Regional Market Access and Intermodal Connectivity: Implications for Area Economies and Transportation Planning

by

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ABSTRACT

While a significant body of research has focused on employment agglomeration at an urban level, this paper presents a broader view that also includes new empirical research on regional and intermodal access and its economic implications. The analysis shows how business clustering (employment agglomeration) can occur at different scales and in different forms, reflecting a range of needs to access local and regional populations, suppliers, and customers, as well as intermodal gateways that provide access to broader national and global markets. These different types of access have broader economic development and productivity implications that are particularly important for transportation planners who evaluate proposals for freight and passenger modal investments connecting communities and intermodal facilities. To address these issues, the paper brings together three complementary perspectives: (a) transportation planning literature that distinguishes types of transportation investment and plans; (b) site location literature that defines business location decision processes and their spatial scale, and (c) economic research that provides a basis for defining scale economies and productivity effects. It presents results of a new US study that develops statistical relationships between types of access and industries in terms of their relative concentration and productivity at a county level. The results show the importance for transportation planners to consider freight access as well as customer and worker access. They also indicate the potential for decision bias if project prioritization and cost-benefit analyses fail to consider the full range of spatial scales relevant for assessing market access. The article discusses implications of these findings in terms practical applications for transportation investment planning, and it highlights remaining needs for further research.

Keywords: access, accessibility, market access, agglomeration, economic impact, productivity, intermodal, regional, connectivity, airport, intermodal rail, port, labor market.

INTRODUCTION

Background and Need. Transportation planners operating at the state or regional level often need to evaluate plans for improving freight and passenger connections between communities as well as ground connections with intermodal facilities. These changes in connectivity can be particularly important for regions with evolving population and economic patterns. In that regard, there has been increasing attention to the role of transportation corridor investments in expanding the accessibility of areas to surrounding markets and intermodal terminals, and resulting regional economic consequences. However, much of the past attention on economic consequences has focused on urban business agglomeration rather than broader regional-scale access and connectivity for freight and passenger travel. There is thus a remaining need for transportation planners to better differentiate the economic benefits and impacts of different kinds of transportation investments in various locational contexts.

Overview. This paper addresses these issues by examining how three distinct lines of research – transportation, regional development, and economics – can provide insight into various dimensions of transportation access and its economic consequences. An important aspect of this analysis is the distinction made between types of access that are relevant depending on the type of transportation investment. This includes measures of access for local labor markets, same-day passenger travel, just-in-time freight delivery, and broader access to airports, intermodal rail terminals and seaports. The paper then presents results of a new US study that analyzes the statistical relationships between these different types of access and their resulting impacts on concentration and productivity of specific industries. These findings can have practical applications for improved transportation investment planning and help to highlight directions for future research.

COMBINING RESEARCH PERSPECTIVES

This paper seeks to bring together three complementary perspectives that together define the application of access concepts in transportation planning: (a) transportation planning literature which defines the nomenclature and classification for distinguishing different types of transportation investment and plans; (b) site location literature which defines business location decision processes and their spatial scale, and (c) economic research which provides a basis for defining scale economies and productivity effects. We show how these three lines of research can together provide more nuanced and insightful findings to inform transportation planning and investment decisions.

Role of Access from the Transportation Planning Perspective

The transportation planning process provides a framework for evaluating access that is necessary for infrastructure investment. This starts with the distinction made by transportation planners today, between (a) effects on saving time and/or cost for existing travel patterns, and (b) effects on expanding possible travel patterns by enabling access to broader areas and opportunities. The latter (access) role was historically important, as investments ranging from ancient trade ports to Roman roads provided access links between Europe and Asia that transformed the economies in both continents (*1,2*). Much later, the US economy developed following the opening of markets enabled by the Erie Canal, transcontinental railroad, and interstate highway systems. While market access impacts have long been considered in transportation planning, the advent of travel demand models and benefit-cost analysis have more narrowly focused attention to investment decision-making based on traveler time and cost savings. More recently, though, the role of improving market access and its effects on enhancing productivity has again gained consideration in the context of wider economic benefits for transportation investment evaluation (*3,4,5*).

Transportation planning and decision making has sought to match investment in different types of modal facilities (i.e., roads, rail lines, airports, and water ports) with the categories of user demand to which they are best suited, using "trip purpose" such as freight delivery, commuting, business passenger travel, and tourism/leisure travel to differentiate needs (*6*). Mode-purpose combinations have a systematic relationship to travel distances that indicate market access ranges. For example, the definitions of labor markets and freight delivery market relate to distinctly different distance ranges; the former typically involves travel times under one hour while the latter may involve travel times of 3 hours or more. (See later discussion of market size thresholds.)

As transportation planners often rely on network models for ground access measurement, they can see airports, rail freight terminals and water ports as network nodes that operate as "intermodal gateways," providing access to broader national and international locations. From that perspective, network connectivity is the process by which links are provided (or enhanced) to expand the effective breadth of markets for labor, freight delivery, and other economic or leisure activities. We can thus view transportation investment effects on access to those markets as dependent on the types of modal facilities and trip purposes that they serve. This view is today reflected in the large volume of multi-modal plans, freight plans and rail plans being completed by US states and MPOs, that often distinguish investments in terms of key commerce corridors, freight corridors, commuting corridors, and intermodal terminal access.

<u>Role of Access from the Perspective of Business Location</u>

Business site location decisions have long been a central concern in the economic development field, which seeks to maximize growth of job opportunities and wages. Economic developers recognize that these goals are tied to increased productivity and expanded markets, which can be enabled by transportation system access. The site location literature follows these issues to provide insight into how business location and clustering decisions vary among industries and at different spatial scales.

