# SMART STREET SYSTEM CONCEPT WHITE PAPER

**Prepared For:**

**H-GAC**

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## HGAC Smart Streets White Paper

### Background

The concept of maximizing traffic flows along arterial streets to increase overall efficiency has sometimes been attributed to a Los Angeles based architect named John Brown. In the mid 1970's, Brown proposed the concept of the "Continuous Flow Boulevard" that envisioned the use of grade separations at cross streets and the elimination of left turn movements to promote traffic flows along arterial streets. Brown recognized that the traffic problems in Los Angeles (and other metropolitan areas) could not simply be addressed by adding more capacity, particularly in already built up areas, but rather should seek to maximize the use of existing facilities. The evolution of the Continuous Flow Boulevard has led to the development and implementation of the underlying concept under names such as "High-Flow Arterials", "Strategic Regional Arterials", "Express Streets" and "Smart Streets"

As early as the 1940's, the concept of improving arterial streets to maximize traffic flow was being contemplated in Houston. The 1942 Major Street Plan for Houston and Vicinity identified Buffalo Drive and West Gray Street as corridors for future arterial capacity expansion. Buffalo Drive eventually became Memorial Parkway/Drive while Allen Parkway was developed as a high level arterial facility parallel to West Gray Street. In 1947, the Houston Freeway Plan included an "Express Streets" designation with several corridors identified in southwest Houston. Almeda and US-59 were subsequently developed as freeways, while IH-610/South Loop now roughly parallels the Express Streets segments of Old Spanish Trail and Long Drive.[1]

The 1982 Houston Chamber of Commerce Regional Mobility Plan identified a substantial expansion of the arterial street network as a major element of that plan. This recommended expansion included grade separations at key arterial intersections to further enhance capacity. In 2005, the Houston-Galveston Area Council (H-GAC) introduced the concept of "Smart Streets" during the development of the 2025 Regional Transportation Plan (2025 RTP) as an approach to increase mobility, improve transit access and improve safety along strategic regional thoroughfares. By applying operational improvements, the Smart Streets concept specifically addresses two of the three major plan policies recommended to achieve the vision of the 2025 RTP. These policies include:

- Increase highway and transit system capacity
- Improve operations management of existing facilities

The concept of Smart Streets allows H-GAC to work cooperatively with implementing agencies to focus limited transportation revenues on improvements that will optimize operational performance along strategic regional thoroughfares thereby maximizing cost effectiveness. By incorporating Smart Streets tools like access management, traffic signal interconnection and coordination, intersection channelization, corridor management and transit service provisions, mobility benefits in terms of improved traffic

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[1] E. Slotbloom Houston Freeways, September 15, 2003

flows and transit service reliability can be enhanced along existing strategic regional thoroughfares and maximized in conjunction with arterial corridor widening projects.

The purpose of this paper is to provide an overview of the concept of Smart Streets and to elaborate on the application of the concept in the context of the H-GAC regional transportation planning process. This paper will initially explore the concept of Smart Streets drawing from the experience of two other metropolitan areas: Orange County, California, and Chicago, Illinois. This paper will then discuss specific elements of the Smart Streets concept and their applicability to the Houston-Galveston metropolitan area.

**What are Smart Streets?**

The HGAC 2025 RTP describes Smart Streets as a means to enhance regional mobility by adding system capacity to some principal arterials thereby partially reducing the need for additional freeway or tollway facilities. Smart Street enhancements are described as being able to "decrease vehicle delay through a range of options such as traffic light synchronization, deployment of roundabouts, medians, constructing or extending (as needed) turn bays, consolidation of duplicate driveways and as appropriate partial grade separation of some traffic lanes at major intersections."[2]

This definition of Smart Streets is generally consistent with the underlying application of this concept in other areas. The Institute of Transportation Engineers (ITE) has defined the concept as Super Street arterials that are "wide, multi-laned arterials with limited access provided from intersecting streets. To the degree possible, major intersecting streets are grade separated, in order to minimize the need for traffic signals. Super Streets take full advantage of as many traffic operations improvements as possible, including:

- traffic channelization;
- street widening;
- intersection widening;
- left/right turn lanes;
- two-way turn lanes;
- turn prohibitions;
- improved traffic control devices;
- removal of parking;
- lighting improvements;
- bus turnout bays;
- grade separations;
- reversible traffic lanes;
- railroad grade separations;
- one-way streets."[3]

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[2] HGAC 2025 RTP Executive Summary, June 2005
[3] ITE A Toolbox for Alleviating Traffic Congestion, 1989

The definition of Super Streets by ITE encompasses a full range of elements that could be applied to meet capacity needs. However, the underlying premise of Super Streets (or Smart Streets) is to maximize the efficiency of an existing arterial street using various system management tools. Typically the application of the Smart Streets concept involves using select elements specific to a given route. For different arterial routes, even within the same metropolitan area, traffic conditions, physical roadway characteristics, adjacent land uses and funding availability can all vary making the most appropriate level of Smart Street improvements also vary. For this reason, the combination of specific elements for improvements to each Smart Street route is usually defined by a detailed analysis that builds upon the underlying principles of the regions Smart Streets program.

## Examples of Smart Streets

To demonstrate the relevant details of a Smart Streets program, the following section will summarize the experience in two distinct and quite different metropolitan areas; the Chicago metropolitan area in Northeastern Illinois, and Orange County in Southern California. In both cases Smart Street programs have existed in some form for more than two decades resulting in the successful accomplishment of many Smart Street related arterial corridor improvements. A more detailed description of the respective programs is included in Appendix A.

### CATS Strategic Regional Arterials

The Chicago Area Transportation Study (CATS) introduced a Smart Streets type concept as part of the 2010 Transportation System Development (2010 TSD) Plan adopted in 1989. As part of a comprehensive strategy to address regional mobility needs, the 2010 TSD designated the Strategic Regional Arterial (SRA) system of high priority regional arterial streets and highways that could be improved to:

- Supplement the primary freeway system;
- Enhance public transportation;
- Accommodate commercial vehicle traffic; and
- Increase personal mobility and reduce congestion.

The SRA concept allowed CATS to highlight specific arterial highway facilities that could provide benefits to regional mobility by maximizing efficiency. A cornerstone of the SRA concept was the development of community-based studies for arterial improvements. The preparation of "pre-phase one" planning and design studies for the specific routes was used to determine the most appropriate combination of capacity and operational improvements for each route.

