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Michigan Department of Transportation

A Michigan Toolbox for Mitigating Traffic Congestion

Texas Transportation Institute

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Researchers created A Michigan Toolbox for Mitigating Traffic Congestion to be a useful desk reference for practitioners and an educational tool for elected officials acting through public policy boards to better understand the development, planning, and implementation of congestion mitigation strategies. The Toolbox provides an overview of traffic congestion, the need for local and state solutions, and project survey responses. Forty-seven specific strategies are presented in the Toolbox. Strategies are organized by transportation system management and travel demand management categories. For each strategy, a detailed review of its characteristics, costs, benefits, and Michigan experiences is given. To help create the Toolbox, researchers conducted an online survey of MPOs focusing on their experiences with mitigation strategies. MPO staff from Michigan transportation management areas was interviewed regarding the congestion management process in Michigan. Researchers identified available benefit-cost ratios for individual strategies in order to gauge their effectiveness. Local and regional transportation agencies can apply these strategies as appropriate to improve mobility and travel reliability throughout the State of Michigan.</td></tr>
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A Michigan Toolbox for Mitigation Congestion Strategies

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Executive Summary

Mobility allows travelers to reach a destination in a satisfactory time and cost. In contrast, congestion is the inability to reach a destination in a satisfactory time due to slow travel speeds. In congestion, travel times are longer and user costs are higher. Reliability is the level of consistency in transportation service (e.g., hour-to-hour or day-to-day). Travelers respond to unreliable systems by adding additional travel time to their trip. Transportation professionals seek to increase mobility, reduce congestion, and increase reliability.

Prior research has identified the following seven sources of traffic congestion:

1. Traffic Incidents – Crashes or stalled vehicles.
2. Work Zones – Construction causes congestion in and around work zones.
3. Weather – Rain, ice, and snow cause delays.
4. Fluctuations in Demand – Variability in demand when the capacity to handle the traffic is fixed can result in congestion.
5. Special Events – High traffic volumes for special event (sporting event, concerts, etc.) cause congestion.
6. Traffic Control Devices – Signals that are not optimized for changing traffic demands are a source of congestion on city streets.
7. Inadequate Base Capacity – Interaction of capacity constraints with the other sources of congestion above also affects traffic variability. For example, a traffic incident that blocks a single lane has a greater impact on a roadway with only two travel lanes than on a roadway with three travel lanes.

A Michigan Toolbox for Mitigating Traffic Congestion is intended to be both a useful desk reference for practitioners and an educational tool for elected officials, often acting through public policy boards. The congestion mitigation strategies documented and presented within the guide will ultimately provide physical benefits to the users of Michigan's roadway network. Through the use of this Toolbox and good judgment by the practitioner through the review and approval of the appropriate policy board members, the travelling public will receive the congestion benefits.

The Toolbox is organized into two parts:

1. Introduction – includes background information, survey responses, the Toolbox organization, and information on how to use the Toolbox.
2. Congestion Mitigation Strategies – describes each strategy, its application, costs, benefits, and Michigan experiences, if any.

Forty-seven strategies are discussed in the Toolbox. Strategies are organized around transportation supply/system management and demand management categories. Within supply/system management, strategies are organized within topic areas of:

- Traffic operations.
- Transit.
- Multimodal transportation centers.
- Freight rail improvements.
- Bicycle and pedestrian.
- Reducing construction/maintenance interference.

Within demand management, the strategies are organized within topic areas of:

- Work schedule changes.
- Land use development.
- Ridesharing/vanpools.
- Parking management.
- Diversified development patterns.
- New community design (smart growth).
- Car sharing.
- Trip reduction ordinance.

The Toolbox also has the potential to provide consistency across Michigan Department of Transportation (MDOT) Regions and Transportation Service Centers (TSCs), along with consistency with MDOT's partnering agencies including the 12 Metropolitan Planning Organizations (MPOs), 14 Regional Planning Councils (RPCs), and even villages, cities, townships, and counties throughout the state.

The Toolbox is meant to introduce the multitude of possible congestion mitigation strategies. Local and regional transportation agencies can apply these techniques as appropriate to improve mobility and travel reliability throughout Michigan.

MDOT plans to make updates to this toolbox available as appropriate. If you have suggestions for updates to the Toolbox, or to request information about available updates, please contact the MDOT Librarian.

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
APA	American Planning Association
ATIS	Advanced traveler information systems
ATM	Advanced traffic management
ATMS	Advanced traffic management systems
AVO	Average vehicle occupancy
BBS	Bus bypass shoulder
BCR	Benefit-cost ratio
BOS	Bus on shoulder
CATS	Chicago Area Transportation Study
CBD	Central business district
CCTV	Closed circuit television
CMAQ	Congestion Mitigation and Air Quality
CMP	Congestion management process
CTR	Commuter trip reduction
DDI	Diverging diamond interchange
DIFT	Detroit Intermodal Freight Terminal
DMS	Dynamic message sign
DOT	Department of Transportation
EIS	Environmental impact statement
EA	Environmental assessment
EPA	Environmental Protection Agency
ESS	Environmental sensor stations
FHWA	Federal Highway Administration
GRH	Guaranteed ride home
HAR	Highway advisory radio
HERS	Highway economic requirements system
HGV	Heavy goods vehicles
HOV	High occupancy vehicle
HSR	Hard shoulder running
ICS	Incident command system
ITE	Institute of Transportation Engineers
ITS	Intelligent transportation systems
KTC	Kentucky Transportation Cabinet
JIT	Just in time
LOS	Level of service
MDOT	Michigan Department of Transportation
MITS	Michigan Intelligent Transportation System
MPO	Metropolitan Planning Organization
MUTIT	Median u-turn intersection treatment
NCHRP	National Cooperative Highway Research Program
NCTR	National Center for Transit Research
NIMS	National Incident Management System
NIPC	National Infrastructure Protection Center
ORBP	MDOT's Office of Research and Best Practices

PDSL	Priced dynamic shoulder lanes
PIP	Public information plan
ROW	Right-of-way
RPC	Regional Planning Commission
SOV	Single occupancy vehicle
STC	State Transportation Commission
TAZ	Traffic analysis zone
TCRP	Transit Cooperative Research Program
TCRPC	Tri-County Regional Planning Commission
TDM	Travel demand management
TDMAP	Transportation demand management assessment procedure
TEA-21	Transportation Equity Act for the 21st Century
TIM	Traffic incident management
TIP	Transportation Improvement Program
TMA	Transportation management association
TMC	Traffic management center
TMP	Transportation management plan
TOD	Transit-oriented development
TOP	Transportation operations plan
TOT	Truck-only toll
TRB	Transportation Research Board
TRO	Trip reduction ordinances
TSC	Transportation service center
TTCP	Temporary traffic control plan
TTI	Texas Transportation Institute
VHT	Vehicle hours traveled
VMT	Vehicle miles traveled
VSL	Variable speed limit

Introduction

Using the Toolbox

Congestion. Michigan's motorists have all experienced it. We've all been stuck in it. But what can we do about it?

The simple purpose of this toolbox is to place the tools in your hands that can be used to mitigate congestion on Michigan's roadways. The toolbox is structured in a user-friendly manner that allows the reader to quickly identify potential congestion mitigation strategies for Michigan's communities.

How Is the Toolbox Organized?

The Toolbox is organized into two parts:

- Introduction – includes background information, survey responses, the Toolbox organization, and information on how to use the Toolbox.
- Congestion Mitigation Strategies – describes each strategy, its application, costs, benefits, and Michigan experiences, if any.

How Do I Use This Toolbox?

This Toolbox is envisioned to be both a useful desk reference for practitioners and an educational tool for elected officials, often acting through public policy boards. The congestion mitigation strategies documented and presented within the guide will ultimately provide physical benefits to the users of Michigan's roadway network. Through the use of this Toolbox and good judgment by the practitioner through the review and approval of the appropriate policy board members, the travelling public will receive the congestion benefits.

This Toolbox can serve as a cornerstone tool in public discussion and strategizing to mitigate local and regional congestion.

The Toolbox also has the potential to provide consistency across Michigan Department of Transportation (MDOT) Regions and Transportation Service Centers (TSCs), along with consistency with MDOT's partnering agencies including the 12 Metropolitan Planning

Organizations (MPOs), 14 Regional Planning Councils (RPCs), and even villages, cities, townships, and counties throughout the state.

How Will Updates to the Toolbox Be Made Available?

MDOT plans to make updates to this toolbox available as appropriate. If you have suggestions for updates to the Toolbox, or to request information about available updates, please contact the MDOT Librarian.

Understanding Congestion

What Is Congestion and What Causes It?

Mobility is the ability to reach a destination in a satisfactory time and cost. In contrast, congestion is the inability to reach a destination in a satisfactory time due to slow travel speeds. In congestion, travel times are longer and user costs are higher. Reliability is the level of consistency in transportation service (e.g., hour-to-hour or day-to-day). Travelers respond to unreliable systems by adding additional travel time to their trip. Transportation professionals seek to increase mobility, reduce congestion, and increase reliability.

The first step in mitigating any problem is a better understanding of the problem—particularly the causes. Prior research identified the following 7 sources of congestion:

1. Traffic Incidents – Crashes or stalled vehicles.
2. Work Zones – Construction causes congestion in and around work zones.
3. Weather – Rain, ice, and snow cause delays.
4. Fluctuations in Demand – Variability in demand when the capacity to handle the traffic is fixed can result in congestion.
5. Special Events/Other – High traffic volumes for special event (sporting event, concerts, etc.) cause congestion.
6. Traffic Control Devices – Signals that are not optimized for changing traffic demands are a source of congestion on city streets.
7. Inadequate Base Capacity – The interaction of capacity constraints with the other sources of congestion above also affects traffic variability. For example, a traffic incident that blocks a single lane has a greater impact on a roadway with only two travel lanes than on a roadway with three travel lanes.

The strategies presented in this Toolbox can mitigate congestion caused by these seven congestion sources.

How Is It Measured?

Typically, measuring congestion requires more than one measure. The number of measures required for comprehensive monitoring depends on the type of analysis being performed, and it depends on what you are ultimately communicating, and to whom. In general, measures that relate to the trip experience resonate well with all audiences. These measures tell them exactly what they experience on the roadway. Measures that capture what is occurring at the regional or areawide level are useful because they can be used to identify how areawide congestion is changing over time.

A number of mobility and reliability measures are typically used for measuring congestion. The authors encourage readers to review *The Keys to Estimating Mobility in Urban Areas: Applying Definitions and Measures that Everyone Understands* for more information about mobility and reliability measures, data to support the measures, and how to compute the measures.

Prior to implementing congestion strategies including those discussed in this Toolbox, it is important to understand that the "benefits" of implementing these strategies will often be measured by their ability to increase mobility and reliability. To demonstrate the benefits of congestion mitigation projects, it is important to obtain travel time information prior to construction with data after construction. A multitude of resources are available elsewhere in the references below to assist the reader in performing such before/after studies to monitor mobility.

What Are General Congestion Trends?

The longest-running, most heavily-cited study of congestion is performed by the Texas Transportation Institute (TTI). TTI's *Urban Mobility Report* tracks urban mobility measures in 439 urban areas in the United States. A multitude of measures are used to track mobility including delay, travel time index, commuter stress index, wasted fuel, and congestion cost.

Table 1 summarizes the major national findings of 2011 TTI's *Urban Mobility Report* and defines the measures used. The *Urban Mobility Report* highlights the following:

- In 2010, congestion causes urban Americans to travel 4.8 billion hours more and to purchase an extra 1.9 billion gallons of fuel for a congestion costs of $128 billion.

- 2009 appears to be the best year for congestion in recent times; congestion worsened slightly in 2010.
- Prior to the economy slowing, just 3 years ago, congestion levels were much higher than a decade ago; these conditions will return with a strengthening economy.

The *Urban Mobility Report* highlights that the most effective congestion solutions are those that impact cooperation by businesses, manufacturers, commuters, and travelers. It goes on to indicate that each region must identify the projects, programs, and policies that achieve goals, solve problems, and capitalize on opportunities—there simply is not one rigid solution that works everywhere.

Table 1. Major Findings of the *2011 Urban Mobility Report* (439 Urban Areas)

Measures of…	1982	2000	2005	2009	2010
… Individual Congestion					
Yearly delay per auto commuter (hours)	14	35	39	34	34
Travel Time Index	1.09	1.21	1.25	1.20	1.20
Commuter Stress Index	--	--	--	1.29	1.30
"Wasted" fuel per auto commuter (gallons)	6	15	16	14	13
Congestion cost per auto commuter (2010 dollars)	$301	$700	$730	$723	$713
… The Nation's Congestion Problem					
Travel delay (billion hours)	1.0	4.0	2.2	4.8	4.8
"Wasted" fuel (billion gallons)	0.4	1.6	5.2	1.9	1.9
Truck congestion cost (billions of 2010 dollars)	--	--	--	$24	$27
Congestion cost (billions of 2010 dollars)	$21	$79	$108	$101	$101
… The Effect of Some Solutions					
Yearly travel delay saved by:					
Operational treatments (million hours)	8	190	325	321	328
Public transportation (million hours)	381	720	809	783	785
Yearly congestion costs saved by:					
Operational treatments (billions of 2010$)	$0.2	$3.1	$6.3	$6.7	$6.8
Public transportation (billions of 2010$)	$6.9	$12.0	$15.9	$16.5	$16.6

Yearly delay per auto commuter – The extra time spent traveling at congested speeds rather than free-flow speeds by private vehicle drivers and passengers who typically travel in the peak periods.
Travel Time Index (TTI) – The ratio of travel time in the peak period to travel time at free-flow conditions. A Travel Time Index of 1.30 indicates a 20-minute free-flow trip takes 26 minutes in the peak period.
Commuter Stress Index – The ratio of travel time for the peak direction to travel time at free-flow conditions. A TTI calculation for only the most congested direction in both peak periods.
Wasted fuel – Extra fuel consumed during congested travel.
Congestion cost – The yearly value of delay time and wasted fuel.

MDOT maps traffic congestion throughout the state. A map of the state showing 2009 congestion levels along roadways is provided in Figure 1 below. The data are from the 2009 MDOT Sufficiency File, which uses a process to generate roadway link level-of-service (LOS). The LOS is then grouped into 3 categories:

- Congested (Red) – LOS F for Freeway ; LOS E and F for Arterials.
- Approaching Congested (Green) – LOS D and E for Freeway; LOS D for Arterials.
- Uncongested – all other links.

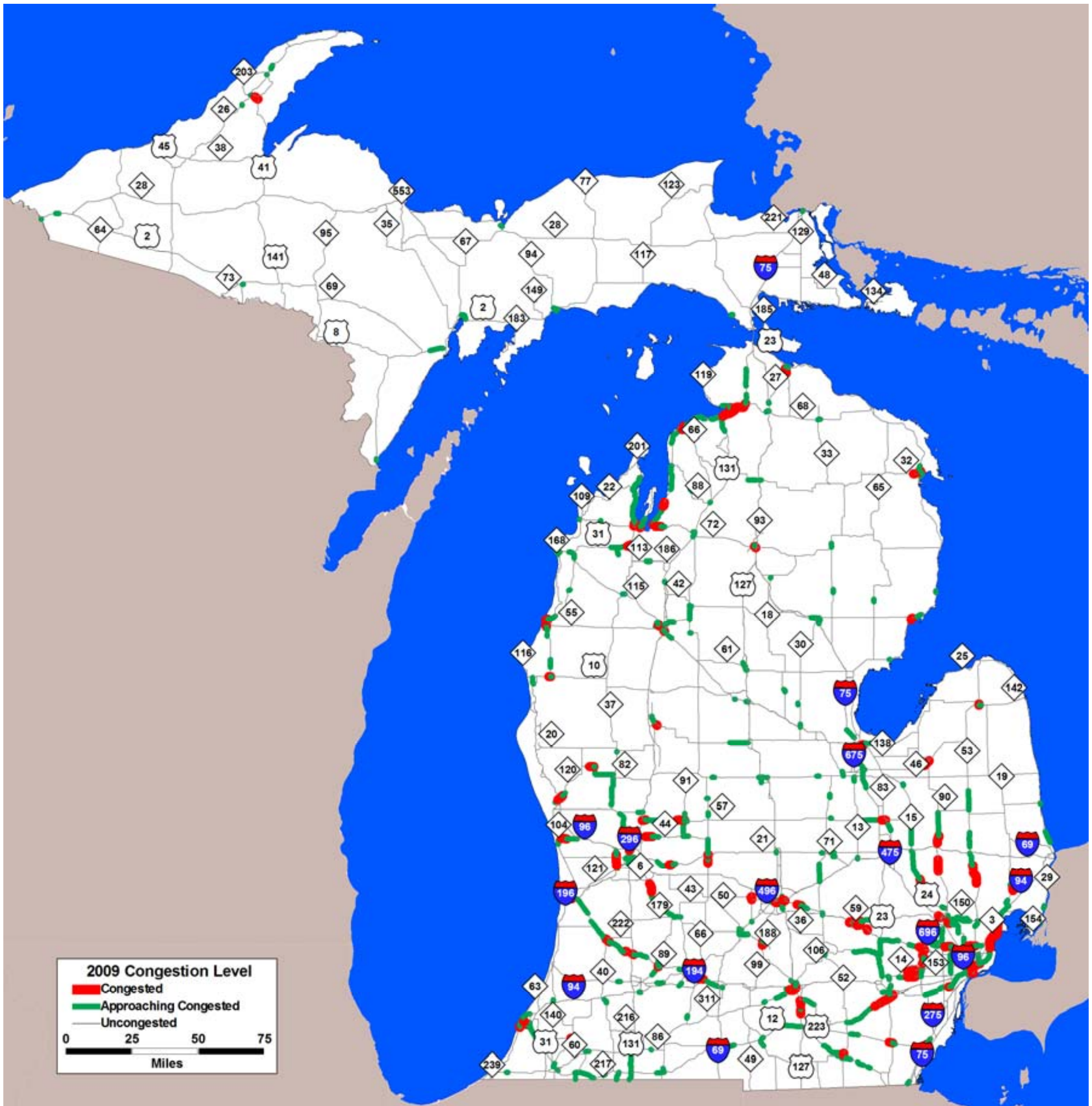


Figure 1. Michigan Congestion Map
(MDOT, 2011)

The *Urban Mobility Report* includes congestion statistics about two Michigan urban areas—Detroit and Grand Rapids. Table 2 and Table 3 summarize congestion statistics and costs for these two urban areas. The impacts of operational treatments and public transportation are also shown. Table 2 demonstrates a very slight increase in congestion in Detroit between 2009 and 2010, but congestion is still lower than the values in 2005. Table 3 illustrates that Grand Rapids was relatively unchanged from 2009 to 2010, including relatively lower congestion in 2008 followed by worsening congestion in 2009. Some of the congestion decreases in both cities from 2005 to 2009 can be attributed to the economic downturn in Michigan. Transportation improvement projects programmed in prior years that are now being constructed and opened also provide congestion mitigation.

Table 2. Congestion Statistics and Costs for Detroit, Michigan

(2011 Urban Mobility Report)

Measures of…	1982	2000	2005	2009	2010
… Individual Congestion					
Yearly delay per auto commuter (hours)	14	36	41	32	33
Travel Time Index	1.09	1.20	1.21	1.15	1.16
Commuter Stress Index	--	--	--	1.19	1.20
"Wasted" fuel per auto commuter (gallons)	6	19	21	16	17
Congestion cost per auto commuter (2010$)	$398	$974	$1,133	$673	$687
… The Effect of Some Solutions					
Yearly travel delay saved by:					
Operational treatments (1000 hours)	--	--	--	3,185	3,170
Public transportation (1000 hours)	--	--	--	1,947	1,937
Yearly congestion costs saved by:					
Operational treatments (millions of 2010$)	--	--	--	75	66
Public transportation (millions of 2010$)	--	--	--	46	40

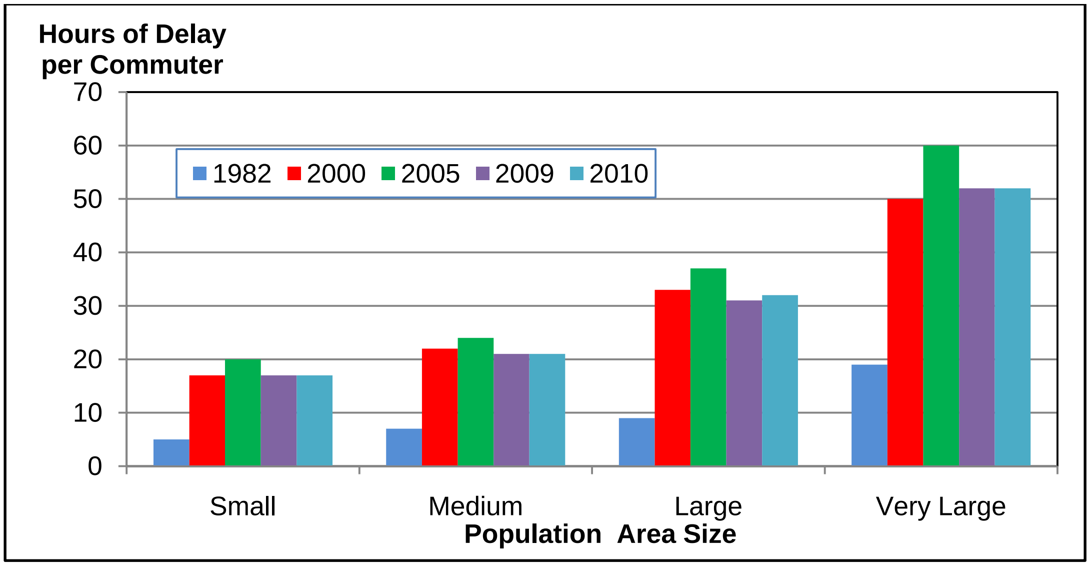
Table 3. Congestion Statistics and Costs for Grand Rapids, Michigan

(2011 Urban Mobility Report)

Measures of…	1982	2000	2005	2009	2010
… Individual Congestion					
Yearly delay per auto commuter (hours)	4	18	19	19	19
Travel Time Index	1.02	1.06	1.05	1.06	1.05
Commuter Stress Index	--	--	--	1.08	1.10
"Wasted" fuel per auto commuter (gallons)	1	4	4	4	4
Congestion cost per auto commuter (20010$)	$99	$454	$482	$375	$372
… The Effect of Some Solutions					
Yearly travel delay saved by:					
Operational treatments (1000 hours)	--	--	--	168	163
Public transportation (1000 hours)	--	--	--	258	250
Yearly congestion costs saved by:					
Operational treatments (millions of 2010$)	--	--	--	4	3
Public transportation (millions of 2010$)	--	--	--	6	5

Can Small Areas Have Congestion?

In a word, "yes." TTI's *Urban Mobility Report* identifies small urban areas as those with a population of less than 500,000. Figure 2 shows that the hours of delay per commuter increased up to 2005 and then began to decrease. However, the reality is that congestion is worse in areas of every size—it is not just a "big city" problem.



Small = less than 500,000
Medium = 500,000 to 1 million
Large = 1 million to 3 million
Very Large = more than 3 million

Figure 2. Congestion Growth Trend by Population Size
(2011 Urban Mobility Report)

It is important to keep in mind that "congestion is in the eye of the beholder." What some would consider congestion in a very small community (e.g., waiting through more than one red light) would not feel like congestion when experienced by someone from a large metropolitan area who is used to experiencing a three-hour peak period returning from work.

Understanding how congestion is defined and experienced in your community will allow for application of the appropriate types and scales of the strategies implemented. It will also assist in establishing targets for congestion levels after implementation of the strategies.

What Are Other Professionals Saying about Congestion Mitigation Strategies?

In a survey conducted for this Toolbox, transportation professionals at MPOs around the country were asked about their experiences developing, planning, and implementing congestion mitigation strategies.

All respondents indicated they have implemented or plan to implement traffic signal coordination and bike racks on transit vehicles.

Nine of ten respondents indicated:

- Additional turn lanes at intersections.
- Traffic signal retiming.
- Traffic signal equipment upgrades.
- Transit vehicle replacement/upgrade.
- Improve bicycle/pedestrian facilities.
- New sidewalks.
- Bike racks at transit stations.
- Bike racks at destinations.

With the exception of the transit vehicle replacement/upgrade, these strategies can be considered low-cost improvements. The other higher cost strategies within the list in Table 4 planned and/or implemented were:

- Incident management strategies of camera monitoring.
- Variable message signs.
- Park-and-ride lots to support transit facilities.

Table 4. Top 20 Most Implemented or Planned Congestion Mitigation Strategies among Respondents.

Group	Action	% of Respondents
Geometric Design Improvements	Additional turn lanes at intersections	96%
	Lengthened turn lanes at intersection for queuing	88%
Access Management	Two-way-left-turn-lanes	88%
	Raised median installation	83%
	Left-turn restrictions	83%
Traffic Signal Strategies	Coordination	100%
	Retiming	95%
	Equipment upgrade	95%
	Adaptive signal controls/demand responsive	82%
Incident Management Strategies	Variable message signs	86%
	Camera monitoring	82%
Transit Capital Improvements	Vehicle replacement/upgrade	91%
Transit Support Facilities	Park-and-Ride lots	82%
	Paratransit	82%
Bicycle/Pedestrian Improvements	Improved facilities (lighting, signing, etc)	95%
	New sidewalks	91%
	Rails to trails developments	86%
Bicycle/Pedestrian Support Services	Bike racks at transit vehicles	100%
	Bike racks on transit stations	91%
	Bike racks at destinations	91%
	Route maps	82%
	Promotional campaigns	82%
	Educational outreach	86%
Workzone Strategies	Work zone management	82%
Work Schedule Changes	Telecommuting	82%
Land Use Strategies	Mixed-use developments	82%
	Infill and densification	82%
Ridesharing/Vanpool Strategies	Marketing and promotions	86%
	Ridematching services	82%
	Guaranteed ride home	82%

The most successful mitigation strategies according to MPO professionals are shown in Table 5.

The highest rated strategy is shoulder use for part-time travel lane; however the number of respondents is very low. Those who have used it like it, but caution should be used in identifying this as a highly successful strategy.

The next most successful strategies are:

- Street-rail grade separations.
- Traffic signal coordination.
- Traffic signal retiming.

Grade separations can be a moderate to high cost project whereas the traffic signal coordination and retiming projects are relatively lower cost.

Table 5. Ten Most Successful Congestion Mitigation Strategies as Identified by Respondents.

		Success		
Group	Action	Rating (1-5, 3=avg)	Strength From Average	n
Lanes without Widening	Shoulder used for part-time travel lane	4.50	1.50	2
Geometric Design Improvements	Grade separations (street-rail)	4.40	1.40	10
	Grade separations (street-street)	4.20	1.20	10
Traffic Signal Strategies	Coordination	4.35	1.35	20
	Retiming	4.30	1.30	20
	Adaptive signal controls/demand responsive	4.23	1.23	13
	Equipment upgrade	4.15	1.15	20
Incident Management Strategies	Traffic/courtesy patrols	4.25	1.25	12
	Response teams	4.14	1.14	14
Contracting Strategies	Allowable working days and working hours	4.14	1.14	7

The strategies considered least successful have very low numbers of responses as shown in Table 6. So for the same reason as the most successful strategies, caution should be exercised in dismissing the program. Lockers at transit stations and destinations have the highest number of respondents.

Table 6. Eight Least Successful Congestion Mitigation Strategies as Identified by Respondents.

Group	Action	Success: Rating (1-5, 3=avg)	Success: Strength from Average	n
Time-of-Day Policies	Truck peak period bans on arterials	2.67	-0.33	3
Ramp Metering Systems	Ramp metering - HOV bypass	2.50	-0.50	2
Freeway HOV	Contraflow - barrier separated	2.50	-0.50	2
Bicycle/Pedestrian Support Services	Lockers at transit stations	2.90	-0.10	10
	Lockers at destinations	2.75	-0.25	8
	Shower facilities at transit stations	2.60	-0.40	5
New Community Design	Transit oriented development design requirements	2.83	-0.17	6
Trip Reduction Ordinances	Trip reduction goal programs	2.80	-0.20	5

Traffic signal timing was the only strategy considered very easy to implement. It is considered the most popular strategy available to areas. Practitioners at Michigan MPOs have indicated the same impressions of traffic signalization. Most of the easiest strategies may be characterized as low-cost projects with the exception of reversible lanes. Reversible lanes, depending on the design, may be high priced if dynamic lane assignments are used and the controls are connected to a traffic management center.

Table 7. Ten Easiest Congestion Mitigation Strategies to Implement as Identified by Respondents.

Group	Action	Ease of Implementation: Rating (3=neutral)	Ease of Implementation: Strength from Neutral	n
Traffic Signal Strategies	Retiming	4.05	1.05	20
	Coordination	3.70	0.70	20
Reversible Lanes	Reversible Lanes	3.71	0.71	7
Bicycle/Pedestrian Support Services	Bike racks at transit stations	3.94	0.94	18
	Route maps	3.89	0.89	18
	Promotional campaigns	3.88	0.88	16
	Bike racks on transit vehicles	3.75	0.75	20
	Educational outreach	3.71	0.71	17
Work Zone Strategies	Advance information	3.83	0.83	12
	Trailblazing/detours	3.70	0.70	10
Work Schedule Changes	Flextime	3.71	0.71	14

Table 8. Ten Most Difficult Congestion Mitigation Strategies to Implement as Identified by Respondents.

Group	Action	Ease of Implementation: Rating (3=neutral)	Ease of Implementation: Strength from Neutral	n
Ramp Removal/Reconfiguration	Freeway ramp removals	1.71	-1.29	7
Geometric Design Improvements	Grade separations (street-street)	1.70	-1.17	6
	Grade separations (street-rail)	1.73	-1.30	10
	Diverging diamond intersections	1.83	-1.27	11
Active Traffic Management	Interchange modifications	1.91	-1.09	11
	Dynamic truck restrictions	2.00	-1.00	2
Land Use Strategies	Shower facilities at transit stations	2.00	-1.00	7
	Transit-oriented developments	2.23	-0.77	13
Trip Reduction Ordinances	Mandated programs	2.00	-1.00	4
	Transportation management districts	2.00	-1.00	5

Grade separations were indicated to be the most difficult to implement. This may be due to the capital investment and right-of-way costs required to modify existing at-grade intersections to grade separation. Freeway ramp removals are also difficult due to strong public reaction by local citizens to the perception or reality of lost accessibility.

Two main barriers to strategy implementation were identified. The first barrier was lack of funding. More projects would be implemented if the funding were available. This coincides with the experiences of MPOs in Michigan metropolitan areas when trying to address congestion issues. Regret about the lack of transportation funding is important because it implies a willingness among practitioners to further mitigate congestion.

The second barrier was public perception and personal choice. To entice citizens to voluntarily make different travel choices presents a strong barrier to professionals. Attractiveness of congestion mitigation strategies must be highly perceived and valued by citizenry to greatly influence personal travel choice.

Overview of Congestion Mitigation Strategies in This Handbook

How Are the Strategies Organized?

Forty-seven strategies are discussed in this Toolbox. Figure 4 shows the levels of strategy organization of the Toolbox in more detail. Strategies are organized around supply/system management and demand management categories. Within supply/system management, strategies are organized within topic areas of traffic operations, transit, multimodal transportation centers, freight rail improvements, bicycle and pedestrian, and reducing construction/maintenance interference. Within demand management, the strategies are organized within topic areas of work schedule changes, land use development, ridesharing/vanpools, parking management, diversified development patterns, new community design (smart growth), car sharing, and trip reduction ordinance.

How In-Depth Are the Strategies Discussed?

While most of the strategies relate to supply/system management techniques, demand management techniques are also included. Each mitigation strategy summary is two to four pages. Typically, the following items are included in the body of the discussion for each strategy shown in Figure 4:

- General Introduction/Description.
- Techniques within the Strategy.
- Application Principles.
- Costs.
- Benefits and Impacts.

- State of Michigan strategy experience, if applicable.
- References.

In general, each strategy in the 2nd through 4th level of Figure 3 also includes a call-out box that highlights the following:

- Cost: 1 to 5 circles are completed to indicate relative cost level.
- Time: Identified as “long,” “moderate,” or “short” for implementation timeframe.
- Impact: The spatial context of the strategy identified as “spot,” “corridor,” and/or “regional.”
- Project Life: Specifies in years (rounded to 5 years), the typical life of the project.
- Sponsors: Indicates the implementing agency (e.g., city, state).

A sample of a call-out box is shown in Figure 3. The information in the call-out box allows for “at-a-glance” comparison of strategies, particularly as it relates to cost elements and the time it takes to implement the mitigation strategy. One black dot for cost implies the strategy is relatively inexpensive to plan and implement relative to the other strategies and, in general, other transportation projects. Five black dots means the strategy should be considered much more expensive than other strategies. These call-out boxes appear in the margins of the strategy descriptions.

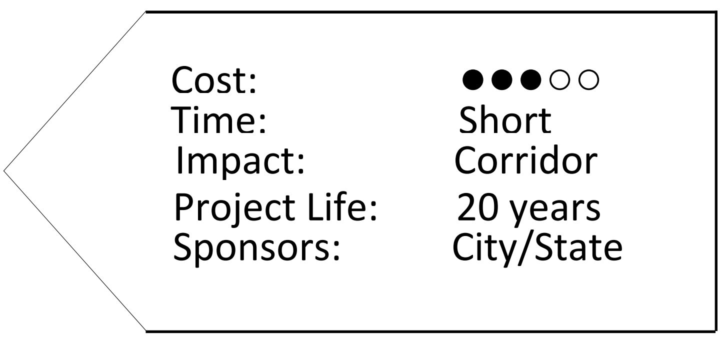


Figure 3. Sample Call-Out Box to Summary Strategies

For those strategies included in the 2nd level of Figure 4, there is a general introduction and actions within the strategy. For the strategies described at the 2nd level, there is not a call-out box that highlights the items shown in Figure 3. This is because generalizations are sometimes difficult when the possible actions within the strategy are diverse.

1. Supply/System Management
    a. Traffic Operations
        i. Increasing number of lanes without widening
        ii. Increase number of lanes by widening/lane additions
        iii. Highway ramp closures/reconfigurations
            1. Diverging diamonds
            2. Loop ramps eliminating left turns
            3. Deceleration/Acceleration Auxiliary Lanes
        iv. Bottleneck removal
        v. Geometric design improvements
            1. Intersection improvements
            2. Auxiliary lanes for merging and diverging
            3. Acceleration/deceleration lanes
            4. Intersection channelization
            5. Commercial vehicles accommodations
            6. One-way streets
        vi. Super street arterials (grade-separated intersections)
        vii. Complete streets
        viii. Improving street continuity
        ix. Vehicle use restrictions
        x. Access management
        xi. Active traffic management
            1. Speed harmonization
            2. Temporary shoulder use
            3. Queue warning
            4. Dynamic merge control
            5. Construction site management
            6. Dynamic truck restrictions
            7. Dynamic traveler information and rerouting
            8. Automated enforcement
        xii. Intelligent Transportation Systems
            1. Advanced traveler information systems
            2. Performance measurement
        xiii. Traffic signals
        xiv. Reversible traffic lanes/changeable lane assignments
        xv. Exclusive lanes
        xvi. Incident management
            1. Service/courtesy patrols
        xvii. Special event management
        xviii. Road weather management
    b. Transit
        i. Park-and-ride lots
    c. Multimodal transportation centers
    d. Freight rail improvements
    e. Bicycle and pedestrian
    f. Reducing construction/maintenance interference
2. Demand Management
    a. Work schedule changes
    b. Land use development
    c. Ridesharing/vanpools
    d. Diversified development patterns
    e. New community design (smart growth)
        i. Compact Development
        ii. Redevelopment and Infill redevelopment
        iii. Mixed use Development
        iv. Jobs/Housing balance
        v. Transit-Oriented Development
        vi. Corridor Land Use and Transportation Coordination
    f. Car sharing
    g. Trip reduction ordinances

Figure 4. Organization of Toolbox Strategies

How Do Strategies Interact?

