

Evaluation of Transportation Demand Management (TDM) Strategies and Its Prospect in Saudi Arabia

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ABSTRACT

Nowadays it is reiterated in the literature to put more emphasis on Transportation Demand Management (TDM) strategies rather than the traditional transportation strategies which are based on “supply-side” tactic specifically in rapidly growing developing countries. The experiences of many cities reveal that as capacity is increased, demand increases at a similar rate, and subsequently in the long-term, drivers experience no net travel time advantages and the society suffers from the impacts of costly road bills and environmental degradation. This paper suggests emphasizing on TDM strategies to ensure sustainable transportation. The increasing trend of passenger cars in Saudi Arabia makes it more important to concentrate on TDM strategies as a tool for curbing vehicular pollution and congestion. This paper investigated the concept of TDM strategies focusing on the effect of TDM strategies on vehicular emissions and congestion. The analysis of limited scale interviews with experts revealed that tele-working, E-government, electronic shopping, congestion and parking pricing, increased fuel pricing, preferential treatment of HOV, Light Rail Transit (LRT) might be the potential TDM measures. The concerned authorities should think of an innovative mode of public transit services and continuously improve the services to encourage people to switch to public transit. Finally, this paper recommends adopting a public participatory approach in developing TDM strategies which will significantly contribute in reducing vehicular emissions and congestion and ultimately ensure sustainable transportation.

KEYWORDS: Transportation Demand Management (TDM), Vehicular emissions, Saudi Arabia.

INTRODUCTION

Traditionally, transportation strategies adopt “supply-side” tactic which addresses the increased demand for transportation facilities by supplying more, in other ways, increasing the capacity of the facility. According to the “predict and provide” philosophy, the transportation planners would predict transport growth trends based on demographic changes and car

ownership and then simply provide the road facilities in order to match this growth (Noland, 2007). Generally, this approach does not consider the high cost associated with the provision for this predicted growth and does not consider that those users do not pay the marginal costs associated with the use of road transport (Noland, 2007). In economics, demand is a function which refers to the relationship between price and consumption, but transport planning often calculates demand at zero price; that is, free roads and parking (Litman, 2006).

Now, researchers and practitioners are realizing the

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failure of “predict and provide” strategy in meeting long-term goals and objectives. The experiences of many cities reveal that as capacity is increased, demand increases at a similar rate and subsequently in the long-

term drivers experience no net travel time advantages and the society suffers from the impacts of costly road bills and environmental degradation.

Table (1): Summary of air pollution effects

Pollutant	Source	Resides in Atmosphere	Effects on		National Ambient Air Quality Standard (USA)			Industrial Limit
			Humans	Plants	Time	Primary Level	Secondary Level	
CO Carbon Monoxide	Incomplete combustion in gas engines	1 mo. 5 yr.	Not toxic Affinity of hemoglobin Central nervous system effects	None	8 hr	10 mg/m ³ (9 ppm)	same	50 ppm (WHO) 8 hrs/day
HC Hydrocarbon	Unburnt fuel	Helps formation of O ₃ & Pan	Odor formation of O ₃ & Pan Carcinogen		3 hr 6-9 AM	160 µg/m ³ 0.24 ppm	same	
NO _x	Burning at high temp. (Excess Air)		NO ₂ damage to lungs Reduces resistivity	NO ₂ – kills plants	NO ₂ Annual Arith. Mean	100 µg/m ³	same	5 ppm (8hrs/day) U.S. limit
O ₃ & Pan Ozone & Peroxyacetyl Nitrate	Needs sunlight NO _z	Morning to mid-day	Strongly toxic lungs	Oxidizer toxic	1 hr not to be exceeded more than once/yr.	2.35 mg/m ³	same	100-200µg/m ³ (8 hrs/day) WHO
Pb Lead	Leaded gasoline	Deposited in ground	Toxic Anemia Brain disease	Plant damage	California standards 30-day average	1.5 µg/m ³		
SO ₂ Sulphur dioxide	Burning of fuels containing sulfur		Toxic to plants & animals Toxic – when acid is formed H ₂ O + SO ₂ – acid rain Increased mortality & respiratory illness in children		Annual Arith. Mean ----- 24 hr	80 mg/m ³ 0.03 ppm ----- 365 mg/m ³ .014 ppm	60 µg/m ³ (0.02 ppm) ----- 260 µg/m ³ 10.10 ppm	10-13 mg/m ³ (8 hrs/day) WHO
Particulates	HC rubber asbestos		Problem in Tunnels can be toxic	Causes damage	Annual Geo-metric mean ----- 24 hr	75 mg/m ³ ----- 260 mg/m ³	60 µg/m ³ ----- 150 µg/m ³	
Ozone O ₃			Irritation of Nose + throat Headache toxic	toxic	1 hr	240 µg/m ³ (0.12 ppm)	same	100-200 µg/m ³ (8 hrs/day) WHO

Source: Compiled from different sources.

