Connecting the Texas Triangle:
Economic Integration and Transportation Coordination

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Submitted for presentation at

Healdsburg Research Seminar on Megaregions

Hotel Healdsburg
April 4 – 6, 2007
Healdsburg, California

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Abstract

The Texas Triangle is formed by the metropolitan areas Houston and San Antonio at the base with Dallas and Fort Worth at the apex. It is one of the ten megaregions initially identified at the University of Pennsylvania in a study supported by the Regional Plan Association, the Lincoln Institute, and the Ford Foundation This paper presents a study of the Triangle by addressing two questions: 1) Is the Texas Triangle an integrated megaregion or it is only a geometric coincidence? And 2) What are the implications for planning and policy making from a megaregion approach for the Triangle? The first question is answered through analyses of the complementarities and interconnectedness of the five Triangle metros with historical and economic census data. Answers to the second question focus on implications for transportation planning in the Triangle. The study verifies empirically the RPA's identification of the Triangle megaregion. To accommodate the expected population growth and to strengthen its competitiveness in the global economy, the Triangle should take a megaregion approach for coordinated transportation and land-use planning. Such a coordinated approach will require changes in Texas law. High-speed rail is strongly recommended to reconnect the Triangle metros.

Acknowledgement:
The study was supported by the Regional Plan Association, the Lincoln Institute of Land Policy, and the Snell Grant for Sustainable Development at the Center for Sustainable Development at the University of Texas at Austin. The authors thank the following individuals for their valuable comments and edits on the paper: Petra Todorovich, Simon Atkinson, Amy Maverick Crossette, and Robert Paterson. Any remaining errors are the responsibilities of the authors'.

Key words:

Megaregion, Texas Triangle, Spatial Development, Regional Planning, Transportation

1. Introduction

Economic globalization and postmodern urbanization in the 21st century are prompting in a new geographical entity throughout the world—the megaregion. A megaregion consists of two or more metropolitan areas linked with interdependent environmental systems, a multimodal transportation infrastructure, and complementary economies. Many agree that megaregions concentrate people, jobs, and capital and play a decisive role in the increasingly competitive global economy. Observing this trend, the Regional Plan Association (RPA 2006) has advocated a megaregion approach, that is, spatial development at the megaregional level, as a useful scale for national planning. Megaregions can enhance current metropolitan and city level planning for economic development, infrastructure investments, environmental protection, and rural and urban land uses. The megaregion approach is also provocative and visionary answers to growing problems such as congestion, development disparity, and air pollution that are facing individual metropolitan areas or cities but are unlikely to be solved by each individually.

The Texas Triangle is one of the ten emerging megaregions in the continental U.S. initially identified by the University of Pennsylvania with RPA and the Lincoln Institute (Carbonell and Yaro 2005). It is geographically encompassed by the metropolitan areas of Dallas/Fort Worth, San Antonio/Austin, and Houston. This paper presents a further study of the Triangle by addressing two questions: 1) Is the Texas Triangle an integrated megaregion (or will it be) or is it only a geometric coincidence? and 2) What are the implications for planning and policy making from a megaregion approach for the Triangle?

The study of megaregion is a new, evolving area of inquiry, for which theories and methods are still developing. Answering these two questions will contribute to megaregion study with empirical lessons learned from the Texas case. The first question is rather unique to Texas, while it also concerns the general conceptual issues of megaregions. Among ten megaregions identified by RPA, the Texas Triangle has invited probably the most discussion. There are different versions of defining one or more megaregions in or around Texas, all which seem plausible.[i] For planning purposes, regions may be defined by political, biophysical, ecological, sociocultural, or economic boundaries. Megaregions often include several of these factors. In this paper we focus our discussion on the complementarities and interconnectedness of the five Triangle metros with historical and economic census data. The study of megaregions as networked metropolitan areas emphasizes not only ‘space of places’ (i.e. individual metro areas) but on the ‘space of flows’ such as transportation, information and business networks (Lang and Vhavale 2005) When answering the second part of the question, we focus on implications for transportation planning in the Triangle. The remainder of the paper is divided into five parts. Part 2 briefly reviews the historical urbanization process of the five Triangle metros and describes the origins of the functional complementarities among them. Part 3 examines the current economic structures of the five metros as they relate to their economic traditions. A trend is evident, demonstrating increasing economic interaction and integration among the four metros. Part 4 explores implications for transportation planning and policy making at the megaregional level in the Texas Triangle. Part 5 identifies local transportation challenges and responses in the Texas context. Finally, the paper ends with concluding remarks.

2. Urbanization Histories of the Texas Triangle Metros

The Texas Triangle has three sides measuring 268, 199 and 243 miles in ground distance (Figure 1). These distances are quite far to navigate even with modern ground transportation and even in the Texas sense of “bigness.” About 130 years ago, passenger and freight trains connected the major Triangle cities with each other. It was the train connection that boosted the initial growth of the settlements. According to Barry Popik (2007), a New York City etymologist, the term “Texas Triangle” appeared as early as 1936 when the Missouri Pacific (MoPac) Railroad announced its new overnight services from St. Louis and Memphis to link Dallas, Fort Worth, Houston, Austin and San Antonio. MoPac was one of the first railroads in the United States west of the Mississippi

River. It operated passenger train services in the southwest in the early years of the 20th Century. "The Texas Triangle" was one section of MoPac's premier name services, "Sunshine Special."

Today, the Texas Triangle train service no longer operates. Three interstate highways, I-35, I-45, and I-10 have assumed the role of providing inter-city connections and delineating the Triangle as shown in Figure 1. To the general public, the term "Texas Triangle" is now probably better known as the tough road trip facing NBA teams against the Dallas Mavericks, the Houston Rockets, and the San Antonio Spurs. Are the Triangle cities economic rivals like their home NBA teams, or do they function as complements? The following is a brief presentation of the functional histories of these cities.