The tables below provide the reader with the list of strategies ordered by cost, implementation time, and project lifetime. They provide an at-a-glance view of mitigation strategy characteristics and may help the user focus attention on those strategies more conducive to their local abilities for strategy consideration. Table 9 provides the Demand Management strategies. Table 10 below provides the Supply/System Management category of strategies. The shaded areas in the tables categorize the number of black dots noting the strategy cost. All strategy costs of four dots and two dots are highlighted.

In many cases, congestion strategies can be combined to provide increased congestion mitigation benefits. In practice it is rather typical to incorporate more than one improvement along a roadway that mitigates congestion. For example, as part of an arterial roadway widening project, multiple access management strategies could be implemented along with improved traffic signal timing.

The Toolbox is meant to introduce the multitude of possible congestion mitigation strategies. Local and regional transportation agencies can apply these techniques as appropriate to improve mobility and reliability throughout Michigan.

Table 9. Demand Management Strategies by Cost, Implementation Time, and Project Lifetime

Strategy	Cost	Implement Time	Project Lifetime
Redevelopment and Infill Development	●●●●○	Long	30
Land Use Development	●●●○○	Long	30
Diversified Development Patterns	●●●○○	Long	30
Mixed Use Development	●●●○○	Long	30
Transit-Oriented Development	●●●○○	Moderate	30
Parking Management	●●○○○	Short	10
Car Sharing	●●○○○	Short	10
Work Schedule Changes	●●○○○	Short	5
Ridesharing/Vanpools	●●○○○	Short	5
Compact Development	●○○○○	Long	30
Jobs-Housing Balance	●○○○○	Long	30
Corridor Land Use and Transportation Coordination	●○○○○	Long	30
Trip Reduction Ordinances	●○○○○	Short	5

Table 10. Supply/System Management Strategies by Cost, Implementation Time, and Project Lifetime

Strategy	Cost	Implement Time	Project Lifetime
Freight Rail Improvements	●●●●●	Long	30
Auxiliary Lanes	●●●●○	Long	25
Improving Street Continuity	●●●●○	Long	20
One-Way Streets	●●●●○	Moderate	25
Increase Number of Lanes by Widening/Lane Additions	●●●●○	Moderate	20
Multimodal Transportation Centers	●●●●○	Moderate	20
Park-and-Ride Lots	●●●○○	Moderate	30
Deceleration/Acceleration Lanes	●●●○○	Moderate	25
Access Management	●●●○○	Moderate	25
Speed Harmonization	●●●○○	Moderate	10
Temporary Shoulder Use	●●●○○	Moderate	10
Queue Warning	●●●○○	Moderate	10
Dynamic Merge Control	●●●○○	Moderate	10
Dynamic Truck Restrictions	●●●○○	Moderate	10
Dynamic Rerouting and Traveler Information	●●●○○	Moderate	10
Advanced Traveler Information Systems	●●●○○	Moderate	10
Detection, Response, and Clearance	●●●○○	Moderate	10
Increasing Number of Lanes Without Widening	●●●○○	Short	20
Diverging Diamonds	●●●○○	Short	20
Loop Ramps Eliminating Left Turns	●●●○○	Short	20
Deceleration/Acceleration Auxiliary Lanes	●●●○○	Short	20
Configurations to Increase Queuing Capacity	●●●○○	Short	20
Exclusive Lanes	●●●○○	Short	10
Intersection Improvements	●●●○○	Short	5
Super Street Arterials	●●●○○	Short	5
Traffic Signals	●●●○○	Short	5
Reversible Traffic Lanes	●●●○○	Short	5
Bicycle and Pedestrian	●●○○○	Moderate	25
Bottleneck Removal	●●○○○	Moderate	20
Road Weather Management	●●○○○	Moderate	10
Commercial Vehicles Accommodations	●●○○○	Short	10
Service/Courtesy Patrols	●●○○○	Short	10
Reducing Construction/Maintenance Interference	●●○○○	Short	10
Vehicle Use Restrictions	●●○○○	Short	5
Special Event Management	●●○○○	Short	5
Complete Streets	●○○○○	Long	20
Performance Measurement	●○○○○	Short	10
Information/Routing and Interagency Cooperation	●○○○○	Short	10

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Note: References for each strategy are provided at the end of each strategy section.

Supply/System Management

The Transportation Supply/Systems Management approach to congestion mitigation seeks to identify improvements to enhance the capacity of existing system of an operational nature. Through better management and operation of existing transportation facilities, these techniques are designed to improve traffic flow, air quality, and movement of vehicles and goods, as well as enhance system accessibility and safety.

Traffic Operations

Supply/System Management ▶ Traffic Operations

Traffic operations strategies focus on optimizing the performance of the transportation system. Operations strategies may be implemented on a regional, area-wide, or project-specific basis, and enable transportation agencies to provide higher levels of customer service in the near-term without incurring the high costs and time to implement major infrastructure projects. Efforts to manage and operate existing transportation systems are important for several reasons:

- Rapidly Increasing Congestion – As travel demand continues to increase, while the amount of new infrastructure that can be developed is limited, traffic congestion in the U.S. has risen dramatically. Congestion is affecting more roads, extending into longer periods of the day than traditional rush hour, and impacting travel times to a greater extent. The worsening of congestion is impacting mobility, the environment and economic productivity, and highlights the need for attention in transportation planning.
- Constraints on Transportation Capacity Expansion – In many metropolitan areas, there are limited opportunities for highway or transit capacity expansion due to environmental and community constraints. Furthermore, infrastructure projects can be very expensive, and limited funding constrains the ability to build all of the potential facilities that might be desired. In some cases, air quality issues also limit the ability of many metropolitan areas to construct new capacity. These constraints have placed increased pressures on decision makers and transportation agencies to find new ways to enhance the effective capacity of the existing transportation network.

- Growing Connectivity, Interdependency, and Operational Impacts across Modes – Over the past several years, there has been an increasing recognition of the importance of weather conditions, traffic incidents, special events, and emergency situations on the reliability and safety of the transportation system. Overall increases in traffic volumes often mean that even small disruptions can have a significant ripple effect on transportation system performance throughout a broad area. These forms of pressure are pushing an increased emphasis on developing mitigation strategies that more clearly and adequately relates regional transportation funding decisions to customer concerns, and to utilizing system management and operations solutions.

Increasing Number of Lanes without Widening

Supply/System Management ▶ Traffic Operations ▶ Increasing Number of Lanes without Widening

Introduction

Transportation planners and engineers have two primary strategies to increase capacity on a roadway without a large-scale widening effort:

- Using one or more shoulders as travel lanes usually during peak hours and in the peak direction.
- Reducing lanes widths to provide additional lanes within the existing pavement.

Cost:	●●●○○
Time:	Short
Impact:	Corridor
Project Life:	20 years
Sponsors:	City/State

These capacity increases are often achieved with some increase in accident rates. Therefore, the design of such lanes must clearly take into consideration the safety aspects of the particular freeway section. Even though such treatments should be considered temporary, one study found that in cities with populations over one million, almost 32 percent of the urban freeway mileage could experience reduced congestion though such low-cost measures (FHWA, 2003).

NCHRP Report 369 summarized the primary advantages and disadvantages in implementing use of shoulders.

Table 11. Advantages and Disadvantages of Shoulder Use

Design Alternative	Advantages	Disadvantages
Use of Left Shoulder	Left shoulder not used as much for emergency stop or emergency enforcement. Less expensive if width is available. Trucks often restricted from left lane.	Usually requires restriping. Sight distance problem with some median treatments.
Use of Right Shoulder	Often the easiest to implement.	Right shoulder is preferred area for emergency stops and enforcement. Sight distance changes are merge and diverge areas of ramps.
Use of Both Shoulders	Not recommended. Use **only** in extreme cases.	Requires restriping. Safety concerns. Enforcement difficult. Incident response longer. Maintenance more difficult and expensive.

Techniques

Temporary shoulder lane use can be implemented where appropriate to temporarily increase capacity during peak travel periods. Specific elements supporting this operational strategy include the following:

- Deployment in conjunction with speed harmonization.
- Passage of enabling legislation and related laws to allow the shoulder to be used as a travel lane.
- A policy for uniform application of the strategy through entrance and exit ramps and at interchanges.
- Adequate installation of sign gantries to provide operational information and to ensure that they are in sight at all times.
- Placement of lane control signals over each travel lane.
- Uniform signing and markings related to temporary shoulder use.
- Closed circuit television (CCTV) cameras with sufficient coverage to verify the clearance of the shoulder before deployment.
- Provision of pullouts at regular intervals with automatic vehicle detection to provide refuge areas for minor incidents.
- Provision of roadside emergency call boxes at emergency pullouts.

- Special lighting to enhance visibility of the shoulder.
- Advanced incident detection capabilities.
- Comprehensive incident management program.
- Connection to a traffic management center that serves as the focal point for the system.
- Dynamic message signs to provide guide sign information and regulatory signs to adapt to the addition of the shoulder as a travel lane (Sisiopiku, 2009).

Data

Planners should use their regional travel demand model to simulate proposed capacity improvements to roadways. Roadway-specific data should be gathered and analyzed to consider the potential congestion mitigation and safety issues of the project.

Application Principles

When shoulder use is being considered for traffic flow, careful planning and design should occur to avoid any potential safety problems. In addition, structural capacity of a highway varies across the cross section. The shoulder is not often constructed to accommodate traffic loads. Pavement failures and subsequent repair under traffic conditions will affect both capacity and safety.

FHWA also recommends that any proposed roadway improvements should also be correlated with state and regional long-range transportation plans, transportation improvement plans (TIP), and air quality improvement plans. As these improvements are generally considered capital projects, they may already be programmed or budgeted; or the proposed improvement might be readily incorporated into another programmed capital project in the same geographic area.

When analyzing and making decisions regarding potential improvements, it is important to remember that changes in traffic and operational patterns resulting from roadway improvements often have an impact that goes beyond the immediate facility that is being improved. Such issues must be considered in the analysis that precedes a decision to improve the roadway and increase capacity (FHWA, 2003).

Costs

This is a low cost strategy relative to building a new roadway or widening long stretches of existing facilities. There are construction and engineering, along with ongoing maintenance costs.

Benefits and Impacts

This strategy will increase capacity and improve travel time reliability. Significant increases in capacity of up to 30 percent and more are possible (NCHRP, 1995).

Based on the results of a simulation model for I-95 in Virginia, researchers concluded that the *combination of hard shoulders and variable speed limits* would be an effective solution to reduce travel delay, delay the onset of congestion, reduce queue length, increase average speed, and increase average fuel economy. It was found that the use of temporary shoulder lanes can have a very positive impact on traffic operations along I-95 when implemented in response to recurrent and/or non-recurrent congestion. In the study, the temporary use of the left northbound shoulder lane for two hours during the morning peak resulted in a reduction in the total network travel time by 34 percent and delay by 71 percent compared to current operations. The use of right shoulder lanes upstream of exit ramps tested in the study provided some relief but had far less impact on network performance compared to the continuous left shoulder lane usage (Xiang, 2009).

Quantification of expected benefits and costs from deployment of temporary shoulder lanes along the I-65 corridor in Birmingham, Alabama found benefit-cost ratios of 3.8 to 13.9:1 depending on the deployment scenario implemented (Sisiopiku, 2009).

For More Information

MDOT Design Division

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Increase Number of Lanes by Widening/Lane Additions

Supply/System Management ▶ Traffic Operations ▶ Increase Number of Lanes by Widening/Lane Additions

Introduction

Widening a freeway to provide additional lanes over several miles is classified as major reconstruction. This is considered a traditional strategy to mitigate congestion along a corridor or roadway. It is also not a mitigation strategy that is emphasized or given a high priority in Congestion Management Processes, including those in Michigan. Projects of this type are long-term and require substantial planning, engineering, and public financial resources.

Cost:	●●●●○
Time:	Moderate
Impact:	Corridor
Project Life:	20 years
Sponsors:	State

Techniques

Roadway improvements that add capacity are subject to planning and environmental requirements that must be followed to secure financial support. This may include:

- An Environmental Impact Statement (EIS) or Environmental Assessment (EA) will have to be undertaken if the proposed improvement is expected to have significant environmental impacts.
- If the urban area is in non-conformance with air quality standards, a conformity analysis must be undertaken to show no additional degradation of air quality due to the proposed improvement.

Data

Planners and engineers should use their regional travel demand model to simulate proposed capacity improvements to roadways. Roadway and corridor-specific data should be gathered and analyzed to consider the potential congestion mitigation and safety issues of the project.

Application Principles

FHWA also recommends that any proposed roadway improvements should also be correlated with state and regional long-range transportation plans, transportation improvement programs (TIPs), etc. As these improvements are generally considered capital projects, they may already be programmed or budgeted; or the proposed improvement might be readily incorporated into another programmed capital project in the same geographic area.

When analyzing and making decisions regarding potential improvements, it is important to remember that changes in traffic and operational patterns resulting from roadway improvements often have an impact that goes beyond the immediate facility that is being improved. Such issues must be considered in the analysis that precedes a decision to improve the roadway and increase capacity.

Costs

FHWA's Highway Economic Requirements System (HERS) includes input values for the typical costs of a variety if highway improvements, including the cost of adding a lane to an existing highway. The unit cost per lane-mile for adding an additional lane includes a portion of the cost to cover bridges, interchanges, environmental issues, etc. for a normal project. However, a project with a large number of bridges, complicated interchanges, major environmental issues, and other extreme engineering and environmental issues will result in a higher cost per lane-mile.

Table 12. Road Widening Costs per Lane-Mile

Area Type	Cost (2006 dollars)
Urban • Standard • Higher density areas	 $2.4–6.9 million $7.3–15.4 million
Rural • Standard • Environmentally Sensitive	 $1.6–3.1 million $5.8–9.9 million

Separate cost factors are used for urban and rural areas. In urban areas, widening costs are further disaggregated by the type of roadway (in 2006 dollars). In rural areas, costs depend upon highway functional class and terrain type. There are also higher construction costs in areas where widening might be especially difficult or costly, such as densely developed urban areas or environmentally sensitive rural areas.

Benefits and Impacts

Increasing the number of lanes on a roadway through widening with lane addition will increase capacity and improve mobility along the roadway and corridor until induced demand fills the additional capacity.

Michigan Plans and Policy

MDOT has numerous road widening projects in various stages of development and implementation throughout the state.

For More Information

MDOT Design Division

References

FHWA, *Freeway Management and Operations Handbook,* September 2003.

Highway Ramp Closures/Reconfigurations

Supply/System Management ▶ Traffic Operations ▶ Highway Ramp Closures/Reconfigurations

Increasing traffic and congestion on a roadway may dictate a need for a ramp management strategy. Highway ramps can be can be reconfigured to mitigate the growing congestion. In some cases, it may be more feasible to close it permanently. The process of selecting ramp management strategies should begin by revisiting agency or regional transportation management program policies, goals, and objectives. Further clarification and understanding of program goals and objectives will help practitioners identify the ramp management strategies that best fit within an agency's transportation management program. A solid understanding of these goals and objectives will also act as the foundation from which strategies can be selected and applied to address existing situations and/or problems. Only the ramp management strategies that support transportation management system policies, goals, and objectives should be considered for implementation. Additionally, ramp management strategies should be viewed as elements of a transportation management program and be applied with other traffic management strategies, where possible, to accomplish transportation management program goals and objectives.

The decision to close a ramp permanently can be a very lengthy process. The many requirements include a detailed traffic analysis to show impacts associated with the closure; an extensive public outreach process to make sure that citizens are informed of the potential change and have an opportunity to provide input; and perhaps a temporary closure to observe and experience the actual impacts before a final decision is made.

The highway ramp strategies considered in the toolbox include:

- Diverging Diamonds.
- Loop Ramps Eliminating Left Turns.
- Deceleration/Acceleration Auxiliary Lanes.
- Configurations to Increase Queuing Capacity.

Diverging Diamonds

Supply/System Management ▶ Traffic Operations ▶ Highway Ramp Closures/Reconfigurations ▶ Diverging Diamonds

Introduction

The Diverging Diamond Interchange (DDI) developed from the concept of the synchronized split phasing design. The idea was to use the crossing over movement on an interchange design. The main goal was to better accommodate left turn movements and potentially eliminate a phase in the signal cycle. The highway portion does not change but the movements off the ramps change for left turns. Through and left turn traffic for the arterial road also maneuvers in a different manner from a conventional diamond interchange because the traffic crosses to the "wrong" side in between the ramps and signals, as shown in the figure below.

Cost:	●●●○○
Time:	Short
Impact:	Spot
Project Life:	20 years
Sponsors:	State

Figure 5. Diverging Diamond Overpass

For example, the diverging diamond interchange eastbound traffic allows a right turn movement to the ramp before the crossover. This right turn ramp will merge with the left turn movement from the westbound direction to provide one ramp to the southbound direction. After the crossover for the eastbound movement, traffic will come in from the southbound direction that wants to head eastward. This traffic will come from the left side of the eastbound traffic. An exit will then be provided on the left for left turn movements to the northbound movement after the highway passes over or under the other highway. The crossover will then occur again to get the eastbound traffic to the right side and finally receive the traffic from the northbound right turn movement. The design is symmetrical for the westbound traffic.

Two signal lights are needed for this design, one at each crossover. Each signal will be two-phased. The ramp phase will be combined with the non-conflicting flow of traffic for the east/west road. The length of the green time for the ramp may not need to be as long as the other green time in the same phase, due to possible queuing problems at the other signal. However, the green time for the second signal in a given direction can be longer than the other phase to prevent the left turn movements from the ramps from queuing a second time in the system. The longer the green time is for the second signal though, the more the signal timing resembles three phases (Chlewicki, 2003).

DDIs have been constructed in the States of Missouri, Utah, Tennessee, and Kentucky.

Techniques

The DDI requires no greater actions and planning resources than a standard interchange project. It is merely a design variation requiring a different approach.

Data

Data requirements are the same as for any other major interchange reconstruction.

Application Principles

Initial research into the concept notes advantages to this design:

- Ability to combine phases in ways that cannot be done in other interchange designs.

- Less conflict points than a conventional diamond interchange.
- Ability to combine lane assignments without changing the phasing of the signals.

Potential issues that could arise with the design include:

- Design may not be able to coordinate all movements effectively if they are all equally as heavy.
- More difficult to implement in urban areas where development is at the corners of a conventional interchange because of the right-of-way acquisition costs.
- Driver confusion is another concern for this design.
- Access to driveways for businesses and residents next to the interchange (Chlewicki, 2003).

Costs

The diverging diamond offers cost savings to DOTs through a smaller project template, reduced bridge length or width, and reduced right of way requirements. Missouri DOT noted that the cost for a diverging diamond interchange in Springfield was $2.9 million, using the existing bridge and not having to buy additional property. A standard interchange reconstruction would have cost about $8.5 million (Missouri DOT, 2010).

Benefits and Impacts

Comparisons between the conventional diamond and diverging diamond interchanges indicate the total delay for the conventional diamond was about three times as great as the diverging diamond. The stop delay was over four times worse for the conventional diamond. The total stops were approximately twice as many for the conventional diamond when compared to the diverging diamond designs.

FHWA research has indicated:

- For higher traffic volumes, the DDI has better performance and offers lower delays, fewer stops, lower stop time, and shorter queue lengths as compared with the performance of the conventional design. For lower volumes, the performance of the DDI and conventional intersection are similar.
- Capacity for all signalized movements is higher for the DDI as compared with the conventional diamond. Especially, capacity of the left-turn movements is twice that of the corresponding left-turn

capacity of the conventional diamond. The DDI design is very superior to the conventional diamond because exclusive left-turn lanes are not necessary.

- Conventional diamond design that is comparable with the four-lane DDI consists of six lanes on the bridge section (two through and one left turn in each direction, east–west and west–east). When higher capacity is needed, it would be a good application to convert to a six lane DDI instead of pursuing the costly option of widening bridges and approaches with dual left lanes in each direction (Bared, 2005).

For More Information

MDOT Congestion and Mobility Unit

References

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Chlewicki, Gilbert, *New Interchange and Intersection Designs: The Synchronized Split-Phasing Intersection and the Diverging Diamond Interchange,* 2nd Urban Street Symposium (Anaheim, California), April 2003.

Missouri Department of Transportation, *Missouri's Experience with a Diverging Diamond Interchange - Lessons Learned,* May 2010.

Photo: Accessed from http://www.inside-lane.com/2009/11/26/new-type-of-freeway-nterchange-could-produce-better-traffic-flow/, June 26, 2011.

Loop Ramps Eliminating Left Turns

Supply/System Management ▶Traffic Operations ▶ Highway Ramp Closures/Reconfigurations ▶ Loop Ramps Eliminating Left Turns

Introduction

Localized bottlenecks can be created at highway exit ramps at major arterials due to left-turn queuing. Vehicles are forced to exit the highway into a signalized intersection. Drivers that desire to turn left at the exit must wait for the signal. This forces other traffic to back up on the exit with subsequent congestion created on the highway. Retiming signals at the intersection to relieve this left-turn congestion may exacerbate queuing traffic on the other intersection legs.

Cost:	●●●○○
Time:	Short
Impact:	Spot
Project Life:	20 years
Sponsors:	State

One solution to reduce delay and queuing is to construct a loop ramp that will feed the left-turn traffic onto the arterial without queuing at the intersection. Loop ramps are often used at cloverleaf interchanges. They can be designed using a constant radius for the entire length of curve, or a 400- to 500-ft spiral can be used to transition to and from a 150- to 240-ft curve of constant radius. Loop ramps are often used in conjunction with collector-distributor roads along the major road to ensure that the design is consistent with driver expectancy, to minimize weaving on the major road, and to provide for a safe speed change for vehicles traveling between the intersecting streets (Bonneson, 2004).

Techniques

The loop ramp configuration is a viable alternative when sufficient right-of-way is available to accommodate the loop roadway. The loop design converts a stop or signal-controlled left-turn movement at the ramp terminal into a merge or yield-controlled movement on a loop ramp.

Moreover, when used in combination with outer connection ramps, the loop ramp can eliminate one signal phase at the ramp terminal intersection with a corresponding benefit to traffic operation (FHWA, 2009).

Data

Analysis of loop ramps can include:

- Micro-simulation modeling.
- Cost/benefit analysis.
- Crash data analysis using data collected before and after project implementation.

In addition, performance measures can be used to assess the effectiveness of the strategy, such as:

- Average speed (travel time).
- Lane density.
- Queue lengths.
- Queue discharge rates.
- Vehicle miles traveled (VMT).
- Vehicle hours of travel (delay).
- Travel surveys (FHWA, 2009).

Application Principles

Loop ramp configurations that eliminate left turns are beneficial when left-turn volumes from either the major road or the crossroad are high.

Costs

This strategy is relatively low cost compared to a major reconstruction of an interchange. Review of the research indicates this project type ranges from $5–15 million. The figure will vary due to local conditions for road construction projects (FHWA, 2009).

Benefits and Impacts

- Increase average speed on highway.
- Reduce delay on ramps and arterial.
- Increase safety.

For More Information

MDOT Congestion and Mobility Unit

References

Bonneson, J., et al., *Development of Ramp Design Procedures for Facilities without Frontage Roads,* Report 0-4538-2, Texas Transportation Institute, September 2004.

FHWA, *Recurring Traffic Bottlenecks: A Primer Focus on Low-Cost Operational Improvements*, June 2009.

Deceleration/Acceleration Auxiliary Lanes

Supply/System Management ►Traffic Operations ► Highway Ramp Closures/Reconfigurations ► Deceleration/Acceleration Auxiliary Lanes

Introduction

Drivers leaving a freeway at an interchange are required to reduce speed as they exit on a ramp. Drivers entering a freeway accelerate until the desired highway speed is reached. Because the change in speed is usually substantial, provision should be made for acceleration and deceleration to be accomplished on auxiliary lanes to minimize interference with through traffic and to reduce crash potential. Such an auxiliary lane, including tapered areas, is sometimes referred to as a speed-change lane. It is defined as an "added lane joining the traveled way of the freeway with that of the turning roadway and do not necessarily imply a definite lane of uniform width. This additional lane is a part of the elongated ramp terminal area" (Meyer, 1997).

Cost:	●●●○○
Time:	Short
Impact:	Spot
Project Life:	20 years
Sponsors:	State

The AASHTO Green Book provides practitioners with guidance about when to incorporate auxiliary lanes into roadway design.

Figure 6. Deceleration Lane on Michigan Highway
(Source: MDOT)

Techniques

For information regarding the required steps in designing a speed change lane, please refer to the MDOT *Road Design Manual.*

Data

Data collection to support bottleneck analysis should be sufficient to capture the duration and extent of congestion. Typically, 15-minute traffic volume counts for all ramps and main lanes for a four-hour peak period are adequate. Other data can be collected through travel time runs, video, or origin-destination studies (FHWA, 2003).

Application Principles

The key elements for acceleration/deceleration lanes are proper driver notification and allowing all deceleration to occur within the deceleration lane away from the mainline. The length and type of lane will depend upon the design speed of the mainline and the reduced speed of the first curve on the ramp.

A speed-change lane should have sufficient length to enable a driver to make the appropriate change in speed between the freeway and the turning roadway in a safe and comfortable manner. In the case of an acceleration lane, there should be additional length to permit adjustments in speeds of both through and entering vehicles so that the driver of the entering vehicle can position himself opposite a gap in the through-traffic stream and maneuver into it before reaching the end of the acceleration lane. This latter consideration also influences both the configuration and length of an acceleration lane (FHWA, 2003).

Costs

Auxiliary lanes are usually a component of a major construction or reconstruction project and their costs are incorporated into the larger project. For isolated construction, the costs may be approximated using lane-mile costs to construct a new roadway lane.

Benefits and Impacts

The impacts of speed change lanes at an interchange include:

- Increase average speed on highway.
- Reduce delay on ramps and arterials.
- Increase safety.

Michigan Plans and Policy

Numerous auxiliary lanes for deceleration and acceleration have been constructed on state highways.

For More Information

MDOT Congestion and Mobility Unit

References

FHWA, *Freeway Management and Operations Handbook*, September 2003.

MDOT *Road Design Manual.*

Meyer, M.D. *A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility*. Institute of Transportation Engineers, Washington, D.C. 1997.

Photo: Accessed from http://www.interstate-guide.com/i-684_ctny.html, June 26, 2011.

Configuration to Increase Queuing Capacity

Supply/System Management ► Traffic Operations ► Highway Ramp Closures/Reconfigurations ► Configuration to Increase Queuing Capacity

Introduction

Configuring an entrance or exit ramp to increase queue capacity involves making geometric or operations changes to the ramp to expedite merging and diverging traffic on highways. These changes are designated ramp terminal treatments and include signal timing improvements, ramp widening, additional storage or new turn lanes on arterials, improved signing, and pavement markings on or adjacent to ramps. These treatments are geared to improving localized problems, or bottlenecks, at either entrance or exit ramp terminals. Ramp terminal treatments provide solutions to problems at the ramp/arterial intersection, on the freeway (e.g., exit ramp traffic queuing onto the freeway mainline), or on freeway ramps. At exit ramp terminals, the strategies are aimed at reducing queue spillback on the freeway, but may also be aimed at improved arterial flow by limiting the amount of freeway traffic that can access certain areas in the arterial network. At entrance ramps, the strategies generally are aimed at:

Cost:	●●●○○
Time:	Short
Impact:	Spot
Project Life:	20 years
Sponsors:	City/State

- Better coordination of ramp terminal signal timing and ramp metering timing.
- Sufficient storage space, either on the ramp or in turn lanes on the arterial, to contain queues from ramp meters or from a congested roadway. This can include use of hard shoulders on the ramps.
- Signing, both static and dynamic, to inform motorists approaching a ramp what to expect at the ramp. The types of signing range from information on the status of ramp meters (on or off), freeway congestion, or ramp closure (FHWA, 2006).

Techniques

Most ramp terminal treatments require no changes to ramp or arterial geometrics. An effective and successful ramp metering strategy meets the goals and objectives it was intended to address. In general, a successful implementation strikes a balance between freeway mainline improvements (generally speed increase and crash reduction) and vehicle wait times and queuing on entrance ramps. In other words, the metering strategy seeks to improve conditions on the freeway while minimizing, to the greatest extent possible, queuing and delay on the ramp. Queuing and delay are impacts that result as vehicle demand approaches freeway capacity and traffic flow begins to deteriorate. Ramp metering helps improve vehicle flow by reducing areas of turbulence (FHWA, 2006).

Data

Data collection to support bottleneck analysis should be sufficient to capture the duration and extent of congestion. Typically, 15-minute traffic volume counts for all ramps and main lanes for a four-hour peak period are adequate. Other data can be collected through travel time runs, video, or origin-destination studies (FHWA, 2003).

Application Principles

At entrance ramps, the timing should be adjusted such that the traffic does not block the intersection when queues form from the ramp meter. The agencies operating ramp meters should coordinate the meter timing with the signal timing on arterials in order to optimize intersection flow. At exit ramps, care should be taken to ensure that queues do not form and back up onto the freeway facility.

FHWA advises transportation planners that a successful implementation of ramp management strategies begins well in advance of deployment of equipment. The program must be well thought out and phased according to when the needed resources (e.g., funding, staffing, equipment) will be available. A phased approach to strategy implementation also helps introduce ramp management to the public in small, more acceptable increments. Public outreach and information programs are vital in capturing the support of the agencies affected by or involved in the implementation of strategies (FHWA, 2006).

Costs

Reconfigurations of ramps to increase queuing capacity can be a low cost strategy. Adjustments to traffic signal timing, restriping lanes, and signage improvements can provide quick, effective solutions to queuing issues. However, a ramp metering program, even at a corridor level, will require much more investment to develop, implement, and maintain.

An evaluation of ramp metering in the Minneapolis-St. Paul area, Cambridge Systematics derived a benefit-cost ratio for the project type of 5.1:1. The analysis of field data indicated that ramp metering is a cost-effective investment of public funds for the Twin Cities area (Cambridge Systematics, 2001).

Benefits and Impacts

Benefits of ramp terminal treatments will vary depending on the type of treatment implemented.

Some advantages of ramp terminal treatments in regard to freeway operations, noted by FHWA, generally include:

- Reduced delay.
- Reduced queuing.
- Improved safety.
- Reduced downstream arterial impacts.

There are possible negative impacts associated with ramp terminal treatments and may include:

- Increased trip length and travel time, in the case of turn restrictions.
- Increased traffic signal delay for some traffic movements for certain signal timing strategies.

Cambridge Systematics conducted an evaluation of the Minneapolis-St. Paul regional ramp meter program and noted the following benefits and impacts:

- Traffic Volumes and Throughput: After the meters were turned off, there was an average 9 percent traffic volume reduction on freeways and no significant traffic volume change on parallel arterials included in the study. Also, during peak traffic conditions, freeway mainline throughput declined by an average of 14 percent in the “without meters” condition.

- Travel Time: Without meters, the decline in travel speeds on freeway facilities more than offsets the elimination of ramp delays. This results in annual system wide savings of 25,121 hours of travel time with meters.
- Travel Time Reliability: Without ramp metering, freeway travel time is almost twice as unpredictable as with ramp metering. The ramp metering system produces an annual reduction of 2.6 million hours of unexpected delay.
- Safety: In the absence of metering and after accounting for seasonal variations, peak period crashes on previously metered freeways and ramps increased by 26 percent. Ramp metering results in annual savings of 1,041 crashes or approximately four crashes per day (Cambridge Systematics, 2001).

For More Information

MDOT Congestion and Mobility Unit

References

Cambridge Systematics, Inc., *Twin Cities Ramp Meter Evaluation: Final Report,* February 1, 2001.

FHWA, *Ramp Management and Control Handbook*, January 2006.

FHWA, *Recurring Traffic Bottlenecks: A Primer Focus on Low-Cost Operational Improvements,* June 2009.

Bottleneck Removal

Supply/System Management ▶ Traffic Operations ▶ Bottleneck Removal

Introduction

According to the FHWA, 40 percent of all traffic congestion is a result of bottlenecks, or inadequate physical capacity. Figure 7 shows the various types of freeway bottlenecks.

Cost:	●●○○○
Time:	Moderate
Impact:	Corridor
Project Life:	20 years
Sponsors:	City/State

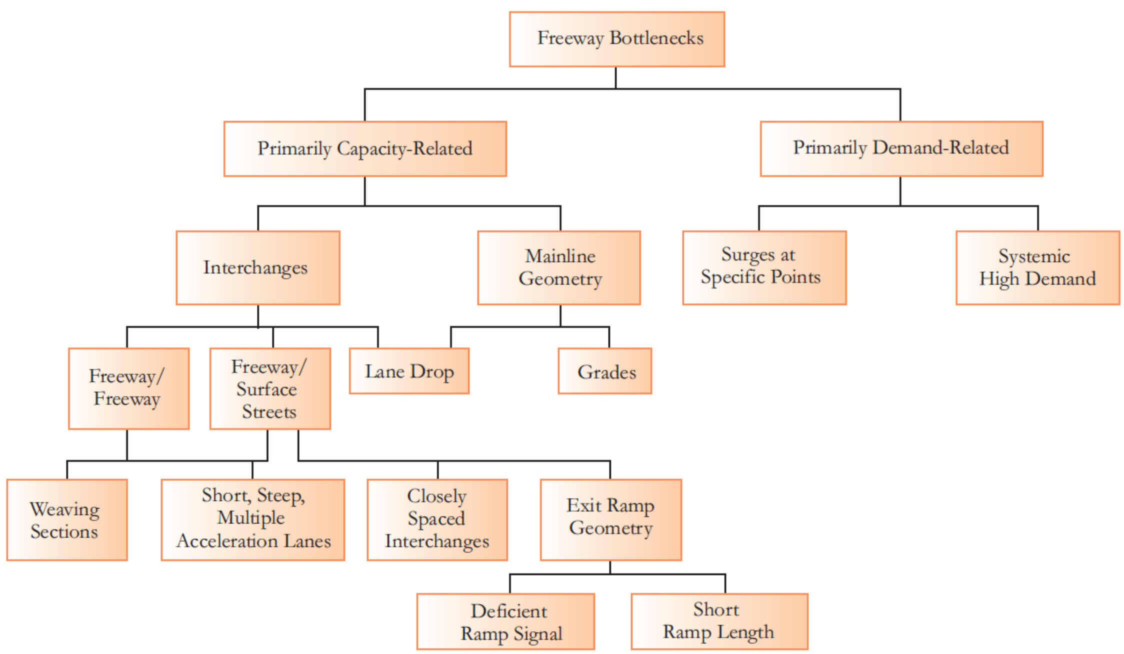

Figure 7. Types of Freeway Bottlenecks
(Cooner,2009)

Techniques

The 2009 FHWA report, *Recurring Traffic Bottlenecks: A Primer – Focus on Low-Cost Operational Improvements,* provides a list of operational and geometric improvements to remove or reduce bottlenecks. From the report:

1. Shoulder conversions – involves using a short section of traffic bearing shoulder as an additional travel lane. Shoulder conversions are appropriate between interchanges or to provide lane congruency with adjacent sections. The shoulder condition must be rated for use as a travel lane.
2. Re-striping merge or diverge areas to provide additional lanes, provide an acceleration/deceleration lane, extend the merge/diverge area, or improve geometrics to better serve demand.
3. Lane width reductions – involves reducing lane widths and re-striping to add an additional travel and/or auxiliary lane.
4. Modify weaving areas by adding collector/distributor or through lanes.
5. Ramp modifications – These could include ramp metering; widening, extending, closing, or consolidating ramps; or reversing entrance and exit ramps to improve operations.
6. Speed harmonization (variable speed limits) – adjusting speed limits when congestion thresholds have been exceeded and congestion and queue forming is imminent. Speed harmonization can also be used to promote safer driving during inclement weather conditions. This mostly European practice reduces the traffic "shock wave" that results through congested corridors, thereby delaying the onset of a breakdown in traffic conditions. The result is decreased headways and more uniform driver behavior, which indirectly benefit bottlenecks and chokepoints.
7. "Zippering," or self-metering that promotes fair and smooth merges – a motorist who is 10th in line knows that he will be 20th to merge into the single lane ahead. This helps to eliminate line jumpers that bull ahead, disrupt the queues, and often block adjacent lanes until they force their way in line. Usually this method of merging requires on-site enforcement, but often is exhibited by regulars who know the process and are willing to abide.
8. Improve traffic signal timing on arterials and ramp terminal intersections – will improve traffic flow and prevent ramp queues from backing up onto freeway main lanes.
9. Access management principles to reduce vehicular conflicts (hence, delays) on arterial corridors

10. Continuous flow intersections – unconventional at-grade intersections which eliminate one or more left turn conflicts at a main intersection. This is achieved through dedicated left turn bays located several hundred feet prior to the main intersection which allow left turning vehicles to move at the same time as through traffic. The left turn traffic signal phase is eliminated, allowing more vehicles to move through the main intersection and thus reducing traffic congestion and delays. These at-grade intersections achieve traffic flow similar to grade-separated interchanges, but at a considerably lower cost.
11. High-Occupancy Vehicle (HOV) or reversible lanes.
12. Provide traveler information on traffic diversions.
13. Implement congestion pricing – congestion pricing entails charging fees or tolls for road use those vary by level of vehicle demand on the facility. The objective is to bring supply and demand into alignment. As public acceptance grows and legislative restrictions are relaxed, congestion pricing will increasingly be viewed by transportation practitioners as a powerful and relatively easy to implement strategy to address bottleneck congestion (FHWA, 2009).

