Chapter 3
EXISTING CONDITIONS

The task of planning for the future multi-modal transportation system begins with analyzing the conditions of the key elements of the transportation system. The sections that follow describe the existing regional transportation network and highlight some of the challenges and needs that exist across different modes of transportation. Existing conditions provide a contextual basis for the investment recommendations of the 2045 RTP.

ROADWAY SYSTEM

H-GAC's transportation system contains a network of over 27,000 total miles of roadway, seen in Figure 3-1, which supports about 185 million miles of travel per weekday.[1] Arterial streets make up almost half of the roadway system and account for 37.5% of the daily vehicle miles travelled in the region.[2] These arterials bring local traffic to more regional destinations and freeways. In comparison, freeways represent only about 13% of road network but convey as much as 40% of the daily vehicle miles travelled. Lastly, local roads, or "collectors," comprise as much as one quarter of the road network but carry only about 7.5% of the daily vehicle miles travelled, most of which occur at trip origins and destinations.

To promote transit and high occupancy vehicle travel, designated "managed" lanes provide travel priority for transit buses, carpools, and vanpools during peak travel periods, and offer tolled access for single occupant vehicles during periods of lower traffic. Managed lanes are an operational

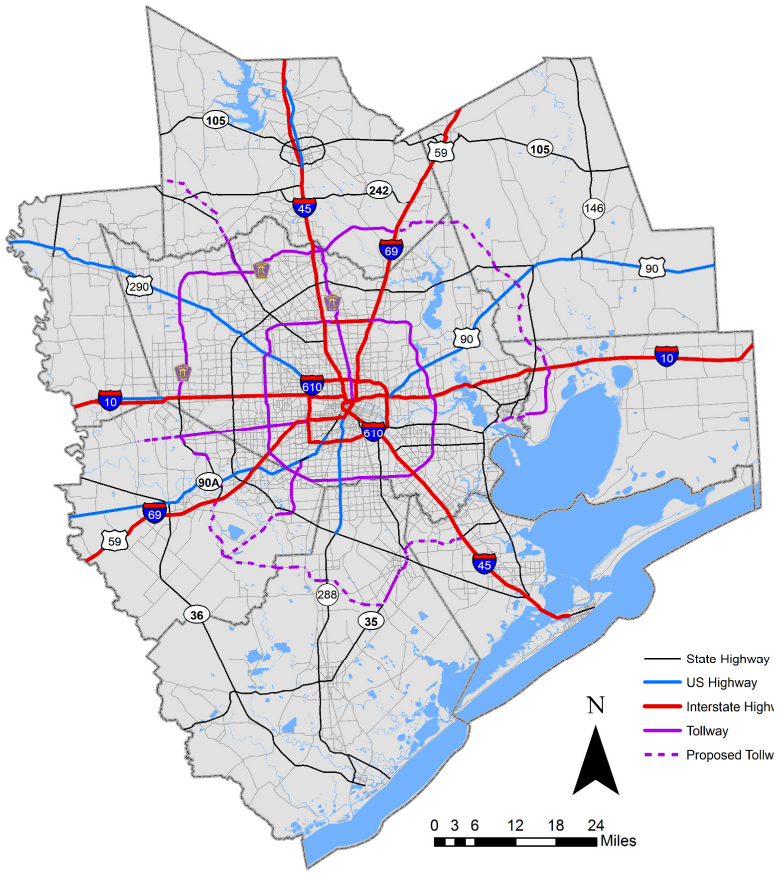


Figure 3-1: H-GAC Regional Roadway Network

[1] H-GAC Travel Demand Model, 2018
[II]Ibid.

strategy that use congestion pricing to encourage a more efficient use of highway capacity.

CHALLENGES

Safety

Safety is a serious concern for roadway travel in the region and is one of the goals of 2045 RTP. Between 2012 and 2016, motor vehicle crashes that occurred regionwide increased by more than 40%. Fatalities from motor vehicle accidents increased by over 20% during the same period. Vehicle crashes cost the region as much as $6.4 billion in 2016 alone,[3] and remain one of the leading causes of death among persons in their teens and twenties.

Congestion

Traffic congestion consistently ranks high in public opinion polls as a regional transportation concern. About 60% of the twenty most congested roads in Texas are in Harris County. So is half of the top ten.[4] The West Loop Freeway (IH 610 W) and Southwest Freeway (IH 69 S/US 59 S) top the list as the most congested and second most congested road segments in the state, respectively. While congestion typically occurs during peak driving periods, IH 610 W experiences about 45% of its delay outside the peak periods.[5]

Connectivity

Connectivity across the region is an important but sometimes overlooked issue. Continuous routes that link the suburban population to the regional employment centers are an important mobility need and can aid orderly development. Area waterways constitute significant obstacles to roadway connectivity in several counties and directly impede north to south or east to west travel. Insightful thoroughfare planning is needed to enhance regional accessibility and provide convenient alternative routes that relieve traffic on congested corridors.

[3] H-GAC Regional Safety Plan; TxDOT 2018.
[4] Texas A&M Transportation Institute, Texas' Most Congested Roadways 2018.
[l]Ibid.

FREIGHT SYSTEM

The Houston-Galveston region is served by an intermodal network of road, rail, water, air, and pipeline facilities through which imported goods are transported to regional distribution centers, raw materials are supplied to local manufacturers, petroleum products are shipped from the region's refineries to statewide, national, and global markets, and consumer goods are carried to local and regional markets. The H-GAC regional multimodal freight network is described in Figure 3-2.

COMMERCIAL TRUCKING

Commercial trucks account for most of the freight movement in the region. Trucks convey small volume loads and container shipments and are largely responsible for the first mile-last mile trips. More than 465 million tons of goods are shipped annually over the region's roadways. The top commercial truck freight commodities include food items, agricultural products, chemicals, plastic resin, building materials, iron and steel articles, machinery, motor vehicles, and consumer goods. It is projected that by 2045, the commercial trucking industry will handle 54% of all freight shipments by weight and 88% of the shipments by value.

Figure 3-2: The H-GAC Freight Network

RAILROADS

Three Class I railroads operate within the Houston-Galveston region: The Union Pacific Railroad (UP), Burlington Northern Santa Fe (BNSF), and Kansas City Southern (KCS)[6] railroads. Together, they operate more than 1,000 miles of track that include over 800 miles of mainlines, 120 miles of siding, and close to 50 miles within marshalling yards. Over long distances, railroads are the most efficient form of land transportation. Houston is a hub for the long haul UP Railroad lines that link the Louisiana gulf coast, the west coast, the upper mid-west and Mexico.

The Class I rail operators haul over 150 million tons of freight annually with chemical products being their main cargo. Over 450,000 carloads of chemicals or refined petroleum products were shipped from

[6] KCS does not own any track with the Houston Region but has trackage rights along with other railroads.

Houston on rails cars in 2016. The bulk of these shipments went to destinations within Texas, the Gulf Coast, and the West Coast.

MARINE FREIGHT

The Houston-Galveston region's marine freight network consists of four deep water ports – Port Houston, Port Freeport, the Port of Galveston, and the Port of Texas City. The Gulf Intracoastal Waterway (GIWW) links all the Gulf Coast ports and provides sheltered access to the nation's system of inland waterways. Water is the least costly freight transportation option available and the ports are the largest generators of freight in the region.

Port Houston is one of the largest ports in the world and holds several distinctions: ranked first among U.S. ports in foreign waterborne tonnage, second in total tonnage, and third in total foreign cargo value.[7] It also leads the nation in exports of general resin products and is consistently the top performing breakbulk port in the nation. Port Houston handles 69% of the container traffic in the Gulf Coast and in 2018, was sixth nationally in total container volumes (import and export).

While the ports of Houston, Freeport, and Galveston all handle a variety of bulk and break-bulk commodities, container cargo, and cruise travel, the Port of Texas City almost exclusively handles liquid products related to the petrochemical industry. Petroleum products, crude oil, and chemicals make up over 85% of all trade flow in the region's ports and is projected to grow with the ongoing expansion of energy production nationally. The widening of the Panama Canal has prompted modernization and expansion efforts at area ports seeking to accommodate the larger vessels and increased cargo that is expected to come into the Gulf Coast market.

