ISSN (e): 2250 – 3005 || Vol, 04 || Issue, 7 || July – 2014 ||
International Journal of Computational Engineering Research (IJCER)

Reducing of Roads Congestion Using Demand Management Techniques

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ABSTRACT:
Normally, people associate congestion with heavy traffic volumes, but it is not limited exclusively to roadways, other examples of congestion as overcrowded buses, trains, and commuter parking lots. Movement of people and goods are adversely impacts by traffic congestion. More delay in travel to motor vehicles and traffic operates less efficiently (motorist dissatisfaction), wasting fuel and increased levels of air pollution. The main objectives of this research are to identify the possible congestion management techniques that are used around the world, and the softwares available to evaluate such techniques. The applicability and effectiveness of some of these techniques are then tested on available national and international data by comparing measures of effectiveness (capacity, LOS, delay, and speed) before and after applying these management measures. It was found that some congestion management measures can be applied urban arterials, while others could not be applied easily. Also it was found that some softwares are more applicable than others when dealing with congestion aspects. Efficiency enhancement appeared in the road that congestion management techniques applied on.

Keywords: *Congestion, demand, supply, Traffic Safety, management techniques.*

I. INTRODUCTION

Living in any place without streets that connect cities with other cities or villages is impossible. Use of any transportation modes is necessary to facilitate the accessibility. Therefore, transportation has to be treated as an integral and basic component of any comprehensive development plan. Congestion management is a key element in any development plan.

Normally, people associate congestion with heavy traffic volumes, but it is not limited exclusively to roadways, other examples of congestion as overcrowded buses, trains, and commuter parking lots. Movement of people and goods are adversely impacts by traffic congestion. More delay in travel to motor vehicles and traffic operates less efficiently (motorist dissatisfaction), wasting fuel and increased levels of air pollution.

Congestion problems appears with the long term, so if the traffic on the roads is acceptable these days, due to growth and the increase in number of cars the roads will not carry the new traffic volumes, and congestion problems will rise again. Congestion management is mainly applied in two ways - either through the supply side or the demand side. In order to achieve low growth in traffic congestion in cities, the rate of increase of supply should match the rate of increase in demand. However, expanding traffic network capacities by building more roads and other infrastructure is extremely costly as well as environmentally damaging.

II. DEFINITION OF CONGESTION MANAGEMENT

Congestion and queuing are now parts of our everyday life with examples aplenty. One of the most significant day-to-day queues manifests themselves on highways despite the improvement in highway design and analysis practices and design. Many urban areas in the world including but not limited to London, Paris, Stockholm, Tokyo, and Beijing have overwhelming traffic congestion that causes significant economic losses. Congestion management is an organized process for managing congestion on all aspects of the transportation system with the main goal of alleviating existing or preventing future congestion, thereby enhancing the mobility of people and goods. Congestion management process includes procedures to monitor the transportation system's performance, identify causes of congestion, evaluate alternative actions, implement cost-effective strategies, and determine the effectiveness of those strategies.

When a volume of traffic generates demand greater than the available road capacity, traffic congestion occurs; and this point is named as saturation. Congestion usually occurs; either due to reduction in the capacity of a road at a given point or over a certain length, or increase the number of vehicles required for a given volume of people or goods.

III. OBJECTIVES OF THE STUDY

There are some studies that have been done before with the specific objectives of congestion management using certain techniques in some cities. So it is important to do this study on the arterial streets, then consider the concepts and apply it on other streets. The main objectives of this research are to identify the possible congestion management techniques that are used around the world, and the softwares available to evaluate such techniques. The applicability and effectiveness of some of these techniques are then tested on available national and international data by comparing measures of effectiveness (capacity, LOS, delay, and speed) before and after applying these management measures.

IV. TRAFFIC DEMAND MANAGEMENT STRATEGIES (TDM)

Transportation management focuses on reducing corridor congestion and improving overall mobility on the existing facility. This alternative includes an integrated package of transportation management strategies that maximize the operational efficiency and person-moving capacity of the corridor by better balancing the demand for travel with the capacity to handle travel demand.