* WHO: World Health Organization.

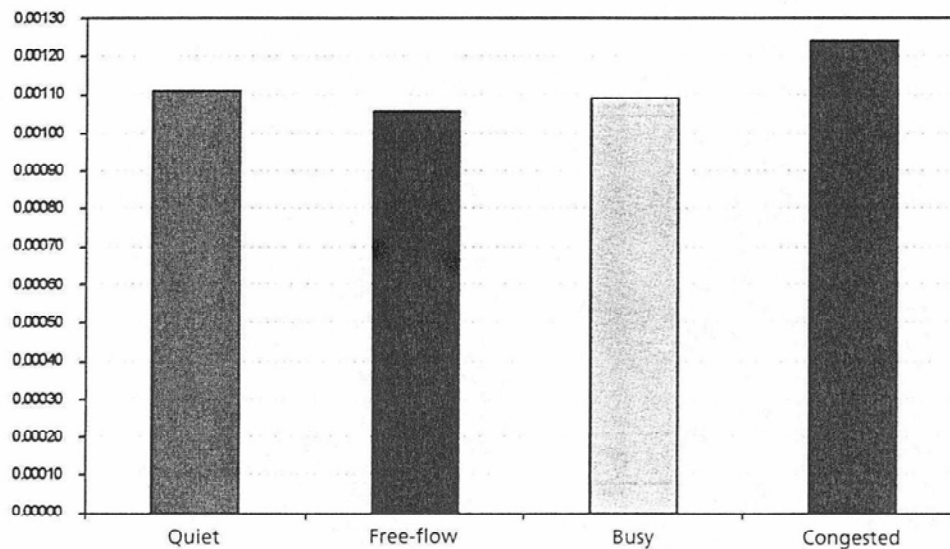


Figure (1): Emissions per vehicle per second, NOx (g.sec/veh) versus traffic conditions (source: Bell et al., 2007)

Sasser (1976) proposed two basic strategies which include “chase-demand” and “level-capacity” strategies. In the first strategy, the capacity is changed to fit the demand and in the second one, the capacity is kept constant and the demand is controlled. In general, balancing capacity and demand is crucial to the success of a company. Heskett, Sasser and Hart (1990) emphasized evaluating the relationships between the nature of demand, the basic measure of risk and the amount of capacity needed by adopting a systems approach to the problem by considering multiple influencing factors in the environment as well as internal capabilities, suggesting that service companies should recognize the need to match their available resources to the demand for their services.

In the USA, about three decades after World War II, public policy aimed to accommodate growth by constructing new facilities which would have adequate capacity to handle future demand without regulating or controlling land use and economic growth (Giuliano and Wachs, 1992). During the 1980’s, the policy goal of accommodating traffic demand started losing its feasibility due to the continuous (and in some areas

explosive) urban growth and automobile use, which led to unprecedented levels of traffic congestion in many metropolitan areas (Hanks and Lomax, 1991).

Transportation demand management has come out as a policy of choice for solving growth and traffic congestion problems by reducing or restricting travel demand, rather than by providing more transportation facilities. TDM refers to “any action or set of actions aiming at influencing people’s travel behaviour in such a way that alternative mobility options are presented and/or congestion is reduced” (Meyer, 1999). The list of strategies include strategies such as shifting solo drivers to carpools or transit, allowing more employees to work at home or adjusting work schedules to avoid peak period auto travel (Giuliano and Wachs, 1992). The presence of TDM can be found at least at the time of World War II, when company buses, carpools and staggered work shifts were introduced to attract employees and manage on-site congestion problems (Giuliano and Wachs, 1992). Even in the early 1980’s, the voluntary, employer-based program was the model for TDM programs which got changed to mandatory programs incorporating specific performance objectives.