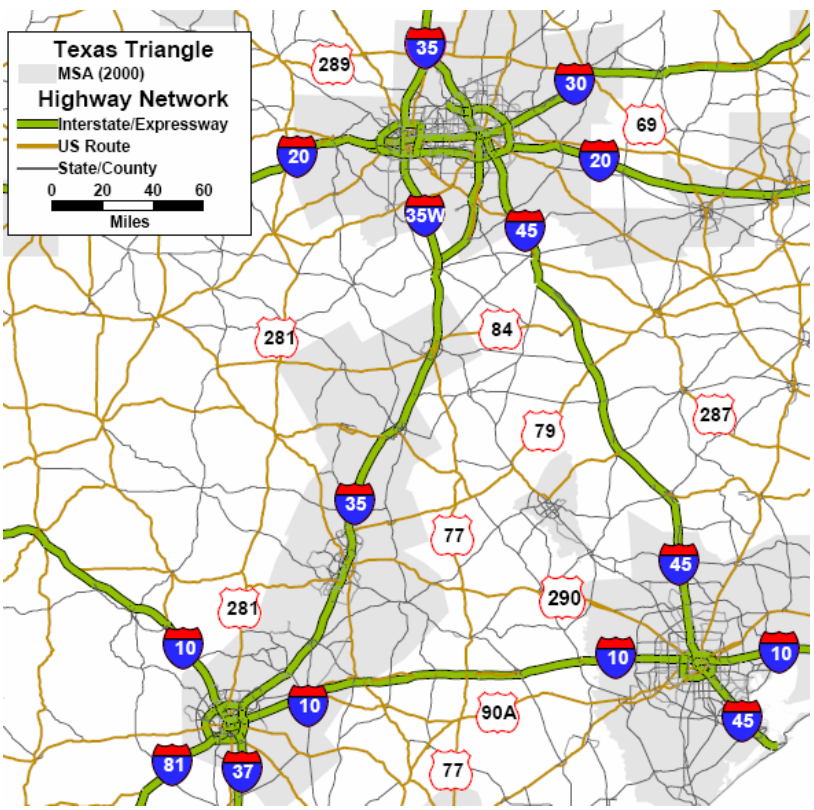

Figure 1. The Texas Triangle Delineated by the Interstate Highway Networks

San Antonio

The City of San Antonio (2000 city population 1,144,646; 2004 metropolitan population 1,889, 797) is located in south central Texas. Spanish explorers founded San Antonio in 1718 as a supply depot for the missions in east Texas and Louisiana. In 1731, San Antonio gained the distinction of being Texas' first municipality, established by San Fernando de Bexar. The Mexican Revolution in 1812 marked the start of a very unstable political period for the San Antonio region. By 1846, San Antonio's population had dwindled to 800 people. However, after the state of Texas joined the Union, San Antonio emerged as a distribution hub for western migration. It increased in population to 3488 by 1850. By 1860 San Antonio had become the largest city in Texas and it held this title until the early 20th century. The formation of the Galveston, Harrisburg, and San Antonio Rail System contributed significantly to San Antonio's prosperity at the time. Nevertheless, by 1930, Houston and Dallas had surpassed San Antonio in size.

During World War I, Fort Sam Houston became the largest military base in the United States. The military influence drastically changed San Antonio's economic landscape. The once agricultural distribution center of the west was transformed into America's training ground for its soldiers. During World War II, over a third of the total population of the city was comprised of military personnel. The population of the city actually doubled during World War II. San Antonio's dependency on the military as the main source of employment and chief economic driver characterized the region's social and economic climate. Being one of the oldest cities in Texas, San Antonio has more recently become one of the top tourist destinations in the United States. The tourist attractions include the River Walk, the Alamo and other Spanish missions, and numerous golf courses.

Figure 2. San Antonio/Bexar 1836 (Source: Nelson 2007)

Houston

The City of Houston (2000 city population 1,953,631; 2004 metropolitan population 5,280,077) is located in Southeastern Texas. The Allen brothers, Augustus Chapman Allen and John Kirby Allen, founded the Town of Houston on the Gulf coastal plain in 1836 and named the town after General Sam Houston. The Texas Congress designated Houston as the capital of the Republic of Texas and incorporated the city on June 5, 1837. The accessibility of water transportation offered Houston strategic advantages. Before the Civil War, Houston was the most interior point with access to the Gulf of Mexico by water. Small river steamships operating on Buffalo Bayou connected the oceangoing ships in Galveston with oxen-drawn wagons in the hinterland. At the turn of the 20th century**,** Houston's population reached 44,683

Major efforts began after the Civil War to dredge a better ship channel. In 1914 the Houston Ship Channel opened, making Houston a deepwater port, later to be ranked the second largest in the U.S. By then, Houston had become a large commercial power, ranking first among Texas cities in terms of volumes of commerce and industry. Shipping was a staple industry in the local economy, especially during World War II. Houston's economy had changed dramatically since the discovery of oil at Spindletop. To ensure a safe distance from Gulf storms, oil companies built their refineries along the Houston Ship Channel. After the war, Houston utilized its natural supplies of salt, sulfur, and natural gas to develop one of the two largest petrochemical concentrations in the United States. With this industry in place, Houston had become a world energy capital by 1970. Today, the Houston economy is still largely based on oil and gas-related industries, though the economy is rapidly expanding from its energy base.

Figure 3. Houston, TX in 1873
Source: Amon Carter Museum, 2007

Austin

The City of Austin (2000 population 656,562;2004 metropolitan population 1,452,529) is located in East Central Texas, where it straddles the Colorado River at the interface of the Edwards Plateau to the west and the fertile Blackland Prairie to the east. On a site used as a camp for Indian hunting parties, a group of Americans established the village of Waterloo which became Austin in 1839 and the capital of the New Republic of Texas. Austin's first mayor, Edwin Waller, proposed a grid system for streets on the north bank of the Colorado River. This grid is aligned on a northeast tending ridge between two creek valleys. That structure remains largely intact in the city's downtown. To the north of downtown, the grid shifts to a true north-south structure. Outside this core, streets ramble more organically across rolling hills and around water systems.

After Texas became part of the United States in 1845, Austin became the permanent state capital. St. Edward's University was founded by Rev. Edward Sorin of the congregation of Holy Cross in 1878 and The University of Texas at Austin followed in 1882. Until the early 1970s, the city's economy was dominated by state government and higher education.

Beginning in the late 19th century, a series of seven dams was constructed on the Colorado River for water supply, flood control, and hydroelectric power. As a result, manufacturing expanded, the University expanded in size, and the seeds for the computer technology industry were planted. Since the 1970s, the city has become an important center for computer technology (such as Texas Instruments, Dell, IBM, Motorola, Samsung, and AMD) and live music (such as Willie Nelson and the Dixie Chicks) and, to some extent, film (such as Robert Rodriguez and Burnt Orange Productions).

Barton Springs provides a popular year-round swimming pool with its constant temperature (68 degrees Fahrenheit) and prolific discharge (32 million gallons per day). Its popularity laid the groundwork for a strong local environmental movement affecting city politics and its local as well as national identity. The Lady Bird Johnson Wildflower

Center and other conservation organizations contribute to this "environmental" orientation. Meanwhile, the large academic, hi-tech, and student populations contribute both to continued technological innovation and a robust live music scene. Austin is also rapidly becoming a national leader in sustainable, "green" building, energy systems, and other infrastructure.