This section describes methods for measuring congestion, factors that affect traffic congestion, and potential strategies for reducing congestion problems, including TDM strategies that reduce peak-period travel demand or improve transportation alternatives, and various ways to increase roadway capacity.

4.1 High Occupancy Vehicles (HOV) Priority, Transit Improvements and Rideshare Programs

HOV Priority strategies favor bus; vanpool and carpool travel, including:

1- Dedicated arterial traffic lanes for HOV, these are sometimes reversible lanes, or like lanes open only to buses which called busways.
2- High Occupancy Toll lanes. These are HOV lanes that also allow low occupancy vehicles if they pay a toll.
3- Queue-jumping lanes, this means that other vehicles must wait to enter a highway or intersection, but HOVs enter directly.
4- Intersection controls that give priority to HOVs. For example, a traffic signal might be set to stay green for several extra seconds if that allows a bus to avoid stopping, or gives separate green time for these lanes.
5- Streetscape changes to favor HOVs, such as improved bus stops.
6- Favorable parking spaces or discounts parking fee provided to rideshare vehicles
7- Special benefits to HOV riders, like include them in commute trip reduction programs.
8- Preferred building access and parking (such as HOV parking located close to the front of buildings)
9- Grade separation for HOV, this means that high occupancy vehicles have separate right-of-way, so they are not delayed by traffic congestion.

Another effective congestion reduction strategies are transit improvements and rideshare programs, to reduce traffic congestion, transit services must:

1- Serve a major share of major urban corridors and destinations.
2- Offer high quality service (relatively convenient, fast, frequent and comfortable) that is attractive to travelers.
3- Be relatively with reasonable cost, low fares and discounts targeted at peak-period travelers.

Figure (1) HOV

The main concept of how transit and HOV reduces traffic congestion is summarized as follows:

If congestion increases, people change destinations, routes, travel time and modes to avoid delays, and if it declines they take additional peak-period trips. The quality of travel alternatives has a significant effect on the point of congestion equilibrium: If alternatives are poorer, few motorists will shift mode, if these alternatives are relatively attractive, motorists are more likely to shift modes.

4.2 Road Pricing

Road pricing involves charging motorists directly for driving on a particular road or in a particular segment. Economists considered road pricing as an efficient and equitable way to pay roadway costs, encourage more efficient transportation, and fund transportation programs. In general road pricing has two objectives: congestion management and profits generation. In certain periods it is required to apply congestion pricing, to reduce the traffic during rush hour, charging higher during heavy congestion periods, usually in the morning and late afternoon (the time of the home-work-home trips of most commuters).

Road pricing can reduce traffic congestion on a particular roadway, particularly if implemented as part of a comprehensive TDM program (transit improvements and rideshare programs…etc). If road pricing applied on just one roadway it may cause traffic to shift routes and so increasing traffic congestion on other roads. A successful strategy is done on some American States called "Cap and trade", in which only licensed cars are allowed on the roads. A limited number of car licenses are issued each year. This guarantees that the number of cars does not exceed road capacity and avoiding the negative effects of it. However since demand for cars tend to be inelastic, the results are very high purchase prices for the licenses.

4.3 Fuel Pricing

Fuel price increases (for example, due to higher fuel taxes) can help reduce traffic congestion. INRIX (2008), evaluated the effects of fuel price increases on U.S. vehicle travel and traffic congestion, The results indicate that increased gas prices in the first half of 2008 significantly reduced VMT and highway traffic congestion. A 28% increase in average fuel prices during the first half of 2008 contributed to a 3% reduction in average national Travel Time Index values.

4.4 Distance Based Fees

Vehicle insurance, vehicle taxes, and registration fees (fixed costs) provides a significant financial motivation when converting into distance-based charges, to reduce driving applying what's called pay as you drive, comparable to nearly doubling fuel prices. Unlike road pricing, distance-based fees affects all travel, not just travel on certain highways, and so provides congestion reduction benefits on surface streets without shifting traffic to other routes.

Distance-based fees provide several benefits:

1- More accurate insurance pricing
2- Increased insurance affordability
3- Increased economic efficiency
4- Reduction in insurance claims
5- Reduced vehicle travel
6- Reduction in vehicle crashes
7- Emission reduction
8- Significant reductions in traffic congestion, road and parking facility costs.