Site location research commonly ties business site location to a decision process with two elements. The first is regional scale – considering the regional availability of workforce, suppliers, and customer markets, as well as unit operating costs (for energy, labor, transportation, and taxes). The second element is local scale – selecting a site location within that region based on requirements for land, ground and intermodal transportation access, utilities, and related amenities.

The role of access for both freight and labor is demonstrated by Area Development magazine's annual survey of national corporate executives, which shows the top ten decision factors in U.S. industrial site location. They include three regional access considerations: highway accessibility, availability of skilled labor and proximity to major markets (*7*). These location factors apply for "traded industries" (e.g., manufacturers), which produce and sell products across regions and hence are locationally mobile – able to choose a regional location that optimizes their revenue and profitability. The importance of highway locations for manufacturing industry sites has also been identified in several European studies

(*8,9*). In contrast, long-distance highway access is not as strong of a factor for “local-serving industries,” which are in contrast to traded industries as they need to locate in areas where they can best access the immediately surrounding population base (*10*). There is extensive research documenting the importance of regional scale access for specific traded industries. This includes studies in the following areas:

- *High-Tech Clusters.* In the US, there has been particular attention to the clustering of high-tech industries, such as computer/software and biomedical/pharmaceutical industries. High tech industries typically cluster in specific metropolitan areas where they can access a sufficiently large workforce to find specialized skills, along with access to university research facilities (*11,12*). The statistical relationship of high-tech employment with access to a large-scale population base, a major university and a major airport has also been documented (*13*). These three attributes correspond to agglomeration benefits of labor pooling/matching, knowledge spillovers, and access to collaborators. High-tech clusters are generally defined at a metropolitan level, as illustrated in Figure 1. Another line of research has shown that, within these metropolitan areas, high-tech businesses tend to locate in places with public transportation access (*14*).

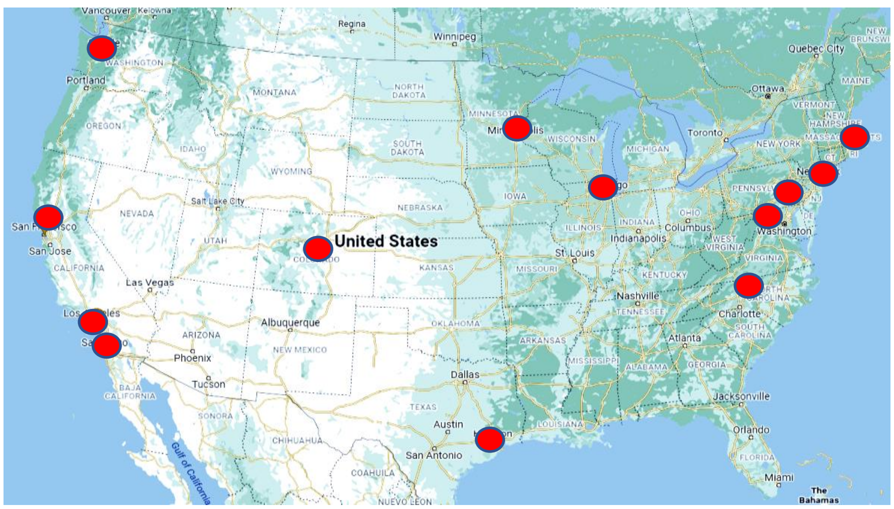


Figure 1. Top US Metro Area Life Sciences Clusters (pharmaceutical + biomedical devices)
Source: Google maps; clusters from JLL 2020 Life Sciences Real Estate Outlook

- *Intermodal Access for Manufacturers.* There is broad body of research on the importance of intermodal terminal access for manufacturers, which represent gateways to broader national and international freight markets. This includes access to intermodal truck/rail terminals *(15*), as well as air and marine freight terminals *(16*). Several studies have focused on the importance of airports to manufacturers and distributors of products with a high value/weight ratio, as they provide access to global-scale markets (*17,18,19*). Others have developed county-level measures of freight accessibility differentiating between air, rail, and maritime gateway access (*20, 21*). The roles of modal terminal access in affecting the concentration of various industries have also been examined *(22*). A related line of studies documented the role of freight accessibility in enabling specific spatial concentrations of both regional logistics and foreign trade related activities (*21, 23)*. Trade-oriented logistics clusters reflect scale economies where ground transportation networks connect consumer and supply chain markets to global freight markets via intermodal air and sea facilities (*24*). They can include both “near dock” and “inland port” facilities (*25*).

- *Same-Day Manufacturing Supply Chains.* The confluence of information technology for inventory control, along with highway network development, has also enabled scale economies in serving wider markets for same-day and overnight delivery. A prominent example is the southeastern US automotive cluster, featuring automobile assembly plants located along several major interstate highways, surrounded by parts suppliers located along highway routes that enable "same-day" delivery to multiple assembly plants *(26,27, 28).* (See Figure 2). This form of clustering enables firms to more reliably source parts, reducing buffer stocks and associated logistics costs.