Data

Data collection to support bottleneck analysis should be sufficient to capture the duration and extent of congestion. Typically, 15-minute traffic volume counts for all ramps and main lanes for a four-hour peak period are adequate. Other data can be collected through travel time runs, video, or origin-destination studies.

Application Principles

Because some bottleneck treatments involve innovative solutions that maximize effectiveness with a minimum of new construction, they are occasionally at odds with highway design standards. Such conflicts have the potential to degrade safety if not properly implemented. For example, the elimination of a shoulder may lead to more collisions with roadside features or may impede incident management activities. Agencies should be in contact with their FHWA Division offices throughout the process as design review may be required, depending on circumstances.

The second potential issue relates to air quality conformity. Because they are short-term in nature, localized bottleneck improvements may emerge as formal projects that have not been previously identified in Statewide Transportation Improvement Programs or MPO-generated Transportation Improvement Programs. Thus, they may not be part of those projects that have been approved to address air quality conformity in the region or state. Such occurrences must be dealt with on a case-by-case basis by agencies wishing to undertake bottleneck improvements (FHWA, 2009).

Costs

The individual strategies listed above are promoted by FHWA and DOTs as low-cost relative to major reconstruction projects. Nevertheless, several of them do require substantial investment of time and resources by DOTs to plan, design, and implement. For example, a congestion pricing program may take years to fully implement and HOV lanes may require substantial reconstruction on a roadway.

Benefits and Impacts

Research indicates several benefits of bottleneck improvements including:

- Operational data at the bottleneck site showed increased volumes, increased speeds, and decreased queue lengths.
- Commuter feedback reveals that they observe reduced aggressive behaviors (e.g., preventing merge, cutting across solid lines, tailgating, etc.) and reduced commute time after improvements were made at a bottleneck location.
- Commuters also report an improvement in their personal stress level after the implementation of improvements (Cooner, 2009).

Michigan Plans and Policy

Michigan DOT currently has a structured Michigan Bottleneck Reduction Program. After a department restructuring, a systems operation and management section was tasked to develop an approach to identify and eliminate bottlenecks throughout the state. One of the first official action steps that the group pursued was to solicit potential bottleneck locations and problem descriptions from each of the seven MDOT regional offices. After review, approximately 125 locations met their definition of a “bottleneck” location and had a potential cost-effective solution that could address the problem (Cambridge Systematics, 2011).

For More Information

MDOT Congestion and Mobility Unit

References

Cambridge Systematics, Inc., *An Agency Guide on How to Establish Localized Congestion Mitigation Programs,* FHWA, March 2011.

Cooner, Scott A., *Freeway Bottleneck Removals: Workshop Enhancement and Technology Transfer,* University Transportation Center for Mobility Project 08-37-16, Texas A&M University, December 2009.

FHWA, *Recurring Traffic Bottlenecks: A Primer – Focus on Low-Cost Operational Improvements*, June 2009.

Geometric Design Improvements

Supply/System Management ▶ Traffic Operations ▶ Geometric Design Improvements

Geometric design improvements are a foundational strategy in transportation planning and engineering for the improvement of roadway operations. For safe and efficient traffic movement, the geometric design requirement for given road classes must be met. An improved network of well-surfaced, high-quality roads is usually required most times on a network. Road design uses stage construction for the progressive improvement of the road to meet increased traffic demands.

The geometric design improvements discussed in the toolbox are:

- Intersection improvements.
- Auxiliary lanes for merging and diverging.
- Acceleration/deceleration lanes.
- Intersection channelization.
- Commercial vehicles accommodations.
- One-way streets.

Intersection Improvements

Supply/System Management ► Traffic Operations ► Geometric Design Improvements ► Intersection Improvements

Description

The American Association of State Highway and Transportation Officials (AASHTO) defines an intersection as "…the general area where two or more highways join or cross, including the roadway and roadside facilities for traffic movements within the area. Intersections are an important part of a highway facility because, to a great extent, the efficiency, safety, speed, cost of operation, and capacity of the facility depend on their design."

Cost:	●●●○○
Time:	Short
Impact:	Spot
Project Life:	> 5 years
Sponsors:	City/State

The State of Michigan includes a variety of basic intersection types as well as alternative intersection designs to facilitate traffic flow. The basic intersection types include: three-leg or T, four-leg, multileg, and roundabouts. Selected alternative intersection designs in Michigan include (with a selected example):

- Median U-turn crossovers (the "Michigan Left Turn") (8-Mile Road in Detroit).
- Reverse Jughandle (M-53 [Van Dyke Ave] and 15-Mile Road).
- Quadrant Roadway (US 24 [Telegraph Road] and Plymouth Road).
- Jughandle and Quadrant Roadway (US 24 [Telegraph Road] and M-153 [Ford Road]).
- Ground Loops (Pennsylvania Avenue and Cedar Street).

A multitude of other intersection treatments are available and performed in other states. These treatments include: split (paired) intersections, super-streets, continuous flow, bowties, or flyover intersections.

According to AASHTO, "the main objective of intersection design is to facilitate the convenience, ease, and comfort of people traversing the intersection while enhancing the efficient movement of motor vehicles, buses, trucks, bicycles, and pedestrians." This is facilitated by considering human factors, traffic considerations, physical elements, economic factors, and the functional area of the intersection.

Because of changes in traffic demand or traffic patterns by any of the users of intersections, it is possible they will need to be improved to accommodate these changes. There are numerous available strategies for improving intersections.

Techniques

There are a number of possible intersection improvements. Picking the appropriate improvements is a function of the users of the system, their needs, and balancing critical design and operational considerations.

MDOT's *Michigan Intersection Guide* provides the following as example strategies to improve safety and operations of signalized and unsignalized intersections:

Signalized Intersections:

- Reduce frequency and severity of intersection conflicts through traffic control and operational improvements (coordinating/optimizing signals).
- Reduce frequency and severity of intersection conflicts through geometric improvements (left-turn channelization, right-turn lanes).
- Improve geometry of pedestrian, bicycle, and transit facilities.
- Revise geometry of complex intersections.
- Construct special solutions.
- Improve sight distance at signalized intersections (remove obstructions).
- Improve driver awareness of intersections and signal control (signing, lighting, visibility).
- Improve access management near signalized intersections.
- Improve safety through other infrastructure treatments.

Unsignalized intersections:

- Improve management of access near unsignalized intersections.
- Reduce the frequency and severity of conflicts through geometric improvements (left-turn channelization, right-turn lanes).
- Improve pedestrian and bicycle facilities to reduce conflicts between motorists and non-motorists.
- Improve sight distance (remove obstructions).
- Improve driver awareness of intersections as viewed from the intersection approach (signing, lighting, visibility).

- Choose appropriate intersection traffic control to minimize crash frequency and severity.
- Guide motorists more effectively through complex intersections.

Application Principles

The intersection improvement strategies suggested here vary in from very short-term to long-term implementation times. Some are relatively low-cost (optimizing signals), while others are very high costs (improving/changing intersection geometry). When properly applied, these intersection improvements can effectively alleviate congestion, and provide for improved safety. MDOT's *Michigan Intersection Guide* further identifies crash reduction factors for several of these mitigation improvements.

Figure 8. US 24 (Telegraph Road) and M-153 (Ford Road)—Jughandle and Quadrant Roadway
(Photo courtesy of MDOT Michigan Intersection Guide)

For More Information

MDOT Traffic and Safety Division

References

Michigan Intersection Guide, Michigan Department of Transportation, July 2008. Available: http://mdotwas1.mdot.state.mi.us/public/tands/Details_Web/mdot_michigan_intersection_guide.pdf.

Sight Distance Guidelines, Michigan Department of Transportation, February 2008. Available: http://mdotwas1.mdot.state.mi.us/public/tands/Details_Web/mdot_%20sight_distance_guidelines.pdf.

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Signalized Intersections: Informational Guide, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-HRT-04-091. August 2004. Available: http://www.fhwa.dot.gov/publications/research/safety/04091/04091.pdf.

Auxiliary Lanes

Supply/System Management ▶ Traffic Operations ▶ Geometric Design Improvements ▶ Auxiliary Lanes

Description

AASHTO indicates that an auxiliary lane is used for speed change, turning, storage for turning, weaving, truck climbing, or other purposes supplementary to through-traffic movement. (AASHTO, 2004) In the freeway setting, AASHTO notes that operational inefficiency may be improved when implementing a continuous auxiliary lane between entrance and exit ramps in the following situations (AASHTO, 2004):

- Closely spaced interchanges.
- Distance between the terminal tapers of the entrance and exit ramps are short.
- No frontage roads exist.

Cost:	●●●●○
Time:	Long
Impact:	Corridor
Project Life:	25 years
Sponsors:	City/State

The AASHTO Green Book provides practitioners with guidance about when to incorporate auxiliary lanes into roadway design.

Techniques

There are a number of methods used to incorporate auxiliary lanes into the freeway setting. A key geometric design consideration is ensuring that lane balance is maintained, especially with possible lane drops at exit ramps. Ensuring lane balance can reduce the number of lane changes of motorists at, or near, the ramps. The AASHTO Green Book also provides guidance and examples of coordinating land balance at entrance ramp and exit ramp locations (AASHTO, 2004).

Application Principles

Recent research by the National Cooperative Highway Research Program (NCHRP) examined the safety and operational impacts of auxiliary lanes (Ray, 2011). In general, the research found that 1) auxiliary lanes have positive safety effects, and 2) at some ranges of traffic volumes and ramp spacings, auxiliary lanes provide major operational benefits.

Safety Benefits of Auxiliary Lanes

In the NCHRP study, researchers found that an auxiliary lane between an entrance and an exit ramp corresponded to an approximately 20 percent reduction in crashes (Ray, 2011). Researchers found that the reduction applies nearly equally to both fatal plus injury crashes and property damage only crashes. Little effect on single vehicle collisions was found with the presence of the auxiliary lane. Researchers developed an equation to estimate the number of expected crashes between the physical entrance gore and physical exit gore on the freeway mainline. The equation is a function of the segment length, ramp spacing, volume upstream of the entrance ramp, entrance and exit ramp volumes, and the presence of an auxiliary lane.

Operational Benefits of Auxiliary Lanes

In the same research, researchers investigated the operational benefits of auxiliary lanes through simulation modeling. Researchers found that regardless of ramp spacing, adding an auxiliary lane improved freeway speeds by 5 mph or more if at least one of the ramps had moderate to near-capacity volume (1,500–1,750 vehicle per hour per lane) (Ray, 2011). Results are shown in the graphic below for a 2,500-ft ramp spacing.

The interested reader is encouraged to review reference *2* for further information and results related to the safety and operational impacts of auxiliary lanes.

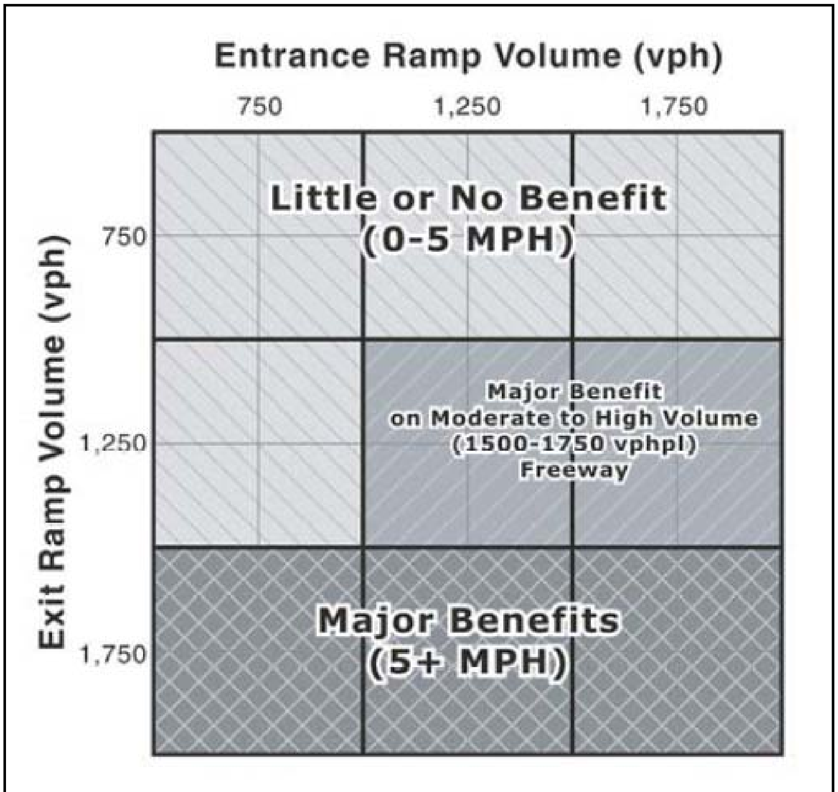

Figure 9. Benefit of Auxiliary Lane on Freeway Speed with 2,500' Ramp Spacing. "Major" Benefit Defined as 5+ MPH
(Adapted from Ray et al., 2011)

For More Information

MDOT Traffic and Safety Division

References

A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, D.C. 2004.

Ray, B.L., J. Schoen, P. Jenior, J. Knudsen, R.J. Porter, J.P. Leisch, J. Mason, and R. Roess, *Guidelines for Ramp and Interchange Spacing.* National Cooperative Highway Research Program (NCHRP) Report 687. Transportation Research Board, Washington, D.C., 2011. Available: http://www.trb.org/Publications/Blurbs/Guidelines_for_Ramp_and_Interchange_Spacing_165126.aspx.

Deceleration/Acceleration Lanes

Supply/System Management ▶ Traffic Operations ▶ Geometric Design Improvements ▶ Deceleration/Acceleration Lanes

Description

In the arterial setting, deceleration/acceleration lanes can provide reduced congestion by making intersection operations safer and more efficient. As described here, deceleration lanes provide for a turn lane opportunity for left or right turns. Acceleration lanes provide for acceleration from a driveway to the arterial street or from one approach of an intersection to another approach.

Cost:	●●●○○
Time:	Moderate
Impact:	Spot
Project Life:	25 years
Sponsors:	City/State

Techniques

AASHTO provides guidance for designing and locating deceleration and acceleration lanes (2004). MDOT's *Michigan Intersection Guide* also provides a number of strategies that relate to turn-lanes for signalized and unsignalized intersections (MDOT, 2008):

- Install left-turn lanes (see MDOT *Traffic and Safety Note 605a* for warranting guidelines [2004]).
- Improve left-turn lane geometry.
  - Lengthen left-turn lane (see AASHTO for length guidance [2004]; TRB *Highway Capacity Manual* [2010]; and MDOT Geometric Design Guide VII-650 Series [MDOT, 2011] for recommended taper and storage lengths).
  - Provide positive offset for left-turn lanes (see AASHTO [2004]).
  - Delineate turn path for left-turns.
  - Four-lane to three-lane conversion.
- Construct right-turn lanes (see MDOT Traffic and Safety Note 604a [2004]).
- Lengthen right-turn lanes (see AASHTO for length guidance [2004]); TRB *Highway Capacity Manual* [2010]; and MDOT Geometric Design Guide VII-650 Series [MDOT, 2011] for recommended taper and storage lengths).

Application Principles

Turn bays reduce conflicts between vehicles by efficiently removing turning vehicles from the through traffic stream. Studies have shown the following positive effects of adding a left-turn bay (TRB, 2003):

- 25 percent to 50 percent reduction in crashes on 4-lane roads.
- Up to 75 percent reduction in total crashes at unsignalized access.
- 25 percent increase in capacity.

Studies have shown the following effects of adding a right-turn bay (TRB, 2003):

- 20 percent reduction in total crashes.
- Limit right-turn interference with platooned flow, increased capacity.

Table 13 shows the crash reduction factors for including a right-turn lane as documented in MDOT's *Michigan Intersection Guide.* The largest reduction is shown for rear end right turns at 65 percent.

Table 13. Crash Reduction Factor for Adding a Right-Turn Lane

(Adapted from MDOT, 2008)

Crash Type	Crash Percent Reduction
Rear-End Right Turn	65
Other Rear End	20
Sideswipe	20

Note: Contact Safety Programs Unit for current reduction values.

In addition, Section 6.0 of MDOT's *Michigan Intersection Guide* provides hourly capacity estimates for different intersections with different traffic control. Table 14 shows the values for a four-left intersection (two-lane highway) and a four-leg intersection (divided highway), including the capacity increases with turn bays included.

Table 14. Hourly Capacity of Selected Roadway Types Showing Capacity Increase with Turn Lanes Present

(Adapted from MDOT, 2008)

Roadway Type	Capacity	Capacity Increase with Turn Lanes
Four-Leg Intersection (Two-Lane Highway)		
Signal Control with center left-turn lane on all approaches	3,700 vehicles per hour for entire intersection	8%
Signal plus left and right turn lanes on all approaches	4,000 vehicles per hour for entire intersection	
Four-Leg Intersection (Divided Highway) Signal Control (All left turns redirected to U-turn crossover)		
Four-lane divided	6,200 vehicles per hour for entire intersection	21%
Four-lane plus right turn lanes (mainline)	7,500 vehicles per hour for entire intersection	
Six-lane divided	7,850 vehicles per hour for entire intersection	6%
Six-lane plus right-turn lanes (mainline)	8,350 vehicles per hour for entire intersection	

For More Information

MDOT Traffic and Safety Division

References

A Policy on Geometric Design of Highways and Streets, American Association of State Highway and Transportation Officials, Washington, D.C., 2004.

Michigan Intersection Guide, Michigan Department of Transportation, July 2008. Available: http://mdotwas1.mdot.state.mi.us/public/tands/Details_Web/mdot_michigan_intersection_guide.pdf.

Traffic and Safety Note 605A: Traffic Volume Guidelines for Left-turn Lanes and Passing Flares at Unsignalized Intersections. Michigan Department of Transportation. Traffic and Safety Division. August 2004. Available: http://mdotwas1.mdot.state.mi.us/public/tands/Details_Web/mdot_note605a.pdf.

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Access Management Manual. Transportation Research Board. Washington, D.C., 2003.

Commercial Vehicle Accommodations

Supply/System Management ▶ Traffic Operations ▶ Geometric Design Improvements ▶ Commercial Vehicle Accommodations

Description

Efficient and reliable transport of goods is essential. The transportation system must be designed and operated for the efficient and safe transport of passenger cars and trucks. In many areas throughout the United States, truck traffic is growing. With the increase in the number of manufacturers implementing just-in-time (JIT) operations, there is an increased need for efficient truck transportation. Commercial vehicle accommodations improve the safety and operation of the roadway, thereby improving congestion.

Cost:	●●○○○
Time:	Short
Impact:	Spot
Project Life:	10 years
Sponsors:	City/State

Trucks have fundamentally different operating characteristics than passenger cars. These characteristics must be considered to provide appropriate geometry on roadways that have substantial heavy-truck use. Truck operating characteristics such as stopping sight distance, acceleration/deceleration on grades, driver eye height, minimum turn radius, and weight/power ratio all play a pivotal role in the planning and design of roadways to handle trucks. The following MDOT manuals provide guidance related to truck design elements and considerations:

- *MDOT Michigan Intersection Guide.*
- *MDOT Geometric Design Guides.*
- *MDOT Sight Distance Guidelines.*
- *MDOT Roundabout Design Document.*

Techniques

There is a wide range of possible accommodations for commercial vehicles. In some cases, these accommodations are applicable to both arterials and freeways. The improvements vary widely in scope and cost. Some are relatively short-term and low-cost, while others are long-term and high-cost. Example strategies to accommodate commercial vehicles include:

- Improve turning radius (reduces off-tracking).
- Improve shoulder width and composition.
- Install acceleration/deceleration lanes.
- Install climbing lanes.
- Separate truck and auto traffic.

Figure 10. Inadequate Intersection Design for Trucks
(Adapted from Middleton, 2004)

Application Principles

Research in Texas recommended that "truck-friendly" design be used when forecast design year volumes were over 1,000 trucks per day (Middleton, 2004). The research indicated that a reasonable criterion for considering special truck treatments is 5,000 trucks per day. The work further stated that at volumes of 25,000 Class 5+ trucks per day there would be justification for building a future separate truck roadway.

There are limited studies of auto-truck separation for long-haul applications and in an urban setting. One study documents an estimated 15 percent reduction in crashes as a result of separating trucks and general-purpose traffic (Douglas, 2004; TRB, 2010). Researchers investigated crash data along the New Jersey Turnpike where auto-only lanes are separated from auto/truck lanes to determine this crash reduction.

For More Information

MDOT Traffic and Safety Division

References

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Additional Resources

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One-Way Streets

Supply/System Management ▶ Traffic Operations ▶ Geometric Design Improvements ▶ One-Way Streets

Description

One-way street operation is often used in high volume situations (i.e., downtown area with closely-spaced intersections). One-way regulations are often incorporated into the original street design and traffic operation for new activity centers such as shopping centers, sports arenas, or industrial parks (ITE, 1997).

Cost:	●●●●○
Time:	Moderate
Impact:	Spot
Project Life:	25 years
Sponsors:	City/State

According to AASHTO, an arterial facility with one or more pairs of one-way streets can generally be implemented where the following conditions exist (AASHTO, 2004):

- A single two-way street does not have adequate capacity and does not lend itself readily to improvement to accommodate anticipated traffic demand, particularly where left-turning movements at numerous intersections are difficult to handle.
- There are two parallel arterial streets a block or two apart.
- There are a sufficient number of cross streets and appropriate spacing to permit circulation of traffic.

Techniques

One way streets are generally operated in one of the following three ways (ITE, 1997):

- A street where traffic moves in one direction at all times.
- A street that is normally one-way, but at certain times may be operated in the reverse direction to provide additional capacity in the predominant direction of flow.
- A street that normally carries two-way traffic, but which during peak traffic hours may be operated as a one-way street usually in the heavier direction of flow.

Application Principles

According to AASHTO, Institute of Transportation Engineers (ITE), and the MDOT *Michigan Intersection Guide* one-way streets provide the following advantages and can provide increased capacity and facilitate multimodal improvements because of the following (ITE, 1997; AASHTO, 2004; MDOT, 2008):

- Traffic capacity may be increased as a result of reduced midblock and intersection conflicts and more efficient operation of traffic control devices.
- Travel speed is increased as a result of reducing midblock conflicts and delays caused by slowing or stopped left-turning vehicles. The increase in the number of lanes in one direction permits ready passing of slow-moving vehicles.
- The number and severity of crashes is reduced by eliminating head-on crashes and reducing some types of intersection conflicts.
- Traffic capacity may be increased by providing an additional lane for through traffic. Although a two-way street with only one lane in each direction may not have sufficient width to accommodate two lanes in each direction, it may have sufficient width to accommodate three lanes in one direction when converted to one-way operation.
- The available street width is used fully through the elimination of need for a median. The lane-width adjustments can provide additional lanes for motor traffic, bicycles, buses, or parking.
- Permits improvements in public transit operations, such as routings without turnback loops (out on one street and return on the parallel streets).
- On-street parking that would otherwise have to be eliminated or curtailed may be retained.
- Permits turn from more than one lane and doing so at more intersections than would be possible with two-way operation.
- Redistributes traffic to relieve congestion on adjacent streets.
- Simplifies traffic signal timing by permitting improved progressive movement of traffic, and reducing multiphase signal requirements by making minor streets one-way away from complex areas or intersections.
- Allows pedestrians to only have to deal with traffic from one direction, reducing conflicts with vehicles.
- Provides more gaps for vehicles and pedestrians at unsignalized crossings.

The following disadvantages of one-way operation are cited by AASHTO and ITE (1997, 2004):

- Travel distances are increased because certain destinations can be reached only by around-the-block maneuvers. This disadvantage is more prevalent if the street grid is composed entirely of one-way streets.
- One-way streets lead to wider pedestrian roadway crossings.
- One-way streets may be confusing to strangers.
- Emergency vehicles may be blocked by cars in all lanes at intersections waiting for signals to change.

One-way operation has a number of advantages and some disadvantages. According to AASHTO, the practitioner choosing between one-way or two-way operation must consider which type of operation serves the traffic demands most economically and with the greatest benefit to the adjacent property (2004). While the proper choice of operation may be immediately obvious, in some cases a thorough study involving all relevant considerations may be needed (AASHTO, 2004). ITE provides additional guidance about when two-way streets should be made one-way (1997).

Crash Reduction Statistics

With the conversion of two-way streets to one-way streets, research has documented a 26 percent reduction in all intersection crash types and between a 33 and 43 percent reduction in all mid-block crash types (FHWA, 2007, FDOT, 2005, KTC, 1996).

In recent years, some Michigan cities (Adrian and Kalamazoo) have converted downtown streets from one-way to two-way.

References

A Toolbox for Alleviating Traffic Congestion and Enhancing Mobility. Institute of Transportation Engineers. Washington, D.C., 1997.

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Super Street Arterials

Supply/System Management ▶ Traffic Operations ▶ Super Street Arterials

Introduction

A super street works by redirecting left turn and through movements from side streets. Instead of allowing those to be made directly through a two-way median opening, as in conventional design, a superstreet sends those movements to a one-way median opening 500 to 1000 ft downstream. Thus, a left turn from a side street will be made by a right turn then a U-turn, while a side street through movement will be made by a right turn, a U-turn, and another right turn (FHWA, 2004).

Cost:	●●●○○
Time:	Short
Impact:	Spot
Project Life:	10 years
Sponsors:	City/State

The super street intersection has only 18 conflict points—places where vehicle streams cross, merge, or diverge—while a conventional intersection with a two-way median opening has 32. Since each conflict point creates potential for a traffic accident, super streets may be safer (Hummer, 2008).

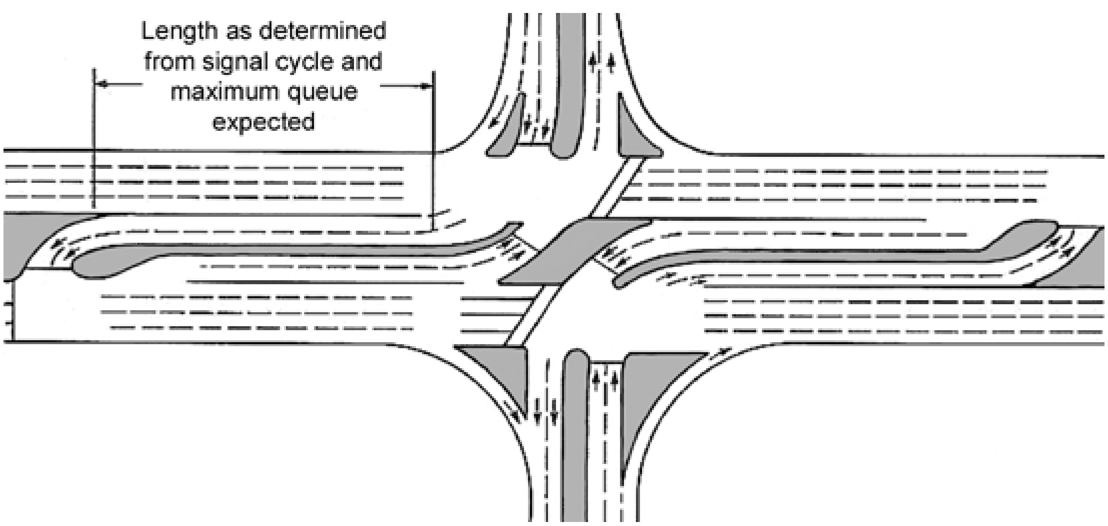

Figure 11. Super Street Concept
(FHWA, 2004)

Traffic signals at a super street require only two major phases instead of the four or more phases usually required at a busy two-way median opening. Since every signal phase introduces extra lost time for all motorists, this reduction in phases leads to significant time savings for travelers.

Another change provided by a super street is in signal progression. With a super street, the traffic signals that control one direction of the arterial have little or nothing to do with the signals that control the other direction. This means that a super street will operate as an intersecting pair of one-way streets, and that perfect progression is possible in both directions at any speed with any signal spacing (Hummer, 2008).

Super streets provide an advantage to pedestrian treatment. Pedestrian crossings can be completely signal-controlled. As a result, crossing pedestrians do not have to concern themselves greatly with turning drivers as at a conventional intersection.

The super street design is similar to the Median U-turn Intersection Treatment (MUTIT), or Michigan Left, but features a break in cross-street traffic that allows the signals on opposite directions of the arterial to operate independently. Arterial traffic can make direct left turns onto the cross-street. The cross-street thru and left turn movements must use the directional U-turn crossovers (Hummer, 2008).

Techniques

The super street concept is very similar to the Michigan Left intersection in use for decades in the state. Planners should consult the *MDOT Road Design Manual* for details on implementing a super street concept while noting the variations in the two designs.

Data

Data needs for implementing this project type is closely related to the requirements for a Michigan Left design. Planners should consult the MDOT *Road Design Manual* for data requirements.

Application Principles

Table 15. Summary of Issues for Super Street Median Crossovers

(FHWA, 2004)

Characteristic	Potential Benefits	Potential Liabilities
Safety	Fewer conflict points	None identified
Operations	Improved delay for major street movements	Longer travel distance and time for minor street movements
Multimodal	None identified	Two-stage pedestrian crossing Potential way-finding challenges
Physical	None identified	Wide median needed
Socioeconomic	None identified	May result in restrictions to access
Enforcement, Education, and Maintenance	None identified	Potential for driver and pedestrian confusion

Costs

The costs to implement a super street are already understood by MDOT. It is similar in design to the Median U-turn Intersection Treatment (MUTIT), or Michigan Left, in use in the State of Michigan for decades. Planners may use current cost of that type of intersection as a basis for comparison when considering super street design.

Benefits and Impacts

Some of the benefits of super streets noted in the research include:

- Reduced delay and better progression for through traffic on the major arterial.
- Increased capacity at the main intersection.
- Fewer stops for through traffic, especially where there are STOP-controlled directional crossovers.
- Reduced risk to crossing pedestrians.
- Fewer and more separated conflict points.
- Two-phase signal control allows shorter cycle lengths, thereby permitting more flexibility in traffic signal progression.

Disadvantages of the concept noted include:

- Possible driver confusion and disregard of left-turn prohibition at the main intersection.
- Possible increased delay, travel distances, and stops for left-turning traffic.
- Larger rights-of-way required for the arterial, although this potentially could be mitigated by the provision of loons on roads with narrow medians.
- Higher operation and maintenance costs attributable to additional traffic signal control equipment if the directional crossovers are signalized.
- Longer minimum green times for cross-street phases or two-cycle pedestrian crossing (FHWA, 2007).

Michigan Plans and Policy

Implementation of a super street would not prove difficult for MDOT. The Michigan Left intersection has been in use for decades in the State of Michigan, especially in the Detroit area. It is sometimes referred to as a super street, although there are technical differences between the concepts. The super street intersection concept is similar in scope and operation.

For More Information

MDOT Design Division

References

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FHWA, *TechBrief: Synthesis of the Median U-Turn Intersection Treatment, Safety, and Operational Benefits*, 2007.

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Complete Streets

Supply/System Management ▶ Traffic Operations ▶ Complete Streets

Introduction

Complete Streets is a transportation planning policy that designates an approach to planning, design, and construction of transportation facilities that takes into account all potential users of a network. A Complete Street is defined as "a street that works for motorists, for bus riders, for bicyclists, and for pedestrians, including people with disabilities." A Complete Street may include: sidewalks, bike lanes (or wide paved shoulders), special bus lanes, comfortable and accessible public transportation stops, frequent and safe crossing opportunities, median islands, accessible pedestrian signals, curb extensions, narrower travel lanes, roundabouts, and more.

Cost:	●○○○○
Time:	Long
Impact:	Regional
Project Life:	20 years
Sponsors:	City/State

Complete Streets policy is aimed at producing roads that are safe and convenient for all users. Complete streets are not limited to a few designated corridors. Complete Streets policies strive for diversity on just about every thoroughfare. By adopting a Complete Streets policy, communities direct their transportation planners and engineers to routinely design and operate the entire right of way to enable safe access for all users, regardless of age, ability, or mode of transportation (Michigan Complete Streets Coalition, 2011).

The concept of Complete Streets originated in the 1970s in Oregon, although the term was not coined until 2003. The policy movement gained momentum in 2001 when the U.S. Department of Transportation issued design guidance in response to new language in the Transportation Equity Act for the 21st Century (TEA-21). The guidance document, "Accommodating Bicycle and Pedestrian Travel," states that "bicycling and walking facilities will be incorporated into all transportation projects unless exceptional circumstances exist." The three exceptions were roads where bicyclists or pedestrians are prohibited by law; where the costs are excessive (more than 20 percent of project costs); and where there is clearly no need. This opened up a greater share of an area's transportation network to consideration of other potential modes and users (McCann, 2005).

Techniques

Public Acts 134 and 135 adopted in August 2010 by the State of Michigan requires MDOT to take specific actions in support of a Complete Streets planning approach. Details are provided below.