An ongoing Ports Area Mobility Study will consider options to improve the efficiency of freight movement through the ports while limiting their contribution to congestion in the surrounding urban core.

PIPELINE

The Houston-Galveston region has over 21,500 miles of pipelines which transport more than 445 million tons of liquid bulk annually. Pipelines are the predominant mode for moving crude oil, natural gas, and refined oil products from the oilfields to the refineries and on to regional markets or export terminals. In terms of market share, as much as 60% of the products moved by pipelines are bound for the export market while 40% are imported products bound for US markets. By 2045, the volume of goods shipped by pipeline is expected to increase by over 20% to about 540 million tons annually.

Energy pipelines provide a cost-effective means of transporting large volumes of freight that is consequently kept off the highway and rail network. For example, a pipeline that transports 150,000 barrels of oil per day conveys the equivalent of 750 tanker truckloads or 225 rail cars. By reducing the demand for trucks and rail cars, pipelines help to ease roadway congestion and contribute positively to regional air quality and transportation safety.

[7] USACE Navigation Data Center.

AIR FREIGHT

Air cargo is a fast and very reliable mode for moving freight – but is also one of the most expensive. Air cargo is characteristically low weight and limited in bulk compared to truck or rail cargo. The Houston-Galveston region has three major airports: George Bush Intercontinental Airport (IAH), William P. Hobby Airport (HOU), and Ellington Field (EFD). IAH handles about 98% of the freight transported by the Houston Airport System. In 2017, over 420,000 metric tons of cargo passed through this airport, ranking 19th among the nation's cargo-service airports. About 52% of this cargo is international, with Europe being the major trading partner.

HOU handles comparatively less air cargo than IAH while Ellington Field does not handle commercial traffic. From the airport, air cargo is distributed throughout the region by truck. Intermodal connectors linking air cargo facilities to the highways are important components of the region's freight system.

CHALLENGIES

Perhaps the biggest challenge to the regional freight system is congestion. Because ports are such large generators of freight, it is critical that the freight corridors leading to and from these facilities have the capacity to accommodate the level of traffic generated. Region-wide, the increase in demand placed on the transportation freight network by a growing economy may exacerbate the effect of bottlenecks within the transportation system and lead to untenable and costly delay.

DISASTER PREPAREDNESS

EVACUATION PLAN

Evacuation routes are designated by the Texas Department of Public Safety (DPS) in coordination with local counties and municipalities. These routes are designated to evacuate part or all of the region in the event of natural or man-made emergencies or other threats to public safety. The Houston-Galveston region has 24 signed state roadways designated as evacuation routes (Figure 3-3). These evacuation routes are described in a Texas DPS Emergency Evacuation Traffic Management Plan. Houston TranStar serves as the regional emergency center and houses multi-agency operations that manage traffic incidents and respond to regional emergencies such as hurricanes and floods.

H-GAC coordinates with counties, municipalities, and the state to manage the database of regional evacuation routes and is responsible for periodic updates to the Emergency Evacuation Traffic Management Plan. H-GAC also administers the Regional Evacuation Viewer – a secure web application which provides near real-time updates of evacuation resource deployment and other related information. Users of the viewer can access current Evacuation Traffic Management Plans by county, city or corridor.

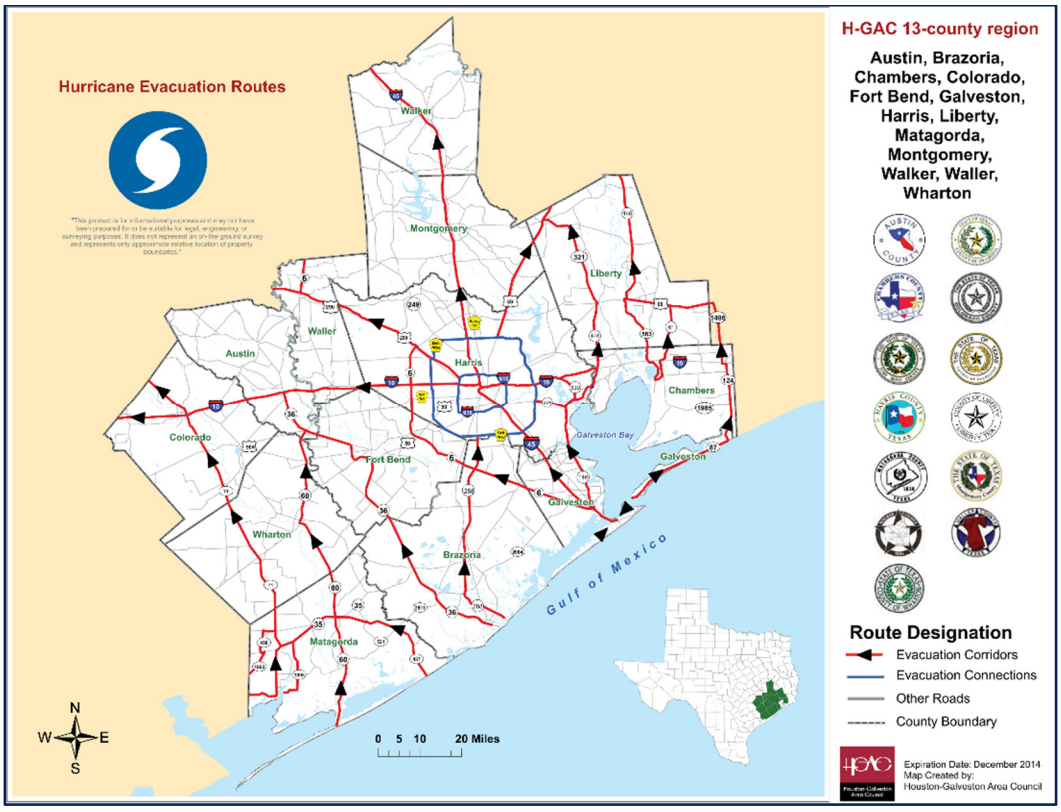


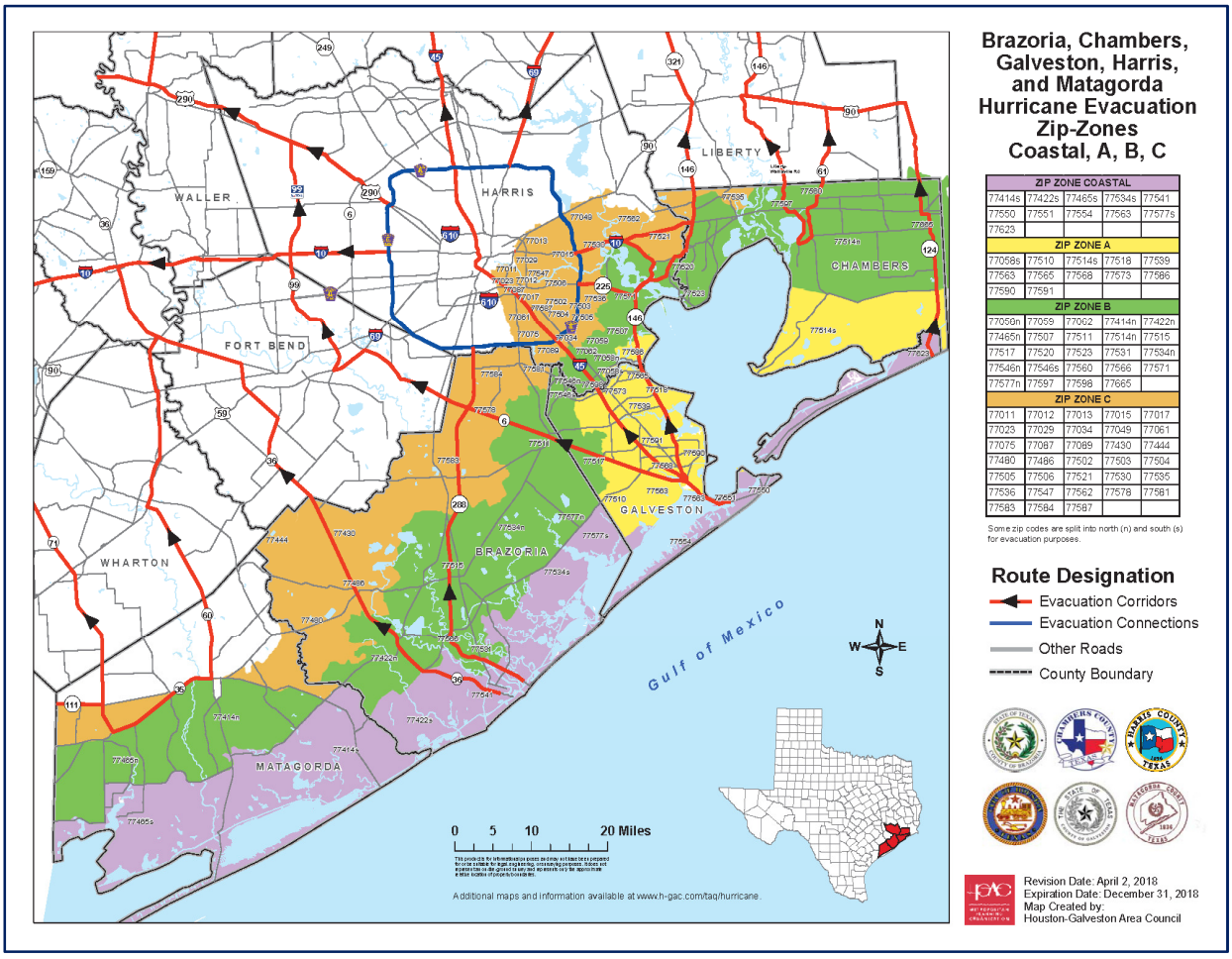
Figure 3-3: H-GAC Hurricane Evacuation Routes