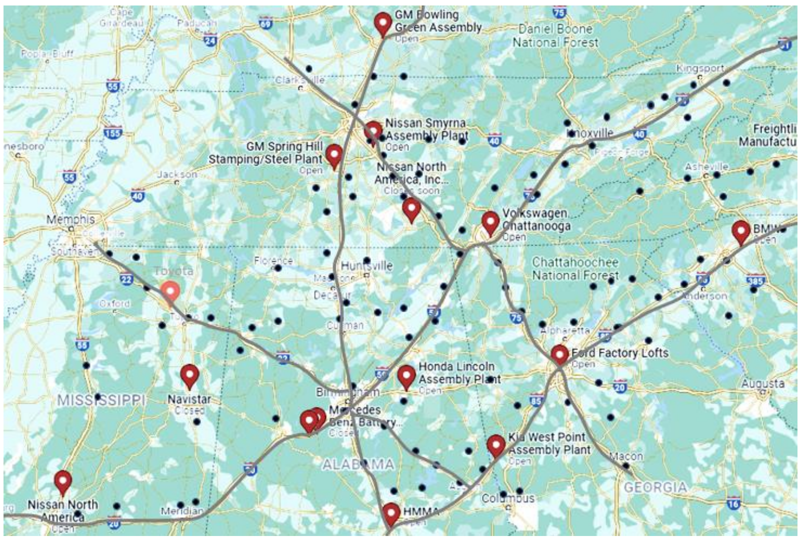


Figure 2. Southeast US Automotive Supply Chain Cluster

Note: Red circles denotes automotive assembly plants (source: Google maps); Black dot denotes automotive parts suppliers (source: Driving Workforce Change, The US Auto Supply Chain at a Crossroads, http://drivingworkforcechange.org/reports/supplychain.pdf)

- *Regional Distribution Centers.* Fueled by expansion of e-commerce, massive warehouse clusters have developed in regions around Los Angeles, New Jersey, Pennsylvania, Dallas, Atlanta, and Chicago. This form of development builds on integrated supply chain management that utilizes information and communications technologies to enable regional distribution centers that can utilize scale economies to serve wider delivery markets (*29*). This has been characterized as "logistics sprawl" because these distribution clusters are further from urban centers than older, local warehouses (*30*). An example is the cluster of distribution centers spread along a 120-mile stretch of I-81 in Eastern Pennsylvania. Illustrated in Figure 3, this cluster is situated where same-day round trips can be made to four large metropolitan areas on the east coast. I-81 is a popular route for trucks that avoids the more congested and older I-95 route that directly connects these metro areas.

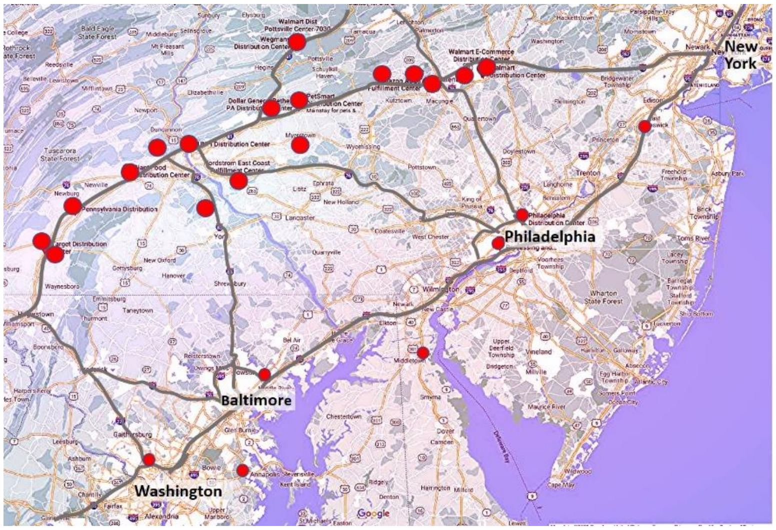


Figure 3. Cluster of Distribution Centers Focusing on I-81 in Pennsylvania
Source: Google Maps, Red circles denote distribution centers

- *Tourism and Visitor Support Industries* depend on customer access to their services. A variety of studies have documented the role of airports in providing market access for national and international tourism industry development (*31,32,33*). Tourism is considered a traded industry in that it involves interregional commerce bringing an inflow of money to a region, though in this case the customer comes to the producer, in contrast to manufacturers who normally deliver the product to the customer.

Taken together, these examples show how various types of traded industries cluster to maximize access to relevant labor, supplier, and customer markets, as well as sources of technology knowledge. The various types of clusters differ in terms of spatial scales and densities, reflecting a range of attraction and dispersion productivity factors that depend on transportation networks and facilities. These factors are discussed next.

<u>Role of Access from the Perspective of Economic Evaluation</u>

The economic research literature on "agglomeration effects" evaluates how areas with higher concentrations of business activities can also have higher productivity. These effects draw upon both scale economies in accessing surrounding markets (urbanization effect), and scale economies in drawing upon similar and complementary businesses located nearby (localization effect).

One line of research on agglomeration has focused on regional area effects – showing how the productivity of specific industries at a state or metropolitan level relate to the density, scale, and connectivity of activities (*34,35*). Other studies have focused on agglomeration at a finer zone level, assessing the concentration of employment among UK wards or US census tracts. This latter line of research has highlighted the effects of proximity to similar firms in explaining productivity effects. Graham (*3*) developed the concept of "effective density" to capture the combined effects of a zonal concentration of industry activity and a gravity model function that captures industry concentration in surrounding zones weighted by travel time proximity. Studies have shown that zones with a higher effective density of employment in specific industries have relatively higher levels of value added and wages per capita (*36,37,38*).

This research is important in demonstrating that business agglomeration reflects transportation access and is associated with positive impacts on productivity. It makes the case that improving transportation access can have wider economic benefits. However, there are two notable limitations to the application of these findings for transportation planning processes. First, studies that measure impacts at a fine level of spatial detail can best capture local urban clusters of producer services (office districts) and retail/consumer services (shopping centers and districts). That level of zonal analysis is less capable of directly capturing industrial and supply chain agglomerations that stretch out to follow highways or locate around intermodal terminals. It also cannot discern dispersion economies – i.e., productivity gains associated with firms locating to avoid congestion for time-sensitive truck deliveries or spacing to serve multiple supply chains. These limitations most directly apply to manufacturing and distribution industries.