Application Principles

Two main issues have arisen in the short experience of Complete Streets policy. First, finding enough right-of-way can be a challenge. Even if the right-of-way is in the transportation agency's hands, any widening, even for a sidewalk, may be rejected by local residents wanting to preserve existing landscaping and parking, or informal, private use of the right-of-way.

Second, fear of high public costs is an equally great obstacle. Complete Streets policies are not specially funded, and project budgets are sometimes set before bicycle and pedestrian facilities are considered (McCann, 2005).

Costs

Advocates state that incorporating the Complete Streets philosophy into the transportation planning process will lower overall costs of the system. Widespread implementation of the policy is still in its infancy, so it is difficult to conclude its effect on project costs.

Benefits and Impacts

- Increase use of alternative modes.
- Increase safety.

Michigan Plans and Policy

In August 2010, the State of Michigan adopted Public Acts 134 and 135 incorporating changes to Act 51. The legislative act is considered the State Complete Streets policy (Michigan Complete Streets Coalition, 2011). Elements of the legislation include:

- Requires counties, cities, villages, and MDOT to consult with one another when planning a non-motorized project affecting a transportation facility that belongs to another road agency.

- Identifies non-motorized facilities contributing to complete streets as eligible for funding.
- Requires the State Transportation Commission (STC), within two years, to adopt a Complete Streets policy for MDOT, and to make model Complete Streets policies available to municipalities and counties.
- Requires state and local road agencies to consult with each other and agree on how to address Complete Streets for projects that affect a roadway under another road agency's jurisdiction.
- Allows MDOT to provide technical assistance and coordination to local agencies in the development and implementation of their policies.
- Requires MDOT to share expertise in non-motorized and multimodal planning in the development of projects within municipal boundaries.
- Allows agencies to enter into agreements with one another to provide maintenance for facilities constructed to implement a Complete Streets policy.
- Creates a 16-member Complete Streets Advisory Council within MDOT, to advise the STC and local agencies in the development, implementation, and coordination of Complete Streets policies. One member of this council will be a representative of the Michigan Municipal League.
- Modifies the definition of "streets" to include all legal users, including bicyclists and pedestrians.
- Expands the elements that may be included in a master plan to encompass all transportation systems that move people and goods.
- Specifies that transportation improvements identified in a plan are appropriate to the context of the community and considers all legal users of the public right of way.
- Ensures that transportation elements of the master plan will be implemented in cooperation with applicable county road commission or MDOT.

For More Information

MDOT Intermodal Policy Division

References

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Improving Street Continuity

Supply/System Management ▶ Traffic Operations ▶ Improving Street Continuity

Introduction

The mobility provided by a roadway system is affected by its street continuity. A lack of continuous streets is a result from changes in the number of lanes or from inadequate planning for street location between neighboring developments. Capacity reducing changes in a street cross-section may include reduction in the number of lanes, reduction in lane width, reduction in lateral clearance to obstructions, reduction in median width, reduction in pavement quality, etc. Changes in alignment that affect street continuity include sharp horizontal or vertical curves. These types of curves can limit operating speeds in the vicinity of the facility. Discontinuity can also occur with secondary facilities within the right-of-way, such as bicycle and pedestrian facilities. Bicycle and pedestrian facilities may be disjointed in locations where facilities start and stop without connections to other bicycle/sidewalk facilities in the area (TTI, 2001).

Cost:	●●●●○
Time:	Long
Impact:	Corridor
Project Life:	20 years
Sponsors:	City/State

Techniques

Relatively minor reconstruction projects to upgrade “weak links” of facilities may result in significant increases in mobility for large portions of the facility. For example, a two-lane bridge serving four lanes on either side could be upgraded to a four-lane bridge. Limiting sections of roadway may be upgraded to match the number of lanes of adjoining sections. Sections of roadway that have gaps in bicycle and pedestrian facility networks can be retrofitted to link with existing bicycle/pedestrian facilities. Locations with substandard vertical and/or horizontal alignment for prevailing volumes and speeds can be redesigned. Roadways with reverse curves (a curve in one direction followed immediately by a curve in the reverse direction) can be redesigned with a longer single curve to provide a smoother flow through transitions in roadway alignment (TTI, 2001).

Application Principles

Planners should consult the MDOT *Road Users Manual*.

Costs

Improving continuity on a major roadway is usually incorporated into a major reconstruction project and therefore expensive. Minor roadways, sidewalks, and bicycle lanes can be improved at a moderate cost.

Benefits and Impacts

- Increased speeds.
- Delay reduction, if improving a bottleneck.
- Increase safety.

Michigan Plans and Policy

MDOT is currently conducting a US-12 Improvement Study that addresses system continuity for the roadway. Improvements are necessary in order to enhance the roadway's function in relation to five major roadways that serve the study area. The study area contains the only two-lane segment of US-12 between Saline and Detroit. Beyond the study area to the east and west, US-12 becomes a five-lane roadway.

For More Information

MDOT Design Division

References

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Vehicle Use Restrictions

Supply/System Management ▶ Traffic Operations ▶ Vehicle Use Restrictions

Introduction

Vehicle use limitations/restrictions are techniques for restricting the use of certain types of vehicles in a given geographic area or specified time period. Vehicle use restrictions apply to both operations and demand management. Strategies include:

- Truck tolls.
- Lane restrictions.
- Delivery restrictions.
- Development of intermodal facilities.
- Access improvements to reduce total or peak-period truck traffic and/or shift freight traffic to other modes.

Cost:	●●○○○
Time:	Short
Impact:	Regional
Project Life:	5 years
Sponsors:	City

The applicability of lane-use restrictions is generally limited to sections of roadway with at least three lanes in one direction. This allows trucks to be restricted to the two right-most lanes, leaving one lane for truck-free operation. Most often, these are freeway facilities, including interstate routes. The emphasis on efficiency is the original objective given by agencies for the introduction of lane restrictions involving trucks. The FHWA *Handbook on Freeway Management and Operations* also states that "the goals of various forms of truck lanes are to improve traffic operations, improve safety and facilitate the flow of goods" (FHWA, 2003).

Strategies to reduce truck traffic have been implemented in a very limited number of situations, primary at major ports or on already-tolled facilities with significant amounts of truck traffic, and with the intent of shifting trips out of peak hours rather than accomplishing significant mode shifting or other methods of truck trip reduction. Many smaller cities and towns have restrictions that limit deliveries only to *daytime* hours out of concern for after-hours noise. There are no known cases of cities in the United States implementing the reverse policy, restricting deliveries to off-peak hours to combat congestion. New York City conducted an Off-Hour Truck Delivery Pilot Program with 20 participants, funded by USDOT, which ran from late 2009 through 2010 (Holguin-Veras, 2011).

Techniques

Vehicle restrictions should be implemented in conjunction with other travel demand management (TDM) strategies, including improvements in alternative travel options and other disincentives to reduce driving. Generally, vehicle use restrictions are a localized strategy, but they may be applied along an entire facility or throughout a subarea. They are typically applied in locations where right-of-way (ROW) constraints prohibit the addition of turn or additional through lanes.

Implementation of controls must involve consideration of time periods and routes currently being used for movements, direct costs to businesses for the controls, and indirect costs to the economy for changing truck movement patterns. Therefore, local traffic and economic data are essential to planning controls (Jones, 2009).

Data

The application of vehicle use restrictions can be evaluated using the methodologies in the Highway Capacity Manual and/or arterial simulation packages. Data typically required for this analysis includes turning movement counts, lane configurations, signal phasing and timing, and travel speed. Because turn prohibitions force drivers to use alternate routes, consideration should be given to the additional VMT generated. Turn restrictions are not recommended if they force detours greater than 0.5 mile (FHWA, 2003).

Application Principles

Cities can regulate the movement of trucks within some areas at certain times. Historically, these programs have involved restricting trucks on local streets in certain areas of the central business district during peak hours, designating specific loading zones, delivery schedules, and truck routes, as well as multiple business delivery consolidation. However, controlling truck movements requires various legal restrictions that practitioners should definitely consider when proposing such measures. The cooperation and support of the trucking industry are crucial to program success. TDM strategies addressing freight are often more effective when implemented as part of a larger strategic initiative, considering approaches such as congestion pricing or off-peak delivery incentives that may have adverse impacts on freight shippers.

Collaborative effort between agencies is best for developing freight delivery restrictions in urban areas. Adequate curb space is essential to prevent double-parking of trucks. Off-street loading space in new buildings/developments should be provided in municipal zoning ordinances. With respect to this strategy, one of the most commonly cited issues is the fact that trucking companies are frequently at the mercy of their customers and require delivery access outside of the restricted times (TxDOT, 2007).

Costs

The costs of developing and implementing truck use restriction strategies would vary by scope of affected area and number of affected vehicles. Much of the analysis of this strategy has been performed in the context of value pricing studies; therefore the cost of this individual strategy is not disaggregated from the overall program. Costs include program and enforcement expenses, increased travel costs and reduced mobility for motorists, and possible spillover effects (such as increased driving at other times or in other areas).

Benefits and Impacts

Vehicle use restrictions are designed to maximize operational efficiency of the existing system by eliminating turning or parking conflicts, reducing the impacts of trucks, or freeing up roadway capacity. For example, parking restrictions during peak hours allow the curb lane to be used as an additional through or right turn lane. On roadways with no separate left turn lanes, turn restrictions eliminate queues and conflicts thus reducing delays and improving travel speeds by eliminating conflicts.

An important advantage of this strategy is that increased operational efficiency is achieved at a relatively low cost and without the need for construction or additional ROW. Potential benefits of this mitigation strategy include:

- Increased throughput.
- Increased capacity.
- Decreased primary and secondary incidents.
- More uniform speeds.
- Decreased headways.

- More uniform driver behavior.
- Increased trip reliability.

In the New York City pilot program, receivers found that fewer deliveries during normal business hours allowed them to focus more on their customers and that their staff was more productive as they waited less for deliveries that were tied up in traffic. Carriers found that their trucks could make more deliveries in the same amount of time; they saved money on fuel costs and could use a smaller fleet by balancing daytime and nighttime deliveries, and that legal parking was more readily available. Their drivers reported feeling safer and less stressed.

A potential disbenefit of parking restrictions is the economic impact to businesses related to reduced parking. For turn restrictions, a potential disbenefit is increased VMT as vehicles circumvent restricted areas or avoid prohibited movements (Holguin-Veras, 2011).

For More Information

MDOT Intermodal Policy Division

References

FHWA *Handbook on Freeway Management and Operations*, 2003.

Holguin-Veras, José, et al., *Overall Impacts of Off-Hour Delivery Programs in the New York City Metropolitan Area*, TRB 90th Annual Meeting Compendium of Papers DVD, 2011.

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Access Management

Supply/System Management ▶ Traffic Operations ▶ Access Management

Description

According to the Transportation Research Board (TRB), access management "is the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to a roadway," (TRB, 2003). Access management programs attempt to reduce and combine access points along major roadways while encouraging complete circulation systems. The product is a street system that functions safer and more efficiently while creating a more attractive and pleasant transportation experience. As development grows along a roadway, there may be a need to manage street access to increase public safety, extend the life of the roadway, reduce congestion, support alternative modes of transportation, and improve the overall appearance of the roadway (Michigan DOT, 2011).

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	25 years
Sponsors:	City/State

Access management is a set of proven techniques that can help do the following (Michigan DOT, 2011):

- Reduce the number of crashes and improve safety.
- Reduce traffic congestion.
- Preserve the flow of traffic.
- Preserve the public investment in roads.
- Enhance the value of private land development.

When there are many closely spaced access points to businesses and other destinations along a corridor, it makes it difficult for users to enter and exit the access points. In turn, this can discourage travel to these congested areas and the patronage moves to safer and more convenient business establishments at other locations within the community. Quick solutions to the above problems such as street widening and adding traffic signals often create more issues in the future. Additional (and costly) bypass roadways usually must be built to accommodate through traffic and attempt to improve circulation (Michigan DOT, 2011).

Techniques

As the TRB definition of access management implies, some of the specific ways that transportation planners can influence the functionality of a roadway is through traffic signal spacing, location of driveways, median openings, and multimodal options.

- Traffic signal spacing is among the most important access management component. According to TRB, decreasing signal spacing from four to two per mile decreases total delay by nearly 60 percent and vehicle-hours of travel by nearly 50 percent (TRB, 2003).
- The location and design of driveways and median openings are important elements of access management. As an example, if the predominant roadway pattern includes major arterial cross-streets at one-mile spacing. Providing for signalized intersections at these major cross-streets (whether traffic signals are installed initially or not) and allowing full access with median openings at a mid-point between intersections is appropriate for most major arterials. Other access points should be designed as right-in/right-out only with no median openings (Michigan DOT, 2011).

Multimodal planning refers to early consideration of transit (routes, stop locations, waiting facilities) and bicycle/pedestrian facilities (sidewalks, bike lanes, trailheads, etc.) The key point is that it is much easier to plan for these facilities as an early step of planning than it is to retrofit them to existing facilities. Including them in an access management plan can encourage property owners and developers to incorporate them into private development plans.

Application Principles

One way that MDOT implements access management through its Access Management Program is through the completion of access management studies that result in access management plans to guide MDOT, local municipalities, and developers in locating future access points and to provide local municipalities with direction for new (or updated) ordinances (Eisele, 2010). Such plans are developed with consideration of the concepts and techniques identified in the *Michigan Access Management Guidebook* (Wycoff, 2001). Through the adoption of the access management plans and access management ordinances, many aspects of implementing access management are improved including (Eisele, 2010):

- Local site plan review and approval processes include all responsible road agencies. This is facilitated when an access management committee is formed as the result of a study.
- Applications for driveway permits are reviewed by staff representing the member agencies of the access management committee prior to the site plan approval.
- Roadway reconstruction and resurfacing projects need are reviewed in light of the access management plan to address access improvement opportunities.

MDOT teams with local transportation agencies to implement access management. Access management training and corridor access management planning is provided by MDOT. Municipalities can establish land development regulations such as subdivision controls or lot dimension requirements that can influence access issues. Often access issues can be improved when redevelopment occurs if the local transportation agency has appropriate ordinances in place. As shown in the photograph below, development of large parcels with outparcels can be designed such that no direct access is provided to the state highway from outparcels. In addition to ordinances to implement access management, MDOT and local transportation agencies can implement access management through the physical design of interchanges, intersections, medians, driveways, auxiliary lanes, etc.

Figure 12. Bank with No Direct Access to State Highway
(Adapted from Eisele, 2010)

For More Information

MDOT Project Planning Division

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Speed Harmonization

Supply/System Management ▶ Traffic Operations ▶ Active Traffic Management ▶ Speed Harmonization

Introduction

Agencies use an expert system to monitor data coming from field-deployed sensors on a roadway and automatically adjust speed limits when congestion thresholds are exceeded and congestion and queue formation are imminent. The intent is to adapt the speed limit to obtain a consistent and homogenous traffic flow and delay the onset of breakdown. Speed harmonization may also be referred to as variable speed limits or dynamic speed limits. Two common purposes for deploying speed harmonization are for weather-related conditions and congestion management:

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

- *Weather Related Speed Harmonization* is often used on roads where fog, ice, rain, or other factors often impact safety. When weather conditions deteriorate to the point that hazardous conditions are impending, the operating agency reduces the speed limit to one that helps minimize the likelihood of incidents.
- *Congestion Related Speed Harmonization* is used during periods with high traffic volumes or congested situations. When volumes and/or speed exceed a predetermined threshold, the operational strategy is deployed. The intent is to foster better uniformity in speeds and a sustainable traffic flow.

In both cases, the decrease of the speed limit is intended to alert drivers of changing conditions downstream. Ideally, these changes are automated and do not require intervention from any operator. The speed limit changes in increments of 5 or 10 mph to progressively decelerate the flow of traffic. Depending on the goals of the agency, the speed can either be mandatory or advisory.

In the State of Michigan, speed limits on state roads are set at the 85th percentile of speed measurements. This policy is required by state law in the Michigan Vehicle Code.

Techniques

Speed harmonization is commonly used with automated queue detection/warning and lane control signs and is regularly used in combination with temporary shoulder use. General criteria for speed harmonization include the following:

- Elements that are essential to speed harmonization:
  - Level of service E or F for 3 hours during the peak hour and 5 hours per day.
  - Right of way available for overhead gantries and DMS at regular intervals.
  - At least one location where queues regularly form and warning is warranted.
  - At least five incidents related to queuing, merging/diverging per week.
- Preferable elements to speed harmonization:
  - Willingness to automate the deployment of the strategy.
  - Existing ITS and connections to the TMC.

Data

- Weather conditions.
- Pavement conditions related to weather.
- Traffic volumes.
- Travel speeds.
- Incident presence and location.

Application Principles

For weather-related deployments, Sydney, Australia, implemented a fog warning system which includes advisory speeds. During fog, the advisory speed limit is continuously adjusted to the speed of the preceding vehicle within the speed limit (Coleman, 1995). In Denmark, studies found that a DMS indication of slippery road, fog, and other hazardous road conditions reduced the traffic mean speed by 1 to 2 km/h. When the speed harmonization sign showed a speed limit of 80 km/h instead of 100 km/h, the mean speed was reduced by 3.4 km/h. In adverse road conditions, such as black ice, the speed limit was lowered from 120 km/h to 100 km/h mean speed dropped by 5.1 km/h. The speed harmonization signs also reduced speed variance (Rama, 2001). The Netherlands also deploy speed harmonization for weather conditions.

Visibility sensors are used to measure the level of fog and when visibility drops to 140 m or 70 m, the speed limit is dropped to 80 km/h or 60 km/h, respectively. After implementation of the speed harmonization during fog conditions, drivers reduced their speed by 8–10 km/h (Kuhn, 2006).

For congestion-related deployments, the United Kingdom has seen a decrease in emissions by 2 to 8 percent, a noise reduction around 0.7 decibels, 20 percent fewer property damage only crashes, and 10 percent fewer injury crashes (Kuhn, 2004). Implementation has also resulted in an improvement in travel time reliability, a smoother flow, a better lane balance, and a calmer driving experience. Facilities in Germany with speed harmonization had travel times reduced by 5 to 15 percent, the number of crashes decreased by 30 percent, and a 5 percent increase in capacity (Kuhn, 2006, Coleman, 1995). In Denmark, the implementation of speed harmonization resulted in speeds decreasing by less than 5 km/h and reduced speed variance. A survey showed that 46 percent of Danish travelers felt safer after the implementation (Kuhn, 2006).

In the past two years, the States of Washington and Minnesota have deployed active traffic management systems to achieve speed harmonization. Washington's program is based in the United Kingdom's approach.

The following are key factors to consider that can help facilitate successful deployment:

- The success of speed harmonization is closely linked to the extent to which drivers comply with the signing, so it is important that agencies communicate with the public and inform them of new measures and regulations as they are put in place.
- Speed harmonization needs to be implemented in response to an actual situation. If users do not believe the system is legitimate, compliance rates will be low. Therefore, if the reason for the new speed limit is not apparent, it should be explained through appropriate signing.
- Speed limit signs have to be visible to all vehicles; therefore, the signs are to be placed on gantries over every lane of traffic. DMS should be placed regularly to either give explanation for the lower speed limits or warn about extraordinary events.

Costs

The costs of installation speed harmonization within a corridor varies considerably depending on the existing infrastructure and the selection and spacing of overhead gantries, DMS, and other related signage.

Benefits and Impacts

- Increased throughput.
- Decrease in primary incidents.
- Decrease in incident severity.
- More uniform speeds.
- Decreased headways.
- More uniform driver behavior.
- Increase trip reliability.
- Delay onset of freeway breakdown.
- Reduction in traffic noise.
- Reduction in emissions.
- Reduction in fuel consumption.

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Temporary Shoulder Use

Supply/System Management ▶ Traffic Operations ▶ Active Traffic Management ▶ Temporary Shoulder Use

Introduction

Shoulder use, also known as hard shoulder running (HSR), is a dynamic measure designed to adapt roadway capacity to high traffic flow on a temporary basis. By allowing vehicles on the left or right shoulder under reduced speed limits, it is possible to serve a higher number of vehicles and avoid congestion, either totally or partially, during peak hours. The decision to implement shoulder use on a segment is taken by the operator in the traffic management center, although the need to open the shoulder is based on volume considerations.

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

Two approaches to temporary shoulder use are implementations allowing all vehicles or only transit vehicles to use the shoulder.

- *Shoulder use for all vehicles* allows all vehicles on the roadway to utilize the designated shoulder when open. Traffic control devices over or adjacent to the shoulder instruct drivers when driving on the shoulder is permitted.
- *Transit-only shoulder use*, also known as a bus bypass shoulder (BBS) or bus on shoulder (BOS), allows only transit vehicles to utilize the designated shoulder under specific conditions and driving regulations. The bus drivers are instructed to use the shoulder under specific circumstance to ensure the safety of the operation and all the freeway users.

Techniques

Temporary shoulder use is commonly used in combination with speed harmonization. General criteria for temporary shoulder use for all vehicles include the following:

- Elements that are essential to temporary shoulder use for all vehicles:
  - Level of Service (LOS) E or F for at least 2 hours per day.
  - Facility segment under consideration at least 3 miles in length.

- No expected bottleneck downstream of the shoulder use segment.
  - Low volumes entering and exiting the facility, especially if going through interchanges.
  - Minimum shoulder width of 10 ft.
  - Available right of way for emergency refuge areas and acceleration/deceleration tapers.
  - Sufficient pavement strength on the shoulder to bear the traffic.
- Preferable elements to temporary shoulder use for all vehicles:
  - Active incident management.
  - Connection to a TMC that serves as the focal point for the system.
  - Existing sensors and ITS.
  - Presence of speed harmonization on the facility.

General criteria for temporary shoulder use by transit vehicles only include the following:

- Elements that are essential to transit-only shoulder use:
  - Predictable congestion delays, LOS D for 2 hours per day.
  - Minimum 10 ft shoulder width available.
  - Sufficient pavement strength to sustain bus load.
  - Minimum service of 50 buses/hour (freeway) or 25 buses/hour (arterial).
- Preferable elements to transit-only shoulder use:
  - Travel time variability higher than 1 minute per 2 miles.
  - Few conflict points at interchanges.
  - Facility segment servicing multiple bus routes.
  - Acceptable changes for on street operation (arterial).

Data

- Traffic volumes.
- Travel speeds.
- Incident presence and location.
- Shoulder availability.

Application Principles

The Netherlands implemented temporary right shoulder use in 2003 as part of a larger program to improve use of the existing infrastructure. The strategy is utilized on more than 1,000 km (620 mi) across The Netherlands, and only operates during time periods of congestion or when incidents occur along instrumented roadways (Kuhn, 2010). Since 1996, Germany has deployed temporary shoulder use to provide additional capacity during times of congestion and reduced travel speeds. Operated on more than 200 km of roadways across the country, it is only deployed in conjunction with speed harmonization when maximum allowable speeds are 100 km/hr (62 mph) and if dynamic message signs are used for lane control (Kuhn, 2010). Temporary shoulder use in Great Britain is deployed as part of an overall operational active traffic management (ATM) scheme, and is only deployed in conjunction with variable speed limits and when speeds are reduced (initially to 50 mph).

In the U.S., temporary shoulder use varies. On Massachusetts State Route 3 and I-93 and I-95 in the Boston area, all vehicles are permitted on shoulders in the peak periods only. Similarly, in Virginia on I-66, the shoulder carries general purpose traffic from 5:30 a.m.–11:00 a.m. (eastbound) and 2:00 p.m.–8:00 p.m. (westbound); however, during this time, the interior general purpose lane is open to high occupancy vehicle (HOV) traffic only. I-66 uses extensive traffic signals and signage in order to communicate the active times of service. In the Seattle area, the right shoulder on the US 2 trestle near Everett is opened to all traffic in the eastbound direction during the afternoon peak period. A similar operation is provided on H1 in Honolulu in the morning peak on the right shoulder. A unique combination of strategies is operational on I-35W in Minneapolis where a segment has the left shoulder open during the peak periods. Known as priced dynamic shoulder lanes (PDSL), transit and carpools use the shoulder for free and MnPASS customers can use the shoulder for a fee.

BOS programs are operational on over 290 mi of freeways and arterials in the Minneapolis metropolitan area, and are also operational in California, Delaware, Florida, Georgia, Maryland, New Jersey, Virginia, and Washington. This operational strategy is generally a low-cost and quickly implemented solution that does not require costly expansion of highway right-of-way.

The following are key factors to consider that can help facilitate successful deployment:

- Temporary shoulder use is typically implemented in conjunction with speed harmonization.
- When implemented with speed harmonization, speed limit signs and lane control signals need to be visible to all vehicles; therefore, the signs are to be placed on gantries over every lane of traffic. During normal operation, i.e., when the use of the shoulder is prohibited, all the signs—including the sign over the shoulder—are blank.

- Either the left or right shoulder can be used for the application, depending on the facility conditions. It is not recommended to apply shoulder use on both left and right shoulders of a facility at the same time.
- To ensure the safety on the shoulder, video cameras should be placed regularly to allow operators to check for obstacles before opening the shoulder to traffic and monitor operations while shoulder use is permitted. To avoid having stranded vehicles on a used shoulder, emergency refuge areas should be located at regular intervals along the shoulder with proper signing.
- Overhead guide signs should adapt to the current used width of the roadway. In other words, when the shoulder is open to traffic, guide signs should provide information to the shoulder lane as if it was a permanent travel lane. This can be accomplished with DMS.
- When acceleration and deceleration tapers are needed, additional tapers are placed on the right side of the shoulder since the original tapers are usually on the shoulder. The additional tapers are meant to be used only while traffic circulates on the shoulder.

Costs

The costs of implementing temporary shoulder use within a corridor varies considerably depending on the existing infrastructure and whether speed harmonization will be deployed in conjunction with the shoulder use. As one example, a scanning/feasibility study on active traffic management conducted for Washington State Department of Transportation (WSDOT) showed that shoulder use is an effective way to increase to capacity and reduce congestion in a small amount of time. The cost of preparing a freeway for shoulder use was estimated at $2.7 million per mile (*Active Traffic Management Feasibility Study,* 2007).

Benefits and Impacts

- Increased throughput.
- Increased capacity.
- Increased trip reliability.
- Delay onset of freeway breakdown.

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Queue Warning

Supply/System Management ▶ Traffic Operations ▶ Active Traffic Management ▶ Queue Warning

Introduction

The basic principle of queue warning is to inform travelers of the presence of upstream queues, based on dynamic traffic detection and using warning signs and flashing lights. This strategy allows the traveler to anticipate a situation of emergency braking and limit the extent of speed differentials, erratic behavior, and queuing-related collisions. Queue warning can be used on its own with dynamic message signs (DMS) placed on overhead gantries that show the symbol or word when a queue is close. It can also be included with speed harmonization and lane control signals to provide incident management capabilities. The system can be automated or controlled by a TMC operator. Work zones also benefit from queue warning with portable DMS units rightfully placed upstream of expected queue points.

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

Techniques

Queue warning is often deployed in conjunction with other ATM strategies, such as speed harmonization. General criteria for queue warning include the following:

- Essential criteria:
    - LOS E/F for at least 2 hours per peak period.
    - Presence of queues in predictable locations.
    - Sight distance restricted by vertical grades, horizontal curves, or inadequate illumination.
    - Right of way for overhead gantries and DMS.
    - At least five incidents related to queuing merging and diverging per week.
- Desirable criteria:
    - Large mix of high profile vehicles or inability to control speeds.
    - Willingness to automate the deployment of strategy.
    - Existing intelligent transportation systems (ITS) and connections to traffic management centers (TMC).

Data

- Traffic volumes.
- Travel speeds.
- Incident presence and location.

Application Principles

Queue warning deployment on the A8 Autobahn between Ulm and Stuttgart in Germany show that it improves the quality of traffic flow, reduces speeds with closer headways, encourages more uniform driving speeds, and slightly increases capacity. Since drivers anticipate the risk of queues, accidents are less severe and less frequent. It was also noted that users are interested in knowing the location of the queue and what route they should take to avoid it (Kuhn, 2006).

When queue warning is included in a larger traffic management project that has lane control signals and variable speed limits with DMS, it is possible to reduce the speed incrementally between gantries and evacuate traffic from one lane to provide access and shelter for emergency vehicles. In Sweden, this type of system helped to reduce accidents by 23 percent overall, specifically serious accidents decreased by 35 percent, and secondary accidents decreased by 46 percent. In Germany, accidents were reduced by 20 percent on an autobahn with queue warning while they increased by 10 percent on a similar autobahn without queue warning (Tignor, 1999).

Work zones also take advantage of queue warnings. Many agencies use mobile DMS to warn approaching traffic of queues. The results are very positive, an example being, in Belgium where 60 percent of rear-end crashes were avoided (Steinke, 2000). On some roads, like on both the inner and outer ring roads in Paris, France, congestion occurs so regularly that users are much more interested in knowing the expected travel time to their exit than the presence of downstream queue (*Good Traffic Management Techniques Know No Bounds*, 2001). A study in Washington found that queue warning could reduce congestion related collisions by 15 to 20 percent and that the benefits were estimated to outweigh the cost within 1 to 3 years (*Active Traffic Management Feasibility Study,* 2007).

The following are key factors to consider that can help facilitate successful deployment:

- Queue warning can be more effective when deployed in conjunction with speed harmonization.
- When implemented with speed harmonization, the queue warning pictograms and/or flashing lights need to be visible to all vehicles. During normal operation, all the signs are blank. The signage should also be consistent and uniform to clearly indicate congestion ahead.
- An expert system that deploys the strategy based on prevailing roadway conditions without requiring operator intervention is optimal.

Costs

The costs of implementing queue warning within a corridor varies considerably depending on the existing infrastructure and whether speed harmonization will be deployed in conjunction with the queue warning.

Benefits and Impacts

- Decrease in primary incidents.
- Decrease in secondary incidents.
- Decrease in incident severity.
- More uniform speeds.
- Decreased headways.
- More uniform driver behavior.
- Increased trip reliability.
- Reduction in traffic noise.
- Reduction in emissions.
- Reduction in fuel consumption.

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Dynamic Merge Control

Supply/System Management ▶ Traffic Operations ▶ Active Traffic Management ▶ Dynamic Merge Control

Introduction

Dynamic merge control, or junction control, is used to dynamically meter or close specific lanes upstream of the interchange to manage access based on traffic demand (Mirshahi, 2007). It is an operational treatment that addresses the geometric condition when the sum of both freeway general purpose lanes and merging lanes at an interchange is higher than the number of downstream general purpose lanes. A typical U.S. application of this condition would be a lane drop for one of the outside lanes or a merging of two inside lanes, both of which are static solutions. The intent is to provide priority access to the higher traffic stream. Dynamic merge control can be a permanent application at known bottlenecks, or it can be used temporarily until a downstream roadway is widened (Tignor, 1999). It is a practical approach to handling varying demand on the main lanes and the merging lanes to effectively utilize existing capacity.

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

Techniques

Dynamic merge control can be easily facilitated with lane control signals and can work in conjunction with temporary shoulder use. General criteria for dynamic merge control include the following:

- Essential criteria:
  - Significant merging volumes (> 900 vph).
  - Available capacity on general purpose lanes upstream of the interchange that can be borrowed with no worse than LOS E after implementation.
  - Non-simultaneous peak traffic upstream on the general purpose lanes and merging lanes.
- Preferable elements to dynamic merge control:
  - Active incident management in the corridor.
  - Existing ITS and connections to the TMC.
  - Combination with shoulder use.

Data

- Maximum capacity of upstream general purpose lanes.
- Traffic volumes on general purpose lanes and merging ramps.
- Travel speeds on general purpose lanes and merging ramps.
- Incident presence and location.

Application Principles

The German approach is applied using lane control signals to close the rightmost general purpose lane upstream of the on-ramp to allow two ramp lanes to merge onto the motorway. In the Netherlands, a pilot test of dynamic merge control on the A1 showed promising results (Kuhn, 2006). In the State of Washington, this measure—if implemented—is expected to reduce collisions by 20 to 25 percent; the benefits of avoided collisions would most likely outweigh the primary cost in about 6 to 8 years (*Active Traffic Management Feasibility Study,* 2007).

The following are key factors to consider that can help facilitate successful deployment:

- Effective dynamic merge control uses lane control signals on the main lanes and merging lanes of a freeway to dynamically adapt to varying demand. It is important that these signs be installed on gantries that are sufficient enough to ensure advance warning to roadway users.
- An expert system that deploys the strategy based on prevailing roadway conditions without requiring operator intervention is optimal.
- To handle emergencies, a bypass lane for emergency vehicles, transit, or other identified exempt users is optimal.
- Dynamic merge control can be implemented in conjunction with temporary shoulder use as long as the overhead gantries with appropriate signing and lane control signals are part of the implementation.

Costs

The cost of implementing dynamic merge control within a corridor varies considerably depending on the existing infrastructure and whether temporary shoulder use and/or speed harmonization will be deployed in conjunction with the merge control.

Benefits and Impacts

The following are potential benefit and impacts of dynamic merge control, depending on local conditions and deployment approach:

- Increased throughput.
- Increased capacity.
- Decrease in primary incidents.
- More uniform speeds.
- More uniform driver behavior.
- Increased trip reliability.

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Dynamic Truck Restrictions

Supply/System Management ▶ Traffic Operations ▶ Active Traffic Management ▶ Dynamic Truck Restrictions

Introduction

Dynamic truck restrictions require all truck traffic to use designated lanes in a dynamic manner during peak periods. The intent is to increase the homogeneity of speed on each lane and to minimize the disruption in traffic flow caused by heavy vehicles. The dynamic nature of the treatment allows for more flexibility in application as opposed to static restrictions. The activation of the signs indicating the presence of restrictions is usually automated and is triggered by real-time traffic volumes. The signs should be placed on overhead gantries for visibility.

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

Techniques

General criteria for dynamic truck restrictions include the following:

- Essential elements:
  - Significant proportion of truck traffic.
  - Available right of way for overhead gantries.
  - No left side exits in the controlled section.
- Preferable elements:
  - Existing ITS and connections to the TMC.
  - Combination with speed harmonization.

Data

- Traffic volumes, including truck volumes.
- Travel speeds.
- Weather conditions.
- Incident presence and locations.

Application Principles

In the Netherlands, until the dynamic aspect was introduced recently as a test, the restriction took place at fixed times of the day mainly during peak hours. The dynamic restriction is activated when necessary and is displayed on overhead gantries. The approval rates for the dynamic variation are better among truck drivers and fewer violations were reported (Middleham, 2006). Some sections where speed harmonization is present also have dynamic truck restrictions that are implemented at the same as the speed harmonization. The combination of these two strategies has showed to reduce accidents enough to pay for itself in three years (Jarema, 1997).

Depending on the location, truck restrictions might not be a solution for a congestion problem. In England, a section of the M5 that regularly experienced congestion with up to 19 miles of queue was used as a pilot scheme for truck restrictions. The restriction applied to towing vehicles, buses and heavy goods vehicles (HGV). Although the right lane usage by trucks increased from 84 to 91 percent, the levels of congestion were not significantly affected as the congestion was mainly due to car traffic (Department of Transport, 2005).

The following are key factors to consider that can help facilitate successful deployment:

- Agencies will need to seek enabling legislation and related laws to allow dynamic truck restrictions.
- An expert system that deploys the strategy based on prevailing roadway conditions without requiring operator intervention is ideal. It is very important that this expert system by reliable and accurate in order to gain the trust and acceptance by system users.
- The installation of sign gantries needs to be sufficient to ensure that at least one sign displaying the restrictions is visible at all times.

