a 'business as usual' consumption rate. The factor enables vehicles to consume less energy/fuel to travel the same kilometres which will otherwise need more energy. It is also measured in terms of energy/load-km and the lower the consumption rate, the higher the efficiency. EE assessment wasalso considered separately for passenger and goods vehicles. The trends are similarly to the EnI trends, showing little low carbon achievement in passenger vehicles with an irregular pattern for goods vehicles indicating little or no historical improvement in the later subsector.

The next driver of energy demand, which is user attitude, is a measure of the level of utilisation of road transport activities or in other words, it is indicating the extent of vehicle travels that are prudently used and not wasted. This component of the transition is a symbol of behaviour, culture, practice, etc. which are usually influenced through public enlightenment and motivation (for instance, through media publicity) for a participatoryapproach for low carbon transitions. It is measured in terms of total vehicle-kilometres divided by the useful vehicle-kilometres (vehicle-kilometres per load-kilometres). Public behaviour in support of the low carbon transition has not seen any significant improvement throughout the transition period (1990-2016) in view of the irregular dynamics of its indicator values.

Table I: Low Carbon Transition Indicators in The UK Road Sector [5],[14] [15],[16],[17],[18],[19]

	Indicators	1990	2000	2005	2010	2012	2014	2016
BD	Veh-km (pass, $x10^9$)	346.1	385.7	403.1	395.5	395.7	403.2	413.5
	Veh-km (goods, $x10^9$)	64.8	80.4	90.7	92.4	91.4	98.3	106.3
	Pass-km ($x10^9$)	645	694	720	699	699	704	710
	Ton-km ($x10^9$)	131	150	153	139	143	128	148
	Mtoe - passenger	27.51	29.07	29.51	27.69	26.92	26.78	27.18
	Mtoe - goods	11.31	12.01	13.08	12.69	12.55	13.18	14.27
HI	Emissions (total, mtco2e)	111.13	117.13	120.51	110.76	108.97	109.63	114.54
	Emissions (pass, mtco2e)	78.72	83.05	83.72	75.90	74.59	73.80	76.03
	Emissions (goods, mtco2e)	32.41	34.02	36.43	34.54	34.10	35.57	38.30
	EI (pass, kco2e/pass-km)	0.134	0.130	0.119	0.107	0.107	0.106	0.105
	EI (goods, kco2e/ton-km)	0.244	0.235	0.250	0.259	0.238	0.288	0.267
	- EnI (pass, koe/pass.km)	0.047	0.046	0.042	0.039	0.039	0.039	0.038
	- EnI (goods, koe/ton.km)	0.084	0.082	0.088	0.094	0.087	0.106	0.098
	- CI (mtco2/mtoe)	2.863	2.851	2.830	2.743	2.761	2.743	2.762
SI	*% Biofuel*	0.00	0.00	0.217	3.111	2.524	3.238	*3.39(est.)*
	% EV	-	-	0.01	0.01	0.1	0.6	1.4
HI	Energy Demand (mtoe)	38.82	41.08	42.59	40.38	39.47	39.96	41.45
SI	*EE pass. (toe/pass-km)*	0.06	0.059	0.059	0.058	0.057	0.057	0.058
	EE goods (toe/ton-km)	0.296	0.274	0.278	0.291	0.276	0.312	0.28
	Att.pass. (veh-km/pass-km)	0.537	0.556	0.56	0.566	0.566	0.573	0.582
	Att.goods (veh-km/ton-km)	0.495	0.536	0.593	0.665	0.639	0.768	0.718

Notes:
i. Dataonroad vehicles for passengers and goods (where not given directly) were obtained by considering data for LDVs/HDVs and for all the other road vehicles respectively.
ii. Data relating to low carbon performance were considered from other sources other the UK where available.
iii. Market share of Electric Vehicles (EVs) is assumed to be proportional to EV share on the road.

C. Forward indicators(FI) and Policy Milestones (PM)

There are many policies, programs and projects that have been planned, processed or on-going in the UK green vehicle industry which can contribute to carbon cuts in the road transport sector. Also, several policies with potential contributions to low emission vehicle projects have made important impacts. Some important FI and PM are listed in Table II below.