Second, while these studies statistically relate business agglomeration to productivity, they generally cannot discern industry-specific causal effects. For instance, business agglomeration can reflect any combination of urbanization, localization, or knowledge economies, when these factors may in reality be more or less important for a given industry. Some economic research studies have sought to isolate the differing industry-level incidence and causal roles of localization, urbanization, and knowledge economies (*39*). Others have attempted to distinguish differing roles of physical density, residential market access, and employment proximity within an urban area (*38*). The previously discussed business location literature can carry us further in providing insight into causal effects and limiting effects that apply to passenger movement, freight movement, and intermodal connectivity at different spatial scales. By drawing on both business location research and economic evaluation, giving attention to the literature on transportation planning needs, we can develop more robust and useful insight for transportation planning processes.

A GENERAL MODEL

From the preceding discussions of research literature, we can identify three organizing principles:

(1) *Agglomeration occurs at different spatial scales.* There are at least seven different patterns of business clustering and agglomeration effects that are transportation dependent, as shown in Table 1. This table covers the traded industries examples previously shown, and adds two major categories of local-serving industries. While this typology is not exhaustive, it clearly demonstrates that there are widely varying combinations of business cluster scale, spacing, and location relative to transportation networks and facilities.

(2) *Business agglomerations reflect efforts to optimize various attraction and dispersion factors that are tied to transportation access.* This typology of clusters reflects attraction, dispersion, and clustering factors that can affect productivity. It was originally introduced in NCHRP Report 786 (40). We have expanded the range of cluster types and factors to provide a more comprehensive summary in columns 2 – 4 of Table 1. These factors are tied to scale, concentration and/or dispersion economies in accessing some combination of supplier markets, labor markets, customer markets, and/or learning economies.

(3) *The roles of access factors are differentiated by spatial levels and transportation mode/purpose.* The spatial levels are local market (travel within a labor market or metropolitan area), regional market (same day travel), and intermodal market (access for long distance travel). Each can also be differentiated by mode/purpose: commuting, freight delivery, personal/leisure, and business travel.

TABLE 1. Illustrative Categories of Industry Clustering and Agglomeration Effects

Cluster Type	Maximizing Factors (urbanization economies)	Cluster Factors (localization economies)	Minimizing Factors (dispersion economies)
High Tech: Metro-scale, Knowledge Clusters (e.g., biotech, computer software products)	In metro areas with access to universities, airports, and a large base of educated workers with specialized skills	Locate with similar firms to gain knowledge spillovers (technology information sharing)	May avoid high rise office districts to reduce real estate cost
Manufacturing: Peripheral, Corridor Clusters (*e.g.,* industrial parks, districts, corridors)	In regions where they can maximize truck access to parts suppliers and buyers (including assembly plants)	Concentrated at highway access routes to reach regional markets, rail connections (to national markets), or optimize same-day truck deliveries for just-in-time manufacturing	At the periphery of metropolitan areas and spread along intercity corridors to avoid congested roads
Bulk Resource Processing Clusters (e.g., agriculture, metal/ mining products)	In rural areas with access to material resources	In the vicinity of rail/marine bulk loading facilities for national and global distribution	At periphery or outside urban areas to minimize land cost and road congestion
Distribution/Logistics Clusters (e.g., warehousing, distribution centers)	In and around major metro markets with intermodal terminals, to maximize reach for regional customers + global markets	Concentrated around intermodal terminals (especially airports) and highway intersections to maximize regional and global connectivity	At the periphery or adjacent to major metro areas to maximize available land and minimize land cost
Visitor Services Clusters (e.g., lodging, meals, recreation)	In areas that have visitor attractions along with a large regional population base for day trips	Largest clusters are near visitor attractions that are served by airports for access to national and international markets	Dispersed around the vicinity of the visitor sites or along access corridors to minimize congestion
Producer Services: Office Clusters (e.g., finance, insurance, business services)	In metro areas that have a broad regional workforce with required education and skills	Concentrated in office districts to maximize knowledge spillovers (learning benefits); at urban core and outlying transport nodes to maximize labor market reach	
Consumer Retail Clusters (shopping districts and centers)	Most highly concentrated in metro areas with a large surrounding customer base	At major transportation network nodes and clustered to create and share greater market power – with differentiated offerings	

Source: based on [40], with additional categories added

Following the literature review and previously cited organizing principles, we can expect both employment concentration and wage rates for each industry "i" to be a function of market access in terms of the following dimensions:

Emp Concentration(i)$_i$ or Wage Rate(i)
= *fn* (Local Market$_{P,F}$, Regional Market$_{P,F}$, Intermodal Market$_{P,F,T}$)

where
Local Market = opportunities within a metropolitan, micropolitan or rural labor market area; Regional Market = opportunities reachable by ground access for same-day business, leisure, or freight delivery trips; Intermodal Market= destinations reachable by transfer from ground to air, water, or rail transportation networks.

P=population access (for labor market or customer markets), F=freight access (for industry supplier or buyer markets), T= terminal type (for access to broader national and global markets via air, water, rail).

EMPIRICAL RESEARCH

Study Design. Our empirical analysis sought to test the preceding general model, drawing explanatory factors from the three research perspectives discussed earlier: (1) transportation planning literature on the importance of distinguishing modal connections and freight/passenger trip purposes; (2) business location literature on the importance of regional markets and intermodal connections; and (3) economics literature on the usefulness of measuring both employment and income impacts. We recognize that there has been substantial prior research on the economic agglomeration patterns among and within local market areas, but far less attention to the roles of regional and intermodal market access in affecting the clustering and productivity of economic activities. So we designed regressions to help fill this gap.