Costs

The cost of implementing dynamic truck restrictions within a corridor varies considerably depending on the existing infrastructure and whether speed harmonization is deployed in conjunction with the restrictions.

Benefits and Impacts

- Increased throughput.
- Increased capacity.
- More uniform speeds.

- More uniform driver behavior.
- Increased trip reliability.
- Reduction in emissions.
- Reduction in fuel consumption.

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Dynamic Rerouting and Traveler Information

Supply/System Management ▶ Traffic Operations ▶ Active Traffic Management ▶ Dynamic Rerouting and Traveler Information

Introduction

An important component of transportation operations, dynamic rerouting and traveler information is the practice of providing rerouting and traveler information in a dynamic manner to system users. The intent is to provide users with viable route alternatives, and the approach can be especially beneficial in helping reduce the impact of noncurrent congestion (Mirshahi, 2007). When the main road is congested, rerouting traffic on a parallel road to relieve further congestion can be an efficient strategy. The implementation can be automated, but needs to include detailed information about both roads, such as short range expected volumes, construction, or special events.

Cost:	●●●○○
Time:	Moderate
Impact:	Regional
Project Life:	10 years
Sponsors:	State

Techniques

When considering dynamic rerouting and traveler information, there are two signing strategies that can be applied: substitution and addition.

- *Substitution:* In the substitution strategy, rotating panels on guide signs turn and indicate the suggested secondary route. The problem encountered with this method is that the first route is no longer displayed, and some mid-trip destinations may be missed.
- *Addition:* In the addition strategy, orange arrows show the recommended diversion route while keeping the original signing. In both cases, full matrix DMS can be used to display any of those strategies (Jarema, 1997).

General criteria for dynamic rerouting and traveler information include the following:

- Essential elements:
  - LOS E or F for 2 hours per day.
  - At least 3 incidents per week resulting in severe congestion.
  - Viable parallel corridor to accept rerouted traffic no farther than 2 mi from primary corridor.
  - Available capacity on parallel route.
  - Available right of way for overhead gantries if necessary.
- Preferable elements:
  - Existing ITS and connections to the TMC.
  - Combination with speed harmonization and temporary shoulder use.

Data

- Traffic volumes.
- Travel speeds.
- Weather conditions.
- Incident presence and locations.
- Conditions and availability of alternate routes.

Application Principles

A study on dynamic rerouting and traveler information in Copenhagen, Denmark suggested that more travelers followed the alternative route (up to 12 percent of the time) as the displayed travel time between the original and alternate route increased. The relatively low portion of route changers may be due to erratic displays on DMS at the time of deployment. Surveys conducted showed that 80 percent of the driving public was in favor of this system (Kuhn, 2006).

In the Netherlands, rerouting information is displayed using through full matrix DMS that provide useful information for drivers to make the appropriate decision based on their needs. These signs are usually set at entrances of cities. Evidence indicates that the use of these signs has helped reduce congestion. For instance, after implementation on the Amsterdam ring road, congestion dropped by 25 to 33 percent. Drivers give more credit to the provision of accurate information (62 percent) to DMS information than to radio (52 percent) (Middleham, 2006). In normal conditions, 8 to 10 percent of drivers are reacting to the information. This trend can have a major effect on roadway operations and recurrent congestion (Kuhn, 2006).

In England, an expert system in the TMC computes the remaining capacity on a facility and the anticipated demand for the duration of an incident. If the anticipated delay exceeds a set threshold, the demand on alternate routes and the presence of road works, weather problems, or special events is evaluated before communicating the alternate route to the traffic (Kuhn, 2006).

The following are key factors to consider that can help facilitate successful deployment:

- The implementing agency needs to make a commitment to providing alternate route information to roadway users in response to nonrecurrent congestion.
- Dynamic rerouting and traveler information can be more effective when deployed in conjunction with speed harmonization and temporary shoulder use.
- The agency needs to ensure that there is an adequate installation of sign gantries along the facility at critical locations to ensure that sufficient advance notice of alternate routes is provided.
- Dynamic rerouting and traveler information is most effective when connectivity to adjoining TMCs exists to coordinate alternate route information based on roadway conditions and special events in adjoining regions. Coordination with local communities to minimize the impact of alternate route information on the arterial network is also important.

Costs

The costs of implementing dynamic rerouting and traveler information within a corridor varies considerably depending on the existing infrastructure and whether speed harmonization will be deployed in conjunction with the operational strategy.

Benefits and Impacts

- Increased throughput.
- Decrease in primary incidents.
- Decrease in secondary incidents.
- More uniform driver behavior.
- Increased trip reliability.

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Intelligent Transportation Systems (ITS)

Supply/System Management ► Traffic Operations ► Intelligent Transportation System (ITS)

Intelligent Transportation Systems (ITS) apply advanced technologies of electronics, communications, computers, control and sensing and detecting in all kinds of transportation system in order to improve safety, efficiency and service, and traffic situation through transmitting real-time information.

ITS is classified into five systems according to their functions as follows:

- Advanced Traffic Management System (ATMS) detects traffic situations, transmits them to control center via communication network, and then develops traffic control strategies by combing all kinds of traffic information. ATMS makes use of facilities to carry out traffic control and transmits the information to drivers and concerned departments, and implements traffic management measures, such as ramp metering, signal control, speed control, incident management, electronic toll collection, and high occupancy vehicle control.
- Advanced Traveler Information System (ATIS), with advanced communication technology, allows road users to access real time information in the car, at home, in the office, or outdoors as the reference of choosing transportation modes, travel trips and routes.
- Advanced Vehicle Control and Safety System (AVCSS) applies advanced technologies in vehicles and roads, and helps drivers control vehicles in order to reduce accidents and improve traffic safety. The AVCSS mainly includes anti-collision warning and control, driving assistance, automatic lateral/longitudinal control, and the long-run plans of automatic driving and automatic highway system.

- Advanced Public Transportation System (APTS) applies the technology of ATMS, ATIS and AVCSS in public transportation in order to improve the quality of service, and increase efficiency and the number of people who take public transportation.
- Commercial Vehicle Operation (CVO) applies the technology of ATMS, ATIS and AVCSS in commercial vehicle operation such as trucks, buses, taxes and ambulances in order to improve efficiency and safety. The system mainly includes automatic vehicle monitoring, fleet management, computer scheduling and electronic payment.

The toolbox focuses on two ITS strategies:

- ATIS.
- ITS Performance Measurement.

Advanced Traveler Information Systems

Supply/System Management ▶ Traffic Operations ▶ ITS ▶ Advanced Traveler Information Systems

Introduction

Advanced Traveler Information Systems (ATIS) is defined as systems that acquire, analyze, and present information to assist surface transportation travelers in moving from a starting location (origin) to their desired destination. ATIS may operate through information supplied entirely within the vehicle (autonomous system) or it can also use data supplied by the traffic management centers. Autonomous systems utilize vehicle position determination and stored map data. The use of data from the traffic control centre assists the driver in knowing the current status of the traffic in real time, and to make intelligent decisions. The information can include locations of incidents, weather and road conditions, work zones, optimal routes, recommended speeds, and lane restrictions (FHWA, 2011).

Cost:	●●●○○
Time:	Moderate
Impact:	Regional
Project Life:	10 years
Sponsors:	State

ATIS has become a viable congestion mitigation strategy in the last two decades due to implementation of ITS, increased development of internet capabilities, and the creation of the 511 calling code traveler information system. It increases efficiencies in a transportation network through:

- Time management – For example, changing a departure time to avoid or accommodate delays or inclement weather.
- Trip modifications – Changing the route of travel, the destination, or the mode of travel based on conditions or situations.
- Reduction in stress – Understanding the cause of a delay or the upcoming road conditions and an estimate of the impact to reduce driver stress (Deeter, 2009).

For commuters, research has shown three main information needs that ATIS can provide:

- Route-specific information describing the current travel time or speed of travel.

- Information about specific circumstances affecting travel (e.g., incidents, closures, major congestion).
- Current alerts of transit delays or service interruptions (Deeter, 2009).

Techniques

The FHWA Real-Time Traveler Information Program provides numerous examples of ATIS, including best practices and planning and implementation information.

Application Principles

Researchers have shown the effectiveness of ATIS applications in congestion mitigation (Xiao Xen, 2010; FHWA, 2011). However, deployment of systems has presented several challenges. These are:

- The traveler information that is being delivered receives limited use.
- A gap exists between what is possible in the state of the art in data collection, information generation, and delivery, and what occurs in today's state of practice.
- Both public and private traveler information providers face funding and budget challenges (Deeter, 2009).

Costs

Based on FHWA RITA information, deployment of an ATIS on a major roadway ranges from \$5–\$10 million depending on the scope of the project along with the technology used. Subsequent upgrades and improvements to the system can cost from \$100,000 to several million depending on the scale of the improvement (FHWA, 2011).

Benefits and Impacts

Through the applications of advanced information and communication technologies, ATIS offers several potential benefits to travelers including:

- Reduced congestion.
- Increased safety.
- Efficiency and management of capacity.

Michigan Plans and Policy

MDOT uses the MI Drive website (www.michigan.gov/drive) is the direct link between the MITS Center and the public. The site is updated in real time with:

- Freeway Incidents.
- Construction.
- Camera Feeds.
- Speed Data.

MDOT uses a system of dynamic message signs to disseminate information to travelers.

MDOT has also been awarded a federal grant to study the implementation of 511 for traveler information.

For More Information

MDOT MITS Engineer Manager

References

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ITS Performance Measurement

Supply/System Management ▶ Traffic Operations ▶ ITS ▶ ITS Performance Measurement

Introduction

Performance measurement is the use of statistical evidence to determine progress toward specific defined organizational objectives. This includes both evidence of actual fact, such as measurement of pavement surface smoothness, and measurement of customer perception such as would be accomplished through a customer satisfaction survey. In a service industry such as transportation, the performance measurement process starts by defining precisely the services that the organization promises to provide, including the quality or level of service (e.g., timeliness, reliability) that is to be delivered. The performance measurement process starts by defining the services that the organization promises to provide. There are often good opportunities for collecting feedback from system users in "real time," since the transportation service is often "consumed" at the same time it is "produced." Performance measures provide information to managers about how well that bundle of services is being provided. Performance measures should reflect the satisfaction of the transportation service user, in addition to those concerns of the system owner or operator (Cambridge Systematics, 1999).

Cost:	●○○○○
Time:	Short
Impact:	Regional
Project Life:	10 years
Sponsors:	State

Performance measures provide:

- Accountability.
- Efficiency.
- Effectiveness.
- Communications.
- Clarity.
- Improvement.

Federal ITS performance measures, used to evaluate ITS programs, include:

- Safety.
    - Reduction in crash rates—Total, fatalities, and injury.

- Mobility.
  - Reduction in travel time delay.
  - Reduction in travel time variability.
  - Improvement in customer satisfaction.
- Efficiency.
  - Increased throughput.
  - Productivity.
  - Reduced travel costs.
- Energy and environment.
  - Reduced emissions.
  - Reduced energy consumption (Shaw, 2003).

Techniques

NCHRP Synthesis 311: Performance Measures of Operational Effectiveness for Highway Segments and Systems: A Synthesis of Highway Practice provides a wealth of information pertaining to the development and use of performance measures in ITS applications.

Data

Many ITS performance measures are based on the following data:

- Annual person-hours of delay.
- Percent or hours of congested travel.
- Travel time index.
- Planning time index.
- Buffer index.

Application Principles

The FHWA Research and Innovative Technology Administration ITS Joint Program Office provides lessons learned pertaining to performance measures for ITS applications. Readers are urged to consult the program website noted in the references below.

Costs

Performance measure program costs are minimal, primarily annual data gathering, analysis, and reporting.

Benefits and Impacts

The use of information collected using ITS technologies are the primary operational environment where performance measures are most likely to be employed. ITS technologies and strategies also provide the greatest opportunity to share resources in the collection of data needed to support mobility performance measures. ITS performance measures are intended to evaluate the benefits of providing ITS and are typically a mix of output measures and operational-related outcome measures (Shaw, 2003).

Michigan Plans and Policy

MDOT has adopted performance measures for mobility in its current long-range plan. None of the measures specifically address ITS operations, but several are focused on congestion mitigation such as bottleneck removal, improving travel time, incident management, and delay reduction and use MITS operations to achieve them (Wilbur Smith, 2006).

For More Information

MDOT Bureau of Transportation Planning

References

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Traffic Signalization

Supply/System Management ▶ Traffic Operations ▶ Traffic Signalization

Introduction

Traffic signalization strategies represent the most common traffic management technique applied in the United States. Traffic signalization increases the efficiency of traffic flow at intersections by improving interconnection and coordination of signals, leading to reductions in travel times, delay, and stop-and-go driving. Traffic signalization can be as simple as updating equipment and/or software or improving the timing plan. These projects are generally the most available tool for reducing congestion on local and arterial streets. Significant improvements in travel speed and/or time can be achieved.

Cost:	●●○○○
Time:	Short
Impact:	Spot
Project Life:	> 5 years
Sponsors:	City

Because signal improvements reduce travel times and stop-and-go driving conditions, they can measurably reduce congestion. Measurable benefits to local congestion relief are common in downtown areas and major activity sites or corridors.

However, traffic signalization improvements may encourage additional traffic, increasing vehicle miles traveled (VMT). An increase in VMT along a roadway with improved traffic flow would offset some of the short-term congestion improvements generated by faster, more consistent travel speeds. Also, by reducing travel time on affected corridors, traffic signalization may attract additional vehicles and divert motorists from alternative modes of transportation.

Techniques

Traffic signal improvements can include the following:

- Updating traffic signals to utilize more modern hardware, allowing for more sophisticated traffic flow strategies to be planned.
- Timing traffic signals to correspond to current traffic flows and patterns, reducing unnecessary delays.

- Coordinating and interconnecting signals to better interface pre-timed and traffic actuated signals, actively managed timing plans, and master controllers to minimize the number and frequency of stops necessary at intersections.
- Removing signals at intersections no longer requiring signalized stop control to reduce vehicle delays and unwarranted stops.

Data

Accurate existing information is highly important. This includes signal timing, peak hour volumes, and geometrics. Travel time runs should be conducted to thoroughly understand traffic flow along each corridor. Depending on the goals of the project, the use of traffic simulation can provide added value. If traffic volumes are high, traffic simulation should seriously be considered (Trueblood, 2009).

Application Principles

MDOT's *Michigan Intersection Guide* provides the following as example strategies to improve safety and operations of signalized intersections:

- Reduce frequency and severity of intersection conflicts through traffic control and operational improvements (coordinating/optimizing signals).
- Improve driver awareness of intersections and signal control (signing, lighting, visibility).

When the primary focus has been placed on congestion management, the traffic control system which has been operated principally for the purpose of congestion mitigation has mainly been evaluated against congestion length and travel-time delays. Along with the growing diversity and complexity of social issues, however, social demands on traffic control are also getting diversified to incorporate safety and environmental measures. In order to explain to the public the sophistication of traffic control enabled by introduction of technologies and a resulting relief in traffic congestion in a comprehensible manner, it is of high importance to generate specific figures that represent reduction in travel time, congestion length, etc. (Shimazu, 2005).

Costs

The costs of a traffic signalization program will vary depending on the type of improvement and number of signals involved. Updating a signalized intersection requires a new traffic controller or traffic control software strategy. Timing plan improvements entail a labor-intensive data collection effort to determine new signal timings and subsequent re-timing of signals at each location. Signal coordination and interconnection require cable installation, as well as a series of controllers or a centralized computer-based master control system. To remove signals, a field survey must be performed to substantiate the elimination of the signals. Fieldwork is also necessary to remove the equipment.

Benefits and Impacts

The traffic signalization strategies presented are relatively low-cost. When properly applied, these strategies can effectively alleviate congestion, and provide for improved safety. MDOT's *Michigan Intersection Guide* further identifies crash reduction factors for several of these mitigation improvements. Even small congestion reductions during peak hours relate to benefits related to reductions in user delay and air emissions. One study of signal improvements showed reductions in delay ranged from 5 percent to over 25 percent (Trueblood, 2009).

Michigan Plans and Policy

MDOT has an extensive traffic signalization improvement program that takes into account local and regional congestion mitigation goals and programs.

For More Information

MDOT Traffic and Safety Section

References

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Reversible Traffic Lanes

Supply/System Management ▶ Traffic Operations ▶ Reversible Traffic Lanes

Introduction

Reversible traffic lanes, also called changeable lane assignments, increase the directional capacity of a congested roadway by designating an additional lane from the non-congested direction to the congested side of the roadway. The strategy may be implemented by using combinations of lane control signals and conventional signal indications. While these functions are usually implemented on a time of day basis, they may also be implemented on a traffic responsive basis. This strategy requires special traffic controls to effect the desired movements. Two basic types of operations using surface street directional controls include:

Cost:	●●●○○
Time:	Short
Impact:	Corridor
Project Life:	5 years
Sponsors:	City/State

- Reversible Flow – Dynamically operating a street as one-way inbound, one-way outbound, or two-way. Applications may include:
  - Heavy imbalance of directional traffic flow for relatively short periods such as in and out of central business districts.
  - No alternate solutions such as one-way pair or street widening.
  - Severe congestion and need to increase directional capacity.
  - Nearby parallel street capable of handling minor directional flow during peak one-way operation.
- Off-center lane movement – Partial reversal of traffic flow where only one or two lanes are reversed. Applications are similar to reversible flow.

Current techniques for controlling directional movement use signs or a combination of signs and lane control signals. Change of operational mode is usually on a time-of-day basis (FHWA, 2005).

Techniques

Directional control is often used for the following purposes:

- Assignment of roadway lanes to prevailing directional traffic flow requirements.

- Control of traffic flow during maintenance operations.
- An element in incident response plans.

Reversible lane control has proven the most common use for lane control signals (LCS). Examples include:

- Toll booths.
- HOV lanes.
- Reversible transitways on freeways.
- Arena/stadium traffic.
- Parking control.

Other applications include:

- Restriction of traffic from certain lanes at certain hours to facilitate merging traffic from a ramp or other freeway.
- Lane use control for:
  - Tunnels.
  - Bridges.
  - Freeways (FHWA, 2005).

Data

Some of the data that should be available when considering this strategy include:

- Current volume-to-capacity ratio on roadway.
- Right-of-way availability for signage.
- TDM analysis of activity post-implementation.

Application Principles

Installation of a changeable lane assignment system as part of a major intersection reconstruction project in Houston was estimated to help provide a 5 percent reduction in volume-capacity ratio after implementation (HGAC, 2005).

Costs

The cost of this strategy is moderate, primarily planning studies and equipment.

Benefits and Impacts

Reversible traffic lanes will reduce congestion by increasing roadway capacity in the congested direction. This strategy can also increase work zone safety.

Michigan Plans and Policy

None of the four CMPs adopted by TMAs in Michigan refer to changeable lane assignments or reversible traffic lanes as part of their congestion mitigation strategies. However, MDOT regularly uses movable concrete barriers on major roadways, such as I-75 and I-96, to mitigate congestion during holiday weekends or other periods of expected increases in traffic.

For More Information

MDOT Operations Division

References

FHWA Office of Operations, *Traffic Control Systems Handbook*, October 2005.

Houston-Galveston Area Council, *Congestion Mitigation Analysis State Highway 99 (Grand Parkway, Segments E, F-1, F-2, and G*, December 2005.

Exclusive Lanes

Supply/System Management ▶ Traffic Operations ▶ Exclusive Lanes

Introduction

Exclusive lanes use vehicle eligibility to achieve operational objectives. It provides an exclusive lane to certain vehicle classifications. Most often this is dedicated to buses or large trucks. Examples include exclusive busways, transitways, or truck facilities serving a specific type of vehicle, with barrier separation and limited access points. Some facilities allow use by taxicabs and bicycles. Exclusive lanes also can provide emergency vehicles with congestion-free routes. Exclusive lanes have been built next to highways, in the medians of arterial streets, in abandoned rail corridors, and in tunnels (FHWA, 2008).

Cost:	●●●○○
Time:	Short
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

Exclusive bus-only lanes act to provide an incentive to transit riders. By providing a special lane for the exclusive use of buses, these vehicles achieve a travel time advantage as opposed to vehicles in the general-purpose lanes (Collier, 2004).

Truck lanes operate in much the same fashion as bus-only lanes. However, the objective is different. The goal in separating truck traffic from passenger traffic is to improve the flow of a facility and provide an increased level of safety by reducing possible conflicts between large trucks and other vehicles. Separate truck lanes may be feasible in areas where truck volumes exceed 30 percent of vehicular traffic, peak-hour volumes exceed 1,800 vehicles per lane-hour, and off-peak volumes exceed 1,200 vehicles per lane-hour (FHWA, 2008).

Transit malls are a type of exclusive public transport lane. They are sections of street, generally located in a city centre, where several transit lines operate with little or very limited private traffic.

Techniques

An assessment of safety, traffic operations, and pavement performance should be considered before implementing the strategy (Vidunas, 1998).

Data

When considering exclusive lanes, data collection should, at the very least, include traffic volumes and vehicle mix percentages as well as information concerning delays caused by incidents (Vidunas, 1998).

Application Principles

The most effective purpose built exclusive guideways are designed to serve several different public transport routes (for example, a bus tunnel in a downtown area) (Vidunas, 1998).

The method of separating exclusive lanes from other traffic is an important factor in determining their effectiveness. Painted lanes are least effective and lanes separated by barriers or on their own right-of-way are best (FHWA, 2008).

As for trucks, research results indicate that carriers are willing to use optional Truck-Only Toll (TOT) lanes when no costs exists, and that a pricing mechanism could successfully keep TOT lanes at free-flow levels. Results also indicate strong pressure from shippers regarding delivery times, thus leading carriers to conduct business during hours of peak highway/demand. This information suggests that increased capacity is critical to reducing congestion, while attempts to change the times at which trucks operate by pricing trucks during peak periods may not address the issue (Short, 2007).

Costs

Exclusive lanes for cars and trucks appear to be economically beneficial (Vidunas, 1998). However, building a separate right of way is a costly improvement but can be worthwhile, especially if it serves as the catalyst for implementing other transit priority improvements. Even given their high cost, these improvements can be less expensive than building new heavy rail public transport systems.

Benefits and Impacts

- Increased safety.
- Reduced travel times for eligible vehicles.
- Increased speeds on main lanes.

References

Collier, Tina and Goodin, Ginger, *Managed Lanes: A Cross-Cutting Study*, FHWA, October 2004.

FHWA, *Managed Lanes: A Primer*, August 2008.

Short, Jeffrey, *Survey of Motor Carrier Opinions on Potential Optional Truck Only Toll (TOT).*

Lanes on Atlanta Interstate Highways, TRB Conference, 2007.

Vidunas, Joseph E. and Hoel, Lester A., *Exclusive Lanes for Trucks and Cars on Interstate Highways*, Transportation Research Record 1576, Transportation Research Board, Washington, D.C., 1998.

Incident Management

Supply/System Management ▶ Traffic Operations ▶ Incident Management

Introduction

Traffic incident management (TIM) provides a coordinated approach to managing incidents that occur on the highway. It is "the systematic, planned, and coordinated use of human, institutional, mechanical, and technical resources to reduce the duration and impact of incidents, and improve the safety of motorists, crash victims, and incident responders. Effectively using these resources can also increase the operating efficiency, safety, and mobility of the highway. This results from reducing the time to detect and verify an incident occurrence; implementing the appropriate response; safely clearing the incident; and managing the affected flow until full capacity is restored" (FHWA, *Freeway Management Operations Handbook*, 2003).

Stalled vehicles, traffic stops, highway debris, spilled loads, and crashes are examples of traffic incidents that account for about one-third of all delay due to traffic congestion on our nation's highways. Along with weather, construction, and special events, these non-recurring incidents are responsible for nearly 60 percent of delay caused by traffic congestion.

Traffic congestion caused by incidents affects the safety and mobility of all travelers. Major incidents can affect thousands of vehicles in an entire highway corridor or across a major portion of an urban area. Traffic incidents cause secondary incidents that also require response from the same agencies already engaged in the primary incident. Secondary incidents are not just crashes but also include engine stalls, overheating, and running out of fuel. Approximately 20 percent of all incidents are secondary incidents.

Techniques

Focus is given to two individual TIM strategies in the toolbox:

- Detection, Clearance, and Response.
- Information/Routing and Interagency Cooperation.
- Service Courtesy Patrols.

Detection, Response, and Clearance

Supply/System Management ▶ Traffic Operations ▶ Incident Management ▶ Detection, Response, and Clearance

Introduction

Traffic Incident Management (TIM) is a planned and coordinated process by multiple public agencies and private sector partners to detect, respond to, and remove traffic incidents and restore traffic capacity as safety and quickly as possible. Detection, response, and clearance strategies are greatly enhanced by ITS in a region.

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

The National Incident Management System, adopted in 2004, provides a more formal structure to TIM program and essential components as noted by FHWA in the table below.

Table 16. Traffic Incident Management-National Incident Management System Program Components

TIM Program Areas	NIMS Concepts	TIM Program Concepts
Strategic	Preparedness	Planning Training and exercises Ensure readiness of personnel and equipment Mutual-aid agreements Multi-agency operations agreements TIM Task Forces and/or Teams
Strategic	Resource Management	Identify and type resources Identify location of resources Mobilize resources Reimbursement
Tactical	ICS	On-scene command and control procedures
Support	Communications and Information Management	Develop information policies Develop interoperability standards Utilize common terminology Develop communication systems

Techniques

The table below from FHWA presents the key TIM program elements and their respective purposes.

Table 17. Traffic Incident Managment Program Elements

Element	Purpose
Legislative or Administrative Authorization	Provides top-down authorization for resource sharing and joint operations
Strategic Mission and Accompanying Goals	Sets direction and establishes accountability for program performance
Written Operational Policies	Provides unambiguous guidance for on-scene operations
Dedicated Staff	Establishes TIM as core job function rather than secondary or tertiary activity
Ongoing Training	Keeps responder skills current based on most recent state-of-practice
Well-Defined Responsibilities	Solidifies relationships across disparate agencies and mitigates "turf battles" among responders
Clear Reporting Channels	Establishes chain of command and ensures accountability
Dedicated Funding	Lessens impact of budgetary fluctuations

Data

Data are collected through a communications infrastructure, a closed-circuit television system, and sensor detection system. The information is then used to make real-time traffic management decisions and provide motorists with information through dynamic message signs, radio travel advisories, and a telephone advisory system. Travelers may also access an interactive online GIS mapping service for major roads to obtain average speed, traffic conditions, and lane closures. Travelers can also view selected road conditions through online video links (AASHTO, 2010).

Application Principles

Thirteen state DOTs with implemented congestion management strategies were surveyed by researchers at the Kentucky Transportation Center. When asked to identify the most effective or best strategy, incident management programs were among the top four responses (Kreis, 2005).

The FHWA website offers over 30 publications pertaining to all aspects of developing, planning, adopting, and implementing traffic incident management programs. They are available at: http://www.ops.fhwa.dot.gov/publications/publications.htm#tim.

Costs

As an example, the cost for development and implementation of 30-mile fully integrated freeway/incident management program as part of a freeway expansion/improvement project is $33.2 million, or $1.1 million per mile. Annual operations and maintenance costs will be $1 million per year.

The majority of the costs are for surveillance, detection, and information equipment and communications hardware. Information equipment includes detection technologies such as acoustic sensors, loops, and digital detectors, closed circuit television (CCTV) cameras, dynamic message signs and lane control systems, and supporting fiber optic communications infrastructure (FHWA, 2010).

Benefits and Impacts

The primary benefits of detection, response, and clearance are delay reduction and improved travel reliability.

Benefits from the incident management program could be derived mainly from crash cost savings. Vehicle operating cost (VOC) savings for road widening, ramp metering, and incident management are negative because of the expected increase in speed after improvement, which causes increased fuel and oil consumption. Researchers found a benefit-cost ratio of 12.3:1 (Choocharukul, 2002).

Michigan Plans and Policy

MDOT has a Traffic Incident Management (TIM) Unit in the Operations Division of the Bureau of Highway Delivery. MDOT is continuing to enhance traffic incident management in the state. It provides safety training workshops to first responders, develops partnerships among agencies, and maintains the MI Drive website that disseminates information pertaining to roadway incidents to the public.

For More Information

MDOT Traffic Incident Management Unit

References

Cambridge Systematics, *Traffic Congestion and Reliability Trends and Advanced Strategies for Congestion Mitigation*, September 1, 2005.

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Information/Routing and Interagency Cooperation

Supply/System Management ▶ Traffic Operations ▶ Incident Management ▶ Information/Routing and Interagency Cooperation

Introduction

Traffic Incident Management (TIM) is a planned and coordinated program process to detect, respond to, and remove traffic incidents and restore traffic capacity as safely and quickly as possible. Larger-scale incidents may involve agencies from multiple jurisdictions; and incidents of national significance, managed in accordance with the National Incident Management System (NIMS), involve a host of federal, local, and state response agencies. The responsibilities of the multiple jurisdictions and agencies involved have the potential to overlap. Agencies must manage resources effectively, including technology, to maximize the effectiveness and safety of incident management efforts (FHWA, 2010).

Cost:	●●○○○
Time:	Short
Impact:	Regional
Project Life:	10 years
Sponsors:	City/State

The process involves a number of organizations, including:

- Law Enforcement.
- Fire and Rescue.
- Emergency Medical Services.
- Transportation.
- Public Safety Communications.
- Emergency Management.
- Towing and Recovery.
- Hazardous Materials Contractors.
- Traffic Information Media.

Once a coordinated TIM program is in place, effective interoperable interagency communications and information exchange are vital. The different responding agencies need access to important pieces of information that other agencies know or collect to better manage and improve on-scene operations. The term “interoperable” refers to “the ability of two or more systems or components to exchange information and to use the information that has been exchanged." It is not enough for TIM response partner agencies to be able to send and receive data or information; they must develop common terminology, definitions, and usage to facilitate understanding (FHWA, 2010).

The FHWA graphic below shows the different types of information that different responding agencies may require as they play their role in traffic incident response.

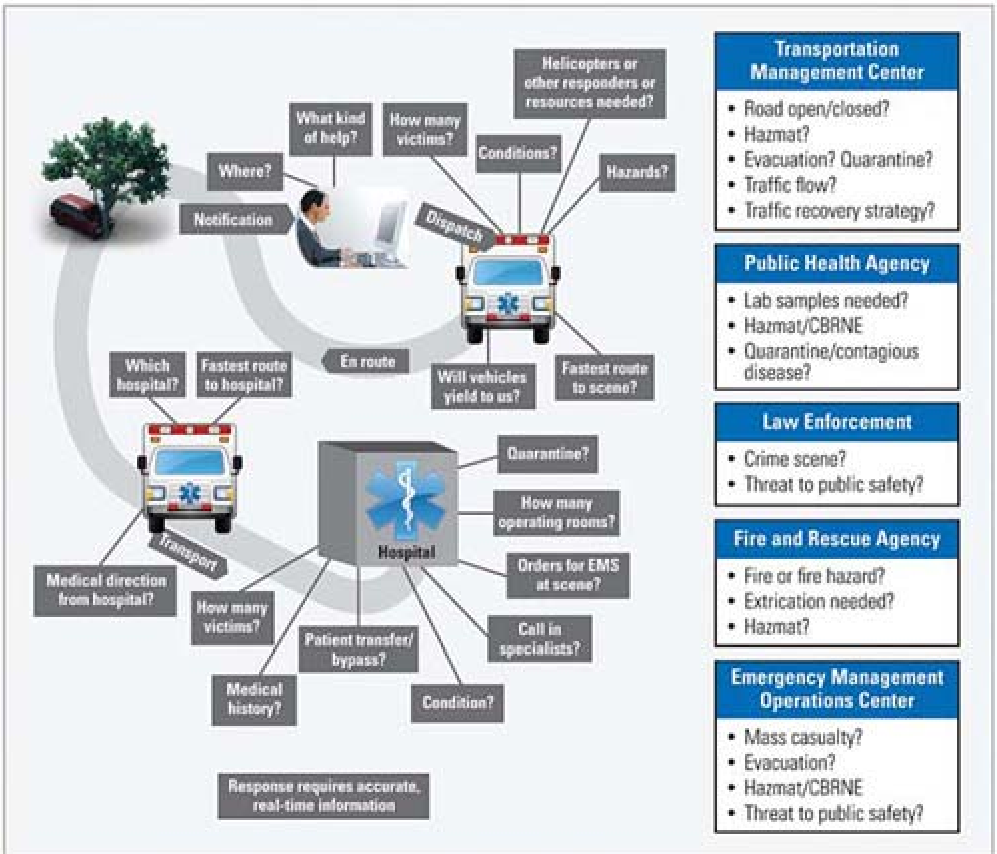

Figure 13. Example of Information Flows in Incident Management
(FHWA, 2011)

Techniques

To ensure success of a multi-agency regional or statewide TIM program, adoption of agency coordination plans prior to the incident is needed. This institutional coordination, best performed at executive level, provides the policy and program tools needed to assure that partner agencies will work closely together at all levels of the program and will coordinate and assist each other in the budgeting process to provide resources each agency needs to be full, active partners in the program (FHWA, 2010).

Data

Data requirements to develop interagency cooperation agreements are minimal. Knowledge of agency processes and equipment capabilities is important to determine the extent of any required changes to enhance interoperability and information sharing.

Application Principles

The FHWA *2010 Traffic Incident Management Handbook Update* provides several examples of best practices and case studies in establishing successful interagency cooperation and information sharing techniques and processes in TIM programs.

Costs

Costs to adopt interagency cooperation are minimal as the effort is focused on discussion and negotiation between agency executives. The cost of changes to agency processes required by subsequent interagency agreements could be significant if new equipment or modifications to existing equipment (i.e., communication devices, software) are needed.

Information dissemination processes may require software upgrades and equipment changes or improvements. These costs could be significant depending on the size of the responding agency and the equipment needed.

Benefits and Impacts

The primary benefits of information routing and interagency cooperation in TIM programs are delay reduction and improved travel reliability.

Michigan Plans and Policy

MDOT has a Traffic Incident Management Unit. MDOT is continuing to enhance traffic incident management in the state. It provides safety training workshops to first responders, develops partnerships among agencies, and maintains the MI Drive website that disseminates information pertaining to roadway incidents to the public.

For More Information

MDOT Traffic Incident Management Unit

References

FHWA, *2010 Traffic Incident Management Handbook Update.*

Service/Courtesy Patrols

Supply/System Management ▶ Traffic Operations ▶ Incident Management ▶ Service/Courtesy Patrols

Introduction

Service patrol programs generally consist of trained personnel who use specially equipped vehicles to systematically patrol congested highways searching for and responding to traffic incidents. These programs operate under a variety of names: freeway service patrol, motorist assistance program, and courtesy patrol. State and local sponsoring agencies are using service patrols as a strategy to reduce traffic congestion, improve travel time reliability, and improve highway safety (FHWA, 2008). Service patrols and CCTV cameras allow for quicker identification of and response to incidents, a major source of non-recurring congestion (Cambridge Systematics, 2005).

Cost:	●●○○○
Time:	Short
Impact:	Corridor
Project Life:	10 years
Sponsors:	State

Service patrols are often part of a larger state and/or regional Traffic Incident Management program.

