CANADIAN TRANSPORTATION RESEARCH FORUM
LE GROUPE DE RECHERCHES SUR LES TRANSPORTS AU CANADA

PROCEEDINGS OF

SEVENTEENTH ANNUAL MEETING

CANADIAN TRANSPORTATION RESEARCH FORUM

Volume 1

MONTREAL, QUEBEC

MAY 26, 27 & 28, 1982

Compiled by: R. Lande
&
K. Tansey

A CASE STUDY OF ENERGY CONSUMPTION IN URBAN TRANSPORTATION

By

N. Irwin, Managing Director
S. Stewart, Senior Associate
S. Hayto, Senior Professional

CTRF Annual Meeting
Montreal, Quebec

May, 1982

The growing world-wide concern about the increasing scarcity and cost of energy focusses particularly on petroleum. Oil and its derivatives have been a dominant form of energy for the past 50 years, particularly for applications requiring portability, ease of handling and high energy content per unit volume. Transportation is such an application, and it is therefore not surprising that 42 percent of petroleum fuels consumed in Canada are used in the transportation sector. While petroleum fuels are used by the marine, air and rail modes, automotive transportation is the major user, consuming some 85 percent of transportation fuels used in Canada, or 36 percent of total Canadian petroleum consumption. Of the petroleum fuel used in the automotive sector, private automobiles are the dominant users accounting for some 70 percent of consumption.

Clearly, urban automotive traffic, and particularly private automobiles, are a prime target for efforts to conserve petroleum. These efforts can include conservation and the use of alternative fuels. This paper summarizes the results of a study undertaken by the authors who reviewed a series of conservation measures, with particular emphasis on more efficient traffic operations, incentives to increase vehicle occupancy and greater use of transit, and incentives to reduce or smooth travel demand.

Study Purpose and Approach

The primary objective of the study was to develop a Transportation Energy Management plan for the Regional Municipality of Hamilton-Wentworth. The Transportation Energy Management measures considered in the study are listed in Exhibit 1. As indicated, these are grouped under five headings:

- traffic operations (eight measures)
- transit related measures (ten measures)
- legislative measures (two measures)
- high occupancy vehicle (HOV) related measures (three measures)
- other measures (three measures)

In total, some 26 Transportation Energy Management measures were considered.

EXHIBIT 1

LONG LIST OF MEASURES

1. TRAFFIC OPERATIONS

1.1 Alternative Signal Timing Plans for a Signal Network
1.2 Eliminating Localized Congestion Problems
1.3 Selected Removal of On-Street Parking
1.4 Signal Timing Flexibility Near Major Traffic Generators
1.5 Traffic Signal Night Flashing Operations
1.6 Alternative Traffic Control Measures at Local Intersections
1.7 Reversible Lanes in Corridors with High Directional Splits
1.8 Two-way Left Turn Lanes

2. TRANSIT RELATED MEASURES

2.1 Exclusive or Shared Lanes for Buses and HOV's
2.2 Public Transit Level of Service and Pricing
2.3 More Frequent Bus Service During Rush Hours
2.4 Special Promotion of Off-Peak Bus Travel
2.5 Downtown Mini-Bus or Free Bus
2.6 Implementation of Express Bus Service on Selected Routes
2.7 Reduced Deadheading
2.8 Transit Vehicle Priority at Traffic Signals
2.9 Selected Installation of Bus Bays
2.10 Bus Stop Spacing and Location

3. LEGISLATIVE RELATED MEASURES

3.1 Control of Parking and Loading in Some Downtown Areas
3.2 Privately Operated Jitneys or Shared Taxis

4. HIGH OCCUPANCY VEHICLE (HOV) RELATED MEASURES

4.1 Preferential Treatment of HOV's
4.2 Additional Promotion of Car Pool and Van Pool Programs
4.3 Fringe Parking Lots as Car Pool and Van Pool Assembly Areas

5. OTHER MEASURES

5.1 Flexible and Staggered Hours, or Compressed Work Weeks
5.2 Improved Transportation Facilities
5.3 Educational Program to Encourage Grouping of Trips

A two step process was applied in evaluating these measures. The first step was a preliminary evaluation based on published documentation. The second step was a detailed analysis of the highest priority measures identified in the preliminary evaluation.