4.5- Parking Management and Parking Pricing

Parking management and parking pricing are one of the most effective measures to reduce automobile travel in urban congested areas. More efficient pricing of on-street parking would make urban driving more expensive but more efficient. Driving and parking are almost ideal complements: you need a parking space close to every destination.

Some specific parking management strategies are described below.

4.5.1- Parking Use Regulation

Regulating parking facilities can enhance travel and encourage more efficient use of parking resources. This involves making the most convenient parking spaces available to certain higher-value uses.

4.5.2- Shared Parking

Sharing parking spaces allows more users compared with assigning each space to an individual user. Since different activities have different peak demand times a greater reductions are possible with mixed land uses. For example, a mall can share parking with a company complex, since mall parking demand peaks in the evening while company parking demand peaks during the middle of the day.

4.5.3- Remote Parking

Motorists usually prefer the closest parking location, but given a choice some will park further away to save on parking fees. Remote parking involves encouraging motorists -like commuters and residents- to use off-site or fringe parking facilities (typically located a few blocks from a commercial center), so the most convenient spaces are available for priority users (such as service vehicles and customers).

4.5.4- Other Strategies

a) More Accurate and Flexible Parking Standards
b) Improve User Information and Marketing
c) Improve Walkability
d) Increase Capacity of Existing Parking Facilities
e) Park & Ride

4.6- Access Management

Access management is defined as "the process that provides access to land development while simultaneously preserving the flow of traffic on the surrounding system in terms of safety, capacity, and speed" (Maine Department of Transportation, 1994). Access control is a very important feature in preserving road capacity and reducing accidents. Ideally, arterials should have few, if any conflict points other than at intersections. Continuous access for adjacent development should not be permitted nor should be extensive on-street parking.

Access management should address the following areas:

- Corner clearance
- Two-way-left-turn lanes
- Median treatments and median openings
- Frontage and backage roads
- Dedicated turning lanes
- Driveway related
- Street connections

4.7- Traffic Signal Spacing and Timing

Traffic signal coordination is one of the most widely used traffic management measures. The signals at two or more adjacent junctions are coordinated (linked) on a common cycle time and the relative timings set so that the traffic that leaves one junction arrives at the downstream junction when the signals are green. For a well-designed coordinated signal system, vehicles flow without having to stop at every intersection, MUTCD, 2000 recommends that signals within 0.5 mile (0.8Km) of each other be coordinated on major streets.

Colorado and Florida considered that intersection spacing along major (arterial) urban and suburban streets should follow the pattern given in Table (1).

Table 1: Recommended Intersection Spacing

Main Roadway	Intersecting Minor Roadway	Recommended Intersection Spacing
Freeway	Arterial	1 to 2 miles minimum
Arterial	Arterial	1 mile or greater
Arterial	Collector	0.5 mile or greater

Source: City of Florida and Colorado Regional Government (1996).

4.8- Freight Transport Management

Although freight trucks represent a relatively small portion of total traffic but it can make a relatively large contribution to congestion, due to their large size and slow acceleration. Freight transport management can reduce total freight traffic and shift freight to less congested routes. It is expected that trucks making off-peak hour deliveries instead of at peak hours experienced fewer delays, easier parking, reduced congestion and significant savings.

Different ways can be used to improve freight transportation efficiency by shifting and improving the quality of efficient freight options (such as rail and integrated distribution services), providing incentives to use the most efficient option for each type of delivery, improving logistics, increasing load factors, and reducing unnecessary shipping distances and volumes.

4.9- Car-Free Cities and Town Planning

Car-free cities and town planning are strategies to establish zones with restricted access for automobiles within the cities (reducing automobile travel at particular times and places). Although the concept may seem unusual today, there are cities, like Venice, that have prospered throughout the ages without car access. Car free cities (or areas) often have pedestrian-oriented commercial streets. Pedestrian streets should have good access to public transport and parking.