Techniques

Service patrols typically render assistance to motorists when needed and can push vehicles off the road, provide gasoline, and change flat tires or provide minor repairs to help motorists safely drive the vehicle from the highway. More robust programs provide additional functions such as clearance and recovery services, emergency management, and assistance with emergency services (FHWA, 2008).

Data

The most common measures for freeway service patrols are:

- Number (or frequency) of incidents.
- Detection time.

- Response time.
- Clearance time.

Application Principles

Freeway service patrols remain one of the more cost-effective congestion mitigation strategies. Almost all metropolitan regions with a traffic incident management program have some form and level of service patrol. For further information on application of the strategy, planners should consult the FHWA *Service Patrol Handbook*, available on the FHWA website.

Costs

Annual operating budgets for service patrol programs can range from $275,000 for District 5 in Pennsylvania to $19 million covering several urban areas in Florida. Funding can affect service areas, hours of operation, training, local and state staffing, and equipment (FHWA, 2008).

Benefits and Impacts

Some of the congestion mitigation benefits of service patrols include:

- Reduced incident duration (because of decreased detection, response, and clearance times).
- Quicker debris removal.
- Traffic control and management.
- Ability of service patrol operators to provide real-time updates on traffic conditions that enable more accurate traveler information about freeway conditions.
- Improved traffic flow as a result of reduced incident duration and better traffic control.
- Reduced travel time, fuel costs, and vehicle emissions.
- Improved travel time reliability.
- Reduced number of lanes closed for an incident.

Research conducted in 1998 indicated benefit-cost ratios for metropolitan freeway courtesy patrol programs. The table of ratios by metropolitan region is presented below.

Table 18. Benefit-Cost Ratios for Service Patrol Programs

Location	Patrol Name	Year Performed	B/C Ratings
Charlotte, NC	Incident Management Assistance Patrol	1993	3:1 to 7:1
Chicago, IL	Emergency Traffic Patrol	1990	17:1
Dallas, TX	Courtesy Patrol	1995	3.3:1 to 36.2:1
Denver, CA	Mile High Courtesy Patrol	1996	20:1 to 23:1
Detroit, MI	Freeway Courtesy Patrol	1995	14:1
Fresno, CA	Freeway Service Patrol	1995	12.5:1
Houston, TX	Motorist Assistance Program	1994	6.6:1 to 23.3:1
Los Angeles, CA	Metro Freeway Service Patrol	1993	11.1
Minneapolis, MN	Highway Helper	1995	5:1
New York & Westchester County, NY	Highway Emergency Local Patrol	1995	23.5:1
Norfolk, VA	Safety Service Patrol	1995	2:1 to 2.5:1
Oakland, CA	Freeway Service Patrol	1991	3.5:1
Orange County, CA	Freeway Service Patrol	1995	3:1
Riverside County, CA	Freeway Service Patrol	1995	3:1
Sacramento, CA	Freeway Service Patrol	1995	5.5:1

The benefit-cost ratios range from 2:1 to 36.2:1 (Fenno, 1998). A cost-benefit analysis by SEMCOG of MDOT's Freeway Courtesy Patrol in 2008 indicated that for every dollar spent on the program, a $15.20 benefit was realized, 15.2:1, in line with 14:1 ratio for Detroit in the earlier 1990s study (SEMCOG, 2008).

Michigan Plans and Policy

MDOT's Freeway Courtesy Patrol was established in 1994 to assist stranded and distressed drivers in Southeast Michigan. The Courtesy Patrol provides assistance to motorists by reducing potential crash situations, relieving traffic congestion, and helping to create safer driving environments. MDOT provides a map of the program service area on their website.

Figure 14. MDOT Freeway Courtesy Patrol Coverage Area
(SEMCOG, 2008)

Currently, the Courtesy van fleet includes 24 vans and employs 24 drivers. In 2008, the Courtesy Patrol saved an estimated 11.5 million hours of delay on freeways in the coverage area. Based on the hours of delay, there were also significant reductions in air pollution.

For More Information

MDOT Courtesy Patrol

References

Cambridge Systematics, *Traffic Congestion and Reliability Trends and Advanced Strategies for Congestion Mitigation*, September 1, 2005.

Fenno, David W. and Michael A. Ogden, *Freeway Services Patrols: A State of the Practice*, paper presented at the 77th Annual Transportation Research Board Meeting, Washington, D.C., January 1998.

FHWA, *Service Patrol Handbook*, July 2008.

SEMCOG, *MDOT Freeway Courtesy Patrol in Southeast Michigan: FY 2008 Evaluation Report*.

Special Event Management

Supply/System Management ▶ Traffic Operations ▶ Special Event Management

Introduction

Planned special events (PSE), such as sporting events and concerts, produce nonrecurring congestion as attendees simultaneously attempt to enter and exit the event, overloading the local transportation network. These types of events can have a significant impact on traffic operations, particularly in areas where limited infrastructure is available to access and egress the venue. PSE congestion is not limited to large urban or metropolitan areas and that congestion in rural and small urban areas can be as severe as that in urban areas.

Cost:	●●●○○
Time:	Short
Impact:	Spot
Project Life:	5 years
Sponsors:	City

Techniques

The Federal Highway Administration (FHWA) *Managing Travel for Planned Special Events* handbook states that several key criteria need to be considered when planning for PSE traffic management:

- Existence of limited road capacity to access the event venue and potentially limited parking capacity at the venue.
- Existence of fewer alternate routes to accommodate event and background traffic.
- Existence of limited or no permanent infrastructure for monitoring and managing traffic.
- Generation of trips from a multicounty region.

FHWA has promoted a number of strategies aimed at reducing highway and PSE congestion. These have focused on traveler information and improved coordination between agencies. The focus of these efforts has been improved coordination resulting in faster response times in addressing evolving conditions and improved traveler information that allows the traveler to make more informed travel decisions. Specific PSE strategies (in and around the affected area) include:

- Utilize mobile devices – portable traffic management systems (closed-circuit television, detectors, changeable message signs), portable traffic signals, portable traffic management centers.
- Utilize automated systems- parking management systems, dynamic trailblazer wayfinding signs, lane control signs, blank-out signs.
- Signal retiming.
- Upgrade traffic signal controllers.
- Manual traffic controls.
- Road closures.
- Real-time traveler information.
- Improved ITS technology – CCTVs, digital communication
- Installation of an adaptive traffic control system.
- Interagency event coordination – stakeholder meetings are held before and after a game to plan and refine strategies.

The FHWA Manual provides several organizational actions that will help ensure effective PSE management:

- Achieve early, constant input and participation of involved agencies.
- Predict event-generated travel impacts on both a local and regional level.
- Develop an integrated transportation management plan that can accommodate a range of traffic demands and other contingencies.
- Ensure successful traffic management plan implementation.
- Deploy a well-organized traffic management team equipped with the ability to communicate seamlessly between agencies.
- Conduct continuous traffic monitoring on the day-of-event and maintain protocol for modifying the traffic management plan to accommodate real-time traffic conditions.
- Transfer event management successes into daily applications, and translate lessons learned into future event planning and operations needs (FHWA, 2003).

Data

The data needed to successfully develop PSE programs include:

- Local traffic data.
- Historical traffic data from permanent count stations and associated regional special events.
- Review of available signal technologies.

Application Principles

In practice, PSE planning and implementation in Montana and Florida found several low-cost strategies able to yield tangible benefits, namely signal retiming, manual traffic control, and road closures. These strategies were straightforward to implement and made a significant difference compared with previous events. They were not exceptionally labor intensive (with the exception of manual control), but produced improvements and/or prevented further deterioration in operations from occurring. It has been noted that crucial to the successful application of the PSE strategies is interagency partnerships. Such partnerships allow agencies to identify the equipment and personnel, among other factors, that can be leveraged to manage a particular PSE (CUTR, 2008). This requires:

- Need for stakeholders to assume new or expanded roles.
- Need to work closely with all affected stakeholders to gain their help in identifying concerns and introduce them to mitigation measures that they may be unfamiliar with.
- Need to work closely with involved stakeholders so that a trust relationship is established in order to increase effectiveness of coordination between different levels of agency and government (Lassacher, 2009).

Agencies have concluded that flexibility is the key to managing PSE traffic. For recurring events, overall management should be viewed as a work in progress, with modifications made as needed to the strategies used. In the context of a PSE, plans and strategies will need to be continually reviewed and addressed before and throughout its duration, as well as yearly. This includes meetings with stakeholders to review past successes and challenges (and to present data analysis results, as available). A pre-event stakeholder meeting is also necessary to discuss needed improvements, areas of concern, and any ongoing or planned construction and improvement projects that may affect the PSE roadway network (FHWA, 2003).

Costs

PSE programs are relatively low cost, but costs can rise and lower relative to the scale of the special event. A stadium concert with 100,000 attendees will require a larger response than a high school football game. Programs costs include updated traffic signal equipment, manual traffic control, and public information campaigns.

Benefits and Impacts

PSE programs can have a positive impact on a road network. Some of these benefits include:

- Improved traffic flow.
- Delay reduction.
- Increased safety.

Michigan Plans and Policy

SEMCOG has a current regional transportation operations goal of improving performance for special event planning in their metropolitan region.

For More Information

MDOT Bureau of Highway Delivery

References

FHWA, *Managing Travel for Planned Special Events*, September 2003.

Lassacher, Suzanne, et al., *Traffic Management of Special Events in Small Communities,* TRR 2099, 2009.

Signal Technology Applications to Address Traffic Congestion on US 301 in Starke, Florida, Final Report, USF-UCITSS-II, Center for Urban Transportation Research (CUTR), University of South Florida, October 31, 2008.

Road Weather Management

Supply/System Management ▶ Traffic Operations ▶ Road Weather Management

Introduction

Road Weather Management congestion mitigation strategies are deployed as components of a state and regional ITS. Effectiveness of programs is increased with technological applications disseminating information regarding adverse weather, road conditions, and agency resources. A significant portion of road weather management strategies pertain to winter maintenance and DOT asset management. For purposes of this guidebook, focus is maintained on mobility effects of adverse weather.

Cost:	●●○○○
Time:	Moderate
Impact:	Regional
Project Life:	10 years
Sponsors:	State

Weather impacts roadway mobility by increasing travel time delay, reducing traffic volumes and speeds, increasing speed variance, and decreasing roadway capacity. Capacity reductions can be caused by lane submersion due to flooding and by lane obstruction due to snow accumulation and wind-blown debris. Road closures and access restrictions due to hazardous conditions also decrease roadway capacity. Weather events can reduce arterial mobility and reduce the effectiveness of traffic signal timing plans. FHWA research estimates that 23 percent of the non-recurrent delay on highways across the nation is due to snow, ice, and fog. Rain leads to even greater delay. The following chart from FHWA illustrates these effects (FHWA, 2011).

Table 19. Freeway Traffic Flow Reductions due to Weather

Weather Conditions	Freeway Traffic Flow Reductions (%)			
	Average Speed	Free-Flow Speed	Volume	Capacity
Light Rain/Snow	3–13	2–13	5–10	4–11
Heavy Rain	3–16	6–17	14	10–30
Heavy Snow	5–40	5–64	30–44	12–27
Low Visibility	10–12			12

Three types of road weather management strategies may be employed in response to various weather threats including fog, high winds, snow, rain, ice, flooding, tornadoes, hurricanes, and avalanches:

- Advisory Strategies provide information on prevailing and predicted conditions to both transportation managers and motorists.
- Control Strategies alter the state of roadway devices to permit or restrict traffic flow and regulate roadway capacity.
- Treatment Strategies supply resources to roadways to minimize or eliminate weather impacts. Many treatment strategies involve coordination of traffic, maintenance, and emergency management agencies (FHWA, 2010).

Techniques

Regional ITS applications greatly increase the effectiveness of any road weather mitigation strategy. By integrating environmental data with transportation data, transportation managers can assess the weather impacts on roadways to support operational decisions. By using timely, accurate, route-specific environmental data in decision-making processes, managers can effectively counter weather-related congestion and delay, reduce weather-related crashes, and disseminate relevant information to travelers. Some Traffic Management Centers (TMCs) utilize Advanced Traffic Management Systems (ATMS) that integrate environmental data with traffic monitoring and control software. Traffic managers may access road weather data to make decisions about traffic control and motorists warnings including:

- Advanced traffic signal control systems can be used to modify traffic signal timing based upon pavement conditions. Weather-related signal timing plans modify cycle lengths, splits, and offsets to accommodate changes in driver behavior and decrease arterial delay.

- Reduce speed limits with Variable Speed Limit (VSL) signs and Dynamic Message Signs (DMS).
- Restrict access to affected bridges, specific lanes, entire road segments, or designated vehicle types (e.g., high-profile vehicles).
- Lane use control signs, flashing beacons, Highway Advisory Radio (HAR), and DMS are typically employed to alert motorists of weather-related hazards and access restrictions.

Treatment strategies supply resources to roads to minimize or eliminate weather impacts. The most common treatment strategies are application of sand, salt, and anti-icing chemicals to pavements to improve traction and prevent ice bonding. Maintenance vehicles are equipped with plow blades, chemical storage tanks, spray nozzles, and material spreaders to clear roads of snow and ice (FHWA, 2011).

Data

There are three main types of road weather information:

- Atmospheric data.
- Pavement data.
- Water level data.

Atmospheric data include air temperature and humidity, visibility distance, wind speed and direction, precipitation type and rate, cloud cover, tornado or waterspout occurrence, lightning, storm cell location and track, as well as air quality. Pavement data include pavement temperature, pavement freezing point, pavement condition (e.g., wet, icy, flooded), pavement chemical concentration, and subsurface conditions (e.g., soil temperature). Water level data include stream, river, and lake levels near roads, as well as tide levels (i.e., hurricane storm surge) (FHWA, 2011).

Application Principles

FHWA maintains a Road Management Program website that offers several reports highlighting best practices from areas throughout the nation who have utilized these strategies. The web address is provided in the references below.

Costs

The goal of road weather management programs is a more efficient and effective deployment of local, regional, and state resources in the face of adverse weather. State DOTs are already aware of the potential weather effects on their system and have resources already in place. Management programs create cost-savings in improved efficiencies in weather information dissemination and agency response.

To establish a road weather program is a moderate cost to a department. Purchase of technology and equipment, along with linking them into an ITS structure, are the greatest expense.

Benefits and Impacts

The mobility benefits of road weather management strategies include:

- Improved safety due to reduced crash risk.
- Increased mobility due to restored capacity, delay reductions, and more uniform traffic flow.

Michigan Plans and Policy

All four TMAs with Congestion Management Processes in place acknowledge in their plans the potential of adverse weather affecting their transportation network. TCRPC in Lansing has made improved road weather management a priority component of their ITS.

MDOT has deployed a Road Weather Information System in the Superior and North Regions. Using federal grant funding, MDOT is installing a system to monitor atmospheric and road surface conditions in an effort to better manage winter maintenance activities and to provide more travel information to motorists. The system consists of a network of Environmental Sensor Stations (ESS). The stations combine several types of sensors to measure air and road surface temperatures, barometric pressure, wind, salt concentrations on the road surface, frost depth and dew point, as well as cameras to verify conditions at the site. Using the data collected from the 25 existing stations installed from 2008 to 2010, MDOT and the contract county road commissions providing maintenance services are able to better predict when ice will begin to form on the roadway or bridge decks, or see when snow is blowing and drifting across the road, improving efficiency in those operations.

References

FHWA Road Weather Management website, http://ops.fhwa.dot.gov/weather/index.asp, accessed June 2011.

MDOT Road Weather Information System.

Transit

Supply/System Management ▶ Transit

Public transit is ideally suited to increase capacity and improve passenger flow in congested transportation corridors. In addition to improving mobility in general and in addressing recurring congestion, transit service (and ITS transit technologies and strategies, which improve transit service) is effective in addressing nonrecurring congestion caused by incidents, work zones, and planned special events. However, transit capacity in corridors is often underutilized because transit service is not flexible and convenient enough to accommodate the needs of all customers.

There are two primary means of improving transit operations. First, system/service expansion projects attempt to increase ridership by providing new rail system services and/or expanding bus services. For buses, the number of routes can be increased, higher service frequencies can be implemented, or routes can be extended to reflect new development. Express bus services can be an alternative to single occupancy vehicles (SOVs) by providing faster routes between suburban communities and downtown areas.

For rail transit, there are four major types of transit services:

- Heavy rail rapid transit is characterized by high speeds (more than 70 mph) and high capacity (between 20,000 and 34,000 passengers per hour), and is considered to be most efficient when serving areas with more than 50 million square feet of nonresidential development.
- Light rail transit systems are designed for medium capacity (ranging from 2000 to 20,000 passengers per hour) and less developed urban areas.
- Commuter rail is characterized by high-speed, station-to-station service and is designed to transport people from suburbs to downtown areas.
- Fully automated rail systems circulate within urban areas and allow people easier access to congested facilities such as downtown areas or airports.

The second method of improving transit operations is system/service operational improvements focusing on geographic coverage and scheduling changes that make mass transit a more attractive option to residents and commuters. Improved transfer procedures between transportation modes such as car/transit, pedestrian/transit, and bicycle/transit may encourage increased ridership on public transportation. One such strategy is park-and-ride lots discussed in the next section.

Park-and-Ride Lots

Supply/System Management ▶ Transit ▶ Park-and-Ride Lots

Introduction

Park-and-ride/fringe parking facilitates passenger transfer to transit services, carpooling, and vanpooling. The lots are usually located at key highway interchanges or along heavily traveled corridors remote from the central business district or major activity centers. Their availability promotes the use of transit services and the implementation of rideshare programs.

The parking lots accommodate drivers who wish to use transit or join carpools or vanpools at the lots to complete their trips to the work site. This results in a decreased number of vehicles entering congested areas and, as a result, reduces traffic congestion. State or local transportation agencies may informally designate or formally establish these parking facilities.

Cost:	●●○○○
Time:	Moderate
Impact:	Corridor
Project Life:	30 years
Sponsors:	State

Nearly all major metropolitan areas and many rural areas have implemented some form of park-and-ride program to provide support facilities for transit, congestion relief, or as staging areas for ridesharing. Often, these facilities are developed according to a plan based on predetermined implementation criteria, which provides for a systematic program of investment and implementation, also addressing demand for service.

Techniques

At a minimum transportation planners should consider the following steps in establishing a park-and-ride lot:

- Market study to estimate demand.
- Acquisition of land.
- Coordination with construction of road facility.
- Coordination with local transit agencies.
- Agreements with local merchants or private interests, if needed (EPA, 1999).

Data

- Number of parking spaces.
- Number of SOVs.
- Number of carpools.
- Number of new carpool participants.
- Trip origin and destination of lot users.

Application Principles

EPA has noted key characteristics of good park-and-ride lots. These include:

- Located conveniently near interchanges of HOV lane or major highway – The preferable location is within one quarter mile or adjacent to the roadway entrance ramp. Also, lot locations convenient to transit (rail or bus) are likely to experience greater use.
- Effective market capture area or distance that major park-and-ride facilities attract users is about 5 miles – According to several surveys, most lot users drove 5 to 7 miles, with a trip time of 12–20 minutes maximum.
- Lot locations upstream of congestion and on the side of the morning commute direction.
- Safety – A lot should be visible, well lighted, and preferably, have a telephone nearby. It should also be regularly patrolled by state police if it is a state-owned lot or by a security guard if it is a shared facility.
- Good ingress and egress – Safe and efficient traffic movement is a major concern. Access to the lot should be convenient to both transit and auto.
- Projected demand – Demand for park-and-ride spaces is based on analysis of individual travel corridors. Estimation of demand provides a guideline as to the most effective size for the lot.
- Visibility from roadways – The lot should be visible from freeways and major roadways. Visibility of facilities contributes to the recognition by passing motorists of their availability. Visibility of a lot is also a deterrent to vandalism.
- Signing/marketing – Motorists should be informed of the lots location with directional roadway signs. Marketing is as important as planning and development of facilities. New lots should be promoted, as well as the overall park-and-ride program.

- Accessibility to HOV lanes – Sites located adjacent to HOV lanes, HOV priority ramps, or other priority facilities provide benefits to park-and-ride users. Coordination of the location of park-and-ride sites with HOV facility development can increase the usefulness and efficiency of both facilities.
- Fewer and larger (300 spaces or more) lots are preferable.
- Express bus transit service at the lot may help utilization.

Intelligent Transportation Systems (ITS) strategies such as traveler information systems and electronic payment systems can add to the convenience of park-and-ride lots. Internet availability providing users with the location of lots, transit stations in the vicinity, links to transit provider websites, and the location of telework centers would also benefit users (EPA, 1999).

Costs

The costs of this congestion mitigation strategy are relatively high but not as expensive as HOV facilities. Design and construction of the site and operation and maintenance after it is built are the main investments. Land acquisition costs may be significant, but many lots are built in system highway or transit right-of-way next to transit stations or centers.

Based on 1992 EPA estimates, the 2010 cost of building surface park-and-ride lots is $4,000–4,500 per parking space. This includes paving, drainage, lighting, signage, and striping. It also assumes a four inch pavement section, relatively flat location, and lots that are adjacent to the freeway. Land costs will vary substantially depending upon the location of the lot. At a cost of $500,000 per acre, land costs would add $3,700 per parking space, based on an area of approximately 325 square feet (stall plus driveway area). These figures are an example and local conditions will determine the price per parking spot (EPA, 1992).

Benefits and Impacts

- VMT reduction.
- Increase in carpool/vanpool participation.
- Increase in transit use.
- Trip reduction in employment centers/CBD.

Michigan Plans and Policy

MDOT has maintained an extensive network of carpool parking lots throughout the state since the 1970s. There are 239 lots in the state with 9,816 spaces available. MDOT estimates as of February 2011, a utilization rate of 41 percent. Individual lot information is available by region, county, facility name, and exit number at http://mdotwas1.mdot.state.mi.us/public/carpoolpark/.

For More Information

References

AASHTO, *Guide for Park-and-Ride Facilities, 2nd Edition*, 2004.

MiCommute, accessed June 2011.

USEPA Office of Air and Radiation, *Transportation Control Measure Information Documents*, Washington, D.C., March 1992.

USEPA Office of Air and Radiation, *Benefits Estimates for Selected TCM Programs*, March 1999.

Multimodal Transportation Centers

Supply/System Management ▶ Multimodal Transportation Centers

Introduction

Multimodal transportation centers are places where interface occurs between transportation systems. The centers can be new facilities or an existing railroad passenger terminal which has been or may be modified as necessary to accommodate several modes of transportation, including intercity rail service and some or all of the following: intercity bus, commuter rail, intra-city rail transit and bus transportation, airport limousine service, bicycle and pedestrian facilities, airline ticket offices, rent-a-car facilities, taxicabs, private parking, and other transportation services. The term also implies a high degree of connectivity and interchange between modes improving passenger convenience, reliability, and options for residents, commuters, and visitors. Such a facility, with its potential as a center of activity, may be a catalyst to help link and connect surrounding districts and support new development and employment growth.

Cost:	●●●●○
Time:	Moderate
Impact:	Corridor
Project Life:	20 years
Sponsors:	City

Intermodal facilities can take several forms depending on their location, types of transit services offered and passenger characteristics. In most cases, any specific facility will not fall neatly into one category but rather contain characteristics of two or more types.

- Intercity Terminal.
- Downtown Commuter Transit Center.
- Interchange – An interchange is a specialized intermodal facility that principally serves as a place for passengers to transfer between transit services.
- Park-and-Ride.
- On-Street Transit Facilities/Transit Mall.

Techniques

Large-scale multimodal transportation centers require close coordination between several different layers and types of governmental agencies, along with private transportation providers. A major multimodal transportation hub can require several years to plan, approve, design, and construct. Many steps are required pertaining to feasibility studies, market studies, environmental analyses, transportation planning and conformity, negotiated agreements between public and private interests, community involvement, right-of-way acquisition, and securing funding. Several of these steps have required actions mandated by federal and state law.

Data

- Vehicle trips in area adjacent to center before and after implementation.
- Transit use in area adjacent to center before and after implementation.
- Bicycle and pedestrian mode use in area adjacent to center before and after implementation.
- Traffic volumes on arterials in area adjacent to center (SMWM/Arup, 2004).

Application Principles

Multimodal transportation center design should include a clearly defined waiting area for transit riders, be open to the public at large and equipped with amenities for bicyclists and pedestrians including adequate lighting, benches, weather protection, system information, maps, trash bins, bicycle parking, and a land pad accessible to a disabled person. Final plans should contain lifetime maintenance plans for the facility.

The main deterrent to the use of multimodal facilities is the availability of large quantities of free auto parking near transit centers. Continuing to offer this type of parking creates a vicious cycle of increased lot use hence increased demand for parking at staggeringly escalating costs per car space. Enabling many customers to reach the transit station in other ways will free up valuable car parking space for those who truly need it (Williams, 2004).

Costs

Multimodal transportation centers can cost several millions of dollars depending on location, land values, and scale of the center.

Benefits and Impacts

- Increase in transit mode.
- Increase in bicycle and pedestrian modes.
- Increased activity associated with an improved intermodal transportation facility may result in additional traffic on the adjacent roadway network – depending on the access arrangements, parking provision and demand characteristics of the facility, the local network may need to accommodate additional transit and/or private vehicle access.

Michigan Plans and Policy

The Troy/Birmingham Transit Center is currently being developed jointly by the two cities. The transit center will serve as a hub for regional public transportation, using existing Amtrak rail infrastructure along the Wolverine Corridor while providing a transfer point to SMART bus services, taxi and sedan connections consistent with the Detroit Regional Mass Transit Plan. It will also create more transportation opportunities for patrons of the Oakland/Troy Airport. The projected total cost of the project is $9.9 million (City of Troy, 2011). The City of Lansing has an intermodal transportation center in its downtown with local and regional bus service.

References

SMWM/Arup and Associated Consultants, Sacramento Intermodal Transportation Facility: Final Conceptual Transit and Joint Development Programs, September 2004.

Williams, Kristine and Seggerman, Karen, Model Regulations and Plan Amendments For Multimodal Transportation Districts, National Center for Transit Research, University of South Florida, March 2004.

City of Troy, Michigan website, http://troymi.gov/TransitCenter/BusGrant.pdf, accessed April 2011.

Freight Rail Improvements

Supply/System Management ► Freight Rail Improvements

Introduction

Many improvements to freight rail movement include the development of intermodal transportation centers. This involves the consolidation of train-truck interactions with ground freight transport into one large location, thus increasing the efficiency of goods movement in a metropolitan region. These centers have become increasingly important to regional economic development plans over the last two decades. In some cases, these intermodal centers are developed adjacent to major airports with air cargo transport, thus combining three freight modes into one coordinated area.

Cost:	●●●●●
Time:	Long
Impact:	Regional
Project Life:	30 years
Sponsors:	City/State

Another aspect of freight rail improvement is railroad-highway crossing upgrades and safety improvements. These projects can provide congestion mitigation benefits along major arterials in metropolitan regions.

Techniques

Freight rail improvements require close coordination between several different layers and types of governmental agencies, along with private railroad corporations. A major intermodal transportation hub can require a decade or more to plan, approve, design, and construct. Many steps are required pertaining to feasibility studies, environmental analyses, transportation planning and conformity, negotiated agreements between public and private interests, community involvement, right-of-way acquisition, and securing funding. Several of these steps have required actions mandated by federal and state law.

The Railway-Highway Grade Crossings safety program has explicit federal requirements for funding and reporting.

Data

Data requirements for analyzing the congestion mitigation effects focus on before and after implementation. These data may include:

- Average daily traffic at location.
- Average daily truck traffic.
- Average speed.
- Regional truck VMT.
- Average delay at rail crossings (FHWA, 2006).

Application Principles

Intermodal is an attractive option for shipments over 500 miles. The economic and environmental benefits of intermodal ground freight service are maximized over long hauls, where the fuel and cost savings from the rail part of the trip are high enough to recoup the extra fuel and handling costs to transport and transfer trailers and containers between trains and trucks.

Costs

There are substantial public and private costs in the planning, design, construction, and operation of intermodal transportation centers. Costs range from hundreds of millions to billions of dollars, depending on the size and scope of the center. The Detroit Intermodal Freight Terminal (DIFT) project is currently estimated to cost $650 million in public and private funding.

Rail grade crossing improvement costs are smaller and receive federal funding.

Benefits and Impacts

- Reduce vehicle-rail conflicts and crashes.
- Improve traffic safety.
- Decrease regional truck VMT.
- Reduce truck traffic on local roads.
- Increase in truck traffic at intermodal center.
- Improve average speeds near previous centers.

Michigan Plans and Policy

Michigan's rail system carries about 18 percent of all the state's commodity movements. These commodities totaled over $278 billion in 2006 (MDOT, 2009).

The DIFT Project has completed its environmental impact analysis and is entering its design phase. The project involves all four class I railroads operating in Michigan—CSX, Norfolk Southern, Canadian National, and Canadian Pacific—and will consolidate their metropolitan freight hubs into an intermodal center in southwest Detroit (MDOT, 2009).

In the latest MDOT five year plan, the department states that it will continue to respond to any economic development activity related to freight movement, while continuing to focus its efforts on safety and preservation. MDOT is expected to invest at least $42.3 million through the Capital Development Program, Freight Economic Development Program, and Local Grade Crossing Program. Projects planned for this five-year timeframe include the repair of two state-owned rail bridges, as well as freight-related economic development projects and safety enhancement projects at local railroad crossings.

For More Information

MDOT Freight Services & Safety

References

FHWA Office of Safety, Guidance on 23 U.S.C. § 130 Annual Reporting Requirements for Railway-Highway Crossings, May 2006.

Michigan Department of Transportation, Detroit Intermodal Freight Terminal: Final Environmental Impact Statement and Final Section 4(f) Evaluation, December 2009.

Bicycle and Pedestrian

Supply/System Management ▶ Bicycle and Pedestrian

Introduction

Bicycling and walking represent viable alternatives to most single occupancy vehicle (SOV) trips. Every trip shifted from an SOV to a bicycle or walking results in a reduction in vehicle trips and VMT. Bicycle and pedestrian programs can be adapted to a community's characteristics (e.g., topography, population, and existing infrastructure) and the budget of the administering agency. Common types of bicycle and pedestrian facilities include the following:

- Routes, lanes, and paths.
- Sidewalks and walkways.
- Plans and maps.
- Racks and other storage facilities.
- Shower facilities and clothing lockers.
- Connections with transit.
- Ordinances for bicycle parking.
- Education, media, and promotions.
- Sidewalk furniture.
- Pedestrian safety modifications.

Cost:	●●○○○
Time:	Moderate
Impact:	Regional
Project Life:	25 years
Sponsors:	City

According to U.S. Environmental Protection Agency (EPA) studies, bicycling and walking can substitute for short trips, 5 miles or less in length for bicycle trips and less than one-half mile for walking trips. The amount of VMT reduced may be small, but the air emissions benefits can be much greater because cold-start and hot-soak emissions comprise a large portion of the total emissions per vehicle trip (Litman, 2009).

Bicycle and pedestrian programs are often packaged with other strategies. The EPA notes that many employers provide bike and pedestrian facilities as part of their employer-based transportation management program. Many public transit improvement plans also support bicycle and pedestrian programs by incorporating elements to improve access to transit facilities. Municipal and regional trip-reduction ordinances can mandate these types of programs. Traffic flow improvements may indirectly support bicycle and pedestrian programs by improving signal intersections and increasing safety for bicyclists and pedestrians (EPA, 1998).

Techniques

Several steps are needed to create a good bicycle/pedestrian program, including:

- Facilitate public participation.
- Determine community vision and objectives.
- Document locations of existing facilities and their use.
- Identify and prioritize locations needing improvement.
- Evaluate alternatives and determine solutions.
- Establish key design procedures.
- Evaluate and revise plans.

Data

- Average annual daily traffic in corridor (vehicles/day).
- Speed-based running exhaust emission factor for participants' trip before participating in the bike/pedestrian program.
- Number of households in strategy area.
- Average number of trips per household in strategy area.
- Length of facility (miles).
- Percentage mode shift from driving to bike/pedestrian (decimal).
- Average auto trip length before implementation (miles).

Application Principles

Five main factors affect the viability of bicycling and walking as alternative transportation:

- Trip distance, defined above as 5 miles or less for bicycles and less than one-half mile for pedestrians.
- Location of facilities along usable commuting routes.
- Overall network connectivity.
- Safety, both along the path or lane and at the destination site.
- Weather conditions, since inclement weather is not conducive to either mode (Pedestrian and Bicycle Information Center, 2011).

The EPA reports that the following local factors help to ensure a successful program:

- Short travel distances between residential areas and key trip attractions.
- High concentrations of people under age 40.
- Compatible infrastructure that can be modified into appropriate facilities.
- Areas with localized congestion or crowded parking facilities.
- Marketing and education efforts including maps and plans, safety training, promotions, and media events.

Factors that negatively affect bicycle and pedestrian programs are:

- Missing links in the network of lanes and trails.
- Lack of safe routes to work destinations.
- Conflicts with traffic laws that give preference to autos.
- Lack of facilities to accommodate activities (EPA, 1998).

Costs

A metropolitan region-wide bicycle lane project can range from $150,000 to $300,000 per mile over the lifetime of the project (Litman, 2009). Costs for developing, maintaining, and operating a bicycle or pedestrian program may include the following:

- Salary and benefits for a program coordinator and staff.
- Land acquisition.
- Bike lane construction.
- Bike path construction.
- Bicycle lockers and racks.
- Publications.
- Signage striping.
- Maintenance.
- Enforcement.
- Educational materials.

Except for equipment, direct cost to travelers is minimal.

Benefits and Impacts

Bicycle/pedestrian projects can lead to a reduction in vehicle trips, but the benefit is comparatively small and is a long-term strategy for a region. Most programs should have a conservative assumption of less than 1 percent reduction in vehicle trips in a region over the project lifetime (Douma, 2008).

EPA has estimated costs per ton of pollutant removed through the Congestion Mitigation and Air Quality (CMAQ) program as ranging from $551,000 per ton to $7.5 million per ton. Although provided in the context of air pollution reduction, the figures provide a basis for comparison to other project types for cost per trip removed (FHWA, 2008).

Another example is the Kansas City's recently proposed 101-mile bicycle lane program computed a benefit-cost ratio of 11.73 for the entire program along with a 0.4 percent reduction in vehicle trips over 20 years. Analysts estimated a $10,473 annual benefit for congestion reduction for both bicycle and pedestrian modes (Mid-America Regional Council, 2009).

Michigan Plans and Policy

Administered by the MDOT, Section 10k of Act 51 of 1951, as amended, (Michigan's transportation law (MCLA 247.660k)) reserves 1 percent of state transportation funds for non-motorized transportation. These funds can be used for on-road facilities such as paved road shoulders and bicycle lanes or off-road facilities such as shared use trails and sidewalks. However, many of the improvements on a road, street, or highway, which facilitates non-motorized transportation, can be considered qualified non-motorized expenditures for the purposes of this section.

MDOT maintains the MiCommute.com website providing information about bicycle and pedestrian programs and opportunities throughout the state.

For More Information

MDOT Bicycle and Pedestrian Coordinator

References

Douma, Frank and Cleaveland, Fay, The Impact of Bicycling Facilities on Commute Mode Share: Final Report, Hubert H. Humphrey Institute of Public Affairs, University of Minnesota, August 2008.

Litman, Todd, et al., Pedestrian and Bicycle Planning Guide to Best Practices, Victoria Transport Policy Institute, April 2009.

Mid-America Regional Council, Kansas City Regional Tiger Application, Appendix D: KC Bicycle/Pedestrian Project, September 2009.