In the study, each of the measures was evaluated with respect to energy saving, cost effectiveness (i.e. cost per litre of fuel saved), accidents, person delay, and emissions. It is important to point out that, some measures which are now standard engineering practice for safety or other reasons would not necessarily rank high in terms of energy savings.

2 - REVIEW OF TRANSPORTATION SERVICES, DEMAND AND ENERGY CONSUMPTION

The Hamilton-Wentworth planning area consists of six municipalities: Hamilton, Ancaster, Dundas, Stoney Creek, Flamborough and Glanbrook. The 1980 assessed population for the planning area was approximately 410,000 people with an average annual growth rate over the previous seven years of less than .5%. The estimated total employment within the study area is approximately 166,000 ranging from some agricultural employment in the outlying areas of the Region through to heavy industrial employment in the Bayfront area.

2.1 TRANSPORTATION SUPPLY

The major elements of the transportation supply system in Hamilton/Wentworth include Hamilton Street Railway (HSR) and the road system.

2.1.1 Hamilton Street Railways

Hamilton Street Railways is the primary transit operator within the Region. HSR operates approximately 33 transit routes with a service population of approximately 325,000 people, and approximately 14 million kilometres of service and 28,000,000 revenue passengers annually. The service covers the major urbanized areas within the Region. The large majority of the routes operate into the central business district.

The transit service accommodates approximately 85 annual rides per capita which is slightly above the norm for a system of this size.

2.1.2 Road Network

The road network within the region comes under three jurisdictions: the Province, the Region and local municipalities. The Province is responsible for all provincial highways which include the Q.E.W. and Highways 403, 2, 6, and 8 comprising some 750 kilometres within the Region. The Region has jurisdiction over approximately 540 kilometres of regional roads which are defined as roads that connect urban centres, provincial highways and special land use areas.

There are approximately 1500 kilometres of municipal or lower tier roads that are under the jurisdiction of local municipalities. These roads are generally local streets or collectors. The City of Hamilton accounts for the largest share of lower tier roads, over 720 kilometres.

2.2 ESTIMATES OF ENERGY CONSUMPTION

One of the important aspects of a transportation energy management study is assessing the energy impacts of particular measures on the total transportation energy consumption. A basic difficulty in the process is deriving and energy consuption base. Although there are a number of techniques to estimate total transportation energy consumption in urban street systems, the method applied was based on street section characteristics. This technique was considered most appropriate because it provides a distribution of fuel consumption by jurisdiction.

The energy estimate was developed using an equation, shown in Exhibit 2, which relates the length of road section, the average travel time and the number of vehicles, to provide estimates of energy consumption. In applying this equation to the provincial, regional and municipal roads in the study area, data was required on travel demand characteristics such as traffic volumes and speeds. Values for these variables were estimated from various statistics collected by the Region.

Using the equation the base energy consumption for the study area was estimated to be approximately 715 million litres of gasoline and diesel fuel per year

EXHIBIT 2

FUEL CONSUMPTION ESTIMATING EQUATION

$$\text{Fuel Consumed (litres/year)} = \sum_{i=1}^{\tilde{}} (100.4 \cdot D_i + 0.63 \cdot T_i) \cdot N_i \cdot C_1 \cdot C_2 \cdot C_3 \cdot C_4$$

where:

D_i = the total distance of each road type i in km

T_i = the travel time in secs (i.e. the reciprical of the average speed on road type i multiplied by D_i)

N_i = the average annual daily traffic for each road type i

C_1 = 365.25 (a factor to allow for the upgrading of AADT to yearly traffic)

C_2 = 1.220 (a factor applied to allow for increased fuel consumption rates due to cold starts)

C_3 = 0.9635 (a factor applied to allow for the improved fuel efficiency resulting from the automobile fleet change since 1979)

C_4 = 0.001 a constant of the equation

i = the various road classifications for each jurisdiction
e.g. Regional Roads (width and surface type)
Municipal Roads (urban/semi-urban/rural by arterial/collector/local)

taking into account trucks, buses and the impact of cold starts. Because each of the measures evaluated did not specifically address cold starts the base consumption was discounted for comparison purposes to approximately 650 million litres/year.