HURRICANE SURGE ZONE MAP

Each year, H-GAC produces a Hurricane Surge Zone Map ("Zip-Zone Map") for distribution to the public (Figure 3-4). The Zip-Zone Map is a public information tool which shows the parts of the region that are most at risk for hurricane-related storm surges over a basemap of postal zip codes. The Hurricane Surge Zone Map also indicates designated evacuation corridors and evacuation connections. Designation as an evacuation route is one criterion used in the RTP for prioritizing capital improvement projects. It is a critical safety issue that regional evacuation routes have adequate capacity to handle the high levels of traffic that often ensue in a regional emergency.

The Zip-Zone map can be used by elected officials and emergency management personnel to conduct a phased evacuation of coastal counties based on the zip codes of the residents.

Figure 3-4: H-GAC Hurricane Evacuation Zip Zone Map



FAST Act Compliance

Houston TranStar serves as the regional emergency center and houses multi-agency operations that manage traffic incidents and respond to regional emergencies such as hurricanes and floods.

TOGETHER AGAINST THE WEATHER

The "Together Against the Weather" campaign was created to help individuals with disabilities and other special needs plan for disruptions caused by hurricanes, floods, and other weather-related emergencies. The program encourages the formation of supportive partnerships involving family members, community organizations, health care providers, and emergency management personnel, and suggests strategies for addressing challenges that commonly arise during periods of emergency evacuation.

Together Against the Weather offers several tool kits that include educational videos presented in English, Spanish, Vietnamese, and Chinese. Links are also provided to state, county, and municipal offices of emergency management. More information is available at: http://www.togetheragainsttheweather.com/index.shtml.

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REGIONAL TRANSIT SYSTEM

EXISTING SERVICE

The regional transit system consists of nine public transit providers which serve seven of the eight counties in the municipal planning area (Figure 3-5).[8] The principal transit modes in the region include local bus, light rail, commuter bus or park and ride, demand response, and flexible route service. Urban transit service is concentrated in Harris County and is provided predominantly by the Metropolitan Transit Authority of Harris County (METRO).[9]

METRO provides about 90% of all commuter bus service. METRO also provides 23 miles of high capacity light rail service on three routes within Loop 610. Along with METRO, Fort Bend County Transit, Harris County Transit, Colorado Valley Transit, Brazos Transit District, and Connect Transit provide demand response service for disabled persons.

TRANSIT TRENDS

Transit ridership in the region decreased by about 2% in 2017 due to a fall in park-and-ride usage and the impacts of Hurricane Harvey. Regional transit service has, however, expanded in the suburban counties – Brazoria, Fort Bend, Galveston, and Montgomery Counties. The demand for rural transit service is growing in Liberty and Waller Counties, where regional commuter transit options will need to be established to complement existing local service. Bus vehicle reliability, which measures the average distance between mechanical breakdowns, improved 12% in 2017 to 10,800 miles.

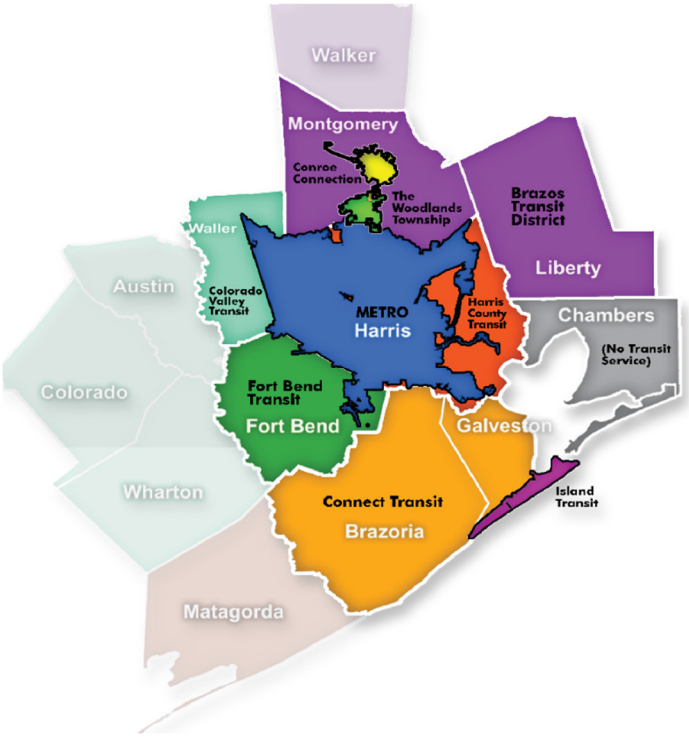

Figure 3-5: Transit Service Providers

NEW TRANSIT MODES

Flexible route service offered by METRO and Fort Bend Transit is a relatively new transit mode designed for areas of medium population density. Expanding this service within and outside of Harris County could create a more robust and better-connected regional transit system. Two other transit modes are in various stages of development. Bus Rapid Transit Service is scheduled to commence service in 2022 in the Uptown

[8] Chambers County has no public transit service.
[9] See Ridership and Miles Chart

Galleria area along Post Oak Boulevard and IH 610. Commuter Rail Service has long been envisioned for the region but has faltered over several issues – including funding.

HIGH CAPACITY TRANSIT EXPANSION

The High Capacity Transit Task Force (HCTTF) was created by the Transportation Policy Council in the spring of 2017 to research the need and opportunity for high capacity transit in the Houston-Galveston region. The Task Force's responsibility is to: "Coordinate with regional stakeholders to identify regional benefits, funding solutions and policy considerations to advance High Capacity Transit throughout the region."

As the result of a two-year planning process, the HCTTF Priority Network was created. The services indicated in the HCTTF Priority Network are mode-, technology- and alignment neutral. All recommendations in the HCTTF Priority Network are conceptual and are subject to further analysis and design. The Priority Network is shown in Figure 3-6.

