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Options for Greenhouse Gas Mitigation Strategies for Road Transportation in Oman

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Abstract

Oman is a fast developing country where about 76% of registered vehicles as of 2014 were private cars with approximately one private car per household. The growth of automobile is faster than the growth of human population. From 2000-2009, Omani population has increased by 2% per annum while automobile usage in the country has increased by 4.3%. The leadership of Sultanate of Oman has pledged to cut down greenhouse (GHG) emissions by 2% as a commitment to United Nation Framework Convention on Climate Change (UNFCCC). Due to very limited public transportation system, traffic congestion and emission from vehicles are high during working days since majority of individuals uses private vehicles as only means of transport. This paper seeks to combine mitigation measures adopted in selected Middle East and North Africa (MENA) and UNFCCC to suggest cost-effective measures suitable in reducing GHG emissions from road transportation sector in Oman. These measures will specifically reduce vehicular emissions during working days where car occupancy rates are very low in an economically sustainable way.

Keywords

Greenhouse Gas, Road Transport, Private Vehicles, Mitigation, Oman

1. Introduction

Urban environment is rapidly dominating the world. The current global urban population is about 50% in early 21st century and it is expected to reach 60% by the year 2060 mostly in developing countries. Carbon dioxides (CO_2) is the major greenhouse gas (GHG) produced by vehicles in the urban areas as well as other gases such volatile organic compounds (VOCs), carbon monoxide (CO), oxides of nitrogen (NO_x) which pose health threat to human population [1]. The amount and type of gaseous emissions produced by vehicles depend on the

quantity of fossil fuel consumed, vehicle technology, fuel quality and land-use planning [2].

Oil is the dominant source of fuel for major modes of transportation of which road transportation alone accounts for 81% of total energy consumed [3]. Transport is responsible for 24% of total global GHG emissions with road transport contributing to 75% CO_2 emissions [4]. Current scientific and political consensus, as represented by the Intergovernmental Panel on Climate Change (IPCC), is that man-made emission of CO_2 and other GHGs are causing a significant rise in global average temperature; over and above that might be due to any natural phenomena [5].

Oman is fast developing in the region where about 76% of registered vehicles as of 2014 were private cars with approximately one private car per household [6]. Governments, policy makers and businesses are urgently required to mitigate global warming and to seek cost effective measures to reduce GHG emissions in response to fast growing interest and concern about climate change over the decade [7]. The overdependence on private vehicles for both passengers and freight transport can be attributed to high income level of the country, low population density and long distance between towns and cities settlements. Another factor that is contributing to high number of private cars is due to cheap fuel, excellent road networks and unfavorable high temperature [8]. Increase in urbanization and centralization of governments ministries, institutes and business in the urban centers in Oman is another driver for high dependence of private vehicles as about three quarters of Oman's population are currently living in urban centers [9]. Several developed and developing nations around the world have started adapting mitigation measures to reduce GHG emissions in road transport sector as an alternative approach of combating global climate change. First and foremost, this paper seeks to assess and evaluate GHG inventories relating to road transportation sector within Middle East and North African (MENA) countries and Sultanate of Oman; secondly, to explore and evaluate the current GHG emission mitigation measures adopted by some selected developing countries. Finally, to recommend medium-term and long-term mitigation measures appropriate reducing GHG emissions in road transport sector in Oman.

2. Current Transportation System in Oman and MENA Region

The transportation is an important sector as it supports businesses and commerce and facilitates movement of general goods and services and other social activities thereby contributing to sustainable development. Thus, a good transportation system should not only harmonize economic growth with land-use planning and promotion of public transport systems but also conserve resources in environmentally friendly manner [10]. For instance, Oman needs a sustainable transport policy to reduce the traffic volume and reduce other road related problems such as accident and congestion, but the prospect of introduction of efficient metro and inter-city bus services would require effective and efficient

road transportation policies and great amount to resource to implement it [6].