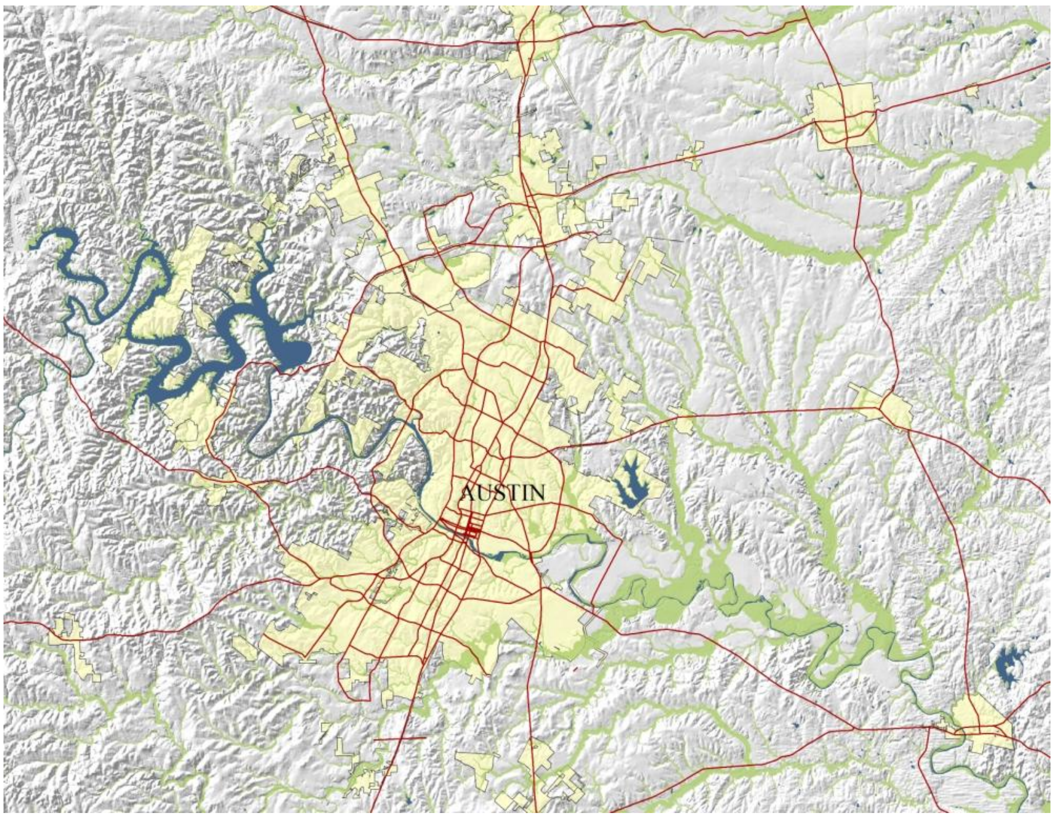

Figure 4. Austin Built Area and the Environment

Dallas

The City of Dallas (2000 city population 1,188,580; 2004 metropolitan population 3,893,123) is located along the Trinity River in Northeast Texas. John Neely Bryant was the first American explorer settling in the Dallas area in 1841. Rich soil and ample water made the area an ideal place to settle. Initially a trading post by the Trinity River, Dallas as a county was officially formed on March 30, 1846, by order of the Texas State

Legislature. Soon its role as an inland transportation hub was established when two Texas highways converged there. Providing services in dry goods and groceries stores, shoe and boot shops, and drugstores, Dallas reached a population of about 800 by 1860.

Fort Worth

Fort Worth (2000 city population 534,694; 2004 metropolitan population 1,926,352) is located along the Trinity River, 32 miles west of Dallas. At the end of the Mexican-American War in 1849, Major Ripley S. Arnold founded Camp Worth at the Clear Fork and West Fork of the Trinity River. The camp was officially named Fort Worth in honor of General William Jenkins Worth, a hero of the Mexican war. At war's end, the fort was relocated further west, settlers took the initial fort area and built department stores, a general store, a hotel, a doctor's office, and a flour mill. Fort Worth also served as the western terminus on the way to California for overland mail service and a stagecoach line. Fort Worth, like Dallas, benefited from the natural resources the area had to offer. However the Civil War caused shortages in money, food, and water supply. Dallas/Ft. Worth did not experience a strong growth until the arrival of rail connections in the late 1870s.

In summary, both Dallas and Houston started as distribution centers due to their transportation advantages, with Dallas as a land transportation hub in the inland and Houston as a water transportation hub on the coast. San Antonio and Ft. Worth started as military posts, whereas Austin was created in a strategic place as a political-institutional establishment. There were some overlapping functions among them, especially in recent decades. Nevertheless, in the early days, their geographical separations made their relations more like isolated economic entities than competitors or co-producers.

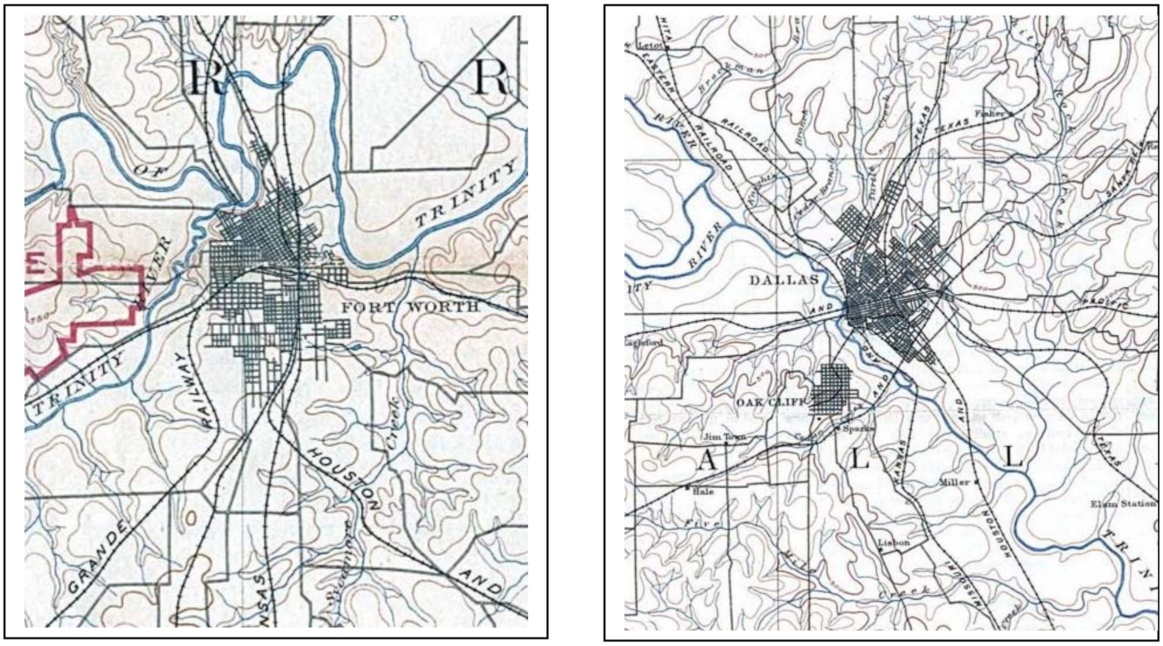

Figure 5. Fort Worth in 1894 (left) and Dallas in 1893 (right)
Source: UT Library 2007

3. Economic Structure of the Triangle Cities

In contemporary times, the Triangle cities continue to perform their traditional functions while new economic activities and services are produced and expanded. Through economic base analysis we are able to gain a quick understanding of the current economic structure and industrial composition of the metro areas. Robert W. Gilmer, Vice President of the Federal Reserve Bank of Dallas performed the following analyses with data from the US Economic Census. Table 1 reports the Location Quotient (LQ) values he calculated for the export industries for each of the four major metro areas in the Texas Triangle and for the Triangle as a whole (the five metro areas combined). An LQ is calculated as the ratio of an industry's share in the local economy (e.g., a metro area) over that industry's share in the national economy (or any reference economy in which the local economy resides). As a simple analytical tool, LQ allows us to quickly identify locally specialized industries, i.e., the export industries. Local economic growth, as the economic base theory suggests, is driven mainly by the expansion of export industries.

The larger the LQ is for an industrial sector, the more specialized the local economy is in that sector in comparison with other metro areas in the country.

Evident from the LQs in Table 1, the Triangle metros continue to play the strategic roles they have played in the past. For instance, Austin remains the place where the state government jobs concentrate, whereas San Antonio still presents its strength in federal civilian and military sectors. San Antonio has a large tourist industry, which is shown in a number of retail and services industries. Dallas/Ft. Worth's role as a distribution center is represented by its export industries in such sectors as trucking and warehousing, wholesale trade, air transportation, and transportation services. Houston's expected strength in resource production shows up in transportation (air, water, pipeline, and related services) and especially in oil and oil-related industries (oil and gas extraction, petroleum and coal products, chemicals and allied products).

The LQs reported in Table 1 do suggest the existence of head-to-head competition in several industrial sectors among the Triangle metros. For example, Austin and Dallas/Ft. Worth compete in the High Tech industries, specifically, in the sectors of communications and electronic and electrical equipment. Dallas/Ft. Worth, Houston, and San Antonio all have a focus on oil and gas extraction. Competition is apparent in air transportation between Dallas/Ft. Worth and Houston (or between the American Airlines, Continental and Southwest Airlines). Houston and San Antonio overlap in heavy construction as well as transportation services. Between Austin and Houston, some evidence of competition appears in the industrial machinery and equipment sector.