One of the difficulties with a multifaceted transportation energy management program is that it is extremely difficult to determine actual consumption characteristics and therefore monitor the impact of any specific energy conservation program other than through fuel sales. But fuel sales reflect various other factors, the most noteable being vehicle fuel efficiency levels and is thus an imperfect indicator.

3 - DESCRIPTION AND PRELIMINARY EVALUATION OF TRANSPORTATION ENERGY MANAGEMENT MEASURES

3.1 DESCRIPTION OF MEASURES

Exhibit 3 summarizes the 26 transportation energy management measures that were analyzed, provides a brief description of these measures, and, where appropriate, identifies the locations and times for which the analysis was undertaken. In certain traffic operation measures two or three sub-measures were also examined. For example, signal timing improvements and pedestrian actuation of traffic signals were assessed as part of 1.2, Eliminating Localized Congestion.

As is evident in reviewing Exhibit 3, the 26 measures included supply improvements to the transportation system such as improved traffic operations; incentive measures to alter travel demand characteristics such as improved public transit and increased promotion of carpools and vanpools; disincentives such as higher parking rates; and public education and information such as the encouragement of grouping trips. With this range of measures it was possible to develop a comprehensive program which took into account the complementary and supportive nature of the various measures such that two or three measures implemented in a coordinated fashion would achieve benefits that exceed those of implementing the measures independently.

EXHIBIT 3

DESCRIPTION OF TRANSPORTATION ENERGY MANAGEMENT MEASURES ASSESSED

1.0 Traffic Operations Measures

1.1 Alternative Signal Timing Plans For a Network

- manually assessed the offsets at 9 intersections along Mohawk Road from West 5th to Wentworth and Upper James Street from Hester St. to Brantdale Avenue for the p.m. peak period.

1.2 Eliminating Localized Congestion Problems

- developed alternative signal timing at Queenston Road and Centennial Parkway for the p.m. peak hour.
- implementing pedestrian actuated walk phase at York Boulevard and Dundurn Street

1.3 Selected Removal of On-Street Parking

- assessed the removal of on-street parking on Barton Street between Kenilworth and Strathearn Avenues.

1.4 Signal Timing Flexibility

- examined alternative signal timing plans during 2 selected hours of Saturday operation at the intersection of Queenston Road and Centennial Parkway.

1.5 Traffic Signal Flashing Operations

- evaluated the effects night flash operation at the intersection of Birch Avenue and Brant Street for a typical weekday operation.

1.6 Alternative Traffic Control Measures at Local Intersections

- examined signal coordination versus actuation for the intersections of Barton Street and Green Road and Barton Street and Millen Road.
- examined replacing stop signs with yield signs at three intersections in Crown Point East.
- assessed replacing 4-way stop signs with traffic signals.

1.7 Reversible Lanes in Corridors with High Directional Split

- examined reversible lanes for Main St. West from Cootes Dr. to Osler Dr.

1.8 Two-Way Left Turn Lanes

- assessed two-way left turn lanes for Main St. West from Cootes Dr. to Osler Dr.

2.0 Transit Related Measures

2.1 Exclusive Lanes for Buses

- examined an exclusive bus lane on Concession St. from the top of the Jolley Cut to Henderson Hospital.

2.2 Public Transit Level of Service

- examined the impacts of a 10% increase in the vehicle kilometres of transit service throughout Hamilton.

2.3 More Frequent Bus Service During Rush Hours

- examined increase transit service during rush hours on route 4 and route 5.

2.4 Special Promotion of Off-Peak Bus Travel

- reviewed available literature on increased promotion of transit service.

2.5 Downtown Mini Bus

- briefly assessed the impact of a downtown mini bus.

2.6 Implementation of Express Bus Service on a Selected Route

- examined the impacts of implementing an express bus service between the University and the downtown.

2.7 Reduced Deadheading

- examined the impacts of a remote operating station to store transit vehicles providing service to Stoney Creek.

2.8 Transit Vehicle Priority at Traffic Signals

- reviewed the literature on signal pre-emption and assessed the general impacts in Hamilton.

2.9 Selected Installation of Bus Bays

- assessed the energy impacts of a bus bay at the intersection of Upper James and Mohawk during the p.m. peak hour.

2.10 Bus Stop Spacing and Locations

- reviewed HSR bus stop spacing policy and assessed impacts of longer spacings.

3.0 Legislative Related Measures

3.1 Control of Parking and Loading in Downtown Areas

- examined the impacts of higher long term parking rates in the downtown.