We developed two sets of regression model; the first predicts the magnitude of zonal employment in each industry while the second predicts zonal average wage for employees in each industry. We test the preceding general model to assess the statistical relationships of both employment and wages (by industry) to the three classes of market access: local-scale ground access, regional-scale ground access, and intermodal access. These spatial scales of market access correspond to different types of transportation networks. To further improve applicability for transportation planning, we distinguish between types of clusters most dependent on passenger access for workers and customers (e.g., office, retail, high-tech R&D, and visitor clusters), and those that are most dependent on incoming and outgoing freight delivery access (e.g., manufacturing, distribution, and logistics clusters). We also account for additional explanatory factors such as workforce education level.

Data. The dataset is comprised of 3,053 counties within the contiguous 48 US States that are directly interconnected via highway and rail systems; these represent the study zones. Counties in the US define most small metropolitan areas, micropolitan areas, and rural labor market areas. They are building blocks for larger metropolitan areas. Commonly, each county has a principal city that serves as the county government seat and center of economic activity. For each county, our dataset separately measures employment and mean wage for each of 316 industries – representing 4-digit NAICS codes. The county economic details are derived by IMPLAN using data from the Bureau of Labor Statistics, Bureau of Economic Analysis, and Census Bureau (*41*). Local population is measured by block group using the American Community Survey (ACS), and local employment is measured by the Longitudinal Employer Household Dynamics (LEHD) dataset.

We measure local and regional market size using Census population data and LEHD employment data for census block groups within 30, 40, 50, 60, 120, 180, and 240 minutes of road drive time from the center of the largest city in each county. The drive times are based on the ArcGIS StreetMap network using HERE data. The drive-time polygons were matched to census block groups. For intermodal market access, we calculated drive times to the closest commercial airport, commercial intermodal rail terminal, and commercial water port, based on the above-cited transportation network data and intermodal terminals identified in the National Transportation Atlas Database (NTAD) provided by the Bureau of Transportation Statistics (BTS). We limited airports to those classified by the Federal Aviation Administration as medium or large, based on volume of activity. Travel times were calculated from the center of the largest city in each county using ArcGIS/HERE network data. To represent the roles of intermodal facilities as gateways to broader markets, we attached corresponding BTS data on annual passenger and cargo volumes for airports, and cargo volumes for water ports.

<u>Defining Industry Groups.</u> For the analysis, we utilized the available industry detail to assemble categories corresponding to the cluster types previously shown in Table 1. The classification of industries draws upon BEA input-output data to show the relative labor and freight transport dependence of individual industries, and BTS Transportation Satellite Accounts to distinguish truck, rail, air, and water modal dependence. The category definitions are listed below. We omitted analysis for government, education, and utilities since the location of those activities are generally not driven by economic markets.

Assignment of NAICS Industry Groups to Cluster Categories

<u>(1) High Tech /High Value Manufacturing</u> (knowledge clusters; ship products mostly by air)
- 3254 Pharmaceutical and medicine manufacturing
- 334 Computer, electronic and peripheral equipment manufacturing
- 3364 Aerospace product and parts manufacturing

<u>(2) Manufacturing</u> (all other production; ship products by truck and rail container)
- 112 Animals and Fish manufacturing
- 312 Beverages & Tobacco manufacturing
- 313 Textiles manufacturing
- 315 Apparel manufacturing
- 3255 Chemical products manufacturing (excl. pharma and basic chemicals)
- 332 Fabricated metal products manufacturing
- 333 Machinery manufacturing
- 335 Electrical Equipment manufacturing
- 336 Transportation equipment & parts (excl aerospace)
- 337 Furniture, 339 Miscellaneous manufacturing

<u>(3) Bulk Products</u> (ship mostly by rail and water transport)
- 111 Grains

- 21 Mining products
- 324 Petroleum products
- 3251,3252,3253 Basic chemicals, resin, rubber, fertilizer

<u>(4) Distribution & Delivery</u> (logistics clusters; air cargo transfers, ground delivery)

- 421-429 Wholesale Trade
- 484 Truck Transportation Services
- 49 Warehousing + Mail & Package Delivery

<u>(5) Visitor Services (may reflect regional, national or international travel)</u>

- 71 Tourism, recreation
- 72 Traveler Accommodations, Eating and Drinking

<u>(6) Producer Services</u> (office clusters)

- 51 Info Tech
- 52 Finance
- 54 Professional and Scientific services
- 55 Management

<u>(7) Consumer Services</u> (retail clusters)

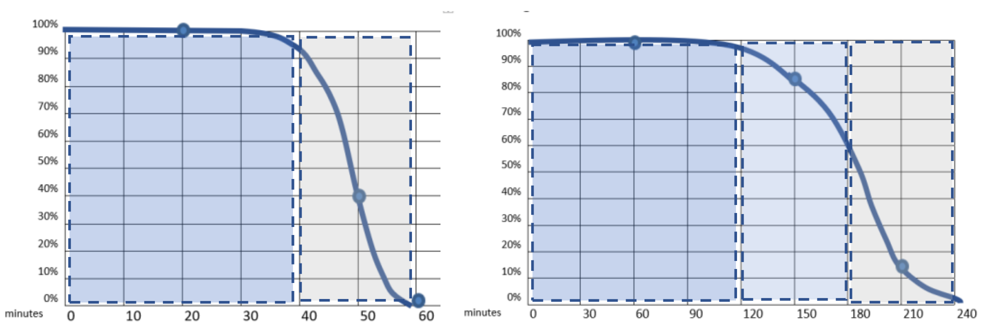
- 44-45 Retail
- 811-814 Consumer Services
- 561 Business Support Services

<u>Spatial Scale: Specific Tradeoffs.</u> The use of county-level economic observations reflects intended tradeoffs. County-level data misses the spatial detail of office and retail clustering that have been well identified in prior studies that rely on more detailed urban zonal systems, including the relative roles of physical density and effective density for accessing similar businesses nearby. However, county-level detail enables greater industry product detail to distinguish modal and intermodal dependencies based on distinctions between bulk materials, manufactured parts, final consumption products, and high value, time-sensitive delivery products. It also enables us to distinguish high tech industries that depend on a highly educated labor market.