Additional statistical analyses of the LQs done by Gilmer (2004a, 2004b) show that, despite competitions in some sectors, the Triangle metros are highly complementary to each other in their economic roles. Specifically, he examined the export industries in the Texas Triangle with the four metros combined (Table 1) and studied change in variance among LQs in the Triangle. When the four metros are combined, the export industries reduces to 16 in number, as compared to 54 when LQs are reported for the metros separately. The variance of LQs also becomes smaller. The decreases in the number of export industries and in the LQ variance indicate that many of the export industries serve the metros within the Triangle and they support each other in performing economic functions.

Table 1. Location Quotients of Selected Export Industries in the Texas Triangle Metro Areas

	Austin	Dallas/ Fort Worth	Houston	San Antonio	Texas Triangle
Federal civilian	-	-	-	1.84	-
Military	-	-	-	4.7	-
State government	2.27	-	-	-	-
Local government	-	-	-	1.16	-
Auto dealers and service stations	-	-	-	1.28	-
Auto repair, services and parking	-	-	-	1.19	-
Business services	1.47	1.35		-	1.17
Chemicals and allied products	-	-	2.43	-	1.21
Communications	1.17	1.82		1.96	1.41
Depository and nondepository institutions	-	1.16		-	-
Eating and drinking places	-	-	-	1.35	-
Electric, gas and sanitary services	-	-	3.69	3.13	2.15
Electronic and other electrical equipment	3.32	2.47		-	1.54
Engineering and management services	-	-	1.4	-	1.2
Food stores	-	-	-	1.29	-
General building contractors	-	-	-	1.16	-
General merchandise stores	-	-	-	1.19	-
Heavy construction	-	-	3.03	1.18	1.73
Holding and other investment offices	-	1.16	2.1	1.72	1.54
Home furniture and furnishings stores	-	1.38		-	-
Industrial machinery and equipment	3.69	-	1.26	-	-
Insurance	-	1.16		2.35	-
Legal services	-	-	1.34	-	-
Miscellaneous manufacturing	-	-	-	1.18	-

Miscellaneous repair services	-	1.37	1.58	-	1.19
Miscellaneous retail	-	-	-	1.18	-
Oil and gas extraction	-	4.82	13.81	1.3	7.49
Petroleum and coal products	-	-	4.97	-	2.22
Pipelines, except natural gas	-	-	6.78	-	-
Private households	-	-	-	1.28	-
Real estate	-	1.54	1.27	-	1.31
Transportation by air	-	2.49	1.4	-	1.71
Transportation services	-	2.12	3.32	2.85	2.52
Trucking and warehousing	-	1.17		-	-
Water transportation	-	-	3.38	-	1.32
Wholesale trade	2.08	1.47		-	1.31

(Source: Adopted from Gilmer 2004a, 2004b)

The above studies on the history and the economic structures of the Texas Triangle metro cities remain focused on what is called the ‘space of places’ (Lang and Dhavale 2005) because these cities have been analyzed as discrete entities. In this sense integrated regions form on the dimension of ‘space of flows’ (Castells 1996 in Lang and Dhavale 2005). The characterization and assessment of the Triangle as an integrated region will require considerable additional research. As a first-cut, however, we examined economic integration and interaction among the Triangle cities by obtained and analyzing a dataset on county-to-county goods movements in the State of Texas. We then mapped truck flows for selected commodities available in the dataset (Figure 6). On each map, the width of a line linking any two counties indicates the proportion of goods moving between the two counties in the state-wide total of flows for that type of goods (for effective viewing, the goods flows in very small volumes are suppressed.) Although truck-transported goods movement does not represent all economic activities in the region, the maps in Figure 6 suggest the relative strength and nature of economic interactions among locations in the Triangle. For example, the flow map shows clearly the central distributional role of Houston for Chemicals/Petroleum products. Although the LQ-based analysis presented earlier has shown competition between Dallas/Ft. Worth and Houston in this economic sector, the stronger flow line in the map suggests a much stronger tie between the two metros than between Houston (Harris County) and other counties in the state. In fact, the two metros specialize in different sub-sectors in the Chemicals/Petroleum production and services sector. (The LQ-based analyses presented above were performed at the 2-digit industrial classification level. Further analyses at 3- or 4-digit level would reveal more detailed information on each metro's specialization in the sector.) The flow maps for Food, Building Materials, and Wood products reinforce this observation of economic interactions between the Dallas/Ft. Worth and Houston metros. Dallas/Ft. Worth's distribution role is vividly shown on the map for Machinery products. Both Austin and Houston also are specialized in the Machinery sector (see LQ analysis above). On this map, they both show a strong connection with Dallas/Ft. Worth. Yet there is also a noticeable interaction between them.

The map that is perhaps the most implicative of the Texas Triangle as an interconnected megaregion is the one for Miscellaneous products (including mixed freight, waste and scrap): it illustrates economic interconnectedness among the four Triangle metros and the distributional roles of the Dallas/Ft. Worth and Houston economies.