CATS most recent plan, Shared Path 2030 identified an expanded Strategic Regional Systems (SRS) concept incorporating arterial highways, bus transit, trucks and intermodal freight, and bicycle and pedestrian facilities. By intergrating different modes the Shared Path 2030 encourages the development of a strong multimodal transportation system. Shared Path 2030 reiterates the intents of the SRA concept by recommending the continued implementation of “strategies that improve the performance of arterial roads with emphasis on providing congestion relief and better integrating use of the region's entire transportation system." [4]

**OCTA Strategic Arterial Improvements/Smart Street Improvements**

As early as the 1970's, the Orange County Transportation Commission (OCTC) recognized that the arterial street system would need to carry an ever increasing share of traffic because of the difficultly of adding lanes to existing freeways or building new freeways. In 1982, OCTC introduced the concept of the High-Flow Arterial that provided for "the increase in capacity of arterial streets and highways (non-freeways) by whatever means are available, low cost or capital intensive (beyond TSM limits)." [5]

In 1984, OCTC proceeded to develop the Super Streets Program for Orange County, specifically identifying a network consisting of approximately 220 miles on 21 designated smart streets. This network of smart streets reflected priorities for addressing future transportation needs in Orange County and represented corridors where "enhancements in capacity may be achieved by a variety of measures" [6]

In 1992, the Super Street network was re-defined and re-named the Smart Street network. Smart Streets are identified as a specific functional class in the Orange County Master Plan of Arterial Highways (MPAH) and are simply defined as a "Principal or Major arterial with enhanced traffic-carrying capacity." [7]

A dedicated funding source for Smart Streets projects is included in the Measure M local option sales tax that provides revenues for transportation projects within Orange County. Incorporated as part of the Measure M Regional Street and Road Programs, approximately 2% of all Measure M revenues are utilized annually specifically for the implementation of Smart Streets related improvements. Since 1990, almost $115 million in Measure M funding has been expended on Smart Streets projects in Orange County. [8]

**Tools in the Smart Streets Toolbox**

An abundant array of tools is available to maximize traffic flow in accordance with the Smart Streets concept. The tools identified in this section are commonly used under the premise of Smart Streets. These Smart Street tools include:

- <u>Road Widening</u>
  Road widening is the most obvious strategy to increase capacity thereby improving traffic flow and reducing congestion. In terms of Smart Streets, road widening typically involves closing gaps and eliminating isolated bottlenecks. In addition, other techniques, such as removal of on-street parking, one-way streets, and reversible traffic lanes, can be used as cost-effective measures of adding capacity.

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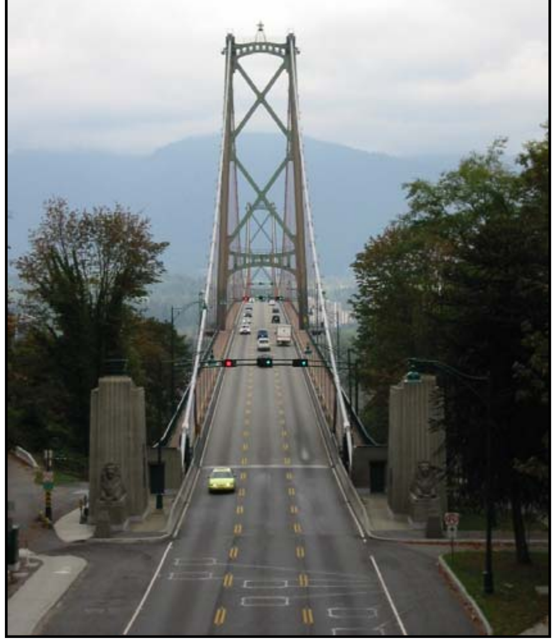
[4] CATS Shared Path 2030 Regional Transportation Plan, October 2003
[5] JEF Engineering <u>High-Flow Arterial Concept Feasibility Study</u>, May 17, 1982
[6] Van Dell and Associates Super Streets Program for Orange County, June 1984
[7] OCTA <u>Master Plan of Arterial Highways</u>, January 2007
[8] Orange County Business Council <u>Measure M Assessment 1990-2005</u>, April 17, 2006

*One-Way Streets* – One-way streets are viable where high volumes of traffic and vehicle conflicts occur. One-way streets allow for traffic signal timing to be optimized and relieve traffic congestion on adjacent streets by redistributing traffic, increasing capacity, and reducing intersection delays.

*Reversible Traffic Lanes* – Peak-hour traffic volumes are often greater in one direction. Reversible lanes allow movement one-way during part of the day and the opposite direction during another part of the day, corresponding with peak travel demand. Reversible lanes may be justified if there is evidence of congestion, the periods of congestion can be determined, there is adequate capacity at the end points, and there is a relatively high ratio split in directional traffic volumes. Reversible lanes typically integrate Intelligent Transportation Systems (ITS) elements such changeable message signs and overhead signals to indicate the direction of traffic flow at a particular time of day.



**Reversible traffic lanes on the Lions Gate Bridge in Vancouver, BC, with overhead signals to indicate direction of traffic flow**

- <u>Access Management</u>

Access management involves coordination between property access to enhance the performance and safety of the street system. Access management techniques typically applied to Smart Streets corridors include turning restrictions, driveway consolidation, and using frontage and backage roads.

**Barrier medians eliminate left turns to and from "Smart Street" Beach Blvd near Knott's Berry Farm in Buena Park, CA**

*Turning Restrictions* – Conflicts with turning vehicles can cause delay and safety problems. Prohibiting turning or restricting turning to select locations may eliminate or reduce such conflicts. Turns can be restricted during certain times of day using appropriate signage or by use of separate signal displays. Physical restrictions or median barriers can also be used to restrict turns.

*Driveway Consolidation* – Driveways are intersections and potential conflict points. Driveways can be consolidated where parking lots are linked or if the same site is served. Consolidation of driveways reduces the number of potential conflict points and linking adjacent parking lots allows vehicles to circulate between properties without accessing the street.

*Using Frontage/Backage Roads* – Frontage roads and backage roads provide physically separated access to properties. Frontage roads and backage roads collect and distribute local traffic to controlled intersections. Frontage roads and backage roads reduce the opportunity for vehicle conflicts by eliminating vehicles entering or exiting driveways directly from the arterial street.

Frontage roads provide on-street parking and access to local homes and businesses along Beach Blvd in Westminster, CA

- <u>Intersection Improvements</u>

Intersection improvements are a medium level of investment for Smart Streets. Intersection improvements separate major traffic movements thereby resulting in reduced vehicle conflict points, improvements in traffic flow and enhancements in safety. Intersection improvement techniques used for Smart Streets typically include channelization and grade separation.

*Channelization* – Channelization is the separation of traffic into definitive paths using traffic islands, pavement markings, or medians. The utilization of left and/or right turn lanes is the most common type of channelization using delineation of dedicated turn lanes and prohibiting undesirable turning movements from a particular lane.

Turning lanes can improve performance by minimizing conflict between turning traffic and through movements. Turning lanes with adequate storage eliminate "lane blocking" when traffic waiting to turn blocks the traffic flow through the intersection. Adding a second turn lane or having multiple turn lanes enable the timing for traffic signal turning phases to be reduced.