Table II:Forward Indicators and Policy Milestones

	Project/policy	Description	Reference
FI	Biofuel projects	World's largest algal biofuel project by 2020	[20]
	Electric charging infrastructure	Funds for development of charging infrastructure for the period 2015-2020	[21],[22]
	Ultra-low emission vehicles	Emissions saving technologies, incentives	[23]
	EV uptake pathway	9% by 2020 and 60% by 2030	[24]
PM	RTFO	Increase in percent biofuel of 9.75% by 2020, 12.4% by 2032 (by volume)	[25]
	EV incentives	Purchase incentives, use and circulation incentives, Tailpipe emissions standards	[19]
	Environmental taxes	Climate change levy, Fuel duties, etc.	[26]
	UK ULEVs support	Purchase grants, funding R&D and chargingpoints	[27], [22]
	CO2 labelling	Labelling relating to vehicle emissions intensity and fuel consumption	[28]

D. Exogenous Drivers

There are some other drivers of emissions that are exogenous to the context of the road sectorscope and can influence the transition process. These include GDP, income, population and as well as costs. Since the aim of sustainable energy transition is to decouple socio-economic growth and development from the consequent environmental pollution and theCCC frameworkindicators were designed to observe such paradigms, exogenous factors can only directly impact the headline indicators of emissions and energy demand (representatives of the factors) and not the supporting or forward indicators. Monitoring and evaluation orprogress of the transition and transition process (which are functions of SI and PM) shall have no link with such emissions influencingfactors.

IV. DISCUSSION AND CONCLUSION

In every socio-technical transition, monitoring and evaluation of the transition and transition process for sustainability is a necessary integral component. In this paper,emissions change in the UK road transport sectorhas been trackedto trace and assess the impact of the goal-oriented low carbon transition program for the period 1990-2016using the CCC indicator framework. This is to examine sustainability in emissions reduction (if any) in the sector.The results revealed that little progress has been made despite obvious efforts aimed at driving down emissions in the road sector in a sustainable manner. Furthermore, the progress is skewed to the passenger vehicles sub-sector, where there was indication of a modest sustainable emissions reduction over the years. This is observed in historical changes in low carbon transition indicators of energy intensity and to a little extent, the adoption rate of alternative ultra-low emission vehicle (ULEV) technologies.This means that there havebeen some improvements in energy efficiency among passenger vehicles but indicators such as carbon intensity of fuels and energy conservation (attitude) show change dynamics that weresomewhat autonomousto the transition. Systemic transition in the road sector in terms of structural change still seems to be at the predevelopment phase(or at best the take-off phase). Lots of activities seem to be changing on the surface without really influencing the deeper structural settings. Headline emissions indicators of total emissions and energy demand were not clearly decoupled from economic growth especially among heavy duty vehicles. The rate of increase in economic activities seems to outweigh the rate of the transition progress.

However, it might not be said that the UK has done nothing in terms of transition to a green road sector but there is obvious evidence that sustainable emissions reduction efforts were not very effective. Although this could be a result of long lead-times of clean transport projects (typical characteristics of a transition at the pre-development phase), it is time for the UK to acknowledge the complexity of socio-technical systems and understand the fact that their transitions cannot be actualised through regular policy processes. The fossil fuel vehicle regime seems to be continually enjoyingstable dominance without evident threat from promising alternatives of road vehicle technologies. To shake the structural embedment of the road transport regime from its deeply rooted foundations, a deep context-enriched understanding of complex systems dynamics and the respective governance processes and instruments are necessary to actualise the targets set for greenhouse gas reductions (carbon budgets).

This will necessitate the streamlining and coordination of all the formal and informal components of the road sector. As a starting point for a cost-effective transition, attitudes towards energy conservation and perceptions towards patronage of ULEVsare crucial for influencingcultures and practices.Energy savings can be enhanced through the reduction of unnecessary travels i.e., avoiding under-utilized journeys to reduce vehicle-kilometre per passenger/goods kilometre. Vehicle-kilometres can be utilised through attitudinal change as a result of energy and environmental sustainability awareness. Although sometimes results might show improvements in veh-km/load-km, this must be closely monitored against other unsustainable influencing factors such as increases in fuel or vehicle costs, or low income, which may cause many vehicle owners to resort to public transports to save cost. Attitudinal measures might be enhanced through public awareness campaigns to ensure sustainability.Widespread adoption and deployment of ULEVs will need policy support and a special transition network which must be nurtured for a sufficient period of timefor its possible emergence. This necessitates the call for a full scale implementation of the concept of transition management cycle in the UK road sector.

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