Most MENA countries share similarities in transportation modes, this could be due to similarities in terms of climate, Gross Domestic Product (GDP) due to similar natural resources but some countries e.g. United Arab Emirates (UAE) and Egypt has had a tremendous improvement in their road sectors over the years. **Table 1** shows a few policies promoting the use of active transportation modes in the MENA region. It has been noticed that national policies regarding the promotion of walking and cycling are nonexistent in Oman and several also in other MENA regions with exception of UAE [11]. Oman is a member of the Gulf Cooperation Council (GCC) countries with less exposure to different mode and services of public, except Muscat ,the capital city where few buses and taxis are available, the situation is even worse in other regions e.g. Kuwait which lacks public transport system for commuters [12]. Limited public transport system in Oman can be attributed to the fact that automobile is increasing in a faster rate than the growth of human population. From 2000 to 2009, Omani population has increased by 2% per annum while automobile fleet in the country has increased by 4.3% [6] with average estimation of about 260 vehicles per 1000 population [9]. **Figure 1** indicates a sharp increase in private vehicles registration of about 76% against other types of vehicles in 2014. This rise could be due to improve standard of living and heavily subsidize importation tax and fuel by the government.

Table 1. Promotion of alternative transport in MENA regions.

Countries	National Policies to Promote	
	Walking or Cycling	Public Transportation
Bahrain	No	No
Egypt	No	Yes
Israel	No	Yes
Jordan	No	Yes
Kuwait	No	No
Libya	No	No
Morocco	No	Yes
Oman	No	No
Qatar	No	Yes
Saudi Arabia	No	Yes
Syria	No	Yes
Tunisia	No	Yes
Turkey	No	Yes
UAE	Yes	Yes
Yemen	No	No

Source: [13].

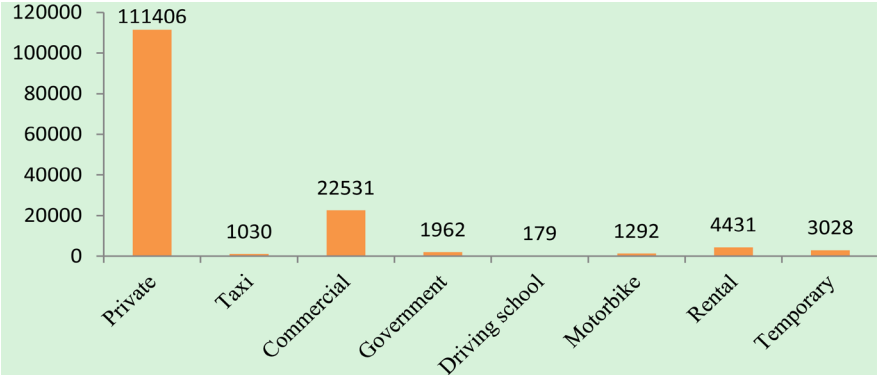

Figure 1. Distribution of registered vehicles by types in Oman in 2014 [14].

3. CO_2 Emissions in Oman and MENA Regions from Transportation

The transportation sector alone in Arab region (including GCC countries) constituted about 22% of total GHG emissions of which 85% was attributed to urban transportation. In 2005, the total gasoline and diesel oil consumption in road transportation alone excluding low income countries like Comoros, Djibouti, Mauritania, Somalia and western Sahara, reached about 84 million tonnes of oil equivalents, and CO_2 emissions reaching about 258.4 million tonnes [15]. Saudi Arabia represent 31% of fuel consumption in road transport, Morocco only 1%, Palestine 0%, Qatar 2% and Oman 2% which equivalent to about 5.2 million tonnes of CO_2 emissions in only road as shown in **Figure 2**.