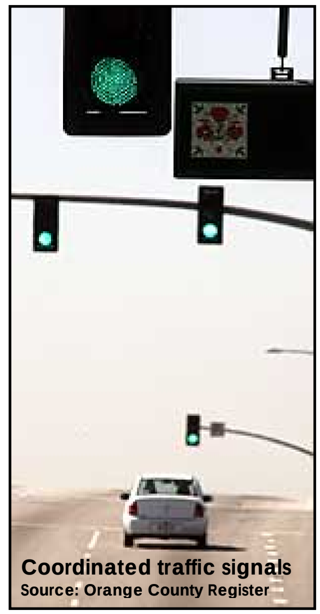

Grade separation of "Strategic Regional Arterial" Palatine Rd at IL-83/Elmhurst Rd in Prospect Heights, IL
Source: Microsoft Virtual Earth

*Grade Separation* – Grade separation is the physical separation of different flows of traffic. Grade separations may include the separation of a specific movements (i.e. a high volume turning movement), through movements on the primary street, or a full interchange separating all traffic directional movements. This technique may

**A grade separated railroad crossing near the Metrolink/Amtrak station in Anaheim, CA, maintains arterial traffic flows on "Smart Street" Katella Ave**

be costly due to construction and right-of-way requirements.

*Railroad Grade Separation* – Vertically separates an arterial street and railroad to improve safety and operating efficiency. Although this Smart Street technique can be high cost, the configuration is the optimum improvement where arterial streets cross railroad lines with high volumes of train traffic and/or frequent long, slow moving trains.



**Coordinated traffic signals**
**Source: Orange County Register**

➢ Signal Interconnect and Coordination

Traffic signal improvements generally provide the greatest payoffs for reducing congestion on surface streets.[9] Basic improvements that can be made to improve traffic flow include interconnected signals and computerized signal systems.

*Interconnected Signals* – Traffic signals can be connected to synchronize consecutive signals and maintain traffic flow. Signal coordination may include using pre-timed traffic signals when traffic patterns can be accurately predicted based on the time of day.

*Computerized Signal System* – Computerized traffic signal systems use master controls to increase timing plan flexibility and coordinate traffic signal operations. Computerized traffic signals can be designed to integrate dynamic traffic responsive control features that allow signals to adjust in response to changing traffic, and can allow on-line monitoring of operations. Installing advanced computer control systems to interconnect and coordinate traffic signal operations can be a relatively low cost improvement that results in substantial improvements in overall corridor mobility.

➢ Corridor Management

Transportation engineering has evolved to include application of flexible traffic control devices, software systems, computer hardware, and communications and surveillance technologies. Typically utilized in conjunction with computerized traffic signal systems, management of traffic using Intelligent Transportation Systems and Traffic Management Centers can further maximize traffic flow.

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[9] ITE A Toolbox for Alleviating Traffic Congestion, 1989

*Intelligent Transportation Systems (ITS)* – Communicating using electronic media, cellular communications devices and variable message signs can inform drivers of conditions or regulations applicable under certain conditions. Current technology allows ITS to have automatic controls that sense traffic and communicate information to drivers. Improved communication reduces uncertainty in drivers allowing for more consistent, steady movement and less indecision that could result in potential vehicle conflict or traffic delay.

**A variable message sign communicates information to drivers on Katella Ave in the Resort Area of Anaheim. CA**

**CCTV allows traffic engineers at a TMC to manage event traffic on Katella Ave near Angel Stadium in**

*Traffic Management Centers (TMC)* – A hub where traffic information is gathered to actively manage the transportation network. The TMC links various elements of ITS such as closed circuit television (CCTV) equipment, traffic data collection and monitoring stations, computerized traffic signal controllers and variable message signs to identify and react to changing traffic conditions in real-time. A TMC is particularly valuable for managing irregular traffic conditions that result from special events or emergency situations by allowing operators to manually override traffic control equipment to help maintain traffic flows.

- <u>Transit Service Provisions</u>

Adjusting bus stop locations and signal phasing, timing, and coordination to expedite bus transit improves general traffic flow and bus reliability. Techniques for providing transit service priorities include bus pullouts and modifications to traffic signal operations.


**A far-side intersection bus pullout along Katella Ave in Anaheim. CA**

*Bus Pullouts* – Bus pullouts can be used at locations where buses stop along arterial streets for passenger boarding or alighting. Pullouts can reduce delay and improve safety by eliminating queuing behind stopped buses. Typically, pullouts are located mid-block or on the far-side of a major intersection allowing buses to clear an intersection before negotiating a stop. For a relatively low cost, bus pullouts can provide substantial benefits, particularly in corridors with high traffic volumes and frequent bus service

*Transit Signal Priority and Transit Signal Preemption* – Granting priority treatment to buses at signalized intersections can contribute to operating buses in an efficient, reliable manner along arterial streets. Transit Signal Priority allows buses to be detected on the approach to a signalized intersection and the timing and phasing adjusted to provide clear passage through the intersection. Active transit signal priority typically incorporates early green actuation (more quickly turns the signal to green) and/or extended green phasing (continues to hold the signal at green) in anticipation of the bus approaching and passing through the intersection.

Transit signal preemption interrupts the signal cycle to facilitate the transit service requiring the approaching bus to communicate the needed green time with the signal. The signal cycle is interrupted to provide the green time for the transit vehicle. After the interruption, the cycle returns to normal signal timing and phasing.

Transit signal priority is most commonly used for Smart Streets applications where general improvements in transit service reliability are desired. Transit signal preemption is typically used in corridors with very high frequency bus service, or with other types of transit such as bus rapid transit or light rail transit, where explicit signal phasing is required to ensure transit service reliability and safety.

- Pedestrian Considerations

Providing facilities that are pedestrian oriented can minimize conflict points and help to maintain traffic flow in Smart Street corridors. Consolidated pedestrian crossings, grade separated crossings, and provision of pedestrian facilities and amenities that distinguish between pedestrian and vehicle circulation can encourage pedestrian movement and improve pedestrian safety.

*Consolidated Pedestrian Crossings* – Consolidating pedestrian crossings minimize the conflict points between pedestrians and vehicles by concentrating pedestrian crossings at the safest, fully controlled locations. Benefits to traffic flows are afforded when pedestrian crossing locations are consolidated and redundant time consuming signal phases specifically for pedestrian crossings can be eliminated.

A grade separated pedestrian crossing of an arterial street
Source: FHWA

*Grade Separated Pedestrian Crossings* – Grade separation of vehicles and pedestrians can be used to increase pedestrian safety and reduce congestion. Although relatively high cost, grade separated pedestrian crossings can be appropriate in areas with high concentrations of pedestrian activity and high traffic volumes along the arterial street.