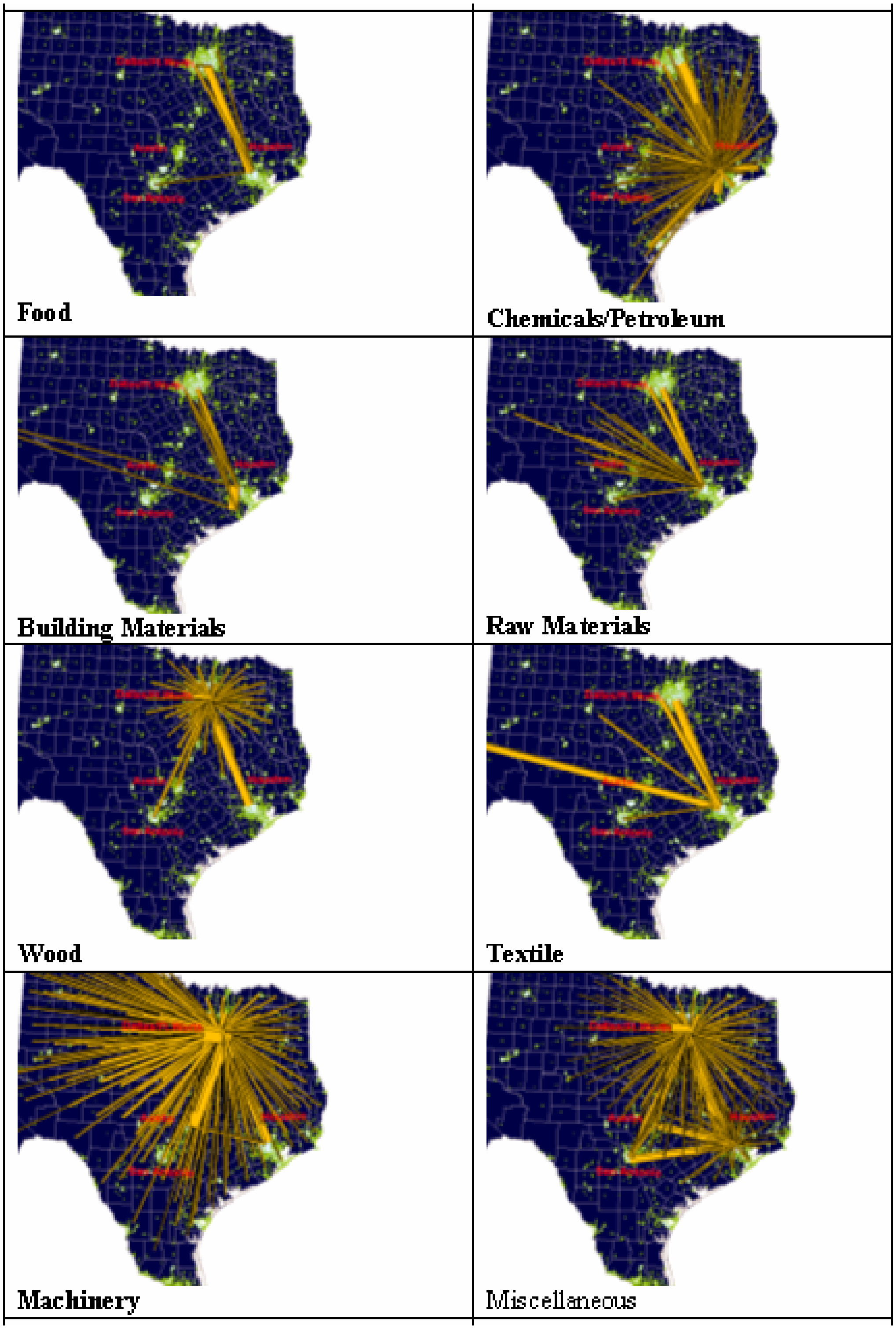

Figure 6: County-to-County Goods Flows in Texas

Air transportation links and Internet bandwidth represent the new elements of regional infrastructure in the information era for inter-metro and international exchanges of people and for transporting information, knowledge, and communications (Moss and Townsend 2000). Table 2 below shows daily flights among the Triangle cities served by the Southwest Airlines alone. Between Dallas and Houston, for example, flights depart every 30 minutes each way. American Airlines and Continental Airlines also offer multiple connecting flights throughout the region. Figure 7 illustrates the top30 U.S. Internet routes ranked by aggregate bandwidth. Although Austin and San Antonio did not make the top 30, the high Internet capacity connecting Dallas/Ft. Worth and Houston indicates a strong business tie between them.

Table 2: Daily Flights Provided by the Southwest Airline

City Pair	Flights per day
Dallas - Houston	29
Dallas - Austin	13
Dallas - San Antonio	15
Houston - Austin	8
Houston - San Antonio	10

Source: Southwest Airlines 2006

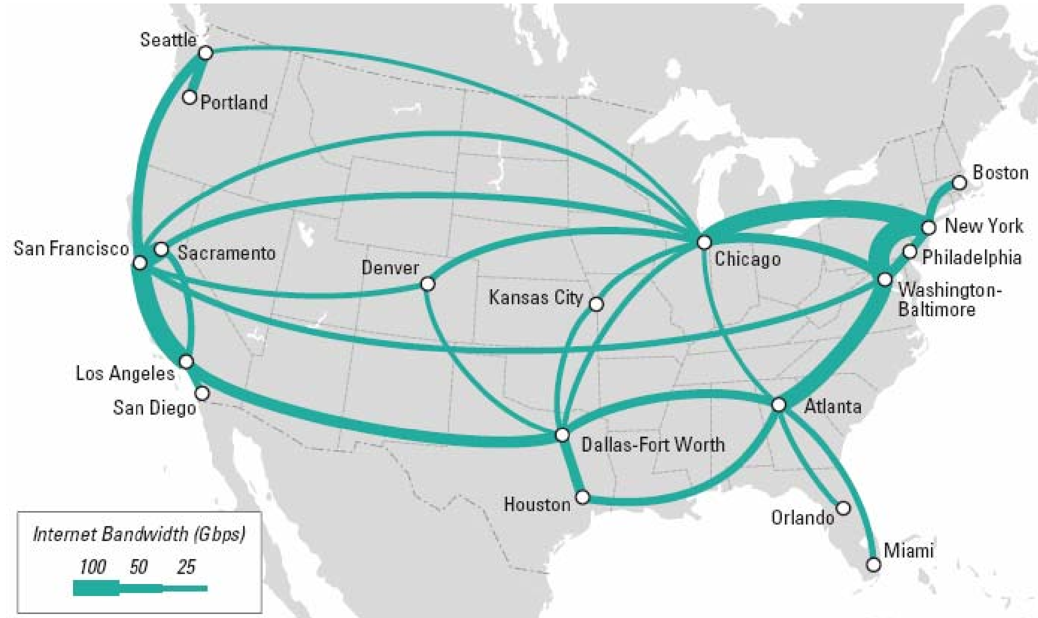

Figure 7. Top 30 U.S. Internet Routes, 2002
Source: TeleGeography, Inc. 2003

Conclusions that we can draw from the mapping analyses are twofold. First, we can conclude that the Triangle metros are closely tied together in performing their specialized economic functions. Second, competitions in some sectors do exist among the metros. There are obvious strategic opportunities that can arise from the development of economic strategies to foster coordinative competition. To do so, treating the Texas Triangle as a single region is a desirable solution. Understanding these relationships and underlying phenomena is an essential step in formulating a more sustainable future.

The urbanized settlements and transportation networks (or economic functions and flows) described above can be interpreted respectively as the point and the line (or link) elements of a region. They form the frame, but not the entirety of the Triangle as a geographical entity. Adding the area element would complete the regional characterization. The area element consists of the eco-environmental systems.

Figure 8 (left) illustrates the locations of major metros and the encompassing eco-regions, as defined by the Environmental Protection Agency (USEPA, 2002). The metros of

Dallas, Austin and San Antonio are located in and along the edge of the Blackland Prairie and Edwards Plateau. Houston and other parts of of the Gulf Coast lie in other eco-regions. These eco-regions are generally perpendicular to the Gulf coastal margin and to the major watersheds and river corridors as they extend to the coast (Figure 8 right).

The Blackland Prairie eco-region is a highly fertile and agriculturally productive province, comprised of fine textured clayey soils and only small remnants of a formerly extensive natural prairie. There is still a considerable proportion of agricultural land, although urban and industrial growth and development is a persistent challenge to preservation of the region's intrinsic resources.

The Edwards Plateau ecoregion is located south and east of Austin and San Antonio, characterized by a hilly limestone terrain that is dissected by many spring-dependent streams of tremendous ecological and recreational/aesthetic value. The Balcones Fault Zone and escarpment provides a sharp delineation of the Plateau eco-region from the prairielands to the east. The native vegetative cover is diverse and largely evergreen, with juniper and live oak. Most of the region is used for livestock and wildlife management, including hunting.

Together these resources and their associated amenities provide critical support to the economic stability of the metro areas.   Water supplies are developed in the upstream regions--immediately west and north of the metros. Agricultural, mining, and other resource-based industries provide a base for many dozens of smaller communities located between the metros. Increasingly, with improved transportation and telecommunication infrastructure, the interstitial zones between the metros are encountering intensive growth and development pressures.