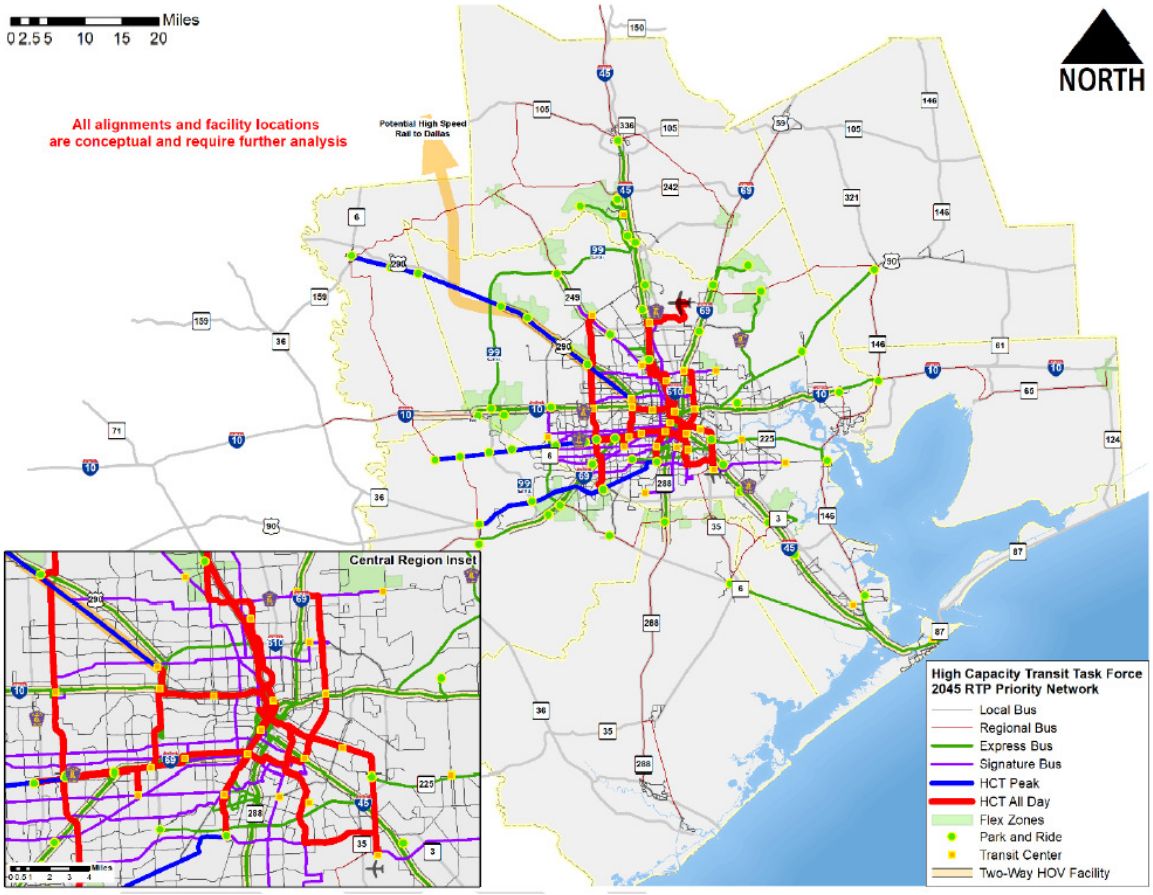

Figure 3-6: High Capacity Transit Task Force Priority Network

CHALLENGES

Funding

Funding for transit services is a challenge throughout the region. Although METRO receives local funding from a dedicated sales tax, its ability to grow existing service without additional revenue is severely constrained. For the other regional transit agencies that depend largely on federal and/or state revenue to cover their operating and capital costs, these funds have historically grown slower than operating and other transit costs. The lack of funding impacts the ability to provide a desirable level of service across the board for the transit dependent population and will probably continue to be a challenge in future years.

Coordination

Travelling around the region by transit is very difficult due to the fragmentation of available service. The lack of coordinated service, scheduling, and interoperability between the different regional providers means a high-quality seamless transit service is unavailable. This particularly impacts the ease of travel between counties. An opportunity to increase the market share for transit exists with better regional coordination and the development of seamless transit operations among regional providers. This would, however, require substantial commitment of fiscal and human resources and community vision.

Service Gaps

Chronic and emerging transit service gaps affect the vulnerable populations. Gaps include the lack of pedestrian friendly infrastructure such as accessible sidewalks, crosswalks, and pedestrian ramps at transit stops. Gaps also include the lack transit routes, non-existent stops, and inadequate service frequencies.

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ACTIVE TRANSPORTATION

Safe and well-connected active transportation infrastructure is an important component of the regional transportation system. Walking and biking as a mode of travel reduces roadway congestion and can contribute to community health and the quality of life of area residents. Over 120,000 people walk, bike, or take transit on their daily commute [10],[11]. The H-GAC region currently has about 19,300 linear miles of sidewalks and 1,443 miles of bikeways (Figure 3-7).

INFRASTRUCTURE DENSITY

Sidewalk density is highest inside the Loop 610 area and in a few suburban communities. Bikeways show local concentrations in the Woodlands, Sugar Land, Kingwood, and a growing network in parts of Houston, Texas City, and Pearland. While more than 263 miles of bikeways have recently been constructed in various parts of the region, additional active infrastructure is needed especially in and around communities identified as sensitive for environmental justice.

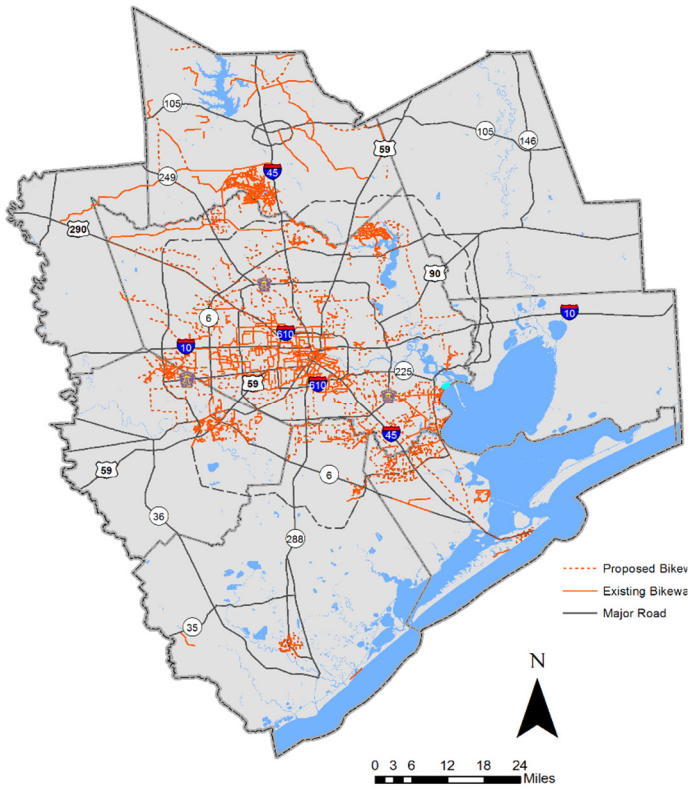

Figure 3-7: H-GAC Bikeway Network

FUTURE DEVELOPMENTS

Funding for walkways and bikeways comes primarily from Transportation Alternatives Set-Asides (TASA), but active transportation projects are also eligible for Congestion Mitigation/Air Quality (CMAQ) funding. The 2045 Active Transportation Plan provides more details on the existing conditions of our regional walkways and bikeways, identifies the places with a higher need for active transportation infrastructure, and outlines recommendations for improving the existing active transportation network (See Appendix H).

[10] We include transit riders because a 2018 H-GAC Transit Origin/Destination survey shows that around 80% of transit riders walk or bike to get to their transit stop and around 90% walk or bike from their transit stop to their final destination.

[11] According to the Bureau of Transportation Statistics, commutes only account for about 15% of all trips, meaning that many more people are using walkways and bikeway every day.

CHALLENGES

Although local governments are building more walkways and bikeways each year, many residents still lack safe infrastructure to walk or bike within and around their neighborhoods. Efforts are also needed to maintain and improve existing infrastructure to encourage area residents to walk and bike for more of their daily trips.

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CONGESTION MANAGEMENT

The federally required Congestion Management Process (CMP) is the systematic process of identifying congestion and its causes, applying congestion mitigation strategies to improve transportation system performance and reliability, and evaluating the effectiveness of the strategies implement.

The CMP is needed to maintain a safe and reliable transportation system that effectively supports economic development and enhances the quality of life of area residents. Congestion management is an integral part of the metropolitan transportation planning effort and provides a mechanism for funding and implementing congestion management strategies either independently, or as part of projects programmed in the RTP. The CMP advances the goals of the long-range plan. Consistent with 2045 RTP, the goals of H-GAC's CMP are to:

- Reduce the rate and severity of crashes for all system users;
- Improve transportation system reliability across all modes and systems of travel in the region;
- Reduce the impacts of incidents on traffic flow;
- Increase opportunities for travelers to use regional and local transit services and participate in Transportation Demand Management (TDM) programs to provide more travel choices;
- Improve system operational efficiency and accessibility to accommodate freight movement within the region; and
- Reduce emissions through congestion management.