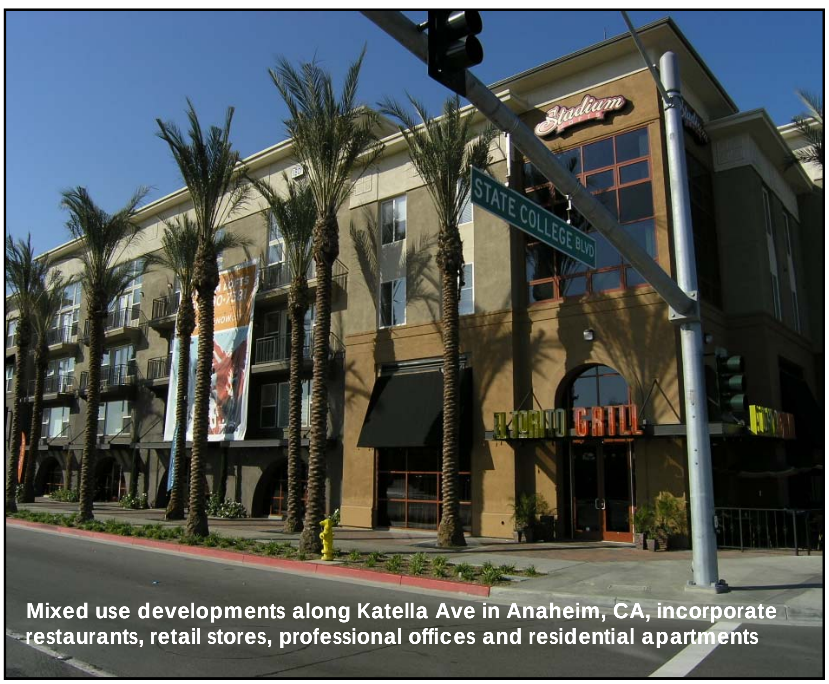
Sidewalks separated from traffic by landscaping promotes walking along Katella Ave in Anaheim, CA

Sidewalk maps at intersections help pedestrians navigate Katella Ave in the Anaheim Resort area

*Provision of Pedestrian Facilities* – Pedestrian amenities that support walking, bicycling, and transit use, such as the provision of wide, well maintained sidewalks and landscaped separation between traffic lanes and sidewalks, can encourage non-vehicular modes of transportation. Where walking, cycling or transit can be encouraged as an alternative to using an automobile, vehicular travel demand and resulting congestion can be reduced.

➢ <u>Land Use Design Considerations</u>

Land uses can have a significant impact on the travel demand and traffic flows along a particular corridor. Land uses along Smart Streets should be designed to consider the scale, size and function of the street. Land use design considerations may include mixed-uses, higher density uses, incorporating frontage or backage roads, internal property circulation, parking lot size, and Transit Oriented Development.




Mixed use developments along Katella Ave in Anaheim, CA, incorporate restaurants, retail stores, professional offices and residential apartments

*Mixed-Use Development* – Creating a multi-use development provides a range of services and attractions that can reduce the number of vehicle trips and encourage different modes of transportation, such as transit, cycling or pedestrian activity. Retail establishments, specialty shops, neighborhood services, restaurants, professional offices and hotel accommodations can be located within the same development. Residential uses can be provided in apartments and lofts above the street-level shops.

*Transit Oriented Development (TOD)* – Transit ridership increases significantly as residential and employment densities rise, thereby allowing for a more efficient and effective use of the transportation system. TOD seeks to actively plan for the collocation of higher density residential, retail and employment land uses in the vicinity of key transit centers. As an element of Smart Streets, TOD can be emphasized in corridors where high frequency transit service is available to potentially better serve future residents and businesses.

*Internal Property Circulation* – Internal connections between properties, such as connecting parking lots between retail centers, allows vehicles to circulate between businesses without having to re-enter the roadway. The shared parking and access can also positively benefit businesses by providing more convenient access from one to another.

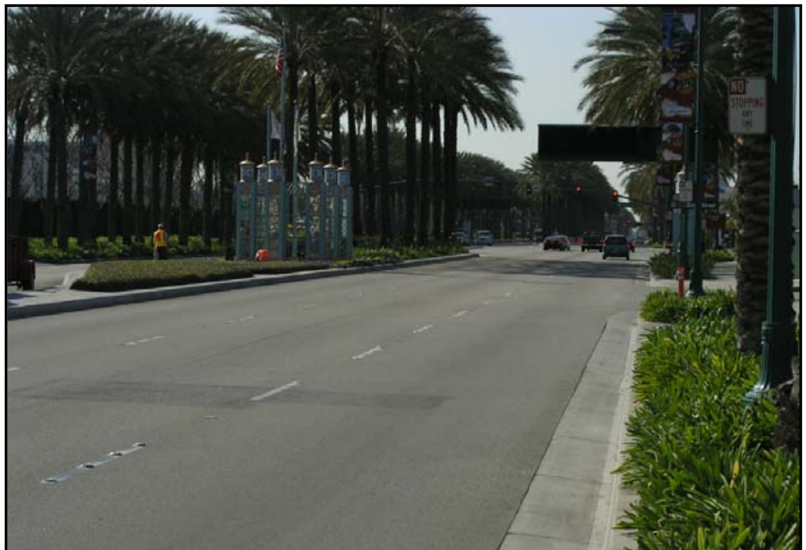
- <u>Aesthetics</u>

Streetscape improvements such as median plantings, crosswalk and intersection enhancements, and traffic sign designs help to streamline traffic flow and focus access into activity centers. Additional measures to improving traffic flow through aesthetics include removing distractions to drivers, such as redundant signage or power lines that can be placed underground.

*Landscaping* – Landscaped medians provide a physical separation between opposing traffic flows. These medians are a standard form of channelization and divide the street profile making it easier for drivers to concentrate on the direction of flow. Landscaping along the edge of pavement can provide a buffer between vehicle traffic and the adjacent land uses and associated pedestrian traffic. Careful consideration is needed to select the proper location and type of plantings to refrain from creating visual obstructions or maintenance problems in Smart Streets corridors.

*Pedestrian Crossing Distinctions* – Many cities and suburban areas have added aesthetic treatments to their crosswalk designs. Treatments include distinguishing crosswalks with the use of brick paving, patterned concrete, cobblestone, granite edging, colored pavement and solid painting. These pedestrian crossing distinctions allow for a well-defined separation between the different transportation systems and uses along the corridor.

*Traffic Signs and Sign Hardware Supports* - Traffic control device supports should be designed to be safe and compatible with their surroundings. Design considerations may include span wire installations for traffic signals to allow the poles to be set back, combination poles that carry street lights and traffic signals, and tapered mast arm traffic signal designs in lieu of span wire. Additional considerations can include the use of clear and concise directional signage to simplify navigation for drivers, the use of consistently themed signage and hardware supports to reflect a specific corridor or district, and programs to reduce the excessive or redundant use of business signage that can create visual clutter and a distraction for drivers.



**Well maintained landscaping, ornamental signage and entrance features help define Katella Ave through the Anaheim Resort area**

**What are the benefits of Smart Streets?**

The underlying premise of Smart Streets is to improve the overall efficiency of the transportation system by maximize the effectiveness of other transportation system investments. Put simply, Smart Streets lets users to get more out of arterial roads and streets.