This broader spatial scale also allows us to highlight the two-stage aspect of business location decisions: (1) the initial choice of site among local labor markets, and (2) the choice of a specific site within the selected labor market. We can thus compare the results of this study which evaluates differences among US counties, with results of our earlier study that focused on differences among zones within a single metro area. For instance, when we use the current dataset to regress producer services employment by population market size (a proxy for labor market size), we find that differences in size of the local population market explains 58% of the variance in producer services employment among US counties. This is far greater than the corresponding finding that variation in access to local population market explains just 17% of the variance in producer services employment among zones within a single metro area (*38*). In other words, labor market size is found to be an important explanatory factor in explaining business location differentials *between* metro areas or labor markets, but it becomes far less important for explaining subsequent choices for location *within* a metro area.

<u>Testing of Market Size Threshold Effects.</u> One of the key aspects of both theory and business location research is the role of space/time "threshold" effects. Simply put, while businesses may cluster, they often draw workers from across a labor market or metropolitan area that is defined by a range of "reasonable" commuting times (42). The threshold is generally considered to be within a range of less than one hour and sometimes 40 minutes. This is supported by the fact that over 75% of US workers have a commute time over 15 minutes yet less than 23% have a commute longer than 40 minutes and less than 10% have a commute over 60 minutes (43). For our regressions, we explored use of travel time decay factors and threshold factors for defining local labor markets. We found that a composite of these factors, pivoting off the 40 minute and 60-minute thresholds, yielded the most consistent and highest significance findings for local access in our regressions. (See Figure 4A and regression results that follow.)

We also explored alternative definitions for same-day (passenger and freight delivery) markets. For truck deliveries, a practical threshold is roughly 3 hours (one way), which is consistent with an 8-hour worker shift with 6 hours of round trip driving and one hour at each end for loading and unloading freight. A similar type of planning time threshold is also applied for tourist day-trips. To account for the possibility of longer trips, we explored the use of alternative time decay factors and threshold factors within a 1 to 4-hour range. We found that a decay function with a sharp drop-off after 3 hours yielded the most consistent and highest significance findings for regional access in our regressions. (See Figure 4B and regression results that follow.)



(A) Local market: 100% of 0-40 minute range + 40% of 40-60 minute range

(B) Regional same-day market: 100% of 0-120 minute range + 85% of 120-180 minute range + 15% of 180-240 min. range

Figure 4. Values and Implied Curves Defining Local and Regional Market Thresholds

Regression Analysis. We utilize a nonlinear regression with a natural log-log transformation, so regression coefficients represent elasticities. This nonlinear regression methodology allows us to estimate exponents that capture nonlinear scale and distance decay factors while simultaneously estimating coefficients, to optimize the goodness of fit of the model. The same explanatory factors are used for predicting employment concentration and wage rates by industry, except that the employment regression has the intercept suppressed to ensure that predicted employment approaches zero as population approaches zero.

For each industry (i) and zone (z)

$$\begin{aligned} \mathit{ln}\,[EMP_{(i,r)} = &\ \mathbf{B1}_{(i)} * \mathit{ln}\,[LOCMKT_{(z)}]^{\mathbf{C1}(i)} \\ &+ \mathbf{D1}_{(i)} * \mathit{ln}\,[REGMKT_{(z)}] \\ &+ \mathbf{E1}_{(i)} * \mathit{ln}\,[(AIR.SIZE)/(AIR.TIME)^{\mathbf{F1}(i)}]_{(z)} \\ &+ \mathbf{G1}_{(i)} * \mathit{ln}[(PORT.SIZE)/(PORT.TIME)^{\mathbf{H1}(i)}]_{(z)} \\ &+ \mathbf{I1}_{(i)} * \mathit{ln}\,[RAIL.TIME]_{(z)} \\ &+ \mathbf{J1}_{(i)} * \mathit{ln}\,[EDUCATION]_{(z)} \end{aligned}$$

$$\begin{aligned} \mathit{ln}\,[WAGE_{(i,r)} = &\ \mathbf{A2}_{(i)} \\ &+ \mathbf{B2}_{(i)} * \mathit{ln}\,[LOCMKT_{(z)}]^{\mathbf{C2}(i)} \\ &+ \mathbf{D2}_{(i)} * \mathit{ln}\,[RGMKT_{(z)}] \\ &+ \mathbf{E2}_{(i)} * \mathit{ln}\,[(AIR.SIZE)/(AIR.TIME)^{\mathbf{F2}(i)}]_{(z)} \\ &+ \mathbf{G2}_{(i)} * \mathit{ln}[(PORT.SIZE)/(PORT.TIME)^{\mathbf{H2}(i)}]_{(z)} \\ &+ \mathbf{I2}_{(i)} * \mathit{ln}\,[RAIL.TIME]_{(z)} \\ &+ \mathbf{J2}_{(i)} * \mathit{ln}\,[EDUCATION]_{(z)} \end{aligned}$$

where:

$A_{(i)}$, $B_{(i)}$, $D_{(i)}$, $E_{(i)}$, $G_{(i)}$, $I_{(i)}$, $J_{(i)}$ are coefficients. They represent industry-specific impact elasticities since the equation is a log-log function.

$C_{(i)}$, $F_{(i)}$, $H_{(i)}$ are exponent decay factors for ratios, that also vary by industry (i).