TRANSPORTATION SYSTEM PERFORMANCE

Congestion has historically been a major transportation problem in the Houston-Galveston region. For the baseline year of 2014, the Planning Time Index (PTI) for the region was 1.58.[12] This means a trip that would normally take 30 minutes under free flow conditions would be completed in 47 minutes because of roadway congestion. The CMP identifies the region's congested corridors and identifies inexpensive strategies to minimize congestion and enhance the mobility of people and goods.

Harris County, which is the most populated county in the region, contains twelve of the twenty most congested roadways in the State of Texas (Table 3-1).

CMP ELEMENTS

1. Performance measures to monitor and evaluate recurring and non-recurring congestion;

2. Definition of congestion management objectives and performance measures;

3. Coordinated data collection and system performance monitoring efforts;

4. Implementation schedule, responsibilities, and potential funding for strategies; and

5. Implementation of a process for assessment of strategies, in terms of established performance measures.

[12] Texas A&M Transportation Institute, 2015.

2018 Rank	Road Name	From	To	Segment Length (miles)	Peak Period Avg. Speed (mph)	Free flow Speed (mph)
1	W. Loop Fwy/IH 610	Katy Fwy/IH10/US90	Southwest Fwy/US 59	3.62	30	62
2	Southwest Fwy/IH69/US59	W. Loop Fwy/IH 610	South Fwy/SH 288	5.44	39	62
5	Eastex Fwy/IH 69/US 59	SH 288	IH 10	3.03	34	61
7	Katy Fwy/IH 10/US 90	N Eldridge Pkwy	Sam Houston Tollway W	3.28	40	64
10	North Fwy/IH 45	Sam Houston Tollway N	N Loop Fwy/IH 610	9.26	42	63
11	Gulf Fwy/IH 45	IH 10/US 90	S Loop E Fwy/IH 610	7.89	37	59
12	South Fwy/SH 288	Gulf Fwy/IH 45	S Loop N Fwy/IH 610	4.80	40	60
13	Katy Fwy/IH 10/US 90	Sam Houston Tollway W	W Loop N Fwy/IH 610	6.62	45	63
16	IH 10/US 90	North Fwy/IH 45	Eastex Fwy/US 59	1.57	35	57
17	Katy Fwy/IH 10/US 90	Eastex Fwy/US	North Fwy/IH 10/US 90	5.65	42	62
18	N Loop W Fwy/IH 610	North Fwy/IH 45	Katy Fwy/IH 10/US 90	6.22	40	62
20	North Fwy/IH 45	N Loop Fwy/IH 610	IH 10/US 90	3.11	42	61

Table 3-1: Most Congested Texas Roadways in Harris County

FEDERAL REQUIREMENTS

MAP-21 and the FAST Act place an emphasis on performance-based planning. The Federal Highway Administration (FHWA) has identified two performance measures to assess congestion that are applicable to metropolitan planning organizations who receive Congestion Mitigation and Air Quality (CMAQ) funding. They are:

1. Annual hours of peak hour excessive delay per capita, and
2. Percent of non-single occupancy vehicle travel time.

These performance measures are incorporated into the 2045 RTP plan. The federal performance measures are discussed in more detail later in this document.

TRAFFIC SAFETY

The number of motor vehicles on area roadways increased substantially over the last several years. The region has, however, also experienced a corresponding increase in traffic-related injuries and deaths. Regionally, motor vehicle crashes increased more than 40% from 2012 to 2016. Fatalities resulting from these crash events increased more than 20% during the same period. Safety is a fundamental need in a transportation system. Just as our mobility is critically dependent on safety, the ability to travel and move goods safely is of great importance to the success of our regional economy and to sustaining our way of life.

H-GAC is involved in traffic safety in several ways: through planning and programming of capital improvements; through funding education and enforcement programs that promote traffic safety; and through the analysis and reporting of traffic safety data and information. These initiatives are represented in the Regional Safety Plan, which was developed to expand collaboration across regional safety stakeholders and provide a framework for development of an action plan to address the traffic safety issues experienced in the region.

CAPITAL IMPROVEMENTS

Safety is a major consideration in the RTP and the Transportation Improvement Program (TIP) development process. H-GAC uses a safety cost-benefit analysis as part of the project selection and prioritization process for both programs. In addition, traffic safety performance measures have been established to further characterize and quantify regional conditions.

EDUCATION AND ENFORCEMENT

Several regional traffic safety initiatives have been implemented to combat different crash types.

a. Teens in the Driver Seat

H-GAC partnered with the Texas A&M Transportation Institute (TTI) to provide traffic safety outreach assistance through its "Teens in the Driver Seat" program. This program prepares high school students to educate their peers on traffic safety, recognizing that teens tend to listen to their like-aged peers more than to adults and other authority figures. This program has expanded to 3 community colleges, 17 high schools, and 13 junior high schools in the region.

b. Child Passenger and Bicycle Safety

H-GAC partnered with Texas Children's Hospital, operating through the Safe Kids Coalition, to promote the child passenger and bicycle safety outreach program. The program trained nearly 150 child passenger safety specialists, including Spanish-speaking associates, distributed 9,600 helmets and 550 child seats to economically disadvantaged families, and engaged the public through bike rodeo events and the distribution of child safety information.

c. DWI Task Force

H-GAC is overseeing a joint Driving While Intoxicated (DWI) task force organized to supplement regional enforcement efforts. The task force is funded through a Selective Traffic Enforcement Program (STEP) grant awarded by the Texas Department of Transportation (TxDOT). The effort includes small local government entities that would not individually qualify for the supporting grant funds. Since its inception in 2013, the task force has made over 1,100 DWI arrests.

TRAFFIC SAFETY DATA REPORTING

The State of Safety in the Region (SOSR) report provides an annual overview of the transportation safety situation in the Houston-Galveston region. The report chronicles trends in various crash types and provides analysis that includes the causes and patterns of different crash types, including age, gender, and ethnicity, time of day, day of week, month of year, and hotspot locations.

FEDERAL SAFETY PERFORMANCE MEASURES

The FHWA established five transportation safety performance measures in 2016. These safety performance measures will help to benchmark and assess regional progress towards safer roadways for all users. The federal safety performance measures are:

1. Number of fatalities
2. Rate of fatalities (per 100M Vehicle Miles Traveled)
3. Number of serious injuries
4. Rate of serious injuries (per 100M Vehicle Miles Traveled)
5. Number of non-motorized fatalities and serious injuries

These measures are part of a federal effort to introduce performance-driven, outcome-based approaches to key decisions. Safety performance measures are discussed in greater detail later in this chapter.

PAVEMENT CONDITIONS

The overall condition of the region's transportation infrastructure has remained stable over the past few years. As much as 81% of TxDOT roads were rated "good" or better in 2017 while as much as 82% of the bridges were assessed as being in "good" or better condition.

INFRASTRUCTURE MAINTENANCE AND PRESERVATION

The regional system of roads and bridges are one of the largest capital assets under the responsibility of the Texas Department of Transportation (TxDOT) and the area local governments. TxDOT currently maintains more miles of highway and more bridges than any other state in the US. The State of Texas has about 69,000 lane miles within the National Highway System (NHS), approximately 12% of which are inside the H-GAC metropolitan planning area. Ensuring the preservation of these roadway pavements and bridges is critical to safety, the efficient movement of people and goods, and regional economic development. With the gradual aging of this infrastructure, emphasis on maintenance and rehabilitation has become paramount. Decisions must be made about when, where, and how to allocate funding for their maintenance and preservation.

The purpose of a pavement management program is to encourage relatively small-scale repairs on roadway and bridge infrastructure before substantial damage occurs that would necessitate more expensive reconstruction. Timely pavement preservation treatments are a cost-effective approach to abate structural decline, safeguard the safety of the road users, improve traffic operations, and promote sustainability of the transportation system resources.

FEDERAL REQUIREMENTS

Federal Performance Asset Management prescribes pavement targets for all roadways on the interstate and non-interstate highway system, regardless of ownership. While the federal performance measures are focused on National Highway System, H-GAC is applies these performance measures to all its pavements and bridges. The FHWA has identified four performance measures to assess pavement conditions applicable to metropolitan planning organizations. They are:

- International Roughness Index (IRI);
- Cracking;
- Rutting; and
- Faulting.