The implementation of Smart Streets allows for increased capacity and improved traffic flow along arterial corridors without adding additional lanes, or to achieve even greater increases in capacity and traffic flow in conjunction with other road widening projects. According to FHWA, "converting a typical suburban arterial with signalized intersections to a super street could increase capacity by as much as 50 to 70 percent, while at the same time significantly reducing delays."[10]

While the benefit of implementing a specific Smart Street element may be limited, the cumulative impact of implementing a complimentary set of Smart Street tools can potentially be substantial. For example, each traffic signal per mile reduces average speed along a roadway by about 2 to 3 miles per hour.[11] As indicated in the following table, any signal spacing greater that two signals per mile (or ½ mile between signals) has a significant impact on traffic flow. Furthermore, the frequency of signals also has a direct relationship to the total number of crashes on a given roadway

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[10] FHWA Urban and Suburban Highway Congestion Working Paper No. 10, December 1987.

[11] TRB Impacts of Access Management Techniques NCHRP Report 420, 1999

**Table 1. Relative Increases in Travel Time as Signal Spacing Decreases**[12]

| Signals Per Mile | Increase in Travel Time |
|---|---|
| 2 | - |
| 3 | 9% |
| 4 | 16% |
| 5 | 23% |
| 6 | 29% |
| 7 | 34% |
| 8 | 39% |

Similarly, the frequency of access points can reduce travel speeds and increase crash rates. Travel speeds decrease by about 0.25 miles per hour for every access points per mile while crash rates increase approximately 4%.[13] Table 2 highlights the combined relationship between crash rates, the frequency of access points and the spacing of signalized intersections.

**Table 2. Representative Crash Rates (Crashes per Million Vehicle Miles of Travel) by Access Density**[14]

| Unsignalized Access Points Per Mile | Signalized Access Points Per Mile | | | |
|---|---|---|---|---|
| | ≤ 2.00 | 2.01 - 4.00 | 4.01 - 6.00 | ≥ 6.00 |
| ≤ 20.00 | 2.6 | 3.9 | 4.8 | 6.0 |
| 20.01 - 40.00 | 3.0 | 5.6 | 6.9 | 8.1 |
| 40.01 - 60.00 | 3.4 | 6.9 | 8.2 | 9.1 |
| ≥ 60.00 | 3.8 | 8.2 | 8.7 | 9.5 |
| **Average for All** | **3.1** | **6.5** | **7.5** | **8.9** |

An access management policy that limits the frequency of access can have a substantial benefit to travel speed and safety by reducing the potential for conflicts in the traffic flow. However, limiting access to arterial streets is sometimes impractical making alternative Smart Street elements appropriate for consideration. Where access to and from the arterial street is required, the use of turning lanes can be an effective means of reducing the impact on traffic flows.

For example, the use of left turn lanes to remove left turn vehicles from the traffic flow can reduce crash rates by roughly 50% and can increase roadway capacity by as much as 33%.[15] Similarly, there is a clear relationship between vehicles making right turns and the delay incurred by through traffic, although the impacts are less substantial. By reducing interference to the traffic flow, the provision of dedicated right

[12] TRB Impacts of Access Management Techniques NCHRP Report 420, 1999
[13] TRB Impacts of Access Management Techniques NCHRP Report 420, 1999
[14] TRB Impacts of Access Management Techniques NCHRP Report 420, 1999
[15] FHWA Benefits of Access Management, 2003

turn lanes can effectively increase capacity in the right most through lane and reduces crashes by about 20%.[16]

Median treatments can also provide a substantial benefit to traffic flow and safety. The provision of a nontraversable median can reduce crash rates by over 40% on urban arterials[17] while median two-way left turn lanes (TWLTL) can reduce crashes by 35% and increase capacity by up to 30%.[18]

By combining multiple Smart Street elements, the benefits to traffic flows are effectively compounded. The use of increased signal spacing, turning lane provisions at intersections, and access management can substantially improve traffic flow and safety in a corridor. Furthermore, the incorporation of ITS elements that monitor and respond to changing traffic can help to optimize traffic flows on Smart Streets during extreme traffic conditions, special events or emergencies. This is relevant in the Houston area where Smart Streets could also serve as secondary hurricane evacuation routes, particularly for shorter trips across the region or to access the primary freeway evacuation routes.

Integrating considerations for other transportation modes can extend the benefits of Smart Streets from just automobile traffic to transit. A prominent example of incorporating multi-modal elements has been the deployment of transit signal priority (TSP) technologies along Cermak Road in Cicero, IL. The project involves 15 signalized intersections along a 2.5 mile segment that have been equipped with TSP equipment that provides early green phase activation and time extension for TSP transponder equipped buses. These buses experienced a 44% increase in average travel speeds, up to a 33% reduction in travel time, and an overall improvement in schedule reliability.[19]

The improved efficiency in transit operations has enabled a reduction in the number of vehicles required to operate routes along this corridor. The coordination of traffic signals and the improvement in transit service operation in the corridor have also realized a modest reduction in average vehicle delay for all vehicles traveling along Cermak Road.

### How Are Smart Streets Implemented?

Typically, Smart Streets are designated at a regional level, often as an element of a Regional Transportation Plan. Smart Streets are typically recommended for implementation as a part of the plans overall regional planning strategy. Screening level criteria is often used to define the Smart Streets network. The network is accompanied by descriptive text outlining procedures for project development.

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[16] FHWA Benefits of Access Management, 2003

[17] FHWA Benefits of Access Management, 2003

[18] Kentucky Transportation Center Quantification of the Benefits of Access Management for Kentucky, July 2006

[19] IDOT Cermak Road Bus Priority Project Final Report, 1998.

The Chicago area Strategic Regional Arterial (SRA) system follows this typical process. Originally introduced as part of the MPOs 2010 Transportation System Development (2010 TSD) Plan, the SRA system was defined through consultation with the various implementing agencies. The 2010 TSD prioritized these facilities for funding and outlined a comprehensive community-based design process for arterial improvements. For the purposes of completing the regional air quality conformity determination, a representative set of SRA related improvements was defined for analysis based on the highest priority and most probable projects, anticipated revenues, and estimated unit project costs. The representative list was not intended to reflect actual priorities for project implementation, but was illustrative for the sole purpose of completing the conformity determination.

Similarly, the Orange County Smart Streets program was initiated in the early 1980's as a recommendation of the Transportation Commission's Citizens Advisory Committee. The following criteria were established to screen facilities for inclusion on the network:

- Existing Street Traffic Volumes Served
- Existing Continuous Length with High Volumes Served
- Existing Number of High Volume Cross Streets
- Future Forecast Street Traffic Volumes Served
- Future Forecast Continuous Length with High Volumes Served
- Future Forecast Number of High Volume Cross Streets
- Future Forecast Roadway Capacity Impacts
- Network Integration
- Land Use Compatibility
- Noise Impacts
- Constraints to Implementation
- Cost
- Cost Effectiveness

The recommended Super Street Network was then refined to prioritize corridors for implementation using the following criteria:

- Existing Daily Vehicle Miles of Travel
- Future Daily Vehicle Miles of Travel
- Existing Daily Vehicle Miles of Travel per Mile
- Future Daily Vehicle Miles of Travel per Mile

The recommended network of Super Streets was subsequently integrated into the Orange County Master Plan of Arterial Highways (MPAH). The MPAH serves as the basis for establishing roadway functional classification throughout Orange County. Smart Streets represent the highest arterial highway function class designation in the MPAH.