LOCMKT = local labor and consumer market size, a function of weighted average of the population within 0-60 minutes (note A)

REGMKT = relative size of regional non-local market, measured as ratio of [(weighted employment within 60-240 minutes) /(employment within 0-60 minutes)] (note B)

AIRPORT.SIZE = annual passenger or cargo ton flows for the closest airport (notes C, D)

AIRPORT.TIME = travel time to the closest airport (note C, E)

PORT.SIZE = annual cargo tonnage flows for the closest commercial cargo port notes C, D)

PORT.TIME = travel time to the closest commercial cargo port (notes C, E)

RAIL.TIME = travel time to the closest truck-rail container loading facility (notes C, E)

EDUCATION = percent of population with a bachelor's degree

*(A) Local market is measured as population living within 0-40 minutes from the largest city in the county + 40% * population living within 40-60 minutes (weighting reflects a decay function)*

*(B) Regional market is a measured as employment within 60-120 minutes from the largest city in the county + 85% * employment within 120-180 minutes + 15% * employment within 180-240 minutes (weighting reflects a decay function). It is measured relative to 0-60 minute market to avoid correlation between local market and regional market size measures. Exception: for visitor services, regional market is based on population rather than employment.*

(C) Closest port and truck-rail container loading facility is based on National Transportation Atlas Database (NTAD). Closest airport is based on the FAA list of medium and large airports; these are the top 64 US airports in terms of enplanements.

(D) Passenger volume is used for visitor services and producer services; cargo tonnage is used for manufactured products. Both are proxy measures for breadth of destination and schedule options.

(E) Travel time is measured from the largest city in the county.

Results. Table 2 shows the regression results, including the statistically significant coefficients and the corresponding t-statistic (in parentheses).

TABLE 2. Regression Results
(statistically significant coefficients are shown)

REGRESSIONS	INTER-CEPT	LOCAL MARKET		REGIONAL MARKET	AIRPORT		WATER PORT		RAIL. TIME	EDUC	R^2
(A) EMPLOYMENT	A1	B 1	C1	D 1	E1	F1	G1	H1	I1	J1	
(1) High Tech/ High Value	N.A.	0.0032 (12.14)**	2.50	n.s.	*1.669 (1.95)**	1.187	--	--	--	5.809 (12.52)**	0.43
(2) Other Manufacturing.	N.A.	0.600 (87.66)**	1.00	0.0044 (2.93)**	--	--	--	--	-0.081 (-4.32)**	--	0.36
(3) Bulk Processing	N.A.	0.618 (15.00)**	0.964	n.s.	--	--	0.160 (3.46)**	0.909	*see note*	--	0.36
(4) Distribution	N.A.	0.251 (12.51)**	1.330	0.0064 (4.22)**	1.306 (3.96)**	1.034	--	--	--	--	0.52
(5) Visitor Services	N.A.	0.178 (10.95)**	1.457	*0.003 (5.01)***	1.484 (4.4)**	0.996	--	--	--	--	0.51
(6) Producer Services	N.A.	0.154 (12.977)**	1.443	n.s.	1.407 (3.07)*	1.307	--	--	--	7.027 (35.18)**	0.69
(7) Retail/Consumer	N.A.	0.352 (17.58)**	1.267	n.s.	--	--	--	--	--	--	0.52
(B) WAGES	A2	B 2	C 2	D 2	E2	F 2	G2	H2	I2	J2	
(1) High Tech/ High Value	10.706 (258)**	0.0002 (10.75)**	2.934	n.s.	0.281 (1.49)	1.941	--	--	--	0.564 (4.87)**	0.13
(2) Other Manufacturing.	7.379 (28.32)**	0.0412 (21.87)**	1.704	0.237 (1.864)*	--	--	--	--	n.s.	--	0.29
(3) Bulk Processing	9.566 (211)**	0.0002 (18.47)**	3.298	n.s.	--	--	0.0954 (4.08)**	0.910	*see note*	--	0.12
(4) Distribution	10.513 (588)**	0.000001 (13.25)**	4.736	n.s.	0.086 (6.29)**	0.672	--	--	--	--	0.13
(5) Visitor Services	9.535 (682)**	0.00003 (20.41)**	4.411	0.0006 (3.68)**	0.174 (7.90)**	1.081	--	--	--	--	0.18
(6) Producer Services	9.547 (260)**	0.0084 (17.60)**	1.722	n.s.	0.281 (7.64)**	1.179	--	--	--	1.357 (17.71)**	0.29
(7) Retail/Consumer	9.514 (589)**	0.00004 (26.55)**	3.691	n.s.	--	--	--	--	--	--	0.19

( ) denotes t-statistic;
*** statistically significant at .99 confidence (p<.01). * statistical significance at.95 confidence (p<.05)*
N.A. denotes not applicable
n.s. indicates market access factor was tested but coefficient was not statistically significant,

-- indicates explanatory factor was not tested for non-relevant modal option. (This also minimizes multicollinearity caused by spatial correlation of air, sea, and rail intermodal terminal location.)
Note: While rail is clearly important for bulk transport, the available dataset on rail intermodal terminals only covered TOFC/COFC (container) facilities which are not generally applicable for bulk transport.