TDM programs are now mandated by means of conditions on development, local ordinance or state law and cover individual firms to large geographic areas. Some examples of TDM programs implemented in California are: trip reduction to mitigate new development, trip ceiling on new development, trip reduction for air quality and land use control to redistribute travel demand (Giuliano and Wachs, 1992).

This paper is going to address three main issues. The following section introduces vehicle emissions and their effects. The next few sections review the concept of TDM, its benefits in general and as an emission reduction strategy, in addition to a case study of TDM strategies. Finally, the paper investigates the prospect of TDM strategies in the context of Saudi Arabia.

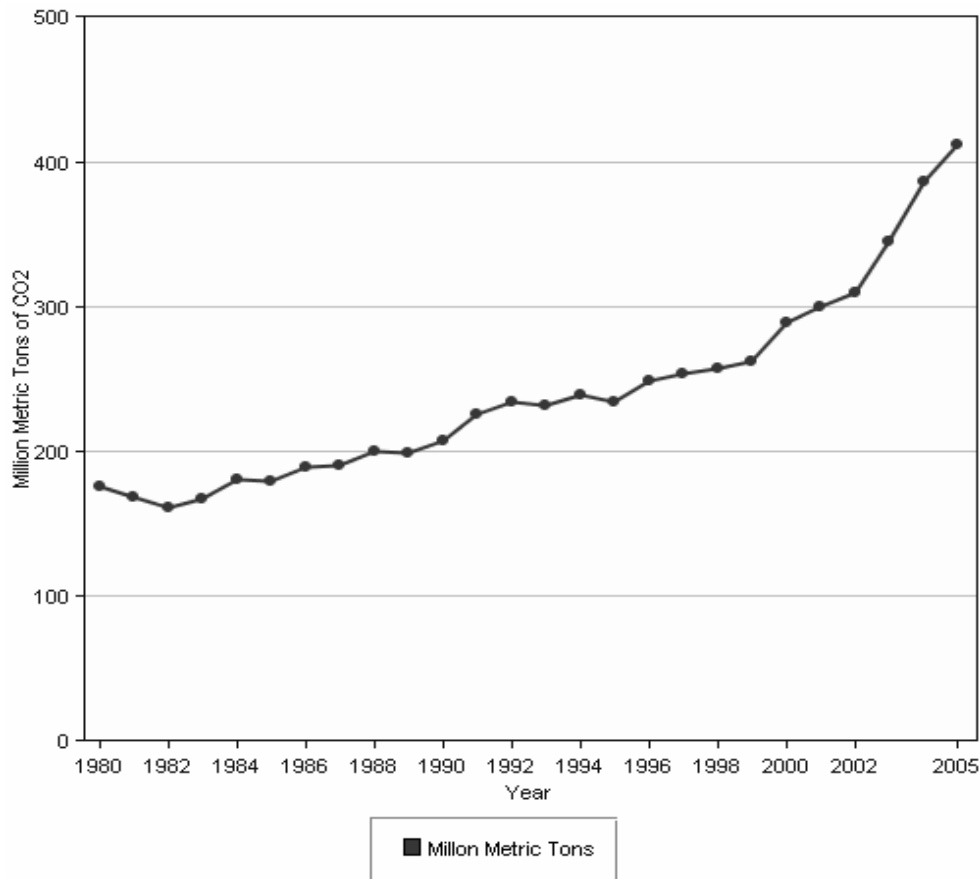


Figure (2): CO₂ emissions in Saudi Arabia. Source: (Energy Information Administration, URL: <http://www.eia.doe.gov>)

VEHICLE EMISSIONS

The main products of the combustion of motor fuels are carbon dioxide and water, but inefficiencies and high temperatures inherent in engine operation

encourage the production of many other pollutants of varying effects. Motor vehicles produce various harmful air emissions, as summarized in Table 1 where some impacts are localized while others are regional or global.