More details on the performance measures for pavement conditions are provided in the Performance Measures section of this document.

RESILIENCY

REGIONAL VULNERABILITES AND RESILIENCE

Due to its low-lying coastal geography and semi-tropical climate, the Houston-Galveston region is vulnerable to extreme weather events like heat, drought, tropical storms, and flooding. The risk of these extreme events impacting the region's population, economy, and transportation infrastructure is expected to worsen because of the amplification of related stressors – land use changes, population growth, congested transportation systems, and climate change.

Federal Highway Administration RESILIENCE DEFINITION

"Resilience is the ability to anticipate, prepare for, and adapt to changing conditions and withstand, respond to, and recover rapidly from disruptions."

Transportation systems and infrastructure are vulnerable to extreme weather. In fact, with sea level rise, temperature increases, and increasingly frequent and severe storms, it can be expected that transportation services and infrastructure will suffer more frequent disruptions or permanent damage which would seriously impede the movement of goods and people throughout the region. A summary of expected impacts to transportation infrastructure is shown in Table 3-2.

Understanding the region's risk to extreme weather, in 2010, H-GAC and local partners established resiliency as a regional priority in the "Our Great Region 2040" plan and adopted increasing the region's resiliency to disaster and a changing environment as a major goal.

FEDERAL REQUIREMENTS

Creating a more resilient transportation system has been identified as a national priority. The Fixing America's Surface Transportation (FAST) Act signed into law in 2015, requires MPOs to:

- Address resiliency in their transportation planning processes;
- Develop a Transportation Asset Management Plan (TAMP) that integrates climate change and extreme weather event resilience approaches into transportation asset management;
- Identify policies and design standards to reduce storm water impacts to surface transportation; and
- Coordinate resiliency planning efforts with organizations and agencies focused on natural disaster risk reduction.

REGIONAL RESPONSE TO FEDERAL REQUIREMENTS

To meet federal requirements, H-GAC staff is incorporating resilience into its transportation planning in the following ways:

a. Transportation Vulnerability Assessment Study

In 2018, the Houston-Galveston region was selected to participate in Federal Highways Administration's (FHWA) Resiliency and Durability Pilot Project. As part of this project, H-GAC will work with federal, state, and local partners to conduct a vulnerability assessment of transportation assets in the MPO region.

Expected Climate & Extreme Weather Impacts to Transportation Infrastructure

Climate Variable	Projection	Impact on Transportation Infrastructure
Relative Sea Level	Over the last century, sea level at Galveston has risen more than 26 inches, which is significantly greater than the global average. In the next 50 years, Gulf Coast sea levels are expected to rise by 1 to 6 feet.	A 4-foot increase in relative sea levels would put a quarter of the region's interstates, 10 percent of rail lines, and nearly 75 percent of port facilities at risk.
Temperature	On average, the region already experiences more than 100 days above 90 °F per year. Average temperatures could increase 2° to 4°F by 2050. Temperature increases will be most severe in highly urbanized areas due to the heat island effect.	Higher temperatures will result in higher construction and maintenance costs. At temperatures above 90°F, highways, bridges, and rail lines deteriorate more quickly. Extreme heat can cause immediate damage such as buckling.
Hurricanes and Tropical Storms	Expected to become from frequent and powerful as the Atlantic Ocean and Gulf of Mexico warm.	Associated extreme rainfall, strong winds, and coastal flooding will damage infrastructure, cause road and evacuation route closures, and overwhelm storm drains.
Precipitation	Heavy rainfall events and droughts have increased; this trend is expected to continue with longer dry periods between extreme rain events.	Heavy precipitation can result in flash floods with impacts ranging from inconveniences (temporary road closures and transit service disruptions) to permanently destroyed infrastructure. Extreme rain events are also correlated to a higher incidence or crashes and delays.

Sources:

- Transit and Climate Change Adaptation: Synthesis of FTA-Funded Pilot Projects, August 2014, FTA
- The Gulf Coast Study Summary, Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: The Gulf Coast Study, Phase 1 Completed in 2008, FHWA
- Gulf Coast Climate Change Adaptation Pilot Study, August 2013, FTA
- Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I, March 2008, The Climate Change Science Program

Table 3-2: Impact of Extreme Weather Events on Transportation Infrastructure

The vulnerability assessment will use FHWA's Vulnerability Assessment Scoring Tool (VAST) and methodology and will include consideration of exposure, sensitivity, adaptive capacity, economic impact, and risk. Resiliency recommendations will be developed based on vulnerability assessment results. Results will also be used to help prioritize funding decisions for future transportation projects.

Work on the Resiliency and Durability Pilot Project commenced in Winter 2018 and should be completed by late Summer 2020. More information about the Transportation Vulnerability Assessment can be found at www.hgacmpo.com/resiliency.

b. Working Group

In 2019, H-GAC will form a transportation resiliency working group with the initial goal of developing a multi-year strategy to meet resiliency-related federal requirements and identify additional resiliency efforts that will reduce risk and improve safety in the region. Through the working group, H-GAC will host workshops, coordinate resiliency work with emergency management (preparedness and response) efforts, develop a plan to reduce and mitigate storm water impacts on surface transportation and more.

c. Texas Resiliency and Planning Workshops

H-GAC has participated in several resiliency workshops hosted by FHWA, TxDOT, the Texas A&M Transportation Institute (TTI), and other metropolitan planning organizations. The purpose of these workshops has been to exchange information, data sources, and resiliency strategies. As part of its transportation resiliency agenda, H-GAC plans to host further workshops focused on asset management and performance measures.

d. Cedar Bayou Initiative

The Cedar Bayou Initiative is a partnership of public and private sector stakeholders in the Cedar Bayou watershed. Its purpose is to identify and pursue priority projects to improve flood management, resiliency, and transportation goals throughout the Cedar Bayou watershed and the greater Chambers, Liberty, and Harris Tri-County area. Projects identified in 2018 can be grouped into three major categories:

- Dredging and other improvements to the main channel of Cedar Bayou, its tributaries and drainage channels.
- Stormwater infrastructure, detention, and runoff quality improvement.
- Improvements to transportation infrastructure to reduce flooding and improve evacuation capacity.

e. Designing for Impact

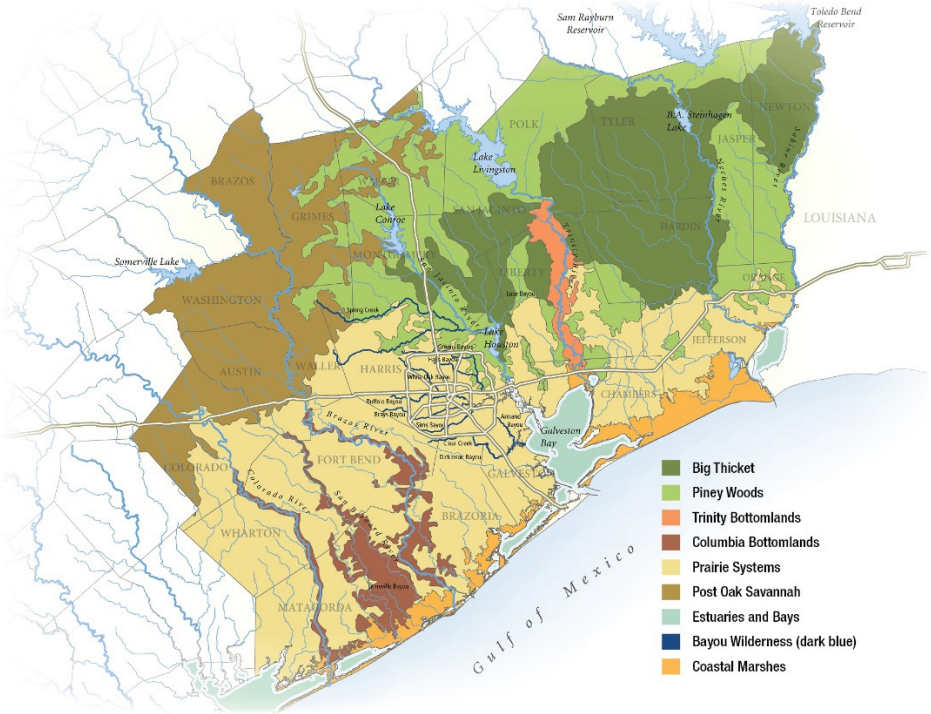
H-GAC is involved in the "Designing for Impact" study which is exploring strategies to reduce the impact of stormwater on the Houston-Galveston region's infrastructure. Working through a voluntary partnership of engineers, developers, architects, landscape architects, municipal and county representatives, the project identifies the Low Impact Development strategy as an effective and economically advantageous approach to addressing the regions' stormwater problems.