4.10- Vehicle Restrictions and Pedestrian Improvements

Vehicle restrictions include various regulatory strategies that limit automobile travel at a particular time and area. Although this seems to be one of the simplest ways to reduce the amount of vehicles, it is often difficult to implement successfully. When effective, vehicle restrictions can reduce traffic congestion, road and parking facility costs, crash risks, pollution emissions and local environmental impacts. They can also have a positive impact on safety. All this can lead to an improvement in the quality of life for citizens and visitors.

4.11- Reversible Lanes

A reversible lane is a lane in which traffic may travel in either direction, depending on certain conditions, for example, into a city center during the morning rush hour and outward during the evening rush hour. This may be controlled by variable-message signs or by movable physical separation.

Figure (2) Reversible lane

It is required more caution to drive on a reversible lane, since driving in a reverse traffic lane puts you in extremely close proximity to oncoming traffic with no buffer between you and it. These lanes are often narrower than what you normally find.

4.12- Ramp Metering

A ramp meter or ramp signal is a device, usually a basic traffic light or a two-section signal (red and green only, no yellow) light together with a signal controller, that regulates the flow of traffic entering freeways according to current traffic conditions. It is the use of traffic signals at freeway on-ramps to manage the rate of automobiles entering the freeway.

Figure (3) Ramp meters control

4.13- Intelligent Transportation Systems

Intelligent transportation systems include the application of a wide range of new technologies, including driver information, vehicle control and tracking systems, transit improvements and electronic. These can provide a variety of transportation improvements, including driver convenience, reduced congestion, increased safety, more competitive transit, and support for pricing incentives. ITS can be seen as tools to help to implement demand management policies and support both, the decision makers as well as the common users to take decisions regarding transport usage.

Motorist information can include changeable message signs, radio reports and Internet information about traffic conditions. These can reduce motorist stress by letting them anticipate conditions. Some of the applications of intelligent transportation system, which guide traffic are summarized below, (Todd Litman, 2009):

a) Traffic reporting, via radio, GPS or possibly mobile phones, to advise road users
b) Support real-time driver information. This includes traffic cameras, congestion mapping and variable message boards (VMB) accessible by the general public.
c) Navigation systems, possibly linked up to automatic traffic reporting
d) Traffic counters permanently installed, to provide real-time traffic counts
e) Automated highway systems, a future idea which could reduce the safe interval between cars (required for braking in emergencies) and increase highway capacity by as much as 100% while increasing travel speeds
f) Parking guidance and information systems providing dynamic advice to motorists about free parking

4.14- Other Measures

- Intersection Improvements
- Grade Separation
- Road Capacity Expansion
- Incident Detection and Management
- One-Way Streets
- Narrow Vehicles
- Urban planning and design
- Flexible Time
- Telework

V. URBAN TRAFFIC MANAGEMENT AND OPTIMIZATION SOFTWARES

Traffic congestion is becoming a daily problem on many arterials in several countries. In Saudi Arabia traffic congestion is growing because the number of vehicles is growing. This section mainly reviews the features of traditionally and state-of -the-art used traffic management and optimization models along with a comparative analysis focusing on urban congested arterials, these softwares is listed below.

1. CORSIM

2. TRANSYT-7F

3. OmniTRANS

4. QUADSTONE PARAMICS

5. VISSIM

6. Highway Capacity Software (HCS)

7. SimTraffic

VI. STUDY AREA

Two major arterials where selected to apply selected congestion management techniques on it. One of them is King Abdullah Road in Saudi Arabia and the other is Faisal Road in Palestine. King Abdullah Road in Al-Khoar area was selected because it is the largest arterial in Al-Dammam and Al-Khobar cities and it is the main entrance of Al-Khobar city. Also, it has a common cycle length. The arterial consisted of three signalized intersections presented in table (2). It consists of four through lanes and two lane left turn storage bay in each direction, and it is located in mixed residential and commercial area.

Table 2: PH, and PHV for King Abdullah Road Intersections

No.	Intersection Name	PH	PHV
1	**King Abdullah Road and Makkah Street**	1:30-2:30	2293
2	**King Abdullah Road and Prince Homoud Street**	1:30-2:30	1890
3	**King Abdullah Road and King Fahd Road**	1:30-2:30	2293

(Abo Olba, 2007)

Faisal Street is a major arterial in Nablus city in Palestine. The main studied intersections along the studied arterial are presented in table (3). Intersection No. 5, 6, 8 are signalized intersections while others are unsignalized.