Most of the NO_x in vehicle emissions are in the form of NO (nitric oxide), which is a by-product of fuel combustion under conditions of extreme heat and pressure, typical of combustion chambers. The emission of NO_x is usually lowest in free-flow condition and gains its peak during congested condition (Fig. 1). Moreover, the presence of heavy vehicles influences this emission. Hydrocarbons include hundreds of organic chemical substances, the most notorious of which are benzene and ethylene, produced by the incomplete combustion of fuel and by its evaporation, and their production is strongly influenced by fuel composition. Moreover, the vehicle speed influences HC emissions. Carbon monoxide is one result of incomplete combustion. The emission rate of SO₂ is directly linked to the sulfur content of the fuel. Particulates typically include suspended airborne particles from diesel fuel combustion, materials produced by tire, brake and road wear, and dust. Lead (Pb) is added to gasoline to raise the octane rate and help lubricate engine components. Lead enters the atmosphere as a fine dust. The aldehydes are a major pollutant group associated especially with engines burning alcohol. Many primary pollutants are transformed into secondary and tertiary pollutants through various chemical reactions.

The volume and composition of individual vehicle emissions are determined by fuel composition, level of engine maintenance, vehicle age, engine temperature, road geometry, type of vehicle and speed and congestion. The majority of vehicles operate most efficiently at constant cruising speeds of between 80 and 100 km/hr (TRB, 1995). Dispersion of pollutants is dictated by prevailing wind direction, weather conditions, roadside vegetation and topography.

A study of Victoria Transport Policy Institute (2002) found out some factors that affect how transportation changes affect energy consumption and pollutant emissions.

- Changes in the number of vehicle trips tend to cause a proportional reduction in energy consumption and emissions.

- Because emission rates are high during the first few minutes of vehicle operation (i.e., cold start), reductions in average trip length provide relatively modest pollutant emission reductions.
- Reductions in the number of short vehicle trips can provide relatively large pollutant emission reductions.
- Older vehicles (more than 10 years) produce relatively high emissions per mile, although they tend to be driven relatively few miles per year. Programs that reduce driving by older or out-of-tune vehicles may provide relatively large emission reductions.
- Non-tailpipe emissions such as road dust, brake linings and tire wear are affected by vehicle mileage and weight.
- Reducing emissions with localized impacts (CO, VOC, NO_x, toxics, particulates) in geographic areas with limited air circulation and inversions provides greater benefits than reductions of the same emissions in other areas.
- Changing from stop-and-go to moderate-speed traffic flow increases fuel efficiency and reduces air pollutant emissions, but changing from moderate speeds to high speeds increases some emissions.

THE CONCEPT OF TRAVEL DEMAND MANAGEMENT (TDM)

Definition

"TDM can be defined as any activity, method or program that reduces vehicle trips, resulting in more efficient use of transportation resources" (Dorsey, 2005). TDM can also be defined as "...an intervention (excluding provision of major infrastructure) to modify travel decisions so that more desirable transport, social, economic and/or environmental objectives can be achieved, and the adverse impacts of travel can be reduced" (IEAust, 1995, quoted in Black et al., 1999).

Objectives of TDM Strategies

The usual objective of the TDM strategy is to

identify the role of various TDM measures, establish priorities and identify resources and responsibilities for implementing these measures, in order to attempt to provide a summary of the advantages and disadvantages of each TDM measure, or examples of where and how these measures have been implemented to include a brief description of each measure and summary comments in regard to certain key parameters such as costs, benefits, effectiveness in achieving TDM objectives and issues (Auckland Regional Council, 2000). The objectives are to encourage people to use the most appropriate method of travel for their journey, to persuade car users to be less dependent on their cars and to raise the awareness of the environmental and social impacts of car use. The primary purpose of TDM can be defined as "... to reduce the number of vehicles using the road system while providing a wide variety of mobility options to those who wish to travel" (Comsis, 1993). The core TDM strategies such as carpooling, vanpooling, transit, bicycling, walking, as well as the promotion of tele-working are supported by strategies, such as parking management, rideshare matching, marketing and promotions, incentives and subsidies and other services (Regional Municipality of Peel, 2004). The use of support strategies facilitates to implement and further increase the effectiveness of the core TDM strategy. TDM measures such as education and behavior change initiatives, promotion of tele-working and flexible work hours, support for ridesharing and implementation of land use policies would reduce the need for vehicle travel, introduction of parking restraints and support for pedestrians and cyclists (Auckland Regional Council, 2000).