3.2 Privately Operated Jitneys

- reviewed the impacts of shared ride taxi operations.

4.0 High Occupancy Vehicle (HOV) Related Measures

4.1 Preferential Treatment of HOV'S

- generally reviewed the importance of preferential parking rates and locations for HOV's.

4.2 Additional Promotion of Car and Vanpools

- reviewed the area wide impacts of comprehensive ride-sharing program for the Hamilton area.

4.3 Fringe Parking Lots as Carpool and Vanpool Assembly Areas

- examined the impacts of installing fringe parking lots near the major highways into Hamilton.

5.0 Other Measures

5.1 Flexible, Staggered Hours or Compressed Work Weeks

- examined the impacts of flexible, staggered hours in the downtown and a compressed work week at major employment centres.

5.2 Improved Transportation Facilities

- generally assessed the impacts for bikeways in Hamilton.

5.3 Educational Program to Encourage Grouping of Trips

- assessed the potential of grouping of trips to reduce energy consumption.

3.2 EVALUATION PROCEDURE

3.2.1 Evaluation Criteria

The primary criteria used in evaluating the described measures include:

- o cost-effectiveness: this criterion deals with the costs associated with each litre of fuel saved. The costs include capital costs which were annualized based on a 5% discount rate, reflecting real interest costs, and the appropriate life cycles, as well as annual operating costs. The annual energy savings were estimated from the actual assessment of impacts for the particular measure;

- o total potential energy savings: for this criterion the energy savings as derived for a specific application of a particular measure were, as appropriate, factored to an area-wide saving based upon the number of potential sites at which the measure could be applied (eg. there are a total of 10 potential locations for pedestrian actuated signal equipment);

- o air pollution: this criterion was assessed in a qualitative/subjective manner based on the fact that air pollution impacts are usually proportional to the energy impacts;

- o effects on accidents: this measure was also assessed qualitatively based, where appropriate, on available published documentation or judgement;

- o interaction with other measures: in some cases the interaction of a measure with various other measures or other modes of travel was included as part of the analysis (eg. increased parking rates in the downtown would have an impact on transit, ride-sharing, etc.);

- o institutional/jurisdictional implications: this criterion generally refers to the ease with which a particular measure can be implemented. In some cases, measures can be implemented quickly, with minimal institutional/jurisdictional problems because the responsibility for implementing the measure would reside with one jurisdiction (eg. improved traffic signal timings). However, in situations where there is a significant degree of interaction between measures and there is more than one jurisdiction involved, implementation can be difficult because of the required cooperation between the respective agencies. In certain cases, the responsibility for implementing measures may lie with agencies external to the region.

In many cases, other criteria such as changes in travel speeds or travel time, mode splits, net change in person travel, etc., were assessed as part of the quantitative analysis of estimating the cost-effectiveness.

3.2.2 Evaluation Approach

In evaluating a number of the measures, the approach was to identify, where appropriate, specific locations for which the measure might reasonably apply. For each of the locations identified, a detailed assessment of impacts was undertaken focusing on energy savings and costs. From this analysis, the cost-effectiveness of a particular measure was estimated. Once the energy savings were identified for a specific location, the potential area-wide savings were estimated based on the additional locations where a measure might be applied. Assistance in identifying these additional locations was provided by City and Regional staff. Thus the degree to which a particular measure truly reflects the area-wide potential is based on the assumption that the site examined reasonably represents an average operating condition.

3.3 EVALUATION RESULTS

Exhibit 4 summarizes the major results of the analysis for the identified measures with particular emphasis on the quantitative criteria such as energy savings, costs, number of area-wide application and possible annual fuel savings area-wide. The table also summarizes qualitative assessments such as impact on air pollution, effects on accidents, interaction with other measures and institutional/jurisdictional implications.

As is evident from the Exhibit, the total potential energy savings for all the measures considered is approximately 3% of base fuel consumption or 20 million litres of fuel per year. This is generally lower than generalized estimates that have been developed and published. The reasons for this include:

- o the estimated base area-wide energy consumption includes a large number of rural areas for which the majority of measures analyzed would have little or no impact, (eg. traffic operations measures such as improved signal timings, improved transit services, etc.);

- o the estimates of site-specific and thus area-wide energy savings potential were intended to be conservative.