Table 2 presents CO_2 emissions levels by sectors in MENA region in 2005. Transport sector, including road, rail, air, water, freight contributes to about 22% of CO_2 in the region while Oman contributes to 13% CO_2 in transport sector with road being the major mode of transportation. A study assessed GHG inventories for energy sector in Oman using IPCC reference approach to analyze Oman's fuel supply of crude oil, natural gas, and petroleum refine products and amount of CO_2 emitted as due to fuel combustion [16]. However, there is no study on GHG inventories in the road transport sector in Oman with regards to type of fuel used, age of vehicles and mileage, therefore hindering accurate estimation of GHG emissions produced from the road sector.

The current major fuel used for road transportation sector in Oman is either petrol or diesel while compressed natural gas (CNG) and electrically operated technologies are still waiting their ground to be explored. **Figure 3** shows sector wise contribution of CO_2 emissions in Oman compiled from sources during 2009, this depicts that power, mostly oil and gas sector including refineries contributed to 35% of GHG emissions followed by transport sector of 26% [17]. Within the transport category, road transportation accounts for about 89% of CO_2 emissions whiles air transportation accounts for only 11%.

4. Suggested Mitigation Measures in Road Transport in Oman

Mitigation of climate change is designed to provide authoritative, timely infor-

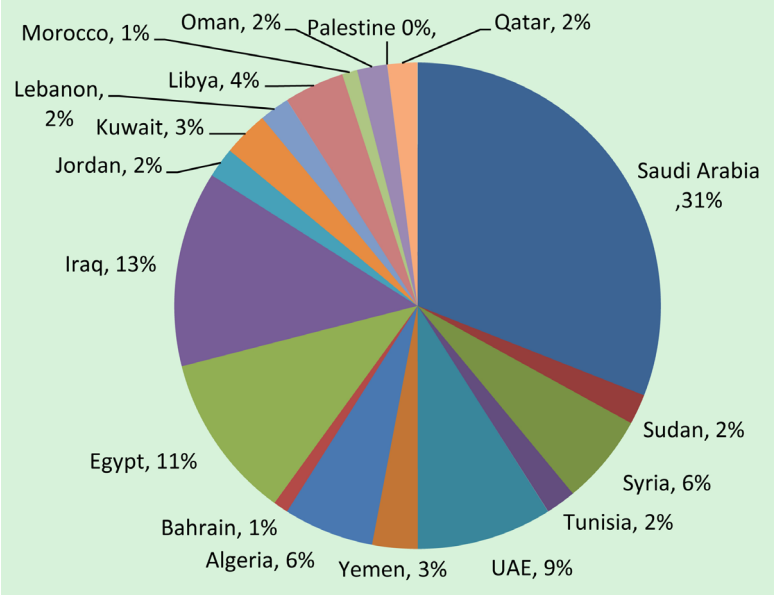

Figure 2. Distribution of fuel consumption in road transport in the Arab countries including Oman, 2009 [7].

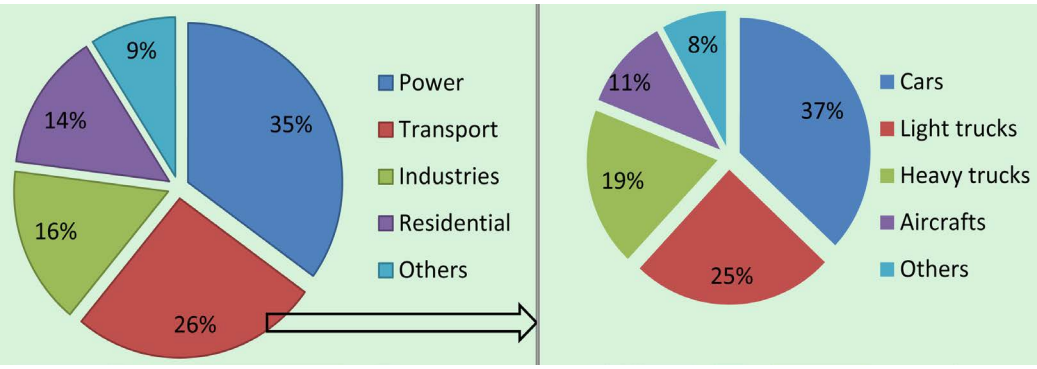

Figure 3. Sector wise CO_2 emissions in Oman and categories of transport contribution during 2009 [17].