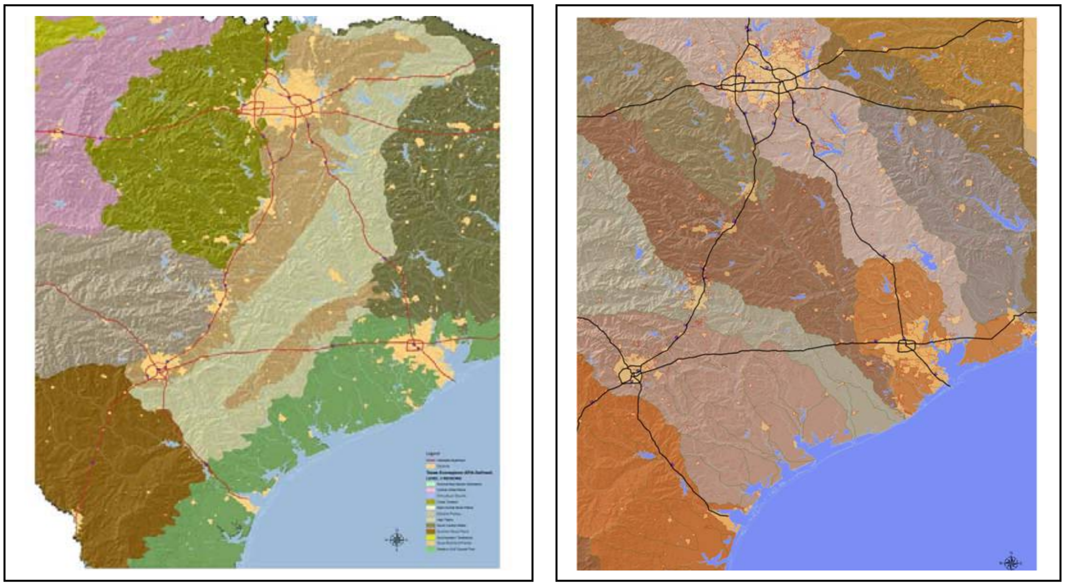

Figure 8. US EPA defined Level 3 Ecoregions (left) and Regional system of watershed in the mega region (right)

The Houston metro and associated communities closer to the Gulf Coast are situated in the Gulf Coastal Plain eco-region. The terrain is very flat and covered mainly in grassland, with forest or savannah-type vegetation in areas further inland. A very large proportion of the eco-region is in cropland. Urbanization and industrial development are the primary agents of change in land cover in this region. The Houston metro, for example, is expected to grow beyond 8 million population in the next 25 years.

The combination of the above described areas, flows, and eco-zones leads us to portray the Texas Triangle as shown in Figure 9: It includes 66 counties with an area of 57,430 square miles and a total population of nearly 15 million (Figure 9 and Table 3).

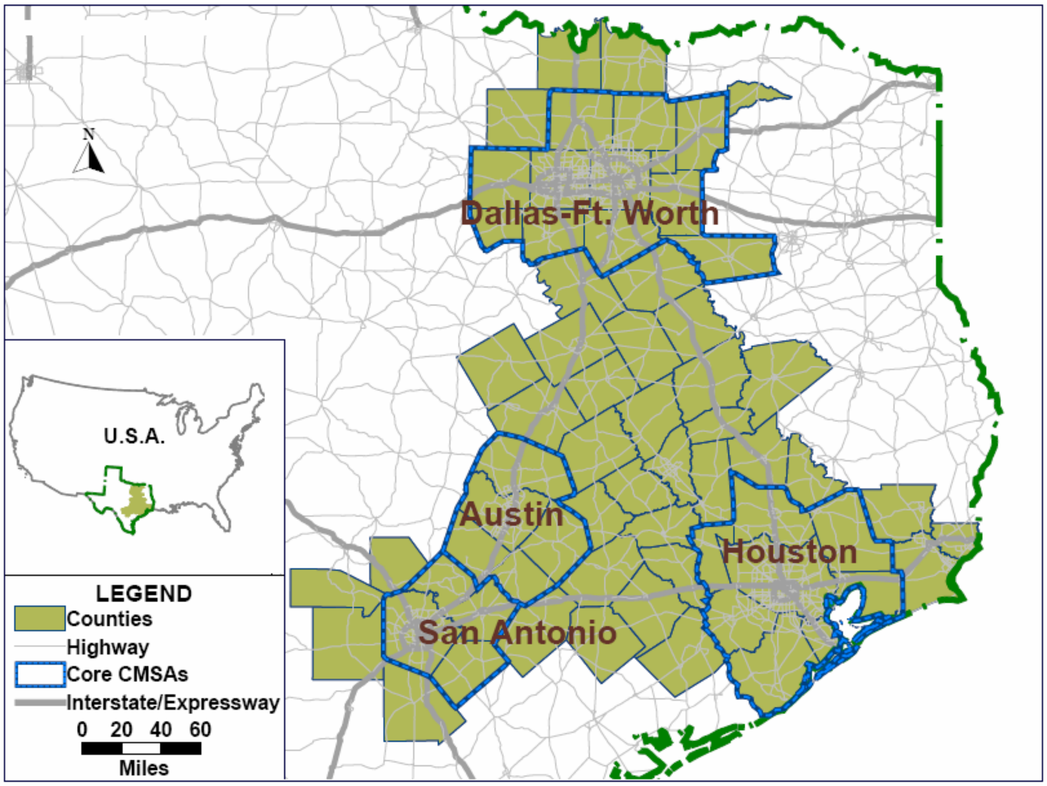

Figure 9. The Texas Triangle Megaregion

Table 3. Vital Statistics of the Texas Triangle Region

	Triangle (66 Cnty)	**4 Core CMSAs**	**Texas State**	**USA**
Area (sq.mi.)	57,430	25,035	268,580	3,794,083
Pop. (1000s)	14,660	12,734	20,852	281,422
GDP ($million)		605,458*	722,832	9,749,104
% of US Total				
Area (sq.mi.)	1.51%	0.66%	7.08%	100%
Pop.	5.21%	4.52%	7.41%	100%
GDP		6.21%*	7.41%	100%

4. Implications for Planning and Policy Making with the Megaregion Approach

The Texas Triangle Megaregion includes 66 counties with an area of 57,430 square miles and a total population of nearly 15 million in the year 2000. The region is expected to grow, as its past suggests, by an additional 10 million people over the next 40 plus years. How can the region prepare to accommodate the expected growth? In this section, we explore answers to that question from the transportation planning perspective. A megaregional approach for transportation planning in the Texas Triangle means that intercity travel between Dallas/Ft Worth, Houston, and Austin/San Antonio become an intra-region movement. Currently, Metropolitan Planning Organizations (MPOs) are responsible for transportation demand forecasting and planning for individual metropolitan areas. The scope of MPO's work typically does not go beyond their designated areas. While individual MPOs provide rather detailed pictures of their areas, forces of growth from the interactions among metropolitan areas and between the metro areas and their hinterlands are not often accounted for. A megaregional transportation plan should, therefore, integrate individual metropolitan transportation plans with consideration of inner-city people and goods movements. A new MPO – a Megaregion Planning Organization – may be necessary to coordinate the efforts of the MPOs and other entities in the megaregion (Lang and Dhavale 2005, p. 26).

A megaregion approach also calls for new ideas, methods and tools for planning beyond the current toolbox of MPOs. For instance, given the geographical scale of the megaregion, travel options to be considered should include air, high-speed rail (HSR), telecommunications, along with the conventional list of non-motorized modes, cars, buses, metro and light rail transit. The concept of commuting, which has been used by the Federal Office of Management and Budget (OMB) to define metropolitan, also needs to be reinvented (detailed below).

In this study, we explore ways to understand the unconventional nature of future transportation demands in the Triangle region through two exercises. One exercise builds on conceptual reasoning, whereas the other involves quantitative modeling. Conclusions from the two exercises converge with respect to recommending supply strategies to meet the future travel demand in the Texas Triangle.

Understanding Future Transportation Demand in the Texas Triangle: A Conceptual Assessment

The megaregion concept emerges in part out of the concern that the concept of the metropolitan area no longer adequately explains the economic and social interactions taking place in the spatial scope beyond the boundaries of individual metropolitan areas. In many cases such interactions even cross state or national boundaries. Hence the megaregion concept should extend from the metropolitan area, just like the extension from city to metropolitan area in the 1960s (Lang and Dhavale 2005; RPA 2006). This conceptual extension is based on the same principle as that used by OMB to define metropolitan area: "a high degree of economic and social integration." Commuting is considered as a key indicator of regional cohesion. In delineating the metropolitan area, OMB applies a commuting rule (along with other considerations). If 15 percent of a county's labor force commutes to daily to work in a central nucleus, the county is included as part of the metropolitan area.