In both examples, Route Concept Studies are an integral part of the project development process to refine the tools applicable to an individual corridor. Route Concept Studies provide a mechanism to evaluate the specific needs of a corridor leading to the development of an overall strategy and a preliminary concept plan.

**What About Smart Streets for Houston?**

For over 50 years, Smart Streets elements have been incorporated on arterial highway projects in the Houston area. As early as 1947, the Houston Freeway Plan identified "Express Streets" in southwest Houston as a means to increase the efficiency of strategic arterial routes. Numerous arterial facilities around the Houston area have been improved to incorporate Smart Streets elements, with Memorial Parkway/Drive, Allen Parkway, Westheimer Road, FM 518, SH 6 and FM 1960 being notable examples. However, the development of these facilities to incorporate Smart Streets elements has tended to be ad-hoc and not reflected in a sustained, coordinated regional Smart Streets initiative.

The Houston-Galveston Area Council (H-GAC) planning and project development processes incorporate the basic framework for implementing a successful Smart Streets program. Specifically, the H-GAC regional transportation plan currently recommends a strategy for integrating Smart Streets improvements on a network of facilities within the region, and H-GAC sponsors the preparation of Access Management Studies and Corridor Mobility Studies along strategic routes for the purpose of identifying "a plan that addresses short-, medium- and long-term solutions for improved mobility, enhanced land use, reduced traffic delays and improved safety that will create an atmosphere for economic vitality within the project area."[20] Providing better linkages between these two fundamental Smart Streets elements, refining program details, and prioritizing funding for Smart Streets projects are necessary to allow H-GAC to emulate the success of the Smart Streets example described.

In 2005, the Houston-Galveston Area Council (H-GAC) introduced the concept of "Smart Streets" as part of the 2025 Regional Transportation Plan (2025 RTP). The Smart Streets concept specifically addresses two of the major plan policies including:

- Increase highway and transit system capacity
- Improve operations management of existing facilities

Incorporating Smart Streets as part of the 2025 RTP is intended to develop the concept as a cooperative, regional strategy for maximizing the efficiency of strategic arterial corridors in the Houston-Galveston metropolitan area. Unlike previous ad-hoc applications of the Smart Streets concept in Houston, H-GAC is seeking to establish a coordinated framework for defining, prioritizing and implementing a network of arterial facilities to be improved as Smart Streets thereby accomplishing the following goals:

- Improve mobility
- Improve safety
- Improve air quality
- Improve travel options

To enhance the effectiveness of the existing Smart Streets initiative, it is recommended that H-GAC incorporate the following considerations:

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[20] H-GAC FM 1960 Access Management Study, October 2004

- Strengthen the underlying policy support for the Smart Streets program in the Regional Transportation Plan (RTP). Although the current RTP proposes the implementation of a Smart Streets program, the plan recommendations should be expanded to address three specific items:
  - Building upon RTP goals relating to mobility, safety, land use integration and environmental quality to develop criteria for selecting arterial highway facilities to be incorporated into the Smart Streets network. The criteria should be clear, concise and measurable leading to the delineation of a defensible network of Smart Streets. Consistent with the underlying goals for Smart Streets in the Houston area, suitable quantitative criteria could include existing and future forecast traffic volumes and levels of service (for both automobile traffic and transit services), existing accident rates, and estimated changes in vehicle emissions and fuel consumption following improvements. Additional qualitative criteria could include the incorporation of multi-modal elements to facilitate transit, bicycle and pedestrian activity, the consideration of land-use policies that reduce trip generation in the corridor, and the ability of a project to eliminate 'gaps' or 'bottle necks' on facilities.
  - Clearly outline the process for advancing Smart Street projects from a plan strategy to actual improvements. In particular, explain the purpose and significance of the Smart Street designation, and the use of Route Concept Plans to develop route specific Smart Street concept plans.
  - Establish policies that prioritize funding for Smart Streets facilities as part of the regional transportation planning and programming process. This does not necessarily require the availability of new funding resources or a specific set aside of funds, but can be accomplished by the establishment of project selection criteria that emphasizes Smart Streets within the context of existing funding programs.

- Clarify the designation of Smart Streets as part of overall regional planning process. A Smart Streets program can be effectively employed at a regional level by providing policies and procedures that help promote comprehensive planning and funding prioritization for facilities along the most significant regional roadways. Cooperation between multiple jurisdictions and transportation agencies is a key to the success of a Smart Streets program and this cooperation can be fostered at a regional level by H-GAC. Smart Streets do not necessarily need to be reflected in local thoroughfare plans for consistency, but should be included in future General Plan Circulation Element updates. Smart Streets could be reflected as an overlay to existing arterial function class designations or by reference in accompanying plan text, and should include, as a minimum, requirements for the preservation of right-of-way (typically a minimum of 120 feet) and development guidelines for adjacent land uses along Smart Streets routes.

- Utilize the current H-GAC Access Management Study process to develop Smart Streets preliminary design concepts for identified corridors. Although the Access

Management Study process incorporates many elements of Smart Streets, the parameters of the Access studies can be expanded to include explicit consideration of the full range of Smart Street tools for the respective study corridors. The Access Management Study process can also be used to emphasize interagency coordination and community involvement to accomplish the benefits of Smart Streets in key regional arterial corridors.

## Access Management in Houston

To illustrate details of Smart Streets in Houston, the following section will summarize three Access Management studies conducted on local regional arterial streets. These studies proposed useful tools used to develop Smart Streets as a means of decreasing travel time, increasing safety, introducing multi-modal roadways and connecting the surrounding land use to the arterial roadway. More information regarding the studies and the access management techniques proposed for the arterial roadways can be found in the respective studies.

### FM 1960 Access Management Study

In 2004 an access management study for FM 1960, a major east-west arterial located in northern Harris County was conducted. Currently there is commercial, retail and residential development along the roadway. Accessing the development long the roadway creates delay to motorists. Below is a summary of the existing conditions and suggested access management tools that could relieve congestion and increase safety while creating a multi-modal, walkable street.

Five corridor goals addressed in the plan are:

- Improve mobility and reduce traffic delay
- Improve safety/decrease the number of crashes
- Provide for an open process in the project's development
- Offer opportunities for enhanced streetscape and land use
- Provide solutions that can be implemented in a timely manner

The existing FM 1960 roadway has a total of seven lanes with a continuous center turn lane. There are a high number of crashes on the roadway and congestion contributes to significant travel time delay. The arterial roadway intersects with two north-south freeways and many major thoroughfares.