Table 3: PH, PHV, and PHF for Faisal Intersections

No.	Intersection Name	PH	PHV	PHF
1	Tunis St and Haifa St	7:00-8:00	1563	0.88
2	Al-Maajeen St and Haifa St	7:15-8:15	987	0.90
3	Al-Aien Camp St and Faisal St	7:45-8:45	1121	0.93
4	Madares Al-Wakala St and Faisal St	7:30-8:30	936	0.85
5	Al-Salam Mosque Intersection	7:15-8:15	2260	0.86
6	Al-Kendy Intersection	7:15-8:15	2662	0.90
7	Saleem Afandi Intersection	7:15-8:15	2305	0.93
8	Al-Haj Nemer Intersection	7:15-8:15	2408	0.80
9	Al-Baloor Intersection	7:30-8:30	1827	0.76
10	Ministry of Education Intersection	7:15-8:15	1372	0.95

Source: (Yassin and Alkalili, 2003)

VII. EVALUATING PROPOSED TECHNIQUES

It is noticed from the described congestion management strategies that some techniques can be adopted and applied on the studied streets. Other techniques can be applied but with some modifications and some are difficult to be applied. Some of the relevant techniques which be tested locally and regionally includes:

A- Operational Improvements, these improvements related to intersections (signalized and unsignalized), since some of the studied intersections have an existing LOS F, and some warranted to have signal in Faisal Road. HCS will be used to evaluate the measures of effectiveness on intersections and arterials, by improving traffic signals (operational improvements).

B- Some improvements related to ITS, this will include testing two characteristics of driver performance, which are the speed factor and the yellow react in King Abdullah Road. Simtraffic will be used to test and evaluate the altering in driver performance through ITS measures (speed factor and yellow react).

7.1 Operational Modification

The analysis on highway capacity software is applied on Faisal street arterial (signalized and unsignalized intersections) on Nablus City on Palestine; the results are shown on the next sections.

7.1.1 Existing UnSignalized Intersections

Using HCS 2000 program for the unsignalized intersections on the studied street, the results of existing level of service (LOS) are shown in Tables (4).

Table 4: Existing LOS for the Unsignalized Intersections on Faisal Street

Intersection No.	Northbound			Southbound			Eastbound			Westbound		
	L	T	R	L	T	R	L	T	R	L	T	R
1	F	---	B	---	---	---	---	---	---	A	---	---
2	---	---	---	---	---	B	---	---	---	---	---	---
3	---	D	---	---	D	---	A	---	---	A	---	---
4	---	B	---	---	---	---	---	---	---	A	---	---
7	---	---	---	---	---	C	---	---	---	---	---	---
9	C	---	---	---	---	---	---	---	---	A	---	---
10	C	---	---	---	---	---	---	---	---	A	---	---

L: left-turn movement / T: through movement / R: right-turn movement.

The unsignalized intersections on the studied arterial operate at an acceptable LOS, except intersections number (1) on Faisal Street, which have (F) LOS, and this should be improved, as shown. Since this intersection is controlled by stop sign, it is checked for signalization warrants, and the result that it is warranted for signalization based on the Peak Hour Volume Warrant, (MUTCD, 2000). The design of the suggested signals is done using (HCS). The result is shown that LOS C for all approaches.

7.1.2 Existing Signalized Intersections

Using the HCS Program for the signalized intersections on the studied street, the results of existing condition are shown in Tables (5). LOS analysis of signalized intersections was based on existing signal timing and phasing.

Table 5: Existing LOS for the Signalized Intersections on Faisal Street

Intersection No.	Intersection Name	NB	SB	EB	WB
5	Al-Salam Mosque	E	F	F	D
6	Al-Kendy	---	---	E	C
8	Al-Haj Nemer	D	---	---	D

Redesign for traffic signals on intersection number 5, which operate at an un-acceptable LOS was done to reach at better LOS, and the improved condition reach LOS E.