mation in all aspects of technologies and socio-economic policies, including cost effective measures to control GHG emissions. However, costly mitigation measures could have adverse effects on economic development. This dilemma facing policy makers results in tension that is manifested in the debate over the scale of the interventions and the balance to be adopted between climate policy and economic development [5]. Sultanate of Oman has experienced rapid urban expansion due to economic growth and economy booming after 1970 [16].

Currently, when public road transport services are attracting significant attention from policy makers globally as means of reducing GHG emissions, yet these services are low in Oman [12]. **Table 3** shows measures adopted by some selected neighboring countries such as Kuwait, Egypt and Jordan (from MENA region) and UNFCC general mitigation measures in reducing GHG emissions in road transport sector. The rational for adapting mitigation measures from these countries was due to similarities in culture. Example, certain countries do not allow women to ride bicycles. Similarities in gross domestic product (GDP), and

Table 2. CO_2 emissions in Oman, GCC, MENA and global by sector in 2005 (extracted and modified from source).

Country/Region	Energy Sector		Manufacturing industries and Construction		Transport		Other Sectors		Total
	Millions Tonnes of CO_2	%	Millions Tonnes of CO_2	%	Millons Tonnes of CO_2	%	Millions Tonnes CO_2	%	Milloins Tonnes of CO_2
Oman	17.08	63	5.1	19	3.61	13	1.19	4	26.98
UAE	53.08	48	31.52	29	22.06	20	3.72	3	110.38
Saudi Arabia	171.79	54	71.44	22	72.52	23	3.74	1	319.68
Qatar	21.05	58	9.04	25	6.14	17	0.14	0	36.37
Kuwait	50.14	67	12.42	17	8.04	11	4.02	5	74.62
Bahrain	11.39	62	4.05	22	2.65	14	0.23	1	18.32
Total GCC	324.53	-	133.57	-	115.02	-	13.04	-	586.35
Iran	108.14	27	76.44	19	100.31	25	122.21	30	407.1
Israel	40.27	67	1.81	3	9.86	16	7.91	13	59.85
Syria	22.3	47	9.78	20	11.74	25	3.94	8	47.76
Libya	23.6	52	7.31	16	11.72	26	2.77	6	45.4
Morocco	18.03	44	7.16	17	1.82	4	14.34	35	41.35
Iraq	29.08	34	17.54	21	29.63	35	8.39	10	84.64
Egypt	61.56	42	37.14	25	31.59	21	17.03	12	147.59
Tunisia	6.78	35	3.85	20	4.54	24	4.11	21	19.28
Yemen	5.76	31	1.83	10	6.18	33	4.92	26	18.69
Algeria	35.59	42	11.18	13	17.78	21	19.75	23	84.3
Jordan	7.02	39	2.91	16	4.78	27	3.2	18	17.91
Lebanon	6.76	43	3.19	20	3.97	25	1.89	12	15.81
Total MENA	689.61	44	313.98	20	348.94	22	223.5	14	1576.03
Asia (excl. China)	1303.11	50	635.89	25	407.53	16	245.46	9	2590.99
Latin America (excl. Mexico)	262.94	28	238.83	25	324.37	35	111.64	12	937.68
Non-OECD Total	6636.35	50	3294.63	25	1856.69	14	1479.87	11	13267.54
World	12307.24	45	5184.04	19	6337.02	23	3308.06	12	27136.36

Source: [18].

per capita income in these countries and will make Sultanate of Oman some flexibility to implement these mitigation measures (Table 3). Institutional capacities and level of human capital stock are common among all these countries especially Kuwait, Jordan and Oman. Integrating these measures will help recommend the suitable short-term and long-term mitigation measures on how Sultanate of Oman can reduce GHG emissions based on their suitability, relevance and Oman's capacity for mitigation in the road sector (Response from a

Table 3. Mitigation measures Adopted by some selected countries and UNFCCC on road transport sector.