There have been suggestions that, with a spatial scale as large as the megaregion, commuting is no longer a valid indicator of regional integration (RPA 1967 in Lang and Dhavale 2005). We adhere to this indicator in our study based on the consideration that commuting behavior and the commuting concept have changed in the past four decades and will likely change in the four decades to come. For example, telecommuting has become a recognized mode of (virtual) travel. Although total substitution of telecommuting for physical travel is unlikely, partial substitution (e.g., a 1-3 day work week), is increasingly popular (Collanters and Mokhtarian, 2003). However, people tend to reallocate time saved from telecommuting for other travel rather than staying home, enabling them to travel to farther locations for larger homes or for better job opportunities. If a worker travels 1-3 days a week, his/her travel time budget would increase by 20-60 percent for the remaining travel days, assuming a fixed weekly travel time allocation. Anecdotal evidence from the Texas Triangle has showed that a growing number of people live in Austin but work in Houston through a combination of telecommunicating and physical commuting.

OMB's method for delineating a region indicates a performance standard for megaregional transportation: *job destinations in the region should be accessible in the reach of average daily commute for its workers*. In other words, the transportation system in the Triangle should provide sufficient mobility and access for the Triangle workers to work in the daytime in one place and return home in the evening to another place that may or may not be in the same city.

The distances between the major Triangle metros range from 199 miles between Houston and San Antonio, to 243 miles between Houston and Dallas/Ft. Worth, and 268 miles between Dallas/Ft. Worth and San Antonio. Assuming an average driving speed of 55 miles per hour, it takes 3 to 5 hours each way to drive between these cities. Apparently, daily commutes within the Triangle megaregion are not feasible by the current dominant form of travel--the automobile.

The above example indicates that for passenger movement, travel modes in high speed are necessary. This may include telecommuting, high-speed rail (HSR), air, or combinations of these modes. Airplanes typically have a cruise speed of around 500 miles per hour. For the distances among the Triangle cities, the average air travel speed declines to 250-300 miles per hour when travel times to/from the airport are taken into consideration. This is essentially the typical speed of HSR (in Shanghai, China, the MagLev train runs 260 miles per hour at a cruise speed.) Coupled with telecommuting, HSR would enable a worker to commute between any pair of cities in the Triangle within an acceptable daily commuting time. Imagine a future where a person can live in Austin and commute to work on a daily basis to Dallas or Houston. When the entire Triangle is within the reach of a daily commute, it then becomes an integrated megaregion meaningful to individual households and firms.

Aggregate Forecasting of Future Transportation Demand in the Texas Triangle

This part of our analysis models future travel demand in the Texas Triangle. It applies an aggregate model developed by Schafer and Victor (2000) who studied world mobility demand in terms of total amount of travel and shares of different travel modes.

The model is developed based on three behavioral characteristics of human travel. The first is income-mobility correlation: As income grows, demand for more and faster mobility increases (Ingram and Liu 1999). The second is travel time regularity, namely, the Constant Travel Time Budget (Mokhtarian and Chen 2004). Worldwide observations have shown that, on average, individuals allocate 1-1.5 hours per capita per day for travel. The third is travel spending regularity, namely, the Constant Travel Money Budget: People allocate 10-15 percent of per capita personal income for transportation related expenses.

With a steady travel money budget, a relationship between income and the amount of travel can be estimated. Based on the state economic and population projections for the Triangle region (TXSDC 2006), we projected total mobility demand in terms of person miles of travel (PMT) and demand by four different travel modes: Car, bus transit, rail transit, and high-speed modes (high-speed rail or air) for the Triangle.

Table 4 and 5 report the results. Evidently, the shares for the three slower modes will decline. However, the total travel in each mode will increase. The total travel in 2050 by bus and auto modes nearly doubles from the figure in year 2000. For travel at high speeds, it is an enormous amount that must be accommodated by 2050. Airlines are already currently providing frequent flights in the Triangle area (see Table 2 above). Airport and airspace congestion will constrain major expansions of air transportation services in the Triangle. Implications of these results reinforce what is presented in the previous section: planning for megaregional transportation should seriously consider high-speed travel in the form of HSR in order to accommodate the future mobility demand in the Triangle region.

Table 4. Mobility Projection in the Texas Triangle and in the US (passenger km)

Year	Per Capita		Total Mobility in Texas Triangle (millions of miles)
	North America[1]	Texas Triangle	
1990	22,078 (actual)[2]	N/A	N/A
2000	27,353 (actual)[2]	26,326 (estimated)	385,935 (estimated)
2020	40,432	42,022	843,345
2050	58,149	66,616	2,035,382

1. Source: Schafer and Victor 2000)

2. Source: Bureau of Transportation Statistics 2006

Table 5: Projected mode shares and total travel by mode for the Texas Triangle

Year		Rail	Bus	Auto	High-Speed
2000	Total (millions pkm)	2,181	11,481	255,877	116,396
	Per Capita (pkm)	148.8	783.2	17,454	7,940
	Share	0.6%	2.9%	66.3%	30.2%
2020	Total (millions pkm)	2,471	15,595	343,871	481,408
	% Increase in Total from 2000	13.4	35.8	34.4	313.6
	Per Capita (pkm)	123.1	777.0	17,134	23,986
	% Change per Capita from 2000	-17.3	-0.8	-1.8	202.1
	Share	0.3%	1.8%	40.8%	57.1%
2050	Total (millions pkm)	3,095	21,636	465,812	1,544,838

% Increase in Total from 2000	41.9	88.5	82.0	1,227.2
Per Capita (pkm)	101.3	708.2	15,248	50,568
% Change per Capita from 2000	-31.9	-9.6	-12.6	536.9
Share	0.2%	10.6%	22.9%	75.9%

5. Implementing Megaregion Approach: Local Challenges and Actions

Differing from most other megaregions that cross the state or even national borders, the Texas Triangle megaregion falls within the state boundaries of Texas. This should offer institutional advantages in formulating and implementing policy strategies to foster megaregion transportation planning. Anticipating future growth in passenger and freight travel demand, Texas has developed a supercorridor plan, 'the Trans-Texas Corridor' (TTC). Each route in the TTC network includes four elements: 1) separate toll lanes for passenger vehicles and large trucks, 2) freight railways, 3) high-speed commuter railways, and 4) infrastructure for utilities including water lines, oil and gas pipelines, and transmission lines for electricity, broadband and other telecommunications services (TTC 2007). Two initial TTC corridors are considered. One runs in parallel to I-35 from Gainesville to Laredo, passing Dallas, Austin and San Antonio. The other extends I-69 from Texarkana to Houston and then to either Laredo or the Rio Grande Valley (Wikipedia 2007). TTC however has met with strong political resistance mainly due to the high costs for construction. In addition, the TTC's 1,200 feet wide right-of-way will require in total about 9,000 square miles of land to be purchased or acquired through eminent domain. While the specific TTC plan remains a subject of debate, the TTC effort does indicate an opportunity to develop a multi-modal transportation infrastructure for the Texas Triangle megaregion.

Nevertheless, transportation planning faces several challenges in Texas. First, transportation planning is not coordinated with land-use planning. Second, counties have practically no planning authority, which exacerbates the ability of county leaders to address growth problems. Third, as the state grows and roadways become more congested, there are not enough public funds to pay for new roads. As a result, state policy makers and transportation planners have turned to toll roads, which face growing opposition from the public. Fourth, although Dallas, Houston, and Austin have begun metropolitan rail systems, there is no intercity rail network among the major Texas Triangle cities.