NATURAL ENVIRONMENT

For a rapidly growing region like the Houston-Galveston metropolitan area, the need exists for a workable and sustainable program to conserve and protect the region's high value natural resources. The parks, open spaces, natural areas, farmlands, and waterways are indispensable and contribute to the economy, and the health and quality of life of area residents. Almost 40% of the region's land cover is categorized as forest, wetland, or grassland (Figure 3-8). However, many of these resources are threatened by development.

As the Houston metropolitan region continues to grow, there will be need for additional housing and employment, and for an expansion of the transportation network. It is projected that about 71% of the 2045 population would be located beyond the Beltway – which is where much of the region's remaining undisturbed forest and grassland resources are. Except proactive action is taken, we stand to lose or significantly impair these resources and the important ecological services that they provide to the region. In addition, the ongoing disappearance of undeveloped land will have serious consequences for air and water quality, agricultural productivity, wildlife habitat, opportunities for recreation and pursuing healthy lifestyles, and keeping the region's character and cultural heritage. The challenge is how to plan for the projected urban growth and increased mobility while conserving our high priority natural resources and preserving the ecological diversity of our region.

Figure 3-8: Ecoregions in the Houston-Galveston Region



Source: Houston Wilderness

The subtropical climate of the Gulf Coast supports several distinct bioregions which perform beneficial functions that improve and protect the environment, improve resilience, and foster economic activity within the region. Table 3-3 lists some of the beneficial functions associated with the region's wetlands, grasslands, and forests.

Benefits from Region's Most Common Ecosystem Types	Coastal Wetland Marshes	Prairies	Forests
Recreation & Ecotourism	X	X	X
Aquifer & Groundwater Recharge	X	X	X
Flood Prevention	X	X	X
Wildlife Habitat	X	X	X
Carbon Sequestration	X	X	X
Erosion Control	X	X	X
Water & Air Purification	X	X	X
Seed Bank		X	
Provides Storm Drainage		X	
Reduces Runoff & Pollution			X
Blocks Noise			X
Reduces Building Energy Costs			X

Table 3-3: Beneficial Functions of Ecosystem Resources

CONSERVING THE NATURAL RESOURCES

One of the goals of 2045 RTP is to conserve and protect the region's natural and cultural resources. This can be achieved by greater integration of resource conservation in the transportation planning process. Transportation regulations require the MPOs to consult with environmental resource agencies, and to incorporate environmental stewardship in the long-range transportation planning process.

Several federal and state resource agencies are tasked with protecting the quality of the human and natural environments through their rule-making responsibilities and the enforcement of federal and state environmental statutes and regulations. H-GAC and its transportation partners consult with these agencies as well with universities, research institutes, and private natural resource conservation organizations in the effort to protect and enhance the environment. The outcomes of these collaborative efforts include

protection and conservation plans for area watersheds, riparian corridors, and the Galveston Bay system; surface water quality monitoring; air quality improvement programs; and the establishment of nature trails, conservation easements, and ecosystem restoration initiatives.

H-GAC is updating its "Eco-Logical" web tool which identifies the high-quality ecotype resources within the metropolitan planning area. Eco-Logical is designed to alert planners of situations where project investments coincide with sensitive habitats, and encourage actions to avoid, minimize, or mitigate the impact of transportation planning on these important environmental resources. The web tool may be viewed at: http://arcgis02.h-gac.com/EcologicalGIS/.

INDIRECT ENVIRONMENTAL IMPACTS

While positive outcomes result from the MPO region's economic development and continued population growth, residents are periodically reminded of externalities associated with this growth – particularly the risk of flooding. Flood risk increases as forests, grasslands, and wetlands in the flat and low-lying metropolitan region are replaced with rooftops and pavement. The results include swifter and greater amounts of runoff to the rivers and streams and prolonged flood stages that disrupt travel, displace thousands of residents, and cause billions of dollars of damage to homes, businesses and civil infrastructure.

The region's vulnerability to inland and coastal flooding was underscored in recent years during the 2015 "Memorial Day Flood," the 2016 "Tax Day Flood," and the 2017 "Hurricane Harvey." H-GAC is keenly involved in regional efforts by the state, local governments, and research institutions to understand the Houston flood problem and to find solutions to mitigate regional flood loses, minimize travel disruptions, increase resiliency, and minimize stormwater impact on transportation infrastructure.

H-GAC also recognizes that transportation infrastructure projects can have foreseeable consequences that occur later in time but not necessarily near the project site. Through its policies, impacts must be considered during the transportation planning process. Strategies for mitigating these impacts include using spatial environmental data tools to evaluate the impact of potential projects; promoting low-impact developmental practices in transportation projects and subsequent development; and coordinating with other air and water quality and land conservation efforts in project areas.

EMERGING TRANSPORTATION TECHNOLOGY

The region's transportation system is nearing its capacity limits with traffic congestion levels remaining high despite billions of dollars of investments in new or expanded highways. To sustain regional mobility, new options for travel must be developed that are convenient and accessible. Future transportation must be able to react quickly to the demand placed upon it. This section focuses on emerging technologies such as autonomous and connected vehicles, and their potential to affect and influence the regional transportation system.

AUTONOMOUS AND CONNECTED VEHICLES

Among emerging transportation technologies, two concepts that have gained prominence are "Autonomous Vehicles" (AVs) and "Connected Vehicles" (CVs). Connected and Autonomous Vehicles (CAVs) employ both technologies simultaneously; the concurrent development of both technologies is anticipated to provide reinforcing and synergistic benefits.

Autonomous vehicles (often referred to as "driverless cars") utilize mapping software, radar, sensors, and other equipment to survey, respond and navigate through their surroundings with little to no human input. Autonomous Vehicle technology is most easily conceptualized using a five-level continuum suggested by the National Highway Traffic Safety Administration (NHTSA), ranging from Level 0 (the human driver is in complete control), to Level 5 (the vehicle is responsible for all driving functions in any environment).[13]

Figure 3-9: Example of an Automated Vehicle

Figure 3-9 shows an example of one of the earliest demonstrations of automated vehicle technology operating at low speeds in a pilot project within pedestrian and urban street environments. This type of vehicle typically accommodates about 10 passengers, travels at up to 25 miles per hour, and has a service range of roughly two miles.

Connected vehicles communicate wirelessly with each other and/or with roadside infrastructure and operate cooperatively to reduce congestion, decrease fuel consumption, and promote safety. Connected vehicle technology allows communications between vehicles ("Vehicle to Vehicle" or V2V); traffic signals and other stationary infrastructure components ("Vehicle to Infrastructure" or V2I); pedestrians and bicyclists ("Vehicle to Pedestrian" or V2P); and any or all entities that may interact with or affect the vehicle ("Vehicle to Everything "or V2X). Figure 3-10 provides conceptual examples of this technology.

1 http://www.nhtsa.gov/About+NHTSA/Press+Releases/2015/nhtsa-will-accelerate-v2v-efforts

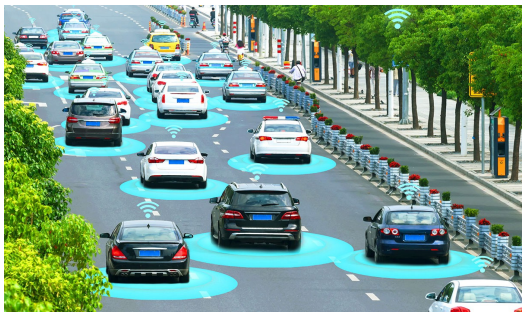


Figure 3-10: Examples of Connected Vehicle Technology

There is currently a significant amount of university and private sector research and investment focused on developing, testing and advancing automated and connected vehicles. Although there are inherent risks in predicting future trends, it is currently envisioned that fully-autonomous vehicles could replace conventional cars with autonomous cars by 2025. It also is projected that autonomous vehicles will reach 50 percent market share by 2035.