Country/ Sector	Source	Mitigation Measure	Capacity to Adopt		Relevance to Oman (If Yes)
			Yes	No	
Kuwait	[19]	• Improvement of fuel energy efficiency for light vehicles	√		Reduction in petrol and diesel demand
		• Use of alternate fuels (compressed natural gas)	√		Reduction in PM_{10} emissions
		• Introduction of travel management demand management system (smart growth land use planning, advance management traffic system)	√		Will reduce traffic congestion and road accidents
Egypt	[20]	• Improvement of vehicle maintenance and turning of vehicle	√		
		• Use of compressed natural gas	√		Reduction in SO_2 and NO_x emissions
		• Re-introduction of electrified rail way in inter-city and intra-city transport	√		Reduction in SO_2 and NO_x emissions
		• Intensifying the use of environmentally sound river transport system		√	Will reduce fuel consumption and decrease fuel congestion
		• Extending metro line transport to newly developed cities		√	
Jordan	[21]	• Improve fuel energy efficiency of vehicles		√	
		• Tax and duty exemptions of newly imported taxis		√	
		• Introduction of double-deck buses in municipalities. Improvement of traffic management system		√	Will reduce emissions and long distance journeys
		• Tax exemptions on hybrid cars and incentives for their use	√		
United Nation Framework Convention on Climate Change	[5]	• More fuel efficient vehicles	√		Reduction in SO_2 and NO_x emissions
		• Hybrid vehicles	√		Reduction in PM_{10} emissions
		• Cleaner diesel vehicles and usage of biofuels	√		Reductions in SO_2 and NO_x emissions
		• Model shift of road transport to railway	√		Will reduce road traffic accidents in Oman
		• Public transport system	√		Reduction in number of private car users
		• Non-motorized transport (walking and cycling)	√		Reduction in money used in other forms of transportation
		• Land-use and transport planning	√		Lowers traffic congestions and road accidents
		• Tax on vehicle purchase and duty exemptions	√		Will increase taxi users, increasing vehicle occupancy rates

focused group discussion carried out for this review).

4.1. Short-Term Mitigation Approach

1) Non-motorized transport, NMT (Walking and cycling): Walking is the most basic urban transport mode for all short-to-medium length travel, cycling also plays a fundamental role in urban transport, especially in low and middle income countries throughout the MENA region. NMT in Cairo, Egypt was estimated to be 32% of all trips in 2001 [11]. Current survey shows that 52% NMT transport modes in Shebin El-Kom and 31% in Faiyum, Egypt and field visits in different cities has higher share in walking and cycling, especially in middle size and smaller cities. The reason behind this high share can be estimated to the rel-

atively short distances travelled to schools, universities and factories as well as cost associated to owning vehicles [22].

In the Netherlands, with strong policies and cultural commitment, the modal share of trains from home is about 35% to 40% [23]. In the UK where over 60% of people live within a 15 minute bicycle ride of a station, NMT has been increased UK due to convenient, secure bicycle parking stations [24]. However, walking and cycling depends on local weather condition [25]. This is totally different in Oman, the walking and cycling is possible in winter month which spans a quarter of the year. For the rest of the year, it is almost hostile to use this option. A target of one quarter of all trips in the major cities in Australia to be undertaken by walking and cycling, compared to the current average share of around 16%, would contribute about 4.4 Mt of the targeted 36 Mt emissions reduction at 2020 [26].