Different Forms

Parking pricing is one of the most effective TDM strategies. One of the effective approaches is the free use of a parking close to office building by carpoolers and vanpoolers while SOVs pay for parking. *Alternative work schedules* aim at reducing peak-hour congestion by spreading the peak. There is a number of options of altering schedules. One of those options is working

staggered hours which require employees to start and end work at different times, this option can have a significant effect on reducing the peak congestion, particularly at large sites with one employer. *Carpools* can be informal, formed by a group of individuals or they can be formal, formed by a public agency. Carpooling is efficient for long trips and for participants who have the same work schedule. *Preferential Treatment for HOVs* has many forms. The simplest one is reserved lane on an urban street for buses, carpools and vanpools. The basic principle of *congestion pricing* is that where and when a commodity is most scarce, its use should be curbed through increased prices that lower the demand for that commodity in that place and time (Zupan, 1992).

Transit related TDM strategies emphasize on increasing transit rider-ship, improving the efficiency of existing services and identifying potential new services to make publicly provided alternatives to single-occupant- vehicle travel, including services and facilities that encourage and support other travel modes. Employer-based TDM strategies include private-sector programs and services that encourage employees to change their commuting practices, incentives that make publicly provided travel modes more attractive, disincentives to solo commuting and employer management policies that offer employees flexibility in travel mode choices. Taxing and pricing related TDM strategies affect the cost of transportation and thereby provide monetary disincentives to some travel behaviors. Emerging demand-management solutions based on advanced telecommunication technologies form a positive TDM strategy being used by many organizations and offering many benefits including cost associated benefits to companies. Land use is the underlying determinant of TDM strategies and has the abilities to shape population density, urban design, land-use mix, travel needs and travel patterns. In fact, land use alters transportation demand by reducing trip length. For example, "compact development, mixed use development and higher development densities can reduce trip lengths and make transit, pedestrian and bike

use practical and affordable” (Deakins, 2001).

Public policy and regulation related TDM strategies include restrictions and regulations that govern private vehicle use and provide political support and guidance to new institutional relationships. TDM strategies include smart growth which influences the timing, location, pattern, intensity and budgeting of development especially where state law provides for smart growth tools, so as to reduce the need for transportation facilities as well as address environmental, social and fiscal issues (OKI, 2004).

Evaluation of TDM Measures

Gärling and Schuitema (2007) reviewed the research concerning effectiveness, acceptability and political feasibility studies of TDM measures. They found out that non-coercive TDM measures alone are unlikely to be effective in reducing car use but coercive TDM measures such as increasing cost for or prohibiting car use may be necessary though they are difficult to implement because of public opposition and political infeasibility. They concluded that the coercive TDM measures are likely to become more effective, acceptable and politically feasible if they are combined with non-coercive TDM measures providing attractive travel alternatives and communicating the benefits of car-use reduction to the public. Gärling et al. (2002) proposed a goal setting and control theories based framework to understand how travel is influenced by the effects of various travel demand management (TDM) measures on time, cost and convenience of travel options. The proposed framework can be utilized when analyzing changes in household travel arising from the range of potential measures available to policy makers such as TDM measures.

Loukopoulos et al. (2004) conducted a focus group survey gauging the creativity of car-using households when contemplating adaptation alternatives, followed by an Internet-based questionnaire study in an attempt to obtain quantitative estimates of the size of car-use reduction goals and frequency of implementation of adaptation alternatives. Based on the study, they

concluded that the effects of travel demand management measures and trip purpose on the setting of car-use reduction goals were small while the cost-minimization principle seemed to dictate stated choices of adaptation alternatives.

Bhattacharjee et al. (1997) proposed a methodology developed using ordered probit models to evaluate commuters' attitudes toward Transportation Demand Management (TDM) strategies and to determine users' preferences for different TDM strategies and help planners investigate the effect of individual socio-economic characteristics on these preferences. The study revealed that among four broad categories of suggested measures, public transportation improvement was found to be the most popular and fiscal restraint to be the least desirable approach. The study also found out that the introduction of rapid rail transit was the most desirable approach whereas increasing parking fees in government offices was found to be the least welcomed solution to the respondents.

Eriksson et al. (2006) modeled the acceptability of travel demand management (TDM) with the aim of reducing private car use. They found out that problem awareness and personal norm, in combination with evaluations of specific TDM measures, are the main issues behind the acceptability of TDM measures. They also discovered that moral considerations and perceived fairness were important for the acceptability of increased tax on fuel, while freedom aspects and problem awareness were of importance for the acceptability of improved public transport.