7.1.3 Arterial Level of Service

Level of service on Faisal Street is conducted using HCS analysis for Muti-Lane Highway. The street is divided into two sections; the LOS for the first section (from intersection 1 to 5) is A, while the LOS for the second section (from intersection 5-10) is F. This is because the second section pass through CBD area.

7.2 Altering Driver Performance through ITS Measures

Simtraffic is microscopic stochastic simulation model used in conjunction with Synchro. The driver parameters can be used to view and change the driver characteristics. They are used to change the driver's reaction rates or to make the driver population more or less aggressive. The two parameters that will be analyzed on are described below.

The first parameter is the yellow react which is the amount of time it takes the driver to respond to a signal changing to yellow. More aggressive drivers will have a longer reaction time to yellow lights. The default value (0.7s for most conservative to 1.7s most aggressive) is tested first, using some ITS techniques like time counters on the signals, the yellow react is adjusted to be (0.8-1.2s) and the measures of effectiveness is compared, see table (5.5).

The second parameter is the speed factor which is multiplied by the link speed to determine the maximum speed for this driver. If the link speed is 50ft/s and the speed factor is 1.1, this driver will attempt to maintain a speed of 55ft/s. The default speed factors (0.75 for most conservative to 1.27s most aggressive) is tested, again using some ITS techniques like variable massages and automated enforcement like radars (Saher), the speed factors is adjusted to be (0.9-1.15s) and the measures of effectiveness is compared, see table (6).

Table (6): Simtraffic Simulation Results

Measures of Effectiveness	Existing Driver Parameter	Improved Driver Parameter	% Change
Total Delay (hr)	86.1	84.3	2.1
Delay / Veh (s)	191.2	186.6	2.4
Avg Speed (mph)	11	11	0
Travel Time (hr)	133.0	130.6	1.8
Total Stops	4750	4701	1.03
NOx Emissions (g)	896	890	0.01
Fuel Used (gal)	131.9	131.9	0
CO Emissions (g)	9899	9403	5.0

The results from the above table show that most of the measures (delay, travel time, total stops, and emissions) on the improved network decreased compared to the existing network. Both average speed and fuel used did not change with the improvements.

Percent change between existing and improved network is limited, because the suggested improvements are also limited. The total delay has improved by more than 2 percent as a result of driver performance improvement at the network level. Carbon-oxide emission has decreased by more than 5 percent, this is due to minimize stop and go operations.

8- Conclusions and Recommendations

Based on the analysis presented in the research, several conclusions were reached. The conclusions are:

- Since we are dealing with a network, solving the congestion on one street may transmit this problem to other streets. There were improvements on some segments, while traffic conditions on other segments got worse.
- Strategies that improve transportation choices, such as ridesharing or transit improvements without HOV Priority are unlikely to provide significant congestion reduction if implemented on a small scale, but may provide some benefit if implemented on a large scale that affects a major portion of total peak-period travelers.
- Some softwares are more applicable than others when dealing with congestion aspects
- There are major differences in driver characteristics and behavior on urban networks which require adjusting some parameters to replicate the local traffic conditions.
- The total delay has improved by 2 percent, and carbon-oxide emission has decreased by more than 5 percent, as a result of driver performance improvement at the network level.
- ITS can provide a variety of transportation improvements, including driver convenience, reduced congestion, increased safety, more competitive transit, and support for pricing incentives.
- An active enforcement program may lower the yellow reaction times and increase the yellow deceleration rate, especially for aggressive drivers because they will be most likely to run lights and cause startup delays to the next movement, these drivers are most likely to cause accidents on the field.
- Using ITS techniques (like Saher, time counter on signals) will enhance the travel time, reduce delay, emissions and fuel consumption as results shows.
- This study showed the importance of applying congestion management measures. As a result of this study, the following recommendations were depicted:
- Encourage development of travel alternatives, including ridesharing, public transport improvements and bicycle facilities.
- Apply congestion pricing on existing roads, not just new facilities
- Choose pricing methods that are cost effective to implement, convenient to users and accurately reflect the costs imposed by each trip
- It is recommended to conduct traffic impact studies for future land developments including congestion management's projects, to mitigate resulted traffic impacts.
- It is recommended to conduct a comprehensive study about the public opinions and acceptance of applying congestion management techniques on urban arterials.

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