2) Reliable public transport (Metro buses ,transit buses): Public transport such as buses are significant from a socially sustainable point of view because it gives higher mobility to people who do not have access to car and also attractive from an economically sustainable perspective [5]. In Jordan, the government is considering the introduction of double-deck buses in Greater Amman and other municipalities to reduce fuel consumption and reduce GHG emissions [20], Abu Dhabi has enriched its public transport infrastructure with taxis and buses and it is offering free services to four major routes, However, the accessibility of public transport depends on perceptions and attitudes of citizens [12]. While buses are not a clean mode of transport, but once bus occupancy exceeds three people, the CO_2 emissions per passenger kilometer are far lower than cars [3].

Currently the Government of Oman has increased the number of buses in major cities in the country as of mid 2016. Muscat governorate is currently operating about 36 buses with 28 buses on inter-city routes in addition to already existing 400 school buses serving various schools in the country. The Government of Oman is planning to increase this number in order to enhance reduction in traffic congestion, road accidents and CO_2 emissions. Though, the patronage of the buses are gradually increasing, the current waiting times for the buses is about 15 - 20 minutes in afternoon and 15 - 30 minutes in the morning and evening when traffic congestion is at the peak level. These waiting times is expected to reduce in future as patronage and number of buses increases and while reducing traffic congestions [27].

3) Eco-driving: This can be explained as changes in driving practices that reduces fuel consumption and reduces emission of pollutants such as CO_2, SO_2, NO_X, CO in vehicles. Fuel-efficient driving practices, smoother acceleration and deceleration, keeping of engine revolution low, shutting off engine when idling, reducing maximum speeds and maintaining proper tire pressure [5] are eco-driving practices.

This option has the potential for both substantial immediate and long term benefits. Slower speed has the potential to provide extensive savings with some 15% - 20% reduction in CO_2 emissions if a maximum speed of limit 80 km/h is

introduced on motorways and truck roads. With lower speeds on other roads such as residential roads, effective compliance is likely to impact CO_2 reduction [28]. This is lacking in Oman, according to a study conducted in 2012 [6] on causes of road accidents from 2000-2009 shows that 50% of the traffic road accidents was due to high speeding, negligence or careless driving accounts for 29% while 3% is due to overtaking. Incorporating eco-driving skills and practices in driving schools and as a requirement for issuing driving licenses will help inculcates eco-driving skills that will contribute to GHG emissions.

4) Increasing urban car occupancy rate: According to European Environment Agency [29], vehicle occupancy rates can be used to explain changes in levels of vehicles ownership and to illustrate changes in the efficiency of mass passenger transport. Efficient usage of passenger vehicles results in the need for less vehicle-kilometer to transport the same number of passengers. Utilization efficiency is one of the main parameters that determine energy and emissions efficiency.

Increasing occupancy rates are the real opportunity to cut emissions provided this is achieved by lowering the number of cars on the road. This is a major focus of policy attention, with appropriate incentives. Government, institution, private companies, families and social groups should promote campaign among themselves and the general public on car shares as means of raising awareness of GHG reduction while reducing congestions and travel cost [26].

5) Taxation and pricing of fuel: Fuel tax encourages consumers to buy more energy efficient vehicles, tend to leads to fewer vehicles being bought, less traffic and more energy efficient driving behavior. Unlike the users of gasoline cars, the users of diesel cars and trucks may not pay the full social cost through fuel tax and other users [30].

This option does not seem to have political support at this time but has an advantage of promoting fuel conservation in many directions, particularly reduced driving and changes in driving behavior including speed in all vehicles [31]. In Oman, in the 2016 oil subsidies were removed by the Government due to the heavy fall in global oil prices, though the tax placed on the fuel was not so adequate to effect significant changes in fuel consumption and rise in decrease in private cars usage. This will still have some reduction GHG emissions as people may be conscious about the rise in fuel cost.