BENEFITS AND DRAWBACKS

The deployment of emerging vehicle technology could provide benefits such as reduced roadway crashes and fatalities due to the elimination of human driver error or impairment, which has been found to cause 94% of all crashes,[14] through faster computer-based reaction times as well as greater reliability. Other potential benefits include smarter driving and navigation, reduced urban parking needs due to autonomous parking capabilities, and increased access to travel by persons who face obstacles due to age or physical impairment. Driverless taxis could enable users to request a ride using smartphone applications, without having to search for and walk to access a vehicle. Such autonomous vehicles enable carsharing companies to seamlessly reposition vehicles to better match demand.

Connected vehicle technology will enable transportation agencies to access vehicle data related to speed, location, and traffic management to address specific problems in real-time. In addition to sending information to drivers, CVs will send information to transportation agencies to enhance their knowledge of road conditions, as well as generate historic data that will help agencies better plan and allocate future resources.

Autonomous vehicles could potentially make congestion worse. Fleets deployed by taxi or rideshare companies could clog the streets of major activity centers as they search for riders. Retail companies could hire entire fleets of automated vehicles to serve as "mobile showrooms" that circulate around city streets waiting to be dispatched to potential customers, and personal automated vehicles could loop around city blocks while they wait for their owners to get coffee or pick up dry cleaning. As with any technology, there is also the potential for malfunction, whether it be the vehicle's on-board navigation system or the communication system that connects it to other infrastructure. The potential, however slight, for automated vehicles to be "hacked" by criminal or terrorist elements is a concern.

[14] https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115

CURRENT AND FUTURE APPLICATIONS

Automated and connected vehicles have the potential to improve public transportation by increasing transit productivity, efficiency, and accessibility; mitigating congestion in an integrated transportation environment; and providing travelers with better transportation information and transit services. Transit-oriented connected vehicle mobility applications support dynamic system operations and management, enable a convenient and quality travel experience, and provide an information-rich environment to meet the needs of travelers and system operators across all modes.

One potential way to enhance public transportation would be by providing first-mile/last-mile (FM/LM) connections, by which autonomous vehicles may be operated more cost effectively without an operator onboard every vehicle. These smaller and smarter vehicles will be able to offer not only fixed route connections between high demand trip generators, but also offer a new type of service customized by each user. Platooning buses is another solution that is being researched by METRO that will allow multiple vehicles to travel in close proximity to one another, much like a train, by utilizing vehicle to vehicle connectivity.

A potential for early deployment of AV technology exists along the region's HOV network, where automated buses could operate in barrier-separated HOV lanes that do not require interaction with general traffic (NHTSA Level 4 Automation). This is supported by a Transportation Research Boar (TRB) study for AV technology readiness[15], which has identified protected operating environments such as HOV lanes as ideal for early deployment of automated buses, including platooning operations. Figure 3 -11 shows the region's HOV connected transit centers and their associated park-and ride lots, which are typically spaced along the region's freeway corridors length about five to ten miles apart.

Vehicle platooning has the potential to increase capacity of roads within existing right-of way. This application of connected vehicle technology also reaches into freight transportation within the Houston-Galveston region. With its heavy reliance on truck movement from container terminals, the region's ports could greatly benefit from truck platooning to, from, and between various port terminals to reduce the impact of truck congestion on the region's roadways.

[15] Functionality of Level 4 transit operations, AV technology readiness and the probable timeline for early deployment are discussed on pp. 18-22 in the research report titled "Impacts of Laws and Regulations on CV and AV Technology Introduction I Transit Operations"; TSU's CTTR served as the Principal Investigator for this study.

Figure 3-11: - HOV Lane Direct Connector Lanes to Transit Center Bus Only Facilities

CHALLENGES

While there is much discussion about these emerging technologies, there is also much uncertainty as to when the technology be widely manufactured and deployed. Many questions regarding the development and deployment of emerging transportation technology remain unanswered. Will people adopt new technologies, and how quickly? Will new technologies be implemented along with electrification of vehicles? Will we see a shared vehicle ownership model emerge or will private ownership models remain? These are questions for which we can only hypothesize the outcomes.

Key challenges that could potentially slow down widespread use of autonomous vehicles include: testing and approval; development of a regulatory framework; affirmative demonstrations of reliability, security and safety; affordability; and public acceptance. AVs also stand to disrupt the norms of both transportation and land use planning, including parking minimums, street design, right-of-way, signage and signalization, access management and integration and accommodation of bicycle and pedestrian infrastructure

PERFORMANCE MEASURES SYSTEM EVALUATION

MAP-21 and the FAST Act legislations introduced Transportation Performance Management (TPM) into the Federal Highway Program, establishing a performance and outcome-based planning system designed to improve policy decision-making, increase accountability and transparency, and to promote the efficient investment of federal transportation funds. The federal performance measures relate to the goals of:

- Improving safety
- Maintaining infrastructure condition
- Reducing traffic congestion
- Improving the efficiency of the system and freight movement
- Protecting the environment

A performance measure (PM) is an indicator of the progress made towards attaining desired goals or targets. The performance measures incorporated in the 2045 RTP were chosen mainly because they are understandable, sensitive to several transportation modes, and have a nexus to the established regional goals. H-GAC's performance categories include Highway Safety (PM 1), Pavement and Bridge Conditions (PM 2), Highway System Performance (PM3), and Transit Asset Management. These performance measures and how they apply are detailed in Table 3-4.

NATIONAL HIGHWAY SYSTEM

The federal performance measures are linked to the National Highway System (NHS) – a network of critical highways that are deemed to be most important to the nation's economy, defense, and mobility. The Houston metropolitan planning area has about 8,784 lane miles of roadway on the NHS. The H-GAC 2045 RTP is, however, focused on all major roads in the metropolitan planning area and not just those listed on the NHS system.

PERFORMANCE TARGET NUMBERS

FHWA final rules require State DOTs and MPOs to establish and report target numbers for each of the federal performance measures. H-GAC adopted the target numbers established by TxDOT. Overall, performance management is a powerful analytical tool for tracking regional performance over time and permits a comparison between planning regions nationwide. Furthermore, target setting, tracking, and reporting are conducted within a relatively short timeframe – from one to four years – which give transportation planners the opportunity to link short-term performance to long-range priorities for the region. H-GAC's performance measures and their target numbers are discussed in detail in Appendix P.

Category	Performance Measure	Applicability	Reporting Frequency
Highway Safety	Number of fatalities	All public roads	Annually
	Rate of fatalities		
	Number of serious injuries		
	Rate of serious injuries		
	Number of non-motorized fatalities and serious injuries		
Pavement and Bridge Condition	Percentage of pavements of the Interstate System in Good condition	Interstate System	Biennially with four-year performance periods
	Percentage of pavements of the Interstate System in Poor condition		
	Percentage of pavements of the non-Interstate NHS in Good condition	Non-Interstate NHS	
	Percentage of pavements of the non-Interstate NHS in Poor condition		
	Percentage of NHS bridges classified as in Good condition	National Highway System (NHS)	
	Percentage of NHS bridges classified as in Poor condition		
Highway System Performance	Percent of the person-miles traveled on the Interstate that are reliable	Interstate System	Biennially with four-year performance periods
	Percent of the person-miles traveled on the non-Interstate NHS that are reliable	Non-Interstate NHS	
	Truck Travel Time Reliability (TTTR) Index	Interstate System	
	Annual Hours of Peak Hour Excessive Delay Per Capita	National Highway System (NHS)	
	Total Emissions Reduction	Urbanized area	
Transit Asset Management	Rolling Stock	The percentage of revenue vehicles that exceed the Useful Life Benchmark (ULB)	Annually
	Equipment	The percentage of non-revenue service vehicles that exceed the ULB	
	Facilities	The percentage of facilities that are rated less than 3.0 on the Transit Economic Requirements Model (TERM) Scale	
	Infrastructure	The percentage of track segments (by mode) that have performance restrictions	

Table 3-4: FHWA Performance Measures