The regression results show that the attraction of business activity (as reflected by employment concentrations) and associated productivity (as reflected by wage rates) are both greatest in locations with connectivity to markets, including local, regional and intermodal (long distance) markets. However, these effects differ significantly by industry. Key findings are noted below:

- *Local Market Access* –This variable is defined as the population accessible within a typical commuting range of the largest city in the area. As noted earlier, it is defined by a decay threshold over the 40-60 minute range and serves as a proxy indicator of the size of local labor and shopper markets. The positive coefficients across industries are in keeping with conventional expectations; it is logical that all types of economic activity increase with higher population. However, the exponent term in the employment equation is notably higher for high tech, indicating notably increasing returns to scale for business attraction. This is consistent with research showing that larger labor markets increase the likelihood of finding workers with specific technological skills. The exponent term was also higher in the wage equation than in the employment equation for all industries, indicating higher wages in larger local markets. Overall, the key takeaway for planners is that transportation links connecting residential communities and urban employment centers can enlarge local markets and thus grow economic activities that depend on population market size. It is also noteworthy that employment concentration and wage rates for high tech and producer services are increased by having a more highly educated workforce. However, effects of education and labor market size appear to be independently important; a multiplicative interaction of these terms was not statistically significant.
- *Regional Market Access* –This variable captures the scale of economic activity (measured by total employment) that is outside of the local market but still accessible via a day trip from the largest city in the area. As noted earlier, regional market is defined by a decay threshold that pivots around a 3-hour one-way travel time. This factor is expressed as a ratio of regional to local market size, to capture situations where there is a disproportionately large regional market relative to the local market size. This factor is shown to be particularly important for the attraction of manufacturing and distribution activities (employment), and it is also a significant factor in manufacturing wages. For those industries, this variable serves as an indicator of the size of additional business supplier and buyer delivery markets that can be reached by same-day truck trips beyond the local market. The implication for planners is that transportation links that enlarge the connectivity of industrial sites to regional delivery markets can particularly support the growth of specialized supply chains and distribution centers.

  Visitor/recreation activities are a special case. Here we define the regional access ratio in terms of the population (rather than employment) as an indicator of the market for same-day personal travel. The finding is that employment and wages in this industry are increased by both the size of the same-day regional market and airport access. We are not able to capture the role of special (historical or geological) attractions which are clearly also important.

- *Intermodal Gateways* – Airports serve as gateways to reach national and global markets. The variable is defined as a gravity model ratio in which the value increases with the size of activity occurring at the airport, and falls with increasing ground distance from the city. The statistical results confirm that both producer services and high value (high tech) manufacturing particularly benefit from access to large airports for fast, time-sensitive travel to reach long distance markets. The interpretation is that both industry groups depend on long distance air travel for business relationships, while high value manufacturing also depends on air cargo for incoming parts and outgoing shipments to business customers. For distribution and visitor services, the results show that airport access is significant with a lower exponent for the distance decay factor. This is consistent with research on airport route and location choices that indicates a high value is placed on having a large choice of intercity routes and schedule times (correlated with high airport activity level), more than they value minimization of travel time to reach the airport. The implication for planners is that transportation enhancement of air service can particularly support industries with national or global markets.

  Marine ports are also gateways connecting to global markets. Since our measure of port activity is annual tonnage, this measure best captures shipments of bulk commodities that typically have a high weight/value ratio. The gravity model formulation (based on tonnage/access time) confirms that production of bulk products is associated with port connectivity, though the causation may be that transportation investments follow rather than lead the location of those business activities. For intermodal rail, our dataset is limited to access time for container loading locations; the results show that proximity to these facilities is important for the location of manufacturing not classified as high tech, though wage rates are not affected. Unfortunately, we were not able to obtain measures of container volume for all marine ports covered in this study, nor were we able to obtain data on bulk intermodal rail facilities (which are often privately controlled).

CONCLUSIONS

The empirical analysis shows how local population markets, regional business markets, and access to intermodal gateways play varying roles in affecting industry concentrations and wage rates. These impacts can potentially inform a broad spectrum of transportation investments in freight routes, passenger routes, and long-distance air and sea connections by public agencies and private operators. Outcomes can vary among sectors of the economy in ways that relate to their differing reliance on workforce, parts/materials suppliers, and buyer/user access. The distinctions between types of access, as shown here, can help enable more targeted project design, more insightful impact modeling and appraisal, and more comprehensive prioritization of proposed projects.

These findings indicate the importance of recognizing freight as well as passenger market access, and the need to also recognize regional and intermodal connectivity, as a part of benefit-cost assessments and prioritization decisions. Omission of these factors in can be a source of modal and spatial bias in transportation investment and prioritization decisions.

This work can also be of value in planning processes, as it shows how one can incorporate considerations of regional and intermodal access to enable more strategic transportation investments that consider policy goals of equity, competitiveness, and economic development. These matters become increasingly important as interest grows in integrating transportation with broader investments to support workforce development, broadband development, and economic growth opportunities. A remaining issue is how public and private organizations interact when considering such investments.

Looking to the future, there are significant needs for further research to improve economic impact modeling and the assessment of wider economic benefits. Specifically:

- *Integration of spatial scales* – This study focuses on regional-scale market access and intermodal access effects, which are particularly important for manufacturing, distribution, and tourism activities. However, this study does not address local density and business proximity effects which have been addressed in prior studies focusing on smaller zones. This study also utilizes the concept of local and regional-scale thresholds for large area effects, in contrast to past studies utilized more continuous gravity model decay functions. There is clearly a need to better integrate these differing spatial scales and perspectives.
- *Definition of access* – This study, like others covered in the literature review, examines access in terms of population and employment reachable within omnidirectional travel times. It does go further in terms of including directional connectivity to specific intermodal terminals. However, it is also possible to measure access by mode and in terms of linkages along and between corridors, or between locations that have complementary industries and resources. Such views can be particularly useful for assessing benefits of improving supply chain connectivity (e.g., between materials, parts producers, assemblers, and distributors) and knowledge links (e.g., enabling regional integration between specific cities and markets, and activities such as high-tech R&D satellite centers). There is clearly a need to advance spatial geography measures of access that recognize complementarities in corridor connections.
- *Time Dynamics* – This study derives findings from cross-sectional data. It would be beneficial to expand this kind of analysis to examine changes occurring as transportation networks develop over time, and as the access needs of various industries change over time. It is also likely that spatial access relationships between residents, activity locations, and business supply chains will further evolve with emerging telework and e-commerce technologies.

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