4.2. Long-Term Mitigation Approach

1) Railway (electric and hybrid trains): For long distance journeys and trades, rail is the only viable alternative. Wheels on rails are seen as ecologically aware form of transportation, being four times more efficient than road transportation for passengers and twice as efficient as freight [3]. In Europe and Japan, electricity is a major energy source for rail while diesel is a major source in North America [5]. In Dubai, construction of the US$ 7.6 billion Metro system started in 2006 and piecemeal operation begun in 2009, once construction is completed, it will feature 87 driverless trains running on two lines comprising more than 75 kilometers of track [11]. Sultanate of Oman has long term objectives in develop-

ing railway networks within the remote towns to ensure efficient transport of goods and services in future.

2) Alternate fuel (Biofuels): There are many alternative fuels on the market, many of which have lower carbon content than petrol and diesel, and including biofuels (methanol, ethanol, biodiesel). Ethanol and biodiesel are potentially most suitable to use in India. The government of India has already introduced a program of 5% ethanol in petrol [28]. In Brazil, ethanol is used either in its pure replacing gasoline or as a blend with gasoline at a concentration of 20% - 25%. It is estimated that with 10% ethanol-gasoline blending and 20% biodiesel-diesel blending in Southern Africa, a reduction of 2.5 Mt of CO_2 and 9.4 Mt of CO_2 respectively can be realized annually [5]. Usage of biofuels may not economically feasible in Oman due to lack of arable lands for cultivation of crops for biofuel production as well as the already existing abundant and low cost fossil fuels.

3) Use of electric and hybrid cars and incentives for their usage: Hybrid vehicles provide an intermittent step between the internal combustion engine and electric motor. Energy management is used to optimize the fuel economy of both engines because electric and combustion engines work better under different driving situations [3].

Hybrid vehicles are currently in mass production with estimated 2006 global sales of 373,000, mainly in Japan and the US, compared with conventional petrol-engine cars, full hybrid can improve fuel efficiency by up to 60%, with higher gains in urban driving [32]. This option can be tried in urban cities of Oman for short journeys which can help to reduce the number of big individual cars in the road. Electric vehicles are driven by electric motors with high efficiency more than 90%. Although, the potential of CO_2 reduction strongly depends on the power mix, CO_2 emissions can be reduced by more than 50% compared to conventional gasoline [5].

4) Improvement of traffic management system: Urbanization and urban development are critical factors for CO_2 emissions and mitigation; better urban designs have potential to influence energy consumptions and GHG emissions reduction [33]. Muscat, the capital city of Oman has well planned and sophisticated road infrastructure which helps the authorities to have a better traffic management system. However, due to the rebound effect, where efficiency gains are cancelled out by resulting increase in consumption. The ever increasing number of private cars may mask the overall expected benefits of traffic planning and management. In such cities, infrastructure development focused on provision for cars and trucks could accelerate the growth in use of these modes and decline in the use of less energy intensive-modes. Provision of non-motorized modes in new infrastructure is an important enabling factor for policies to encourage the use of these modes and to discourage individual car use [30].

5. Conclusion

This review investigates the current road transportation sector in Oman and MENA countries as a whole and how it influences GHG emissions and the sug-

gested plausible mitigation measures. Achieving reductions in road transport GHG emissions requires a much broader policy response [26]. Although certain policies can respond quickly to the pressure, in reality it is a slow process and there is a growing expectation on how new technologies can deliver the solution [3]. Introduction of satellite navigation technology in road transport sector in Oman can provide accurate data on annual mileage of vehicles according to vehicle type, type of fuel, age of the car, purpose of the trip and car occupancy. This will help in planning, management and implementation of appropriate policies to mitigate GHG emissions from road transportation sector. It may be impossible to respond to the challenges of transport sector GHG emission mitigation by the government alone without much support from changes in the conveyance lifestyle from the general public [30]. Public education and awareness from opinion leaders, private and non-governmental organizations on the impact of road transport on the environment can also contribute to GHG reductions from road transport sector in Oman.

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