EXHIBIT 4

SUMMARY OF PRELIMINARY ANALYSIS

MEASURE	SITE SPECIFIC ANALYSIS: ENERGY SAVINGS (INCREASE) L/YR.	REDUCTION IN CONSUMPTION (%)	ANNUAL COSTS	COST EFFECTIVENESS $/L	NO. OF POSSIBLE APPLICATIONS	POSSIBLE ANNUAL FUEL SAVINGS (1)	% RED. IN TOTAL FUEL CONSUMP. AREA WIDE	IMPACT ON AIR POLLUTION	EFFECT ON ACCIDENTS	INTERACTION WITH OTHER MEASURES	INSTITUTIONAL JURISDICTIONAL IMPLICATIONS
1.0 TRAFFIC MEASURE											
1.1 Alternative Signal Timing Plans	6,670/signal	2%	$70./signal	$.01	150 @ 2% 100 @ 1%	1.33 million	.20%	decrease	decrease	negl.	none
1.2 Eliminating Loc. congestion											
excessive demand	300	1% 1.	$50/yr.	$.20	-	-	-	-	-	negl.	none
pedestrian timing	12,000	23% (excess)	$650/yr.	$.05	10	121,000	.02%	decrease	negl.		none
1.3 Removal of On-Street Parking	2,300	3.5%	$45 $2,300	$.02 $1.00	50	115,000	.02%	decrease	decrease	none	local merchants
1.4 Signal Timing Flexibility	6,000	6.6%	$1,600	$.27	16	96,000	.01%	decrease	decrease	negative with signal co-ordination	none
1.5 Traffic Signal Flashing											
existing flash	200	0.6%	$20	$.10	36	33,500	.005%	decrease	increase	none	none
no flash	750	2.1%	$35	$.05	35						
1.6 Alternative Traffic Control											
fixed time to coordination	35,000	37%	$1,175	$.03	30	1.07 million	.171%	decrease	none	none	none
stops to yields	4,500/ intersection	17.4%	$50	$.01	900	4.05 million	.62%	decrease	significant increase	none	community reaction
4-way stops to signals	47,300	39%	$3,200	$.07	10	473,000	.07%	decrease	increase	none	none
1.7 Reversible Lanes	10,000	3.2%	$8,000	$.80	1	10,000	.002%	negl.	potential increase	none	merchants
1.8 Two-way Left Turn	8,400	0.8%	$2,200	$0.26	2	16,800	.003%	negl.	decrease	positive with interconnection	none
2.0 TRANSIT MEASURES											
2.1 Exclusive Lanes	0	0	-	-	1	-	-	-	potential increase	increased transit frequency	traffic -ve impact
2.2 Level of Service Improvements	472,000	-	$1.9 million	$2.30	-	472,000	.07%	decrease	decrease	parking	HSR
2.3 Increased Frequency (peak period)	(48,000)	increase	$449,000	$8.33	20	(960,000)	(.15%)	increase	increase	-	HSR
2.4 Increased Promotion					area wide			possible reduction		improved transit efficiency	HSR
2.5 C.P.D. Mini Bus	Increase	increase				Increase	increase	increase	none	none	HSR

1. Excess means consumption due to stops and delays
*Not reliably measurable

?. Expenditure of 0.31 results in 1 litre increase in fuel consumption

EXHIBIT 4 (Continued)