BENEFITS OF TDM POLICIES AND STRATEGIES

In the USA, TDM got introduced because of the failure of traditional solutions in addressing the huge magnitude of congestion in major metropolitan areas (Giuliano and Wachs, 1992). Mostly the traditional solutions are either financially or practically infeasible. Moreover, the failure of supply side Transportation System Management also contributed in the acceptance

of TDM. Usually, TDM is perceived as a cost-effective policy. For example, providing preferential parking to carpools, subsidies to vanpools or a material appreciation to those who rideshare can cause significant trip reductions though the strategy costs are low. TDM is often the most cost effective solution to transportation problems and can provide multiple benefits, including reduced congestion, road and parking facility cost savings, crash cost savings and consumer cost savings, pollution reduction and more efficient land use (VTPI, 2005). But the whole TDM strategy doesn't aim at supporting all objectives, rather most of the strategy supports several of them, and complementary TDM strategies under a comprehensive TDM program help achieve most transportation improvement objectives.

TDM can provide flexible solutions which expand the range of solutions that can be considered for addressing transportation problems and their solutions. TDM can benefit consumers by providing more travel options or opportunities. Motorists that continue driving are no worse off, and those who reduce their driving must be better off otherwise they would not change their travel habits. Positive incentives by themselves tend to modest travel impacts, but they become very cost effective when implemented with other strategies, such as road and parking charges (VTPI, 2005).

TDM can help achieve equity objectives such as increase of horizontal equity (fairness) by creating more neutral planning and investment practices, and by making transportation prices more accurately reflect costs, increase the benefits of lower-income people by providing direct financial savings and improving affordable transport choices... etc. (VTPI, 2005). But it is not expected that each TDM measure will cover a comprehensive list of equity benefits. The equity benefits of TDM can be particularly large for comprehensive TDM programs which can provide significant financial savings that particularly benefit lower-income households and people who are transportation disadvantaged (McCann, 2000). In fact, TDM program responses are inherently equitable and

efficient in terms of outcomes (Ferguson, 1993).

Usually many public policies do not pay attention to their long-term impacts on travel behavior or land use pattern, but TDM allows public policy decisions to more effectively support long-term transportation and land use objectives, and helps correct current transportation and land use market distortions by increasing consumer choice, encouraging competition, making prices more accurately reflect costs and creating more neutral planning and tax policies. TDM can be implemented within a short period of time and ensures almost immediate results. If employees are given the opportunity to join vanpools, it is often anticipated that vanpools will be rapidly formed (Giuliano and Wachs, 1992).

TDM STRATEGIES TOWARDS EMISSION REDUCTION

In the USA, on-road transportation sources are responsible for 27 percent of VOCs emissions, 35 percent of NOx emissions and 55 percent of CO emissions (USEPA, 2002). Usually, meeting the increasing need of travel demand is achieved by increasing the use of motorized vehicles which depend on fossil fuels and cause an adverse effect on the environment by releasing emissions into the atmosphere. This air pollution problem in built-up areas can be mitigated by ensuring cleaner vehicles in terms of emissions, cleaner fuels and tackling traffic congestion. TDM strategies can significantly contribute in addressing these issues. The United States Clean Air Act Amendments (CAAA) of 1990 pressurizes States and Metropolitan Planning Organizations to implement TDM as a vital part of the response strategy of air quality non-attainment areas (Shiftan and Shrbier, 2002).

TDM strategies reduce motor vehicle emissions primarily by decreasing vehicle miles traveled, which can occur in several ways, including:

- Shifts from driving to other modes, such as transit, bicycling or walking;

- Increasing vehicle occupancy through carpooling or vanpooling;
- Eliminating vehicle trips, through telecommuting, E-government, compressed work weeks or providing on-site services;
- Reducing vehicle trip lengths, such as through better urban design and land use mixing;
- Linking vehicle trips or combining errands;
- Shifts from peak periods to less congested periods, thereby reducing travel delay and idling (Grant et al, 2007 and others).

CASE STUDY OF TDM STRATEGIES

The following TDM strategies tend to be particularly effective at reducing pollution emissions. Now, we are providing case studies based on Distance-Based Emission Fees and Fuel Tax Increase.