Pedestrian and Bicycle Information Center, bicyclinginfo.org, accessed May 2011.

SAFETEA-LU 1808: Congestion Mitigation and Air Quality Improvement Program: Evaluation and Assessment - Phase 1 Final Report, FHWA, October 2008.

USEPA Office of Mobile Sources TRAQ Technical Overview, Transportation Control Measures: Bicycle and Pedestrian Programs, July 1998.

Reducing Construction/Maintenance Interference

Supply/System Management ▶ Reducing Construction/Maintenance Interference

Introduction

Reducing interference in road construction and maintenance work zones requires a transportation management plan (TMP) that lays out a set of coordinated transportation management strategies and describes how they will be used to manage the work zone impacts of a road project. The scope, content, and level of detail of a TMP may vary based on the state or local transportation agency's work zone policy and the anticipated work zone impacts of the project.

Cost:	●●○○○
Time:	Short
Impact:	Spot
Project Life:	10 years
Sponsors:	State

Techniques

There are three major components to a TMP:

- Temporary Traffic Control Plan (TTCP) – A TTCP is a common component for all projects and will contain information (plan sheets, details, special provisions, etc.) on how facility traffic will be maintained. This plan includes the specific traffic control devices, temporary pavement markings, and other such information that will assist travelers in traversing the work zone in a safe and efficient manner.
- Transportation Operations Plan (TOP) – The TOP contains strategies to address the operations and management of local transportation systems affected by the project. Such strategies will include items such as work zone intelligent transportation system (ITS) components, law enforcement, and incident management.
- Public Information Plan (PIP) – The PIP describes how project information will be communicated to affected parties, traveling public, and project stakeholders both prior to and during construction operations. The plan also describes the most efficient method of communicating this information via local media, business groups, message signs, and other such strategies (FHWA, 2005).

Data

In the State of Michigan, all potentially significant construction or maintenance projects are evaluate for possible mobility impacts to the transportation system by being reviewed against the thresholds for the following critical evaluation criteria:

- Volume to Capacity: Threshold – greater than 0.80.
- Travel Time: Threshold – greater than 10 minutes.
- Level of Service (LOS): Threshold – lower than or equal to LOS D or, LOS C if the current operation is LOS A.

Projects exceeding any one of the three evaluation criteria thresholds are considered significant and must have a project specific TMP developed and implemented. Mitigation measures to minimize travel delay are to be designed into the project (MDOT, 2010).

Application Principles

FHWA provides some “key tips” for developing an effective TMP. These include:

- Involve all of the relevant stakeholders early in the process (e.g., operations, construction, planning, design, safety, maintenance, public affairs, technical specialists, FHWA, local transportation agencies, enforcement agencies, utility providers, emergency services, local businesses, community groups).
- Consider potential transportation management strategies and their costs early in planning and programming.
- Consider and develop management strategies for impacts beyond the physical location of the work zone itself, for example, on adjacent roadways and on local communities and businesses.
- Avoid limiting the number and/or type of transportation management strategies that may be considered.
- Balance constructability and construction staging requirements with the work zone management strategies.
- Estimate and budget for the development and implementation of the TMP early in the project development process, and update as appropriate throughout the project. Cost is often a constraint for the development of a TMP, particularly for major TMPs.
- Update the TMP, as needed, throughout project development and implementation. The TMP is a ‘dynamic document’ that must be maintained and revised with changes made by the project team.

- Monitor field conditions and use project logs during construction to identify potential safety and mobility concerns within the work zone and on adjacent roadways, and revise the TMP as necessary.
- Evaluate the effectiveness of TMPs after a project is constructed, and use lessons learned to improve TMPs for future projects (FHWA, 2005).

Costs

Work zone traffic management can account for up to 25 percent or more of project costs and can significantly impact the safety and mobility of workers and road users (MDOT, 2010).

Benefits and Impacts

Reducing interference in road construction or maintenance sites and zones mitigates congestion on major roadways by reducing delay and expediting work on the roadways.

Michigan Plans and Policy

The State of Michigan has adopted a Work Zone Safety and Mobility Policy and has created a corresponding manual to improve safety and mobility in work zones by reducing congestion and traffic incidents. The policy supports and is in accordance with federal regulation 23 CFR 630, Subpart J, referred to as the Work Zone Safety and Mobility Rule, The policy is in agreement with and does not supersede State Transportation Commission Policy 10015, dated September 25, 1996. The process defined in the policy and the manual applies to all state trunklines, regardless of the type of roadway or bridge facility (MDOT, 2010).

For More Information

MDOT Bureau of Highway Delivery

References

FHWA Office of Operations, *Developing and Implementing Transportation Management Plans for Work Zones*, December 2005.

MDOT, *Work Zone Safety and Mobility Manual*, January 2010.

Demand Management

The primary purpose of Travel Demand Management (TDM) is to reduce or spread the number of vehicles using the road system while providing a wide variety of mobility options to those who wish to travel. To accomplish these changes, TDM programs rely on incentives or disincentives to make these shifts in behavior attractive. In terms of congestion mitigation, reductions in the number of vehicle trips reduce vehicle miles traveled (VMT), which in turn reduces congestion.

TDM encompasses both alternatives to driving alone and the techniques or supporting strategies that encourage the use of these modes. The application of such TDM alternatives and the implementation of supporting strategies can occur at different governmental levels under the direction of a variety of groups. The level of impact varies among the strategies. Many are regional in nature, affecting all citizens, while others are smaller scale at the local and/or corridor level.

Demand management strategies in the toolbox include:

- Work Schedule Changes.
- Land Use Development.
- Ridesharing/Vanpools.
- Parking Management.
- Diversified Development Patterns.
- Smart Growth.
- Car Sharing.
- Trip Reduction Ordinances.

Work Schedule Changes

Demand Management ▶ Work Schedule Changes

Introduction

There are three main types of changes to work schedules:

- *Telecommuting* is work done on a regular basis from daily to once a week at an alternative work site such as the employee's home or a telecommuting center. A center is a facility that provides the employer, employee, and customers with all requirements to perform work and services without traveling to the employee's main work site and may be operated by a single or consortium of businesses.
- *Flextime* allows employees to set arrival and/or departure times with the approval of the employer in order to avoid traveling at peak traffic times, but all employees are present for some core period of the workday.
- *Compressed work weeks* are work scheduling programs that condense a standard number of work hours into fewer than five days per week or fewer than 10 days per two-week period. For example, four days at 10 hours per day or 80 hours over nine days.

Cost:	●●○○○
Time:	Short
Impact:	Regional
Project Life:	5 years
Sponsors:	City

The programs may be voluntary, mandatory, or used by employers to satisfy trip-reduction ordinances or air quality regulations (EPA, 1992).

Techniques

Although work schedule changes are relatively easy to administer, they require careful planning and coordination to be successful. Transportation planners need to be aware of employer issues with implementing work schedule changes. Labor hours will be required to plan and implement the changes, increased facility security may be required since some workers will stay later or arrive earlier, and there may be increased utility needs as the facility is used longer in the day. Client relations and intra-department activities within the business or agency accustomed to the previous work hours need to be considered.

Businesses must also ensure that the programs are consistent with union agreements (EPA, 1992).

Data

- Number of participants.
- Average commute distance.
- Number of weekdays utilized.

Application Principles

The EPA Office of Mobile Sources has found that schedule change programs achieve greater success and gain employee approval if employers adopt the changes voluntarily with employee input (CMAQ Report, 2002). The EPA also found that several factors should be considered when attempting to use work schedule changes as a congestion mitigation strategy:

- *Diminished benefits* as the decrease in work trip vehicle miles traveled (VMT) may be mitigated to some extent by increased non work travel for people working compressed work weeks. The potential exists that although employees may benefit from driving on their day off, congestion may not significantly improve overall. However, more trips are likely to be taken during off-peak congestion hours so that the time distribution of trips is widened and congestion is mitigated in peak hours.
- *Potential reduction in ridesharing and transit use by employees* may occur because of variable work hours. Businesses should coordinate the schedule changes, whenever possible, with transit and ridesharing services. Schedules for these services may need to be modified as a response to new arrival and departure times.
- *Pilot programs are recommended* for three to six months before committing to the changed hours so that the policies can be evaluated in terms of employee morale, productivity, and financial ramifications.
- *Applicability* of variable work hour strategies can be an issue for businesses. Organizations that rely heavily on process manufacturing usually need all workers to be present at the same time to work efficiently. Compressed work weeks may be a more suitable option for manufacturing plants than a flextime or staggered hours policy. Service businesses may be more able to rotate worker schedules and permit flextime policies.

- *Location* of the organization implementing a work schedule change may be a factor influencing success. Flextime policies may be more successful in areas of greater workplace density where associated traffic is highly concentrated around peak periods (EPA, 1992).

In the State of Washington, telework and flexible work schedules have brought a wide range of benefits to Washington employers and their employees. In fact, many employers find that the benefits—such as real estate savings, employee effectiveness, and employee recruitment and retention—far outweigh any set-up or administrative costs and feel that it gives them a competitive advantage over businesses without such work options (Cambridge Systematics, 2002).

Costs

Alternative work schedule strategies are virtually costless to implement. For telecommuting, one analysis tool suggested a cost of $3,000 in one-time costs per employee and $1,000 annually, primarily for equipment and services (equivalent to $150 million one-time and $50 million annually for 10 percent of a workforce of 500,000). The same analysis also suggests these costs are far outweighed by improved productivity, office space savings, and other benefits (Niles, 2010).

Benefits and Impacts

Reduction in the volume of commute traffic during peak traveling times

References

Cambridge Systematics, Inc., *Effective Practices for Congestion Management: Final Report*, American Association of State Highway and Transportation Officials (AASHTO), November 2008.

The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience -- Special Report 264, Transportation Research Board, National Academy Press, Washington, D.C., 2002.

Niles, J., *JALA International: Home-based Telecommuting Cost-Benefit Analysis* (website, http://www.jalahq.com/), 2010.

USEPA, Transportation Control Measure Information, March 1992.

Land Use Development

Demand Management ▶ Land Use Development

Introduction

Over the past decade, there has been a notable shift toward more compact land development, including redevelopment of inner city neighborhoods, new transit oriented development, and neighborhoods designed on "neotraditional" or "new urbanist" principles. This has been especially true in larger metro areas with constrained land supply. There are three main locations or situations that changes in land use development are applicable:

Cost:	●●●○○
Time:	Long
Impact:	Regional
Project Life:	30 years
Sponsors:	City

- New developments on previous vacant or undeveloped sites.
- Redevelopment of existing developed sites or retrofits of existing developments.
- Locations that could capitalize on proximity to a transit station.

Mitigation strategies that effect land use patterns to improve travel efficiency and reduce vehicle travel include:

- Infill.
- Mixed-Use.
- Higher Densities.
- Compact/Walkable Neighborhoods.
- Transit-Oriented Development (TOD).
- Pedestrian Design.
- Parking Management.

A recent FHWA review identified over 80 metropolitan areas that have undertaken some form of regional transportation/land use scenario planning directed at affecting land use development patterns. Most of these efforts were characterized as being in the nascent stages of implementation. Land use patterns are slow to change but may have significant potential in the long-term for affecting travel demand and behavior. In the short-medium term, small-scale retrofit practices, rezonings or comprehensive plan amendments can be done. In the longer term, regional-scale policy changes may take a long time to adopt and result in development changes on the ground and integration with transportation systems (Bartholomew, 2005).

Techniques

The following strategies have been identified to support coordination of transportation and land use on a more widespread basis:

- State and regional agency leadership, funding, and technical assistance for regional planning and visioning efforts.
- Funding and technical assistance for implementation activities (e.g., area or site plan development, code revision, supportive infrastructure).
- Revision of transportation project selection criteria to reward transportation efficient land use policies and support investments consistent with regional land use objectives.
- Roadway and transportation facility planning and design practices to support Context Sensitive Solutions.
- Interagency partnerships and agreements (e.g., coordinated plan development, joint review processes).
- Analysis, education, and outreach regarding the transportation and other benefits of efficient growth patterns (Bartholomew, 2005).

Data

Data requirements for changes in land use for congestion mitigation are similar to any proposed development within a region or municipality. This encompasses development of a regional or city plan, zoning maps, demographic and economic analyses.

Application Principles

Political, economic, and social factors will impact the implementation of these practices. These include:

- The disconnect between local land use decision-making and regional or state level transportation decision-making.
- Reluctance of state and regional transportation agencies to become involved in land use planning.
- The market-driven nature of development decisions, which are often difficult for policy to affect.
- Neighborhood/local opposition to higher-density development.

- Lack of coordination of policies and incentives amongst state agencies (e.g., transportation, housing, economic development, environmental) can lead to such policies working at cross purposes
- Locally optimal land use decisions (considering revenue/fiscal, traffic, and other impacts) are often inconsistent with achieving the most efficient land use patterns from a regional perspective.

Land use incentives have limited potential in the near-term (10 to 20 years) to significantly affect vehicle miles traveled (VMT), but appear to have more significant potential over the long-term (30 to 50 years) (Ewing, 2007).

Costs

Costs can vary widely and are difficult to calculate, as they will be shared by local governments, developers, home buyers, businesses, and customers.

Benefits and Impacts

Land use strategies have been demonstrated to reduce VMT to varying degrees through shorter vehicle trips and by supporting mode-shifting to transit, walk, and bicycle. To some extent, the congestion relief benefits of VMT reduction may be offset by more compact development patterns, which concentrate vehicle travel in smaller areas and can lead to increased localized congestion. The Urban Land Institute found specific benefits and impacts including:

- Modeled or measured impacts of site-specific land use strategies, such as infill/redevelopment, transit-oriented development, and pedestrian-oriented design, have ranged from less than 5 to over 50 percent depending upon the nature of the strategy and the context of its application. Overall, it is estimated that residents of compact development drive approximately 30 percent less than those in traditional development.
- A report that compared various metro areas on sprawl indices versus VMT found a significant range, with 27 daily VMT per capita in the 10 most sprawling areas versus 21 in the 10 least sprawling areas (22 percent lower). Households living in developments with twice the density, diversity of uses, accessible destinations, and interconnected streets when compared to low density sprawl drive about 33 percent less.

- Numerous regional-level modeling studies have been conducted to evaluate alternative land use and transportation scenarios. A review of 23 studies found that compact scenarios averaged 8 percent fewer total miles driven than business-as-usual ones, with a maximum reduction of 32 percent. The lower results are typically over a 20 to 25 year time horizon, and longer-term (50-year) studies have found more significant impacts (Ewing, 2007).

The magnitude of benefits that are achievable depends greatly upon the timeframe of the analysis, due to the long time scales involved in changing development patterns. Benefits are small over a 10- to 15-year time horizon, but increase significantly when viewed over a 30- to 50-year timeframe. Impacts also will vary depending upon the rate of growth (i.e., new development) in a particular region (Ewing, 2007).

Michigan Plans and Policy

In Lansing, the Tri-County Regional Planning Commission developed a regional Smart Growth strategy that saves an estimated $1.8–$5.4 billion in transportation costs by eliminating half the congested lane miles which occur if current trends continue, preserves three townships of agricultural land/open space and reduces pollutants by greater than 10,000 kilograms per day. Strong linkages were established between regional land use and transportation goals, objectives, investment strategies, performance measures and project selection criteria and smart growth, along with auxiliary land use strategies such as access management and traffic impact studies.

The Regional Concept of Management and Operations for congested corridors which is emerging from this approach is being applied to all modes “from building façade to building façade,” is performance based and considers safety, wide nodes, narrow roads, road diets, traffic calming, ITS and more traditional traffic engineering treatments. This resulting Regional Concept of Management and Operations makes system’s operations and management itself another land use strategy for implementing smart growth, which reduces congestion and improves safety for all modes and users throughout the corridor (Hamilton, 2004).

For More Information

MDOT Context Sensitive Solutions Team

References

Bartholomew, Keith, Integrating Land Use Issues into Transportation Planning: Scenario Planning: Summary Report, FHWA, 2005.

Ewing, Reid, et al. Growing Cooler: The Evidence on Urban Development and Climate Change, Urban Land Institute, October 2007.

Hamilton, Paul T., Implementing A Smart Growth Land Use Pattern To Manage Congestion & Safety By Integrating Regional Transportation Futures Alternatives Analysis With A Regional Concept of Management and Operations (RCMO): A Case Study in Performance Based Planning, Tri-County RPC, Lansing, MI, 2004.

Ridesharing/Vanpools

Demand Management ▶ Ridesharing/Vanpools

Introduction

Rideshare and vanpool incentives promote and assist state, regional, and local efforts aimed at encouraging commuters to use alternatives to single occupancy vehicles (SOVs) in traveling to work and encourage employers to provide in-house programs that promote ridesharing, transit, bicycling, and walking among employees. The three main categories of area-wide rideshare incentives include the following:

Cost:	●●○○○
Time:	Short
Impact:	Regional
Project Life:	5 years
Sponsors:	City

- Commute management organizations are third-party ridesharing agencies that provide rideshare matching or alternative commute organization or incentive programs. The programs focus largely on employers, given their influence over employee commute and working patterns. Organization services can include computerized carpool matching, vanpool managing, and providing vanpool vehicles, marketing, and technical assistance to employers.
- Transportation management associations (TMAs) provide a structure for developers, property managers, employers, and public officials to cooperatively promote programs that mitigate traffic congestion, assist commuters, and encourage particular modes of travel in specific areas. TMAs can also provide government and private industry with a forum for discussion of current and future roadway and transit needs in an area. According to the EPA, TMA development activities can be very time consuming, often requiring one to two years before the TMA is fully operational.
- State and local tax incentive and subsidy programs provide incentives and disincentives for employers and employees to consider and utilize alternative modes of transportation to commute instead of SOVs.

Although these programs could potentially be provided to an entire metropolitan workforce, the greatest impacts will be realized in central business districts (CBD) and other activity centers in highly congested areas with good transit service.

Techniques

Programs intended to reduce commuting vehicle travel include:

- Alternative Mode Information.
- Transit Subsidies.
- Ridesharing/Ride Matching Programs and Incentives.
- Vanpools.
- Parking Pricing or Cash-Out.
- Guaranteed Ride Home.
- Worksite Bicycle Facilities.

Many metropolitan areas (through the transit agency, MPO, a TMA, or other entity) have established support services to assist employers with providing benefits and promoting the use of alternative modes. These include systems to automatically distribute monthly transit passes. Reduce-cost transit passes especially provide an incentive for employers to offer this option to their employees.

EPA's Best Workplaces for Commuters (BWC) program and some regional programs have attempted to encourage employers to offer benefits by providing technical assistance as well as rewarding them with recognition.

State and local governments can pass laws requiring that employers over a certain size threshold implement transportation demand management (TDM) programs. This approach has been taken at a state level in Arizona, California, Oregon, and Washington. Municipalities such as Cambridge, Massachusetts, Durham, North Carolina, Montgomery County, Maryland, and Pasadena, California, require TDM commitments as a condition for approval of new development (Cambridge Systematics, 2008).

Data

- Number of program participants.
- Number of vanpools.
- Average commute distance of participants.

Application Principles

The benefits of employer-based TDM have generally been modest although not negligible.

The most effective commuter choice strategies are those that provide financial incentives for alternative modes (e.g., subsidized or free transit passes) or disincentives (e.g., parking charges) for driving. SOV use

typically declines by up to 20 percent at worksites where a transit benefits program is implemented—supporting significant reductions in local, peak-period congestion (ICF, 2006).

Impacts will vary significantly, however, depending upon the availability of travel alternatives for the site or region. Central business districts (CBD) in metro areas with high levels of transit service and significant traffic congestion will see the greatest benefit. Studies suggest that telecommuting and alternative work schedules have small but still measurable effects on VMT (ICF, 2006).

The roles and responsibilities of various public, nonprofit, and for-profit organizations involved in promoting ridesharing and other travel alternatives within a region must be carefully delineated so their various efforts are not perceived as either duplicative or conflicting by employers and individuals.

Cambridge Systematics found a number of factors responsible for the limited implementation of ridesharing programs:

- Fiscal incentives are primarily limited by the cost to employers or public agencies of providing these incentives, as well as lack of quality transit service (and therefore employee interest) in many locations.
- Fiscal disincentives (parking charges) are limited by the expectation that parking will be provided free to employees as a benefit, and by the fact that parking supply is not constrained and therefore a market for parking does not exist in most suburban areas.
- Use of alternative modes is limited by employee desires for flexibility (ridesharing, vanpooling, transit) and/or convenience (bicycling, walking). Employers usually have no particular interest in promoting alternative travel options, especially if they are not perceived as desirable to employees.
- Regional agency leadership is required to conduct outreach to encourage businesses to offer benefits to their employees. Such leadership has been stronger in some areas than others (Cambridge Systematics, 2008).

Costs

Ridesharing and vanpool strategies can have a wide range of costs depending upon the specific strategy implemented. A review of the Congestion Mitigation and Air Quality (CMAQ) program conducted in 2002 identified the following annual costs for sampled CMAQ-funded projects:

- $100,000 to $1.7 million for five regional ridesharing programs.
- $1.7 million for a regional vanpooling project in Houston.
- $170,000 to $3.5 million per year for eight regional TDM outreach/promotion programs.

The costs of some of these strategies (such as trip reduction requirements) are largely borne by the private sector. A region wide program of transit subsidies of $30 per month, reaching 10 percent of the workforce, might incur a public-sector cost on the order of $30 million annually for a metropolitan area with a population of two million. Travelers also will benefit from reduced vehicle operating costs which may not be included in these estimates. Strategies that directly reduce parking requirements result in cost savings for developers and/or tenants (CMAQ Report, 2002).

Benefits and Impacts

The costs and benefits of area-wide rideshare incentive programs are difficult to measure. The EPA has found it difficult to establish causality between area-wide incentives and reduced VMT. Commute management organizations, TMAs, and state and local tax incentives and subsidies are supportive of in-house employer programs, but the agency has concluded that there appears to be no evaluation that has estimated the impact of these programs above and beyond that attributable to the employer programs. The programs do improve the effectiveness of employer-based ridesharing programs, produce results among unaffiliated commuters, and serve to maintain existing levels of shared ride modes. It is a difficult task to separate the impacts of these programs above and beyond those reported for employers or to speculate on the increase in VMT if these programs did not exist (ICF, 2006).

Michigan Plans and Policy

MichiVan, sponsored by MDOT and operated by VPSI Inc., supplies fully insured passenger vans to commuter groups. Under this program 5 to 15 commuters share a van along an established route. Riders must pay a monthly fee while one person volunteers to be the primary driver of the van and rides free. The vanpool program is open to individual members of the public. MDOT also helps employers develop vanpools and ridesharing programs for their employees.

The Guaranteed Ride Home Program (GRH) offers reimbursement for taxi fare or car rental should an emergency or unexpected overtime cause

you to miss your carpool or vanpool ride. Local Rideshare Offices may offer this program to registered carpool and vanpool participants.

References

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The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience -- Special Report 264, Transportation Research Board, National Academy Press, Washington, D.C., 2002.

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TCRP 107: Analyzing the Effectiveness of Commuter Benefits Programs, ICF and Center for Urban Transportation Research, 2006.

Parking Management

Demand Management ▶ Parking Management

Introduction

Parking management efforts attempt to reduce vehicle trips and VMT by providing disincentives to single occupancy vehicle (SOV) travel to an area of a city. Strategies favor carpools and vanpools. Increases in parking costs or decreases in availability encourage use of alternative modes. Congestion mitigation benefits through parking management strategies are derived when travelers choose an alternative method to SOV travel because of preferential parking for that mode or limited parking availability in an area for SOV travel.

Cost:	●●○○○
Time:	Short
Impact:	Corridor
Project Life:	10 years
Sponsors:	City

On the other hand, many cities view parking as an economic development tool that can accelerate development and growth of a downtown area. Most lending institutions also believe an ample parking supply is necessary to ensure return on investment. There is a philosophical approach among many cities across the United States to leverage their parking resources to support economic development. The common goal of these cities is to ensure that the right amount of parking is available to users, that all visitors can find parking, and that the public and private sectors work together for this mutual benefit.

Demand for parking can be changed by providing alternatives to the drive alone automobile. The level of transit service can significantly impact parking demand and may be a more cost-effective alternative to construction of parking structures. Additionally, charging parking fees for commuters which realistically reflect the cost of providing parking spaces may encourage some individuals to shift modes to transit, particularly if parking supply for commuters is constrained by limited facilities. Combinations of these types of strategies may be appropriate for evaluation in future plan updates as the region seeks solutions to future congestion problems. Similarly, small increases in the percentage of trip-makers using transit or carpools can significantly reduce demand.

Techniques

Examples of management strategies include:

- Preferential parking pricing programs for high-occupancy vehicles (HOVs).
- Preferential parking for HOVs.
- Parking fee structures that discourage long-term parking.
- Increased parking fees.
- Limitations on new public and private spaces.
- On-street parking and standing restrictions.
- Employer/landlord parking agreements.
- Zoning regulations with parking controls for new developments.

Data

Two primary data resources and tools to develop were noted in Michigan congestion management processes (CMPs). They were:

- Parking inventory for the urban core area and/or activity centers, including a database and digital map file which identifies available parking facilities and spaces by traffic zone, including both on and off street parking.
- Park-walk sub-model within the travel forecasting model based on the parking inventory.

Application Principles

A well-organized system of parking, regardless of ownership, can result in better utilization of existing facilities and reduce the perceived need for additional parking to accompany investments in office or mixed use developments. An important benefit is avoidance of an oversupply of parking that could compete with a growing transit system. In Charlotte, North Carolina, the Center City Transportation Plan traffic analysis assumed a 25 percent reduction in vehicular traffic in Uptown upon full implementation of the Charlotte's 2025 Transit System Corridor Plan (Kimbler, 2005).

Policies that limit available parking supply have a greater chance of success if the following aspects are evident:

- Current parking is well utilized.
- Transit, bicycle and pedestrian, and ridesharing facilities and programs exist to absorb commuters that no longer drive.

- High-density central business districts or activity centers are present.
- The area has high land values and strong economic development.
- Vacant land and neighborhoods in the area do not have the capacity to absorb the parking overflow or are well controlled by parking restrictions.

Jurisdictions in the urban core should evaluate and consider developing programs that encourage long-term commuters to shift to public transit.

Parking management measures may be voluntary or required by ordinance. It is possible that a large amount of political capital may be required to overcome possible business and employer objections to reducing or limiting available parking. Implementing mandatory parking supply reductions may be unpopular with merchants, employers, or residents and require consensus building to implement a policy that is generally accepted. The EPA Office of Mobile Sources reports that cities that already have a comprehensive parking plan for downtown or suburban areas may already have the necessary experience, personnel, and resources to effectively implement a parking supply program.

A transit-sensitive parking model has not replaced traditional predictive or decision models in many cities, and zoning requirements often reflect more traditional approaches to parking. The City of Charlotte, North Carolina, responded to their transit operator’s 2025 Transit Corridor Systems Plan with transit-oriented development zoning standards that discourage excessive parking. Charlotte’s uptown parking supply is 95 percent privately owned, located in decks designed and built to support the employment base, but are not considered visitor-friendly. The Charlotte Parking Collaborative is a marketing, branding, and standards model designed to overcome disadvantages of multiple ownerships, varied signage, and no common branding (Kimbler, 2005).

Costs

Parking management strategies do not require a substantial amount of financial resources to implement (administration, signage, enforcement, and surveys, if needed).

Benefits and Impacts

Since these strategies are implemented as one part of a larger package of measures, the actual impact of parking management measures on SOV travel is difficult to quantify. It is difficult to separate the impacts of this measure itself from the overall program.

Analyzing Australia's experience with mitigation strategies, Booz Allen Hamilton found that parking pricing and supply policies had a medium-to-high cost effectiveness, although they did not provide a specific ratio. They also concluded that parking management strategies had a medium-to-high overall effectiveness in a city or region (Booz Allen Hamilton, 2006).

Michigan Plans and Policy

The Tri-County RPC (TCRPC) in Lansing stated in their 2004 CMP that "future investments in parking facilities should be analyzed in the context of a balance between supply and demand for parking and the relationship between use of transit, roadway congestion, and other regional needs. Parking supply should not be based solely on the desire to provide a parking space for each and every trip-maker."

TCRPC advises that "local officials should consider the ability to finance construction of additional long term parking facilities or expansion of existing facilities in the context of overall transportation system needs…Decisions to bond or finance construction of additional commuter parking facilities may come at the expense of the public's willingness to finance other transportation system improvements for airports, roadways or transit services."

TCRPC staff's perspective is that "no transportation plan or congestion management system can be complete without consideration of parking location, design and related issues" (TCRPC, 2004).

In April 2011, the USDOT awarded a grant to MDOT for the I-94 Truck Parking and Information Management System. The system will deliver real-time information on parking availability through ITS. It will help improve safety on Michigan interstate roadways by allowing trucks to park safely and securely in areas away from moving traffic, instead of alongside the road itself.

References

Booz Allen Hamilton, *Study of Successful Congestion Management Approaches and the Role of Charging, Taxes, Levies and Infrastructure and Service Pricing in Travel Demand Management,* Consultancy Report Prepared for Council of Australian Governments, November 2006.

Kimbler, James D., *Parking Strategies in Transit Oriented Development,* The Charlotte Parking Collaborative, 2005.

Tri-County Regional Planning Commission, *Congestion Management System for the Tri-County Region*, March 2004.

Diversified Development Patterns

Demand Management ▶ Diversified Development Patterns

Introduction

Diversified development pattern is a planning approach to mixed-use development that focuses on creating greater heterogeneity of land uses in a specified area. It is closely related to increased density and New Urbanism design. Higher densities, richly mixed land uses, and pedestrian-friendly designs are believed to lower the rates of vehicular travel. The concept also presupposes that diversity, density, and design are positively associated with the choices of shared-ride, transit, and non-motorized modes (Cervero, 1997).

Cost:	●●●○○
Time:	Long
Impact:	Regional
Project Life:	30 years
Sponsors:	City

Techniques

The impetus for diversifying land use patterns is the result of traditional suburban development pattern typified by strip commercial corridors, separated neighborhoods, and disconnected public spaces. Communities seeking to alter this pattern include diversity of development to promote the development of traditional mixed use neighborhoods in addition to the continued viability of the existing suburban neighborhoods (City of West Melbourne, 2010).

Data

Research has shown that using a dissimilarity index is an effective way of measuring diversity of development in a specified area. The index is derived from the proportion of dissimilar land uses among hectare grid cells within a designated area. The index of spatial mixing proved to be a more powerful predictor and measure of diversity (Cervero, 1997).

Application Principles

This is a long-term strategy that may require a decade or more to evidence benefits.

Costs

The costs to develop and adopt a program to diversify development patterns are minimal. The long-term public investment costs to implement the plan could be substantial depending on the size of the area and its infrastructure needs, along with development incentives.

Benefits and Impacts

Increased diversified development patterns are thought to be associated with higher occupancy levels for personal vehicle travel. It may also lead to greater use of alternative modes of travel. More compact settings with neighborhood retail outlets and pleasant walking environments are thought to induce more foot and bicycle travel and short-hop transit trips. In the case of work trips, pedestrian-friendly environments and the presence of convenience stores near residences may induce commute trips via transit and non-motorized modes (Cervero, 1997).

Michigan Plans and Policy

No recent research or policy regarding diversification of development patterns in Michigan was found. Discussion of land use diversity in the state usually occurs in the context of agriculture, preservation of farm land, and maintaining biodiversity.

References

City of West Melbourne, Florida, *Horizon 2030 Comprehensive Plan, Volume II: Data and Analysis,* October 2010.

Cervero, Robert and Kockelman, Kara, *Travel Demand and the 3Ds: Density, Diversity, and Design,* Transportation Research D, Vol. 2, No. 3, 1997.

Smart Growth

Demand Management ▶ Smart Growth

Introduction

Smart growth is a land use planning and development strategy that enables other more specific congestion mitigation strategies to occur. Smart growth measures involve urban design and transportation measures, guidelines, and regulations designed to reduce automobile trips and to promote non automobile travel associated with the use of a cohesive nexus of activity such as office parks, shopping centers, mixed-use developments, and other areas of vehicle activity.

According to the EPA, the basic principles of smart growth, based on community experiences with the concept, are:

- Mix land uses.
- Take advantage of compact building design.
- Create a range of housing opportunities and choices.
- Create walkable neighborhoods.
- Foster distinctive, attractive communities with a strong sense of place.
- Preserve open space, farmland, natural beauty, and critical environmental areas.
- Strengthen and direct development toward existing communities.
- Provide a variety of transportation choices.
- Make development decisions predictable, fair, and cost effective.
- Encourage community and stakeholder collaboration in development decisions (EPA, 2001).

Techniques

Smart growth management and land use strategies seek to achieve concurrency between transportation infrastructure and land development. The goal of these strategies is to create environments that are conducive to the use of modes other than driving and to shorter trip lengths.

Strategies or concepts that fall into this strategy class include:

- More compact development (higher density).
- Redevelopment and infill development.
- Mixed use development.
- Jobs/housing balance.
- Transit-oriented development.
- Land use and transportation coordination.

Benefits and Impacts

Smart growth management concepts and impacts may be best viewed at the regional level. The primary positive impacts of smart growth management strategies are the elimination of vehicle trips and reduction in vehicle miles traveled (VMT). These impacts are sometimes not immediately realized because of the length of time it may take to implement these strategies and realize their benefits. The development of new or greatly modified urban design codes and regulations requires a significant amount of time and political discussion. If approved, new infrastructure and public services for the activity centers must then be designed and implemented.

The features that distinguish smart growth vary by community. No two streets, neighborhoods, or cities are identical. There is no "one-size-fits-all" solution. Smart growth in Portland, Oregon, has different characteristics than smart growth in Austin, Texas, as it does in Detroit (EPA, 2001).

Michigan Plans and Policy

In *Michigan's Land, Michigan's Future: Final Report of the Michigan Land Use Leadership Council*, the report recommends as a state goal:

> Supporting efforts to make Michigan cities more livable by *expediting the reuse of abandoned properties*, controlling blight, encouraging private investment, *encouraging mixed-use development*, *improving transportation options*, supporting a *full range of housing options*, and attracting and retaining residents who can contribute to the viability of our urban core areas (*italics added*)

References

Michigan's Land, Michigan's Future: Final Report of the Michigan Land Use Leadership Council, August 15, 2003.

What Is Smart Growth? A Smart Growth Fact Sheet, EPA 231-F-01-001A, 2001.

Compact Development

Demand Management ▶ Smart Growth ▶ Compact Development

Introduction

Compact metropolitan development generally means the space needs of a population can be satisfied with less land area. Compact development can take various forms. From a regional perspective, metropolitan areas may limit the extent of development so that it does not extend too far into rural areas. New development can be targeted to specific areas, such as redevelopment areas within established communities. It is primarily a planning tool to promote increased density of development.

Cost:	●○○○○
Time:	Long
Impact:	Spot
Project Life:	30 years
Sponsors:	City

Techniques

Implementation of this strategy is through the local zoning and development approval processes. Compact development also requires regional cooperation to successfully address congestion problems.

Data

A primary method for analyzing the impact of land use strategies on the performance of the transportation network is to use the regional transportation model, combined with regional land use models. Transportation planners and engineers can use these models to evaluate different regional growth pattern scenarios. Those scenarios can include the testing of more compact development, and the impacts on such measures as transit usage, water quality, and regional growth dispersion (EPA, 2001).