MEASURE	SITE SPECIFIC ANALYSIS: ENERGY SAVINGS (L/Yr)	REDUCTION IN CONSUMPTION (%)	ANNUAL COSTS	COST EFFECTIVENESS ($/L)	NO. OF POSSIBLE APPLICATIONS	POSSIBLE ANNUAL FUEL SAVINGS (1)	% RED. IN TOTAL FUEL CONSUMP. AREA WIDE	IMPACT ON AIR POLLUTION	EFFECT ON ACCIDENTS	INTERACTION WITH OTHER MEASURES	INSTITUTIONAL JURISDICTIONAL IMPLICATIONS
2.6 Express Buses	8,000	-	(saves 1 bus)	-	10	80,000	.01%	decrease	decrease	parking CBD	HSR
2.7 Reduced Dead Head During Start-up	9,450	-	$10,800	1.14	2	20,000	negl.	negl.	negl.	none	HSR
2.8 Signal Pre-emption	450 - 900/ tr.sig.	-	$1,080	$1.20 $2.40	100	45,000 - 90,000	.01%	decrease	negl.	cross street traffic	traffic operations/HSR
2.9 Selected Installation of Bus Bays	190 1	-	$1,760	$9.26	50	9,500	negl.	negl.	decrease	-	traffic operations HSR
2.10 Bus Stop Spacing & Location	648,000	-	$16,500	$ .03	-	648,000	.1%	decrease	possible decrease	express buses	neg. public reaction
3.0 LEGISLATIVE MEASURES											
3.1 Controlled Parking and Loading in Downtown	690,000	-	$414,200	$ .60	-	690,000	.09%	decrease	decrease	poss. impact transit HOV's	public reaction
3.2 Privately Operated Jitneys or Shared Ride Taxis	350,000	-	$50,000	$.14	-	350,000	.05%	decrease	decrease	negl.	taxi by-laws taxi operators
4.0 HOV RELATED MEASURES											
4.1 Preferential Treatment HOV's	-	-	-	-	CBD/Major Emp. Centres	-	(4.2)	(4.2)	-	car and vanpool promotion	Major Employers Parking Auth.
4.2 Car & Vanpool Promotion	1.2 million	-	$150,000 - $200,000	$.12 - .17	area wide	1.2 million	.2%	decrease	decrease	parking inc. required	Prov./Region
4.3 Fringe Parking	350,000	-	$35,000 - $47,000	$.10 - .15	9	350,000	.05%	decrease	decrease	Pos. on HOV's	Prov./Region
5.0 OTHER MEASURES											
5.1 Staggered, Flexible Hours and Compressed Work Week											
staggered flex	74,000	-	$25,000	$.17 - $.50	-	74,000	negl. .15%	negl.	negl.	reduce transit peak	Region
Compressed	1 million	-	$75,000	$.02 - $.08	-	1 million		decrease	-	neg. on HOV	
5.2 Improved Facilities for low-energy vehicles	216,000	-	$60,000	$.30	-	216,000	.03%	decrease	possible increase	neg. effect on traffic	Region
5.3 Education Program to Group Trips	8.5 million	-	$850,000	.10	-	8.5 million	1.34%	decrease	decrease	-	Province

- because of the transit market penetration by HSR as reflected by annual rides per capita the extensive network of one-way streets and interconnected signals, and the active traffic signal timing program, the potential energy savings in Hamilton through Transportation Energy Management Measures is probably less than that which might be achieved in most other municipalities.

3.4 MEASURES RECOMMENDED FOR DETAILED EVALUATION

A large number of the transportation management measures reviewed are cost-effective in terms of energy savings and could be implemented immediately and independently. Other measures such as increased transit frequencies during peak periods could be cost-effective eventually as demand is stimulated through other measures (i.e. increased parking rates in the downtown) and as peaking characteristics are altered (i.e. flexible work hours). This interaction of measures is important in the development of a comprehensive transportation energy management program and as such was an important consideration in the identification of measures for more detailed analysis.

The following summarizes recommended measures that were analyzed in more detail.

3.4.1 Traffic Operations Measures

Although the majority of traffic operations measures examined were potentially cost-effective, three were recommended as particularly promising for further analysis:

- alternative signal timing plans for the signal network. The more detailed analysis made use of a traffic optimization program (TRANSYT) on a network of over 30 signals;
- traffic signal flashing to assess, in addition to the energy savings, the safety and accident impacts;
- alternative traffic control measures at local intersections. Specifically, this included an analysis of converting stop sign control to yield, four way stops to signal control and replacing fixed time isolated signals with coordinated control or traffic responsive control. Accidents were of major concern with these measures.

3.4.2 Transit Measures

Only one transit measure was assessed to be cost-effective in the short term: express buses. The detailed analysis of express buses focussed on the potential costs of instituting such a service as well as the degree to which the measure would effect adjacent transit routes.

3.4.3 Legislative Measures

None of the legislative measures was recommended for further analysis. Control of parking was not considered appropriate because of the limited control over parking and the difficulty in instituting legislation to control private parking lots. Privately operated jitney service was not recommended because of the jurisdiction/institutional impediments (local municipal taxi by-laws).