Distance-Based Emission Fees

Distance-Based Emission Fees are mileage-based charges that reflect a vehicle's emission rate (USEPA, 1998). It will encourage the motorists who use higher polluting vehicles to reduce their mileage, and encourage motorists who drive high mileage to choose low polluting vehicles. Fees can vary depending on time and location depending on the sensitivity of the space and time. The use of sensors can measure actual tailpipe emissions when a vehicle is driven. A study of Harvey and Deakin (1998) revealed that a fee based on measured tailpipe emissions, averaging about 1¢ per vehicle-mile (but higher for more polluting vehicles) would reduce mileage by about 2%, but energy consumption would decline by 7% and air pollution emissions would decline by almost 20%.

Fuel Tax Increases

Raising fuel price causes modest reductions in vehicle mileage, and over the long term encourages motorists to choose more fuel-efficient vehicles. It is uncertain how much increased fuel efficiency reduces emissions other than CO₂. Manufacturers design vehicles to meet specific emission standards, and to meet these

requirements they implement more control strategies in vehicles with larger engines than in vehicles with smaller engines. Some emission control strategies reduce fuel efficiency (for example, catalytic converters add weight, and tuning engines to minimize NO_x emissions increases fuel consumption). Reducing vehicle weight and wind resistance tends to reduce non-tailpipe emissions such as tire particles and road dust, but these effects are difficult to quantify. Most emissions decline proportional to mileage. A study of Harvey and Deakin (1998) estimated that a fuel tax increase of 50¢ per gallon (US 1991 dollars) would reduce mileage by about 4%, energy consumption by about 9% and other emissions by about 3.5% .

PROSPECT OF TDM STRATEGIES IN SAUDI ARABIA

Vehicular Emissions in Saudi Arabia

Saudi Arabia is one of the top twenty fossil fuel CO₂ emitting countries by total emissions for 2003 (Marland et al., 2003). Fig. 2 shows the total CO₂ emissions for the past two decades. The air pollution caused is of special concern in Saudi Arabia, where gasoline contains appreciable amounts of lead that converts into lead particulates during combustion (Hamid, 2001). The demand on transportation fuels, especially gasoline, has been increasing dramatically over the past ten years and is predicted to rise even more in the future. The domestic consumption of oil products has risen at an average rate of 24% over the past two decades (Al-Sahlawi, 1997).

The transport sector is growing worldwide and the same trend is also observed in Saudi Arabia, causing increased demand on national and international transport and subsequently increasing the demand on fuels. The growth of global demand is estimated to accelerate to 2.8 % annually between 1999 and 2020, compared to 2.2 % in the 1990s (EIA, 2001). Since coal, gas and renewable fuels are not used on a large scale in Saudi Arabia, this mainly results in increases of oil consumption. In Saudi Arabia, on average,

transportation fuels account for more than 80% of the total oil product demand.

Population growth is one of the key drivers of change in the Kingdom. According to GTZ (2004), the population growth of Saudi Arabia is going to average 2 percent over the next 23 years (2002-2025). The United Nations' "Urbanization Prospects" (2001 revision) in UN 2001 estimate that more than 90 percent of Saudi Arabia's population will be living in cities by 2015 and that more than 50 percent of the population live in cities including Riyadh, Damman, Jeddah, Mecca and Medina. The increasing population of Saudi Arabia along with the shift of the population to urban agglomerations will increase environmental concerns related to the transportation sector.

According to the "Achievements of the Development Plans", domestic consumption of gasoline grew at an average rate of 10.5 percent between 1970 and 2000, and the total fuel consumption in 2000 was 86,854,000 US barrels (MOEP, 2000). Depending on an estimated vehicle fleet of 3.8 Million, fuel consumption amounts to 86,854,000 US barrels or 13,808,683,000 liters (GTZ, 2004). The continuing growth of vehicle fleets and fuel consumption will subsequently increase the associated pollutant emissions and Green House Gas (GHG) emissions.

The problem of vehicle related air pollution in Saudi Arabia is of primary concern because of severe climatic conditions, which accelerate the exhaust, evaporative and refueling emissions of pollutants into the atmosphere. Moreover, the existing cars being used are not equipped with catalytic converters due to the presence of lead in the gasoline that poisons the catalysts present in the converters. The number of vehicles in Saudi Arabia is also increasing due to the rapid economic growth and this increase is translated into increased domestic consumption of gasoline.