Recommendations to improve traffic flow and roadway efficiency on FM 1960 include driveway consolidation, constructing continuous sidewalks and reducing existing signage and adding informative directional signage. The addition of raised medians with channelized median openings to provide turning space, act as refuge for pedestrians crossing the street and limit vehicle conflict points was also recommended.

**Westheimer Corridor Mobility Study**

Westheimer passes through two major regional business districts, and serves as an east-west connector to commercial, residential and recreational development. Improving traffic efficiency while maintaining the street's vitality and usability were taken into consideration during the study. Below is a summary of the existing conditions and suggested access management tools that could relieve congestion and increase safety while creating a multi-modal, walkable street.

Three corridor priorities were established through public involvement. The priorities are:

- Improved traffic flow
- Intersection improvements
- Access to/from properties

In addition to the goals listed above improvements to mass transit, creating a pedestrian friendly environment and improving the aesthetics of the street were identified as the public's greatest concerns for the Westheimer corridor.

Currently Westheimer Road is an eight lane roadway with raised medians, creating four travel lanes in each direction. Westheimer intersects with major north-south highways and numerous thoroughfares along with many local streets. High peak period traffic volumes are experienced which contributes to congested intersections along the roadway. Also adding to the congestion is the high number of driveway access point along Westheimer. Some areas of Westheimer have a 56 driveway access points per mile. The large number of driveways creates numerous conflict points that decrease traffic efficiency.

The study examined the existing street conditions and proposed some access management tools to be implemented in three phases. The first phase would introduce median, intersection and signal improvements along the corridor. During the second phase, governmental officials would work with property owners to install tree lined sidewalks along the roadway and consolidate driveway entrances into retail and commercial locations along the roadway. Long-range visions of Westheimer include the development of pedestrian villages along the roadway. The introduction of tree lined sidewalks would make Westheimer a safer pedestrian street and encourage pedestrian oriented development to occur in appropriate areas, commencing the third phase in the corridor mobility study.

**FM 518 corridor Access Management Plan**

FM 518 is a growing corridor that is experiencing increased congestion and safety concerns fro rapid development. The roadway is a major east-west arterial with four main lanes and a center turn lane. Below is a summary of the existing conditions and suggested access management tools that could relieve congestion and increase safety while creating a multi-modal, walkable street.

Five corridor goals were established through public involvement. The goals are:

- Improve Safety
- Identify Short-Term Transportation Solutions
- Improve Traffic Flow
- Reduce Motorist Delay
- Assess Long-Term Corridor Needs

FM 518 has high crash rates compared to other regional roadways. Driveway consolidation and medians are two recommendations to decrease traffic conflicts and reduce crashes without significant changes to the roadway. Currently there is a discontinuous sidewalk along FM 518. Constructing continuous sidewalks and bike lanes that connect to development adjacent to the roadway will reduce pedestrian-vehicle conflicts and increase safety for all users.

Short term recommendations for FM 518 focus on improvements that do not require additional right-of-way acquisition and have short construction times. The recommendations include traffic signal improvements, intersection improvements, installation of raised medians, and directional signage improvements.

Longer term recommendations require lengthy construction time and coordination with adjacent land owners to implement access management tools. The recommendations are consolidating driveways, park & ride facility improvements, installing sidewalks and crosswalks and expanding bus service.

**What will Smart Streets Cost?**

By developing unit costs for each of the components of Smart Streets and applying those to the network of strategic arterials in the Houston area, it is possible to generate a planning-level cost estimate for implementing a system of Smart Streets. Table 3 below presents the costs of the Smart Street System as defined by the component pieces listed in the 2035 MTP. As the construction costs of grade separations can vary depending on the nature of the grade separation, the Smart Streets with grade separations are presented as a range of potential cost.

**Table 3. Smart Street System Cost (in billion dollars, March 2007)**

| | |
|---|---|
| Streets w/ Grade Separation | $4.80 - $7.42 |
| Streets w/o Grade Separation | $1.38 |
| Total System Cost | $6.18 - $8.80 |

Appendix B presents costs for each of the Smart Street "projects" identified in the 2035 MTP. An important caveat to the costs listed for each project is that the cost was developed by simply applying the unit costs, which are listed in Appendix C, to the project length. The cost does not reflect a detailed review of the specific project to identify unique issues that could possibly increase or decrease the cost estimate. The unit costs are general in nature and reflect best estimates of "typical" cost for a Smart Street component.

# APPENDIX A

## EXAMPLES OF SMART STREETS

**CATS Strategic Regional Arterials**

The Chicago Area Transportation Study (CATS) (now part of the Chicago Metropolitan Agency for Planning (CMAP)) introduced a Smart Streets type concept as part of the Metropolitan Planning Organization's (MPOs) 2010 Transportation System Development (2010 TSD) Plan adopted in 1989. The 2010 TSD recognized that due to increasing regional growth and resulting congestion, the Chicago area freeway system would be unable to meet the future demand for long-distance, high volume auto and commercial vehicle traffic. As part of a comprehensive strategy to address regional mobility needs, the 2010 TSD designated the Strategic Regional Arterial (SRA) system that delineated a network of high priority regional arterial streets and highways that could be improved to:

- Supplement the primary freeway system;
- Enhance public transportation;
- Accommodate commercial vehicle traffic; and
- Increase personal mobility and reduce congestion.

The SRA concept allowed CATS to highlight specific arterial highway facilities that could provide benefits to regional mobility by maximizing the efficiency of these existing facilities. Furthermore, the SRA designation prioritized these facilities for funding as part of the transportation planning and programming process. A cornerstone of the SRA concept was the application of a comprehensive design process that involved the development of community-based studies for arterial improvements and helped to prioritize arterial improvements regionally. Specific route improvements were designed to relieve bottlenecks at intersections, provide alternatives to on-street parking and improve low structural clearances.

In developing parts of the region, expansions of existing roads, new construction and corridor traffic management strategies were identified to accommodate growing traffic and serve major trip generators. Right-of-way preservation, signal coordination, new turn lanes and medians were applied for better traffic control and access along suburban arterials. In rural areas, preserving through-movement of traffic so as not to disrupt the character of the area was identified as a priority. The ability to preserve right-of-way and control access were key elements to minimize disruption and provide for future mobility needs. Strong land development policy was emphasized as being critical to preserving the integrity of the strategic regional arterials in suburban and rural areas.

The original 2010 TSD SRA system comprised a designated subset (about 1,400 miles) of the existing arterial network. Spacing ranged from about three miles in the more densely developed areas to eight miles in the rural areas. This designated subset provided the base upon which to conduct detailed community-based studies over a period of about 10 years.

The preparation of "pre-phase one" planning and design studies for the specific routes was used to determine the most appropriate combination of capacity and operational improvements for each route. The resulting "SRA Design Concept Report" process provided extensive opportunities for local community involvement and incorporated consideration of the following specific elements:

- The types of roadway improvements needed for each route including additional lanes, signalization and interchanges.
- Right-of-way requirements.
- Access to the regional transit system.
- Ways to manage access which would improve through traffic movement and reduce conflicts.
- Coordination of recommended route improvements with projected development.
- Bicycle and pedestrian travel.
- Potential environmental concerns.