3.4.4 High Occupancy Vehicle Measures

All three high occupancy vehicle measures were recommended for further consideration. Specifically, these included additional promotion of carpooling, vanpooling (including preferential treatment at parking lots) and fringe parking lots.

3.4.5 Other Measures

All of these measures were considered potentially cost-effective but only two were recommended for further analysis: staggered, flexible hours and compressed work week; and improved facilities for low energy vehicles (bike-ways). An educational program to encourage grouping of trips was considered an appropriate measure to review with the Province.

4. DETAILED ANALYSIS

Each of the ten measures recommended for further analysis as a result of the preliminary assessment was subjected to a more thorough assessment and evaluation as

part of the detailed analysis. For example, two surveys were undertaken of the major employers in the Region to determine their willingness and interest in participating in various measures such as staggered, flexible work hours, increased promotion of carpooling and vanpooling, etc. In addition, an extensive survey was undertaken of potential fringe parking locations along major commuter corridors both within and leading to the Region. In other cases, a more detailed analysis involved analyzing the energy and other impacts of various measures at a number of different locations.

The ten measures analyzed in detail were evaluated using the following criteria:

- o Potential energy savings - the total litres of fuel saved annually.
- o Cost per litre of fuel saved - the cost per litre of fuel saved per year was calculated based on the estimated annual fuel savings and the annual cost of implementing the measure.
- o Safety - the social costs of accidents involving personal injury.
- o Interaction with other measures - the extent and type of interaction of the measure.

Based on the above criteria and the detailed analysis, Exhibit 5 was prepared. From the Exhibit, it is evident that the total potential savings per year of all of the measures is approximately 12 million litres per year or 2% of the base energy consumption. However, not all measures are cost-effective as reflected by the cost per litre of fuel saved. For example, the estimated the cost per litre of fuel saved when stop signs are replaced with yield signs is $.64 to $1.88 including accident costs. Based on the summary information in Exhibit 5, the following measures were recommended for inclusion as part of a transportation energy management program for the Region of Hamilton-Wentworth:

- o Alternative traffic signal timing plans - this measure provides the largest single possible energy savings - approximately 4 million litres per year. In addition, it is the single most cost-effective measure with the cost per litre of fuel saved being less than 1¢ per litre. In addition, the measure would not be noticeably detrimental in its effect on safety and could be implemented quickly and efficiently as the traffic signal operations are under the control of one department;
- o Traffic signal coordination/actuation - this measure would save an estimated 1 million litres of fuel per year at a cost per litre of between 1¢ and 2¢. The measure would not have any detectable impact on other measures and could be implemented easily given adequate capital funds;

EXHIBIT 5

SUMMARY OF DETAILED ANALYSIS

MEASURE	ENERGY SAVINGS TOTAL (litres/yr)	ENERGY SAVINGS % REDUCTION (area wide)	COST PER LITRE OF FUEL SAVED	SAFETY IMPACTS	INTERACTION WITH OTHER MEASURES
1. Alternative Signal Timing Plans	4,000,000	0.61	$0.002	Negligible	Negligible
2. Traffic Signal Flashing	155,000	0.02	$.26 to $.39 (including accidents)	Significant Increase in Accidents	Negligible
3. Signal Coordination/Actuation	1,000,000	0.15	$.014 Actuation $.024 Coordination	- Minor Reduction in Collisions	Negligible Should be in conjunction with 1.
4. Replace Stop Signs With Yield Signs	3,800,000	0.58	$.64 to $1.88 (including accidents)	Additional 880 Accidents/Year	Negligible
5. Replace 4-Way Stops With Traffic Signals	300,000	0.05	$.12	Negligible	Negligible
6. Express Bus Service	180,000	0.02	$0.37	Negligible	Negligible
7. Additional Promotion of Carpooling and Vanpooling	Phase 1 777,200 Phase 2 1,120,000	0.12 0.17	$0.28 $0.24	Negligible	Fringe Parking Flexible, Staggered Hours
8. Fringe Parking Lots	321,000	0.05	$0.19 $0.23	Negligible	Carpooling and Vanpooling
9. Flexible, Stagged Hours or Compressed Work Week	400,000 800,000	0.06 0.12	$0.20 $0.10	Negligible	Carpooling and Vanpooling
10. Improved Facilities for Low Energy Vehicles	54,000	0.01	$1.10	Possible Increase	Negligible