Application Principles

Accomplishing this strategy requires overcoming a few major obstacles. First, the analytical framework at the core of nearly all regional transportation planning models has difficulty capturing interactions between land use and transportation systems. Other limitations include

models examining only work related travel, not considering walking as a mode of travel, and including very little detail on land use characteristics between travel analysis zones. In spite of modifications, the travel demand models still do not have the ability to examine how good site location and design might increase rates of walking and biking (EPA, 2001).

Costs

According to a study by Michigan State University, the length of the infrastructure for roads, sewer and water provided to each unit increases with lot size. Subsequently, the cost of building these types of infrastructure increases with lot size. The net present value of life cycle costs (including construction, operation, and maintenance up until replacement age) also increases with the lot size of each unit.

The study also showed that, while annual life cycle costs for provision of sewer and water increase as lot size increases, the annual user fees for sewer and water actually decrease for the case study communities. Although there is no physical or economic reason why it should be so, owners of large lots appear to pay lower user fees for public services than owners of small lots. In communities where this pattern of pricing exists, it suggests that large lots are less fiscally sustainable than small lots on revenue grounds, as well as on cost grounds (Najafi, 2006).

Benefits and Impacts

More compact development can reduce travel distances, thus reducing vehicle miles traveled (VMT) and increasing the potential for walk or bicycle travel. It can also be more effectively served by public transit, leading to increased transit use and further reductions in vehicle trips and VMT. A San Francisco Bay Area study has shown that doubling residential density from a suburban level to a level equal to that in the city of San Francisco neighborhoods reduces per capita VMT by 25 to 30 percent.

The Michigan State University study found that, in the 18 communities studied, land consumption and costs for infrastructure and municipal services were far less expensive when Smart Growth principles replaced sprawling patterns of development (Najafi, 2006).

Michigan Plans and Policy

The Michigan Land Use Leadership Council final report recommended that the state provide "new tools to local government to encourage better land use decisions that allow more compact, mixed-use development." Regarding density and land use, the Council report states:

> "The state should reduce overall land consumption by fostering more dense residential development through activities such as:
>
> a. Encouraging minimum allowable housing densities of four units per acre for single-family housing and ten units per acre for multifamily or attached housing commensurate with available water, sewer, and road infrastructure.
> b. Encouraging counties and local governments to use local zoning ordinances to provide for a range of cluster development options in appropriate residential and mixed-use zones, and encouraging developers to use these cluster development options by providing appropriate incentives such as allowing higher density and/or a streamlined development review process.
> c. Promoting development of accessory dwelling units such as carriage houses or accessory apartments.
> d. Providing incentives favoring the development of housing above existing retail in downtown and suburban areas.
> e. Encouraging residential mixed-use and mixed-use zoning."

References

Michigan's Land, Michigan's Future: Final Report of the Michigan Land Use Leadership Council, August 15, 2003.

Najafi, Mohammad, et al. *The Fiscal Impacts of Alternative Single Family Housing Densities: Infrastructure Costs*, MSU Land Policy Institute Report No. 2006-2, May 2006.

U.S. Environmental Protection Agency*, Our Built and Natural Environments,* January 2001.

Redevelopment and Infill Development

Demand Management ▶ Smart Growth ▶ Redevelopment and Infill Development

Introduction

Redevelopment and infill development often refers to new development on vacant, bypassed, and underutilized land within built up areas of existing communities, where infrastructure is already in place. Former industrial sites, declining suburban malls, vacant properties and other underutilized land all provide opportunities for redevelopment. Projects developed on such sites are often pursued for their economic development benefits; however redeveloping underutilized land in cities and suburbs also has the potential to reduce vehicle travel.

Cost:	●●●●○
Time:	Long
Impact:	Spot
Project Life:	30 years
Sponsors:	City

Techniques

A redevelopment and infill strategy includes actions such as reclamation and reuse of abandoned or contaminated property for employment and residential use, maintenance and improvement of the transportation system, financial assistance for infrastructure targeted to support redevelopment and infill projects, improved transportation between existing housing and job centers, and attainment of high levels of educational quality and public safety.

Infill can be effective through a comprehensive plan that contains goals, objectives, and policies that address the location and intensity to guide future development and direction. To encourage infill development projects, local governments should have strategies to make sites attractive for developers through public infrastructure investment including road improvements and improved site access (EPA, 2007).

Data

A primary method for analyzing the impact of land use strategies on the performance of the transportation network is to use the regional transportation model, combined with regional land use models. Several metropolitan planning organizations (MPOs) have used these models to evaluate different regional growth pattern scenarios. These scenarios included the testing of infill and redevelopment strategies and their impacts on such measures as transit usage, water quality, and regional growth dispersion.

Data inputs and post-processed data for infill analysis can include:

- Person trips.
- Average trip lengths.
- Vehicle-miles traveled.
- Vehicle-hours traveled.
- Transit mode shares.
- Walk mode shares.
- Average speed.
- Congestion – Defined in one study as: the amount of congestion is measured as the difference in the vehicle-hours traveled (VHT) under free-flow conditions and the VHT under congested conditions (EPA, 2007).

It should be noted that even when MPOs have incorporated land use feedbacks into their travel demand models, they tend to be regional in nature and fail to capture the key neighborhood level characteristics. It is these smaller scale land use patterns that often contribute most to the reduced driving expected from well designed infill projects. Post-processing of data is usually required to isolate the impacts of these types of strategies.

Application Principles

Redevelopment and infill strategies can occur through a variety of implementing authorities, including local, regional, and state governments, as well as the private development sector. While markets and local zoning regulations generally identify those areas of new development, it is often necessary to provide incentives to achieve development of disinvested areas.

Costs

Many infill development projects are funded through the assistance of county funds, tax increment financing, bond revenues, Community Development Block Grants, and other sources. The costs to develop and adopt redevelopment and infill development policies and strategies are minimal. However, these types of projects may require significant public investment to implement.

Benefits and Impacts

The goal of redevelopment and infill strategies is to create the most efficient pattern of regional land development possible. Redevelopment and infill strategies produce:

- Cost savings through use of existing infrastructure and avoiding costly new infrastructure improvements.
- Travel savings by taking advantage of compact and mixed use development patterns instead of the more inefficient patterns of new development seen on the fringes of metropolitan areas.

EPA noted in a review of several infill studies that actively supporting infill development can be a highly effective regional transportation policy. These strategies have shown that positive impacts result from redevelopment and infill activities in terms of increased transit ridership, reduced vehicle miles traveled (VMT) because of shorter trips, and increased walking and bicycling. If done well, redevelopment creates neighborhoods where residents can accomplish their daily activities with less driving. Site level studies noted by the agency suggest that shifting development to more accessible locations reduces vehicle travel per person by 30–60 percent (EPA, 2007).

Michigan Plans and Policy

The Michigan Land Use Leadership Council recommended that cites make “better use of existing public infrastructure by encouraging public and private investment in already developed areas.”

State of Michigan legislation includes the *Land Bank Fast Tract Acts of 2004* that enabled local government units to establish land bank authorities and Brownfield authorities through intergovernmental agreement with the state. It also clarified tax policies for land bank properties and further expedited quiet title and foreclosure proceedings and aids private developers who lease, convey, demolish, or rehabilitate property. The *Clean Michigan Initiative* increased state funding for Brownfield redevelopment. The *Planned Unit Developments* provision amended zoning statutes to allow local government units to promote mixed land use and open space preservation through planned unit developments.

References

U.S. EPA, *Measuring the Air Quality and Transportation Impacts of Infill Development,* EPA 231-R-07-001, November 2007.

Michigan's Land, Michigan's Future: Final Report of the Michigan Land Use Leadership Council, August 15, 2003.

Mixed Use Development

Demand Management ▶ Smart Growth ▶ Mixed Use Development

Introduction

Mixed-use development is a broad range of land use regulations, ordinances, and guidelines that require a variety of residential, retail, and other land uses clustered together in a limited land space rather than segregated and spread in a larger area. This clustering of uses may lead to reduced vehicle miles traveled (VMT) and increase alternative modes of travel. Mixed-use developments fulfill the following criteria:

Cost:	●●●○○
Time:	Long
Impact:	Spot
Project Life:	30 years
Sponsors:	City

- Three or more significant revenue-producing uses (such as office, retail, residential, hotel/motel, entertainment, cultural, recreation, etc.) that in well-planned projects are mutually supporting.
- Significant physical and functional integration of project components (and thus a relatively intensive use of land), including uninterrupted pedestrian connections.
- Development in conformance with a coherent plan (which frequently stipulates the type and scale of uses, permitted densities, and related developmental consideration).

Many terms can be used to describe mixed use such as New Urbanism, transit-oriented development, sustainable development, and cluster development. All generally require greater density requirements, smaller lots, less segregation of land use with a mix of housing, business, recreation, and retail industries. Mixed-use development is intended to provide site amenities encouraging ridesharing or transit use, thus decreasing reliance on single occupancy vehicle (SOV) use (EPA, 2007).

Techniques

Implementation of this strategy is through the local zoning and development approval process. However, this strategy type often requires changes to zoning ordinances. The creation of mixed-use zoning districts adjacent to established areas (e.g., hamlets, villages, cities) directs higher-density, pedestrian-oriented developments next to existing neighborhoods. This allows for the expansion of existing infrastructure and circulation patterns, as well as the mixed-use development's support of established neighborhoods. Ordinances should address site connectivity, building façade and orientation, sidewalk location and pavement width, streetscape features, and revised parking standards which permit shared and curbside parking (EPA, 2001).

Data

A primary method for analyzing the impact of land use strategies on the performance of the transportation network is to use the regional transportation model, combined with regional land use models.

Data inputs and post-processed data for infill analysis can include:

- Person trips.
- Average trip lengths.
- Vehicle-miles traveled.
- Vehicle-hours traveled.
- Transit mode shares.
- Walk mode shares.
- Average speed.
- Congestion – Defined in one study as: the amount of congestion is measured as the difference in the vehicle-hours traveled (VHT) under free-flow conditions and the VHT under congested conditions (EPA, 2007).

When metropolitan planning organizations (MPOs) have incorporated land use feedbacks into their travel demand models, they tend to be regional in nature and fail to capture the key neighborhood level characteristics. It is these smaller scale land use patterns that often contribute most to the reduced driving expected from well designed infill projects. Post-processing of data is usually required to isolate the impacts of these types of strategies.

Application Principles

Mixed use development is a long-term strategy to be implemented in sufficient magnitude over a multi-year period of time. EPA concluded that in a region experiencing considerable sprawl-type development over many years, land use policy actions to encourage high density, mixed use development in existing urban cores may take ten to 20 years to have a significant impact on development trends and emissions from motor vehicle travel. Location and the mix of uses are critical to a development's success. Locating buildings adjacent to or within walking distance of residential areas facilitates residents' use of transit alternatives; this can contribute to a reduction in vehicular traffic. While on-site residents are potential users of mixed-use establishments, commercial uses should also complement the larger community's needs. Mixed-use developments increase usage throughout the day, residents and customers use facilities at different times for different purposes. This generates increased customer traffic for businesses by other occupants and users of the development (EPA, 2001).

Costs

The costs to develop and adopt mixed use development policies and strategies are minimal. However, these types of projects may require significant public investment in transportation infrastructure improvements to implement.

Benefits and Impacts

The advantage of mixed use development is the ability to shift and shorten some trips that would otherwise end up on regional roads, and to encourage walking and bicycling to destinations. An EPA study showed that commercial centers with even a narrow range of mixed uses can eliminate 25 percent of trips consumers would have made going to separate destinations. At business parks, on-site services and shopping can eliminate 20 percent of the VMT by office workers. Hillsborough County, Florida has established minimum requirements for clustering on-site jobs and shopping for some new residential developments that can effectively keep up to 24 percent of all trips on-site. EPA notes that accessibility to a variety of trip purposes, as in mixed use developments, may induce additional trips; however, these trips are shorter and are more likely to be made by walking than trips in areas where mixed land uses are not available (EPA, 2007).

Michigan Plans and Policy

There are numerous mixed use development projects throughout the State of Michigan. These projects are primarily proposed and marketed for land development and economic growth, indirectly as congestion mitigation strategies. The Congestion Management Processes developed by transportation management associations (TMAs) in the state prioritize VMT reduction and alternative modes, both of which are conducive to development of mixed use sites.

References

EPA Guidance: Improving Air Quality through Land Use Activities, U.S. Environmental Protection Agency, EPA420-R-01-001, January 2001.

Measuring the Air Quality and Transportation Impacts of Infill Development, EPA 231-R-07-001, November 2007.

Jobs-Housing Balance

Demand Management ▶ Smart Growth ▶ Jobs-Housing Balance

Introduction

Jobs-housing balance is a planning tool, rather than a regulatory tool that local governments can use to achieve a roughly equal number of jobs and housing units (or households) in a jurisdiction. Ideally, the jobs available in a community should match the labor force skills, and housing should be available at prices, sizes, and locations suited to workers who wish to live in the area. The spatial mismatch between the locations of jobs and housing is considered one important reason for the longer commute trips and deteriorating traffic conditions in many metropolitan regions. When numerous employees live far from their work places and have to drive to work, the result is often longer commutes and greater vehicle miles traveled. Traffic congestion and reduced quality of life can also occur as a result of such imbalances.

Cost:	●○○○○
Time:	Long
Impact:	Regional
Project Life:	30 years
Sponsors:	City

A ratio of jobs to housing is most commonly used to express the concept of jobs-housing balance. Generally stated, the jobs-housing ratio is a ratio between a measure of employment and a measure of housing in a given area of analysis. The most basic measure is the ratio of the number of jobs to the number of housing units in an area (Weitz, 2003).

The goal of this strategy is to reduce congestion by balancing, in each sub-region, the number of jobs with the number households and to balance the style and cost of the housing with the wage level of the jobs. The basic concept is to make it possible for people to live closer to where they work, thereby shortening average commuting journeys. Under most circumstances, long, commuter journeys generate more traffic congestion than shorter ones (Weitz, 2003).

Techniques

Implementation of this strategy is through the local zoning and development approval processes. Jobs/housing balance requires regional cooperation to successfully address issues and design solutions for congestion problems. The American Planning Association (APA) provides a set of steps to implement a jobs/housing balance approach. They are listed below:

1. Determine the appropriate unit of geography for the study and application of jobs-housing balance policies.
2. Determine what jobs-housing measurement will be used, according to the available or obtainable data.
3. Collect data on the jobs-housing measure you select for the study area or areas. Calculate the overall jobs-housing ratio (or whichever measure you choose) for the area and analyze the results of the calculation.
4. Make a value judgment—select a standard and recommend/seek approval of a jobs-housing balance standard.
5. Audit your locality's comprehensive plan to determine the extent to which it promotes your new jobs-housing goal.
6. Amend your comprehensive plan to include the analysis of jobs-housing balance and to include policy statements appropriate to your locality.
7. Prepare and adopt regulations that implement local jobs-housing balance policies (Weitz, 2003).

Data

Use local and regional housing and employment data by traffic analysis zone (TAZ), if available, or census block group to calculate jobs-housing ratios in subareas of a jurisdiction. The Census Transportation Planning Package contains subarea information on employment, household, and commuting patterns that can be used to identify areas with jobs/housing imbalances (Weitz, 2003).

Application Principles

Jobs/housing balance techniques are best developed as part of another study or program, such as smart growth efforts, housing task forces or reports, economic development efforts, general growth forecasting studies, or transportation plans.

The best practice emphasizes jobs/housing balance in the larger sub-region of which a given development is a part, rather than striving for balance within each and every project. A community or groups of communities should strive for a jobs/housing balance within a 3-5 mile area around a development site.

Costs

The costs to conduct a jobs/housing balance analysis and incorporate its results into a local or regional planning approach are minimal. The analysis could be performed in-house or by a consultant.

Benefits and Impacts

Any land use development that helps to bring jobs and housing into better balance has the potential for reducing average commute lengths, thereby reducing VMT. This strategy may also eliminate some of the traffic congestion imposed by commuters traversing other communities on their way to work. The Southern California Association of Governments has adopted a policy of shifting 12 percent of new jobs away from areas of job surplus and shifting six percent of new housing away from areas of housing surplus. This policy was adopted as an alternative to adding roadway capacity in light of a projected regional increase in traffic congestion (Weitz, 2003).

Michigan Plans and Policy

MDOT has noted local jobs/housing balance concerns in the 2005 long range transportation plan:

Tightening of the labor force and relocation of employers to remain in proximity to localized labor pools may cause a change in the jobs-housing balance. This spatial reorganization will need careful analysis by transportation and local governments regarding the impact on their tax base and how these longer-distance commuters are served.

References

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Transit-Oriented Development

Demand Management ▶ Smart Growth ▶ Transit-Oriented Development

Introduction

Transit-oriented development (TOD) has rapidly emerged as the central urban planning paradigm in the United States. Many metro areas leaders have made, or contemplate making major investments in new rail transit capacity, assuming the synergy between compact, mixed-use development and mass transit will change auto-dependent growth and travel patterns.

Cost:	●●●○○
Time:	Moderate
Impact:	Corridor
Project Life:	30 years
Sponsors:	City

The TOD strategy promotes land development patterns that maximize public transportation systems and help achieve cost-effective land use patterns at the same time. TOD promotes urban design features such as mixed land uses (residential, retail, offices), a centrally located commercial core with compact development patterns, a well-connected grid street networks, and ease of pedestrian and bicycle access.

Techniques

This strategy is implemented through the local zoning and development approval process, requiring coordinated efforts among municipal officials, developers, transportation and urban design planners, and members of the community. Although this approval process is generally established by individual counties and municipalities, this strategy could possibly be adopted and promoted at a wider scale through groups such as metropolitan planning organizations (MPOs), transportation management associations (TMAs), and corridor planning groups.

Transit-oriented development requires four primary strategies. These include:

- Create high-density, mixed-use development around a transit station. High densities are necessary because they lead to increased transit ridership. Mixed-use development helps create an environment conducive to pedestrian activity. TOD's development area is usually a radius ranging from a quarter-mile to a half-mile around a transit station. This radius represents the maximum distance people are generally willing to walk to a transit station. Depending on the type of transit used in the development, density requirements range from 3.5 to 15 dwelling units per acre adjacent to the site.

- Design or improve a neighborhood conducive to bicycle/pedestrian activity. Walking and bicycling complement transit because they are ideal methods for people to get to a train from their home or to a destination from the train station.
- Traffic calming and increased connectivity. Traffic calming reduces the speeds of vehicles on the street as well as the number of automobiles, because most drivers will move to a street that does not employ traffic calming. Promoting connectivity ensures that pedestrians can walk from one place to another on a fairly direct path, often connecting to roads via pathways that cars cannot drive on.
- Parking management is also crucial to TOD. Parking spaces in urban environments take valuable land away from productive use and spread destinations farther apart. Reducing the amount of available and/or free parking promotes higher density land uses. Transit use is indirectly promoted by making driving slightly more difficult and/or expensive (Niles, 1999).

Data

A review of current evaluation methodologies applied to TOD indicates they all have limitations. Travel demand modeling, in particular, cannot accurately predict the response of the marketplace to major transportation and land use changes. However, planners should gather local data, before and after implementation, and perform post-processing analysis. This data includes:

- Person trips.
- Average trip lengths.
- Vehicle-miles traveled.
- Vehicle-hours traveled.
- Transit mode shares.
- Walk mode shares.
- Average speed.
- Congestion – Defined in one study as: the amount of congestion is measured as the difference in the vehicle-hours traveled (VHT) under free-flow conditions and the VHT under congested conditions (EPA, 2007).

Application Principles

TOD is most effective when combined with other land use policies, transportation demand management (TDM) strategies such as carpool/vanpool programs and transit incentives, or bicycle and pedestrian improvements within public right of way (ROW). In the context of planning, success of TOD depends on the response of developers, consumers, and taxpayers to the concept and to the public strategies that encourage it. One study identified 16 factors that will determine success at the regional or transit corridor level. Fewer factors will control success at a single station-area, a main focus for planners to date. The table is below (Niles, 1999).

Table 20. Transit-Oriented Development Success Factors

Factor	Station area success	Regional success
Number and location of TODs (station areas)		X
Transit quality		X
Transit technology		X
Street pattern	X	X
Station area parking	X	X
Employment and housing density	X	X
Commercial mix	X	X
Retail site criteria		X
Regional market structure		X
Consumer activity patterns		X
Travel behavior/trip chaining		X
Zoning flexibility/land assembly	X	X
Resident reactions	X	X
Housing type preference/life style & life stage		X
Self-selection in residential choice	X	X
Government policies		X

Costs

From an economic perspective, success of TOD will depend on the benefits—both societal and personal—it produces relative to its costs. The public may experience benefits in the form of congestion reduction and air quality improvements. To the extent that TOD reduces excessive infrastructure costs associated with dispersed development, these would be accounted as secondary public benefits. The principal personal benefits may be travel time and expense saved, in addition to reduced congestion time. Personal benefits also include the possibility that some households can reduce the number of cars they own and operate. Other benefits, of a social nature and more difficult to quantify, may be associated with the enhanced quality of living TOD is believed to produce. Table 21 provides the benefits and costs from the study (Niles, 1999).

Table 21. Costs and Benefits of Transit-Oriented Development

Costs	Benefits
Transit system construction Transit system operations Mitigation of traffic congestion caused by compact development Station-area housing cost premium TOD planning Public incentives to developers	Congestion reduction lowering time delays and fuel consumption Air quality improvement reducing health costs Reduced infrastructure Personal travel time savings Vehicle operation savings Personal vehicle ownership reduction

Public costs are primarily the transit capital and operating costs. The cost of housing in proximity to stations may be higher. Other direct costs may arise. To the extent that increased density does not result in reduced travel, other congestion mitigation measures may be required. There may also be costs associated with TOD planning and any public incentives needed.

Benefits and Impacts

One hoped for benefit of TOD is that a mix of shopping, service, and recreation activities at urban centers linked together by high quality transit will induce citizens to drive less and walk or ride transit more. The success of the TOD concept depends greatly on the response of developers, consumers, and taxpayers to the new land use-transportation configuration.

TCRP Report 128 researchers found that TOD-housing resulted in fewer trips generated in the 17 surveyed TOD-housing projects that were studied. Over a typical weekday period, the TOD-housing projects averaged 44 percent fewer vehicle trips than estimated by the ITE manual (3.754 trips versus 6.715). To the degree that impact fees are based on peak travel conditions, one can infer that traffic impacts studies might overstate the potential congestion-inducing effects of TOD-housing in large rail-served metropolitan areas by up to 50 percent (Arrington, 2008).

Michigan Plans and Policy

No examples were found of transit-oriented development in Michigan. There is discussion and proposal for incorporation of TOD in the planned Woodward Avenue light rail project in Detroit. Researchers at the University of Michigan planned from a TOD perspective three separate stations and their surrounding areas along the proposed line (De Silva, 2010).

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Corridor Land Use and Transportation Coordination

Demand Management ▶ Smart Growth ▶ Corridor Land Use and Transportation Coordination

Introduction

Corridor land use and transportation coordination is a tool designed to promote cooperation among local governments in coordinating transportation and land use solutions aimed at congestion management goals. This tool allows for joint planning among corridor-wide communities for land use and transportation and for the assessment of cumulative impacts resulting from corridor-wide growth. Such coordination is achieved when local governments in a transportation corridor enter into formal intergovernmental agreements specifying a planning process for program implementation.

Cost:	●○○○○
Time:	Long
Impact:	Corridor
Project Life:	30 years
Sponsors:	City/State

Techniques

This strategy is implemented through intergovernmental agreements as authorized under Article 3, Section 5 of the Michigan State Constitution. The Land Bank Fast Track Act of 2003 also provides for the State of Michigan to enter into intergovernmental agreements with townships for land use redevelopment purposes.

Data

Analysis of this mitigation strategy is similar to other Smart Growth techniques. Sorting out the amount of mitigation derived from the intergovernmental agreement may be difficult and, in such cases, planners are encouraged to use their professional judgment and make conservative assumptions based on local data.

Application Principles

This strategy can be helpful when congestion management projects call for a regional or sub-regional approach such as access management, corridor-wide land use design practices, transit access, or jobs/housing balance.

Costs

Costs to develop intergovernmental agreements to coordinate transportation and land use in corridors are minimal.

Benefits and Impacts

This coordinated intergovernmental process allows for examining and implementing land use and transportation solutions to realistic growth forecasts, avoiding negative consequences of growth such as traffic congestion.

Michigan Plans and Policy

The Michigan Land Use Leadership Council supported “creating incentives to encourage interagency and intergovernmental cooperation in addressing land use issues and public investments of more than local concern.”

The Tri-County Regional Planning Commission (TCRPC) in Lansing exemplifies the benefits of regional coordination of transportation.

At plan build-out, their Smart Growth approach estimates savings between $1.8 and $5.4 billion in transportation costs by eliminating half the congested lane miles anticipated if current trends continue. This approach also preserves three townships of agricultural land/open space and reduces pollutants by greater than 10,000 kilograms per day.

The RPC established strong linkages among its townships between regional land use and transportation goals, objectives, investment strategies, performance measures, project selection criteria and smart growth, along with auxiliary land use strategies such as access management and traffic impact studies (Hamilton, 2004).

According to the TCRPC, “the Regional Concept of Management and Operations for congested corridors which is emerging from this approach is being applied to all modes ‘from building façade to building façade,’ is performance based and considers safety, wide nodes, narrow roads, road diets, traffic calming, ITS and more traditional traffic engineering treatments. This resulting Regional Concept of Management and Operations makes system's operations and management itself another land use strategy for implementing smart growth, which reduces congestion and improves safety for all modes and users throughout the corridor" (Hamilton, 2004).

References

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Car Sharing

Demand Management ▶ Car Sharing

Introduction

Carsharing allows people to rent cars on a short-term (hourly or daily), as-needed basis, paying only for the time they use the car and the mileage they drive. The operators of the carsharing program provide vehicle maintenance, repair, and insurance.

Cost:	●●○○○
Time:	Short
Impact:	Regional
Project Life:	10 years
Sponsors:	City

The term “shared-use vehicle” is a broader concept that encompasses both carsharing and station car programs. Station car programs are designed to facilitate transit access in the cases where the final destination of a person who uses public transportation is located too far away from the endpoint of the transit route; people can drive station cars to complete the final leg of their trip.

Shared-use vehicles allow individuals to gain the benefits of using a private car without the costs and responsibilities of owning a car. Members of a shared-use vehicle or carsharing program pick-up and return vehicles at shared use lots that are scattered throughout a particular region or concentrated at a transit station, activity, or employment center. Typically, a member makes a reservation in advance, lets him or herself into the vehicle with a personal card or key, and drives away. When the person is done using the car, she returns the car to its home parking space, locks it, and leaves it for the next car sharer (Millard-Ball, 2008).

Employer-based carsharing, in which employees have convenient access to a fleet of vehicles, is a growing service in several other large cities. Employers pay carsharing organizations based on the time and mileage incurred by their employees. Having an outside party provide a corporate fleet of vehicles may not increase costs to employers, since they already reimburse employees for car use and parking for work purposes. Employer-based carsharing has two important societal benefits: it allows more commuters to choose an alternative to driving alone, and fewer onsite parking spaces are needed (Millard-Ball, 2008).

The primary agencies involved in establishing a carshare program in a region or city is the City Transportation and/or Economic Development Department, the Metropolitan Planning Organization/Regional Planning Agency, and/or a community development corporation or other local potential nonprofit sponsor.

Researchers note that as of January 2011, 27 U.S. carsharing programs claimed 518,520 members sharing 7,776 vehicles (Cohen, 2008).

Techniques

Using an online system, users reserve a car parked in their neighborhood for as long as they need it and return it to the same dedicated parking space, paying for only as much car use as needed.

Data

- Average daily VMT of participants before carsharing.
- Average daily VMT of participants after carsharing.
- Number of participants.

Application Principles

To help develop a carshare program in a city activity center, or region researchers have found several productive techniques. These include:

- Endorsements and outreach from local governments, nonprofits, and community institutions will add to public awareness and legitimacy for a fledgling (or future) carsharing operation. Co-promotions, joint press releases, and media events featuring prominent local figures can help convince potential participants to join, accelerating the development of a viable local market.
- Cities can dedicate a small part of public space to the urban residents who choose to share a vehicle.
- Municipalities can allow developers to reduce overall parking requirements in exchange for carsharing support.
- Exempt carsharing vehicles from local car rental taxes (Cohen, 2008).

Costs

The start up of a carsharing program typically requires public subsidy, often using Congestion Mitigation and Air Quality (CMAQ) funding. In San Francisco, the 2003 budget for the City Carshare program had commitments of more than $300,000 in funding from various public agencies. In Minnesota, the estimated cost of two years of seed funding to enable Twin Cities *hOur Car*® to establish a financially sustainable employer program at $100,000 for each year.

Benefits and Impacts

The benefits of carsharing can include:

- More careful consideration of the necessity, duration, and distance of automobile trips, resulting in decreased vehicle use and ownership.
- Greater consideration given to alternative modes, resulting in increased transit ridership, biking, and walking.
- Cost savings to individuals and employers.
- Reduced parking demand at participating transit stations, member employer sites, and residential locations.

The estimated impact of the Minneapolis program was shown to be if 570, or 3 percent, of the 19,000 daily single occupancy vehicle (SOV) commuters to downtown Minneapolis switched to bus, bike, or carpool/vanpool, the impact would equal 285 fewer SOV trips each year. This would result in a cost of $351 per year for each SOV trip avoided ($100,000 seed funding/285) (InnovativeMobilty.org, 2011).

Michigan Plans and Policy

Zipcar® operates a carsharing program at the University of Michigan and Michigan State University. Students, faculty, and staff can join Zipcar for $50/year. The service is available 24 hours/day, 7 days/week. Hourly rates range from $8 to 9. This covers gas, insurance, and an allocation of free miles (Zipcar, 2011).

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Trip Reduction Ordinances

Demand Management ▶ Trip Reduction Ordinances

Introduction

Trip-reduction ordinances (TROs) consist of regulations or similar measures requiring implementation of other congestion mitigation strategies. TROs may specify specific mitigation strategies or simply require a set reduction in vehicle miles traveled (VMT), trips, or other measure of reduced travel. TROs are applied in a variety of ways, depending upon the needs of a particular locality. The focus of these ordinances has been to encourage socially beneficial travel choices rather than controlling traveler behavior. Most TROs, therefore, offer a range of travel options, but the individual traveler's choice is voluntary.

Cost:	●○○○○
Time:	Short
Impact:	Regional
Project Life:	5 years
Sponsors:	City

TROs require developers, employers, or building managers to provide incentives for occupants or employees to use alternative modes. Programs and ordinances can be implemented state/region wide or by local jurisdictions, and take many different forms. These include:

- Special use permits – Government entities can require permitting for certain uses of land which, by their location, nature or size and density tend to cause traffic and related impacts which are contrary to the public health, safety and general welfare in that they lead to, generate or exacerbate danger and congestion in travel and transportation upon the public streets and/or, parking problems
- Negotiated agreements – Trip-reduction requirements can be used as a bargaining element in negotiations over rezonings and/or as part of a public-private development agreement. Negotiated agreements allow the trip-reduction program to be formulated to mitigate the emission impacts of the specific project under consideration, but may also lead to considerable variation among the requirements imposed on similar projects.
- Trip reduction goal programs – Requires employers of specific-size companies to reduce the number of commute trips made by

employees by a certain amount. Program goals can be mandatory or voluntary for employers. The program encourages use of alternative modes of travel including ridesharing, transit, walking/bicycling, and telecommuting among employees.

- Conditions of approval for new construction – These policies require that adequate public facilities be in place (or at least programmed and funded) before additional development can be approved. They may call for developers to implement specific types of facilities and services (e.g., park-and-ride lots at all major housing developments, sidewalks and bike paths, onsite transit pass sales, and rideshare matching) and/or may establish performance standards with the means of achieving those standards subject to negotiation.
- Mandated Programs – Requires employers who employ more than a certain number of employees to implement ridesharing and/or related alternative commute programs. The reduction goals can vary according to the reduction needs of the locality. Program goals can be measured in various ways including improvement in employee average vehicle ridership or a decrease in employee home-based work trips.
- Transportation Management Districts – Provide concentrated services to encourage the use of transit and other commuting options in major business districts.

Mandatory TROs often apply only to large employers (those with at least 50 or 100 at a worksite), although this limits their effectiveness since the majority of employees in most areas work for smaller companies. Smaller employers can form a Transportation Management Association to provide commute trip reduction (CTR) services in a particular commercial district or mall. Many transportation planning and transit agencies provide support for CTR programs. Developers may implement CTR programs in exchange for reduced parking requirements.

Techniques

To establish a TRO or CTR or related program, a business usually develops corporate goals and objectives, policies and procedures, and services and benefits. Travel surveys of employees are important in helping plan and evaluate programs. TRO programs may be managed by an in-house Employee Transportation Coordinator, a specialized transportation services company, or a local Transportation Management Association. Governments and agencies provide assistance to businesses and other parties in creating the programs.

Some governments and agencies make special efforts to implement CTR programs within their own agencies as a way to demonstrate leadership and as an opportunity to develop tools and experience that can be transferred to non-government organizations.

Data

As with other policy strategies, the congestion mitigation benefit from TROs needs to be apportioned from the benefit of the actual program implemented as a result of the ordinance or agreement. This is usually required for funding mechanisms. Analysis of the programs does require some specific data, before and after implementation, including:

- Mode Split – the portion of participant trips currently made by single occupancy vehicle (SOV), transit, ridesharing, cycling and walking.
- Average Vehicle Occupancy (AVO) – number of people traveling in private vehicles divided by the number of private vehicle trips, excluding transit vehicle users and pedestrians.
- Average Vehicle Ridership – all person trips divided by the number of private vehicle trips, including transit vehicle users and pedestrians.
- Vehicle Trips or Peak Period Vehicle Trips – total number of private vehicles arriving at a worksite.

Application Principles

TROs are applicable in large metropolitan areas and surrounding suburbs. Most measures are geared toward companies or developments of a minimum size. This size restriction reduces hardships on small companies and limits enforcement costs for the jurisdiction. The criterion often used for companies is the number of employees at a location. A TRO usually specifies that if a company has greater than the threshold number of employees, it must begin complying with measures of the local TRO. In some jurisdictions, multiple thresholds exist requiring different levels of participation relative to company size.

Developers of residential, commercial, or mixed-use properties may be forced to adopt a series of measures, depending on the size of the facility. For example, a developer may need to provide vanpool parking if the office complex being built exceeds a certain size or if it will house more than a given number of workers.

Enforcement is another aspect of TROs that needs to be taken into consideration. Some TROs are purely voluntary, relying on the good will of businesses in achieving trip-reduction goals. In areas where compulsory TROs have been enacted, compliance is unavoidable for employers and developers. While some TROs specify no penalties, the majority of programs specify fines for given periods of noncompliance. Enforcement and punishment are usually reserved for organizations that display willful disregard toward the measure.

Costs

The cost to develop and adopt a TRO is minimal. However, ongoing program administration, enforcement, and employer assistance by agencies should be factored into planning.

Benefits and Impacts

- VMT reduction.
- Trip reduction.
- Increase in alternative modes – vanpools, carpooling, transit, bicycle/pedestrian.

Michigan Plans and Policy

In January 2009, the City of Detroit signed the U.S. Conference of Mayor's Climate Protection Agreement that promotes transportation options such as commute trip reduction programs.

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