The SRA concept continues to be an integral element of CATS long range transportation planning process and has been expanded in subsequent plans to incorporate other modal systems. CATS most recent plan, Shared Path 2030 identified four distinct modal systems in order to guide the funding and implementation of particular types of improvements. These include arterial highways, bus transit, trucks and intermodal freight, and bicycle and pedestrian facilities. By intergrating different modes under the expanded Strategic Regional Systems (SRS) concept, Shared Path 2030 encourages the development of a strong multimodal transportation system that includes coordination of service between and among travel modes and project design that promotes "choice" between and among travel modes.

Specific to the regional arterial highway system, Shared Path 2030 reiterates the intents of the SRA concept by recommending the continued implementation of "strategies that improve the performance of arterial roads with emphasis on providing congestion relief and better integrating use of the region's entire transportation system." [21]

*Shared Path 2030* specifically identifies the following operational management techniques to be considered during the development of SRA routes:

- Adopt a comprehensive design that coordinates access to individual land uses with the need to optimize the flow of traffic on the new facility.
- Discourage access permits for individual driveways and entrances in favor of providing consolidated entrances or frontage roads.
- Limit introduction of new traffic signals.
- Provide transit accommodation and priority.
- Provide safe and comfortable accommodation for pedestrian and bicycle travel.

Furthermore, *Shared Path 2030* specifically identifies the following types of new arterial structures where appropriate along SRA routes:

[21] CATS Shared Path 2030 Regional Transportation Plan, October 2003

- River (or other natural feature) crossings in order to relieve congestion or provide improved accessibility.
- Rail – arterial grade separations in order to reduce conflicts and improve safety.
- Arterial – arterial grade separations in order to improve traffic flow and reduce congestion.
- Bicycle and pedestrian grade separations in order to provide improved pedestrian access and promote safety.
- Freeway and tollway interchanges in order to improve accessibility and support efficient economic development.

Figure A-1 illustrates the network of Strategic Regional Arterials identified as part of the CATS Shared Path 2030 Plan. Related improvements to specific SRA routes vary by corridor and range from highest priority fully implemented SRA corridors to lower priority SRA corridors to be addressed in the future. To provide funding for the planning and implementation of improvements to SRA routes (and all other SRS facilities), the CATS regional long range transportation planning and transportation improvement programming processes have incorporated mechanisms that prioritize SRS related projects over other transportation improvement projects.

**OCTA Strategic Arterial Improvements/Smart Street Improvements**

In Orange County, California, the arterial street network carries approximately 50% of total traffic[22]. As early as the 1970's, the Orange County Transportation Commission (OCTC), now part of the Orange County Transportation Authority (OCTA), recognized that the arterial street system would need to carry an ever increasing share of the growing travel demand in the region because of the difficultly of adding lanes to existing freeways or building new freeways in the predominately built-out urban and suburban county. As a result, OCTC (and now OCTA) has emphasized the importance of maximizing the efficiency of arterial streets to increase overall system capacity by establishing the Strategic Arterial Improvement or "Smart Street" concept.

In 1982, OCTC introduced the concept of the High-Flow Arterial that provided for "the increase in capacity of arterial streets and highways (non-freeways) by whatever means are available, low cost or capital intensive (beyond TSM limits)." OCTC felt that substantial improvements in travel time, number of stops, fuel consumption, and vehicle emissions could be achieved through the implementation of a high-flow arterial, or smart street concept by seeking to improve roadway traffic capacity and smooth traffic flow on selected roadway corridors through measures such as traffic signal coordination, bus turnouts, parking restrictions, intersection improvements, and additional travel lanes. OCTC determined that existing delay could be reduced by as

[22] OCTA 2006 Long-Range Transportation Plan, July 24, 2006

Insert Figure A-1

much as 50%, fuel consumption reduced by 16% and emissions reduced by 29% by implementing "optimum" smart street improvements along major arterial highways.[23]

In 1984, OCTC proceeded to develop the Super Streets Program for Orange County, specifically identifying a network consisting of approximately 220 miles on 21 designated smart streets. This network of smart streets reflected priorities for addressing future transportation needs in Orange County and represented corridors where "enhancements in capacity may be achieved by a variety of measures such as:

- Traffic signal synchronization
- Removal of parking and/or pot widening to increase traffic carrying capacity
- Access limitation – right turns only, or no access (streets and/or driveways)
- Frontage roads
- Pedestrian grade separations
- Intersection grade separations (overpasses or underpasses)
- Grade-separated turning movements
- Other elements which may be found useful"[24]

OCTC subsequently selected Beach Boulevard as the first corridor to be improved incorporating elements of the Super Streets concept. Revenues for completing Super Streets improvements were derived from Measure M, the voter approved local option sales tax for transportation in Orange County, which allocated approximately $120 million over 20 years for this purpose.

In 1992, the Super Street network was re-defined and re-named the Smart Street network. Given the magnitude of costs associated with these improvements and the philosophy of completing corridor-wide improvements, OCTA decided to focus funding under the program to no more than the four streets already underway. In March 1993, OCTA determined that the following streets be completed as the initial Smart Streets corridors:

- Beach Boulevard (Pacific Coast Highway to Imperial Highway)
- Imperial Highway (Los Angeles County to Santa Ana Canyon Road)
- Katella Avenue (I-605 to SR-55)
- Moulton Parkway (Main Street in Santa Ana to Del Prado in Dana Point)

Originally comprising these four major arterials, the local agency acceptance of the Smart Street program and the success of completed Smart Street projects have expanded the program. Smart Streets are identified as a specific functional class in the Orange County Master Plan of Arterial Highways (MPAH) and are simply defined as a "Principal or Major arterial with enhanced traffic-carrying capacity."[25] Figure A-2 illustrates the Orange County MPAH including designated Smart Streets. In Orange County, Smart Streets are typically six to eight lane roadways with enhanced traffic carrying capacities ranging from 60,000 to 79,000 vehicles per day, depending on the

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[23] JEF Engineering High-Flow Arterial Concept Feasibility Study, May 17, 1982
[24] Van Dell and Associates Super Streets Program for Orange County, June 1984
[25] OCTA Master Plan of Arterial Highways, January 2007

Insert Figure A-2

number of lanes, degree of access control, peak period loading and the configurations of major intersections.

A dedicated funding source for Smart Streets projects is included in the Measure M local option sales tax that provides revenues for transportation projects within Orange County. Incorporated as part of the Measure M Regional Street and Road Programs, approximately 2% of all Measure M revenues are utilized annually specifically for the implementation of Smart Streets related improvements. Recent Smart Streets projects in Orange County have included the addition of travel lanes, signal coordination and bus turnouts along designated routes. Since 1990, almost $115 million in Measure M funding has been expended on Smart Streets projects in Orange County.[26]

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[26] Orange County Business Council Measure M Assessment 1990-2005, April 17, 2006