- Replace four way stops with traffic signals - this measure would result in approximately 300,000 litres of fuel being saved annually and a cost per litre saved of 12¢. In addition, the analysis indicated that there is no appreciable difference in accident rates between four way stops and traffic signals. Generally, there is little difficulty in implementing traffic signals, subject to meeting signal warrants;

- Express bus service - although the express bus service would not result in large energy savings as compared to the other measures, express bus service could result in other benefits (e.g. reduced parking demand) and the cost per litre of fuel saved is within reason. Moreover, additional express bus service would serve to enhance the general image of public transit;

- Additional promotion of car and vanpooling - this measure is recommended because of the potential energy savings which range from approximately 777,000 litres per year initially through to something in excess of 1.1 million with a mature program. Moreover, the cost per litre of fuel saved is in the range of 24¢ to 28¢ and there are significant other benefits such as reduced air pollution, reduced travel costs etc. Because the measure would have a significant degree of interaction with fringe parking lots and altered work schedules, it would be important that the program be coordinated with these measures. Moreover, there would be an opportunity in Hamilton to combine these three measures with a ride sharing office that could over the longer term provide a broad range of innovative services (taxi pooling, bus pooling, etc.). It should be pointed out that the estimated benefits for this measure were by design conservative because of the limited experience of the concept in Canada;

- Fringe parking lots - this measure would result in an estimated 320,000 litres of fuel saved at a cost per litre saved of between 19¢ and 23¢. This measure has potential interaction with additional promotion of car and vanpooling and as such should be promoted in a joint fashion.

- Flexible, staggered hours or compressed work week - this measure has a potential to save between 400,000 and 800,000 litres of fuel a year at a cost per litre saved of between 10¢ and 20¢. This estimate is based on the adoption of a compressed work week by approximately 5% of the labour force in Hamilton. This was considered a conservative estimate based on the results of the employers' survey but it was considered appropriate given the required cooperation that would be necessary between unions and management in successfully implementing the measure. Because of the complementary nature, especially in terms of staff utilization, this measure should be combined with the additional promotion of carpooling and vanpooling to form a ridesharing office which initially would focus on promotion of car and vanpooling and carpool matching, and altered work schedules.

The above measures are recommended on the basis of potential energy savings and the associated costs. Many of the other measures analyzed, but not considered appropriate from an energy standpoint, may be justified for other reasons.

Two other measures that are recommended but which were not considered in the detailed evaluation are pedestrian-actuated signals and a promotional program to encourage the grouping of trips. From the preliminary analysis it was indicated that the pedestrian-actuated signals would save approximately $12,000 per year at a cost of 5¢ per litre saved. Although this measure does not provide large savings it could be implemented inexpensively as part of a regular traffic engineering program.

As for an educational program to encourage the grouping of trips, the measure offers significant potential but requires more research. In this regard, it might be appropriate for the Province to consider research in this area.

5. CONCLUSIONS

Based on the findings of the study, an urban transportation energy program was developed for the Regional Municipality of Hamilton Wentworth. The program consisted of the seven recommended measures which would yield an estimated fuel saving of approximately 7 to 8 million litres per year. None of the recommended measures exceeds a cost per litre saved of $.37. The estimated initial investment would range from 880,000 to approximately $1 million with subsequent annual operating costs of approximately $300,000.

Approximately 6.3 million litres/year or 75% of the total estimated savings are due to improvements in the operation of the street system. Because these measures can be implemented with relative ease and their potential benefits are clearly understood, they are a top priority. But there is a limit to the potential energy savings through improvements in the efficiency of the system and if there are to be longer term energy savings in urban transportation, changes in travel behaviour will be necessary. Behavioural changes will include a combination of travel reduction and substitution which will require greater use of public transit, carpooling and other forms of

ridesharing, as well as changes in work schedules. In the U.S., such behavioural changes have been precipitated by gasoline and diesel fuel shortages and in response a number of ridesharing offices were established to assist individuals and companies with ridesharing (e.g. carpooling, vanpooling, buspoolng) as well as changes in work schedules. Although we in Canada have not experienced the same energy shortages as the U.S., it is clear that similar programs will be required if we are to significantly reduce our urban transportation energy consumption.