Potential TDM Strategies for Saudi Arabia

The authors didn't find any significant efforts of planned TDM strategies at the city-level or regional-level transportation planning although the need is

mentioned at national-level. The increasing number of autos and CO₂ emissions and the presence of very limited public transportation systems should influence researchers and practitioners to investigate the potential of TDM strategies in reducing pollution and congestion. This study found the presence of casual carpooling in almost all the major cities of the Kingdom. Casual carpooling is defined as a type of ridesharing arrangement whereby drivers wishing to form carpools pick up passengers waiting at roadsides or any specific locations suitable for them. In general, casual carpooling is initiated by commuters and continues to operate without any formal intervention of agencies or organizations (UBC, 2001). According to Casey et al. (1996), one likely reason for the success of casual carpooling is the ease and speed with which a ride may be obtained.

Saudi Arabia as an oil producing country maintains the fuel prices which are generally lower than in most other countries. The incentives to offer cheap fuel to its citizens in fact facilitate growth based on motorized (individual) transport and encourage settlement structures that favor car-based development. This development pattern can be seen country-wide. Most cities exhibit that a car-oriented approach is going on in land-use planning (GTZ, 2004). In order to cover the full internal costs of the fuels and generate state revenues and apply the polluter-pays-principle, appropriate TDM measures such as increasing fuel prices might be adopted. However, the adoption will of this measure should be accompanied with a long-term land use planning strategy to change the form of urban agglomeration which will reduce the number of trips and trip lengths.

Limited scale interviews with a few experts on the transportation sector of Saudi Arabia revealed that unique cultural characteristics of this country might cause failure of many traditional TDM strategies such as car-sharing and car-pooling among the nationals. The analysis of the interviews revealed that tele-working, E-government, electronic shopping, congestion and parking pricing, increased fuel pricing, preferential

treatment of HOV, Light Rail Transit (LRT) might be the potential TDM measures. The increasing use of Internet along with its improving infrastructure might contribute in making full-fledged E-government feasible in Saudi Arabia. The concerned authorities should think of an innovative mode of public transit services and continuously improve the services to encourage people to switch to public transit. On the other hand, these proposed TDM strategies should be facilitated by improvement/enforcement of strong emission standards via technical vehicle inspection and maintenance, air pollution monitoring, assessment of the effects of regulative measures and air quality management strategy in order to reduce vehicular emissions.

The successful implementation of TDM recognizes important local variations in conditions and responding to them in an appropriate manner. Therefore, TDM strategies should be designed and implemented by all relevant institutions of the Kingdom adopting a public participatory approach.

CONCLUSIONS

Nowadays, it seems important to focus on TDM strategies in order to reduce vehicular pollution because the reduction of emissions from vehicles through technological improvement is becoming insignificant. This paper suggests emphasizing on TDM strategies in Saudi Arabia to ensure sustainable transportation. The increasing trend of passenger cars in Saudi Arabia makes it more important to concentrate on TDM strategies as a tool for curbing vehicular emissions and congestion. It is required to analyze the growth of vehicle population and its trend in order to develop a long-term strategy to reduce air pollution caused by motor vehicles whether related to TDM strategy or not. In general, TDM strategies make it expensive to own and use cars. Therefore, proper care is to be taken to

ensure an efficient alternative public transport system. The analysis of limited scale interviews with experts revealed that tele-working, E-government, electronic shopping, congestion and parking pricing, increased fuel pricing, preferential treatment of HOV and Light Rail Transit (LRT) might be the potential TDM measures. The concerned authorities should think of an innovative mode of public transit services and continuously improve the services to encourage people to switch to public transit. The TDM systems should be configured in such a way to make them easy to understand and the schemes should be designed taking into account the needs of users in order to make them acceptable and implementable. TDM strategies should be implemented along with other transportation planning efforts. It should be noted that TDM programs face a number of challenges as emission reduction strategies because the programs need to reduce a larger number of vehicle trips than in the past to show the same emissions reduction effectiveness due to improved emissions control technologies. In order to find out the potential TDM strategies in the context of Saudi Arabia, it is required to understand the unique socio-economic and religious features of it. Moreover, the recent security concern will also play a role in shaping the TDM strategies. However, it is needed to conduct comprehensive studies before suggesting any specific sort of TDM strategies in Saudi Arabia. Finally, this paper recommends adopting a public participatory approach in developing contextualized TDM strategies which will contribute significantly in reducing vehicular pollution and ultimately ensure sustainable transportation.

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