Envision Central Texas has made some progress to address the first two challenges. Envision Central Texas began in 2001 as a five-county, non-governmental regional planning process (www.envisioncentraltexas.com). A vision for the region was published in 2004 and implementation of that vision continues today. Transportation and land use integration became a major focus of those implementation efforts. The vision helped contribute to a successful regional rail election in 2004, which passed with 62.2 percent of the vote. This initiative will create a 32-mile commuter rail service connecting downtown Austin with the northwest suburb of Leander. The rail line will have nine stops and will open in 2008. The growing city of Leander is located at the terminus of this first commuter rail line. Leander city officials redid their downtown plan as a result, essentially creating a transit-oriented development (TOD) center.

Meanwhile, Envision Central Texas continued to sponsor workshops on topics like TODs and continued to bring local leaders together to discuss more effective transportation and land use integration. An especially challenging project was under construction as Envision Central Texas pursued implementation: State Highway 130 (part of the proposed private Trans Texas Highway). This 91-mile toll road crosses the eastern part of the Austin metropolitan region and was designed to help release congestion on the increasingly gridlocked Interstate 35 which runs north from the Mexico border through San Antonio, Austin, Waco, Dallas, Fort Worth, and points north. State Highway 130 (SH 130) will enable motorists to circumvent central Austin.

The small towns and counties in SH 130's path are ill equipped for the land-use problems resulting from the new toll road. Meanwhile, Texas cities possess quite liberal annexation and extraterritorial jurisdiction (ETJ) authority. However, the SH 130 construction presents fiscal challenges to the City of Austin to annex corridor land in its ETJ zone. Envision Central Texas helped organize elected officials and planners from the affected jurisdictions along the SH 130 corridor. These individuals shared their concerns and efforts, which led to an agreement to coordinate their planning. They also identified the need for improved state law to enable better planning. As a result, on March 9, 2007, legislation was introduced to amend state law that would benefit smaller towns, counties, and the city of Austin as follows:

Addressing the Needs of Small Cities

The proposed legislation would:

- Allow municipalities to seek limited purpose annexation if any of their incorporated territory is located within 15 miles of SH 130 and of Austin.
- Maintain that authority even if the Texas Department of Transportation transfers ownership or operation of the road.

Addressing the Needs of Counties

The proposed legislation would:

- Allow county zoning power exclusively in an area that is within 15 miles of SH 130 and of Austin. The proposed bill would have no effect outside Travis and Williamson Counties, nor could it pass over Austin's city limits to affect growth in areas of Travis County far from SH 130.
- Limit those county zoning powers to cover:
    - The height, number of stories, or size of buildings
    - The percentage of a lot that may be occupied
    - The size of yards and other spaces
    - Population density
    - The location and use of buildings and land for commercial, industrial, residential, or other purposes
    - Building construction standards

- Permit an impact fee within the 15-mile zone unless cities are already imposing an impact fee.

Addressing the needs of the City of Austin:

The proposed legislation would:

- Create an infrastructure district within five miles of SH 130 and within Austin's ETJ zone.
- Give the city limited purpose annexation authority over the infrastructure district, including land-use powers and tools that maximize development potential.
- Require the city to assume the district's debts upon annexation.
- Allow the district to collect sales and property taxes to pay for utilities and infrastructure within the district. Either tax rate can be lower—but neither can be higher—than the corresponding tax rates within the city.
- Forbid any taxation within the district until residents there can vote in at least one Austin City Council election.
- Require that tax-supported bonds to pay for infrastructure be approved by voters within the district.
- Stipulate that the Austin City Council serve as the district's board of directors.
- Require public notice and at least two public hearings on the creation of the district.
- Dissolve any part of the district that is annexed into the city.
- Not give eminent domain power to the district.
- Create a process through which landowners in the district, the city of Austin, and other stakeholders jointly discuss how to implement this tool.

Improved planning and growth management legislation has been opposed in the Texas legislature in past, primarily by rural county representatives. However, there are changes that provide hope. The senate sponsor of the proposed legislation is the Democratic former mayor of Austin, the house champion is a suburban Republican, who also chairs the House Transportation Committee. Both have been active in Envision Central Texas. In addition, formerly rural counties in the Texas Triangle are quickly becoming urban and/or suburban. As a result, they support providing counties and smaller cities the tools to manage growth.

If the legislation is enacted, the law would certainly help the more effective planning of the State Highway 130 corridor. It would also strengthen the implementation prospects of the Envision Central Texas vision. In addition, it would lay the groundwork for better transportation and land-use planning in other Texas Triangle metropolitan regions.

Envision Central Texas is but one regional planning effort in the Triangle beyond more traditional MPOs and councils of government (COGs) (see Walz 2005). Not surprisingly, in the Houston region, business interests dominate transportation and land-use policy as exemplified by the 2,000-member Greater Houston Partnership. This partnership has supported both toll roads and Houston’s 7.5 mile light-rail line from downtown to the Reliant Park sports complex (Walz 2005).

In the Dallas-Fort Worth Metroplex, the North Dallas Council of Governments has gone beyond tradition COGs in its advocacy of sustainable development. The North Dallas COG joined with several other groups to launch Vision North Dallas in 2004. This new private-public partnership was formed to increase awareness about growth and remains in its early stages. However, it can build on the successful and popular Dallas Area Rapid Transportation system with 45 miles of light rail lines and 34 stations as well as the 35-mile Trinity Railway Express linking Dallas and Fort Worth.

As these metropolitan initiatives continue, the next step is to link efforts among the regions within the Triangle. Together, the opportunities for transportation and land-use reform increase. Without such reform, the future of the Texas Triangle is bleak.

6. Concluding Remarks

In this paper we briefly reviewed the urbanization history of the Texas Triangle metros and examined their current economic structures as well as the economic interaction and integration among the five metros. From these analyses we empirically verified the RPA's designation of the Texas Triangle as a megaregion. The implications of a megaregion approach for the Texas Triangle are profound, for planning and policy making in general and for developing transportation infrastructure, specifically. A critical starting point in formulating spatial development strategies for this megaregion is probably not the past, nor the present, but the future. We ought to have a vision for the future first, and then connect it with the past through the present. Some Triangle metros, such as the Central Texas (the Austin Area) and North Texas, have embarked on ambitious visioning exercises. As should the Triangle megaregion. Several metros have also created rail systems, including Dallas, Houston, and Austin. However, with the exception of Dallas/Ft. Worth, intercity passenger rail systems are absent. To fully realize its potential, the Texas Triangle cities should be connected with passenger rail systems.

Rail connection once was a major factor leading to rapid urbanization in individual Triangle cities. The automobile outperformed the rail for its flexibility and door-to-door operating speed in the last century. In the 21st century when people's demand for work, social and entertainment activities goes beyond the geographical scope of individual cities or metropolitan areas, the automobile does not provide the necessary speed needed. In addition, governments are reaching their limits to pay for new roads and are increasingly turning to unpopular toll systems. The time for rail has come again. It is the time to resume the Texas Triangle train for the Triangle megaregion, but this time with much more advanced technologies.

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[i] Aside from the triangle version proposed by RPA (2005), Land and Dhavale (2005) propose two corridor megaregions. One is I-35 Corridor going from San Antonio, TX to Kansas City, MO. The other is Gulf Coast stemming from Brownsville, TX to Mobile, AL along the Gulf of Mexico. A version of "Texas Hinge" extending to Mexico also emerged during the 2006 Megaregion Workshop in Madrid, Spain.

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