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Relationships Between Land Use and Freight and Commercial Truck Traffic in Metropolitan Areas

Michael S. Bronzini
George Mason University

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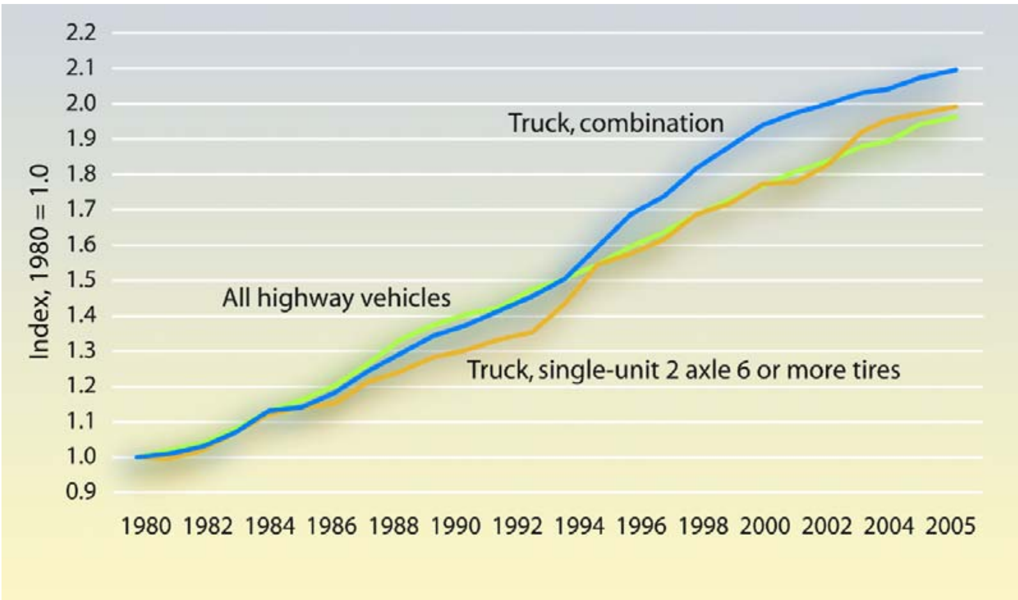
MICHAEL S. BRONZINI
George Mason University

1.0 INTRODUCTION

1.1 Background

Freight traffic on the U.S transportation system is growing rapidly, fueled by growing international trade and modern manufacturing and distribution supply chain practices such as just-in-time delivery. The Federal Highway Administration (FHWA) forecasts that freight tonnage will almost double between 2002 and 2035 (*1*). This translates into comparable increases in truck traffic which, as shown in Figure 1, has been growing at a faster rate than that of all other classes of highway vehicles since about 1995. The same trend has been observed in Europe (*2*). In 2006, EU road freight transport (tonne-km) increased by 25% compared with 2000. Over the somewhat longer period 1995 to 2004 road passenger travel (passenger-km) increased by 16%.

The growth in truck traffic in the U.S. has been even more dramatic in urban areas. Table 1 shows growth in vehicle miles of travel (VMT) on urban roadways for the ten-year period ending in 2006. The overall increase for all classes of vehicles was nearly 30 percent, with truck VMT increasing approximately 40 percent. Over that same period total rural and urban VMT increased 21 percent, and rural truck VMT 10 percent (*3*). The share of urban VMT produced by trucks also increased modestly, from 4.8 to 5.2 percent.



Source: Federal Highway Administration (1).

FIGURE 1 Growth in highway traffic, 1980 to 2005.

TABLE 1 Vehicle Travel on Urban Highways in the U.S. (billion VMT)

Year	Passenger Vehicles	Other 2 Axle 4 Tire Vehicles	Single Unit Trucks	Combination Trucks	Total
1996 VMT	940	508	30.7	42.7	1522
%	61.8	33.4	2.0	2.8	100
2006 VMT	1158	716	43.7	59.2	1977
%	58.6	36.2	2.2	3.0	100
Increase in VMT	218	208	13.0	16.5	455
% Increase	23.2	40.9	42.3	38.6	29.9

Source: Federal Highway Administration, *Highway Statistics*, various issues, Table VM-1.

1.2 Objectives and Scope

Improved and coordinated land use and transportation planning have been posited as the ultimate solution to urban traffic congestion, but would such measures be effective in reducing truck traffic? What relationship, if any, currently exists between land use, urban form, and freight and commercial VMT in metropolitan areas? This paper investigates what is currently known about this relationship. Specific research questions include:

- What have been the trends in VMT growth? What share of total VMT in a typical metropolitan area consists of freight and commercial movements?
- Is there any evidence that the dispersal of employment and residences in metropolitan areas has been contributing to commercial VMT growth?
- How does freight and commercial traffic differ across metropolitan areas?
- Would smart growth reduce freight and commercial VMT?
- What is known about how big box retailing affects goods movement within a metro area, including truck trips from factories or distribution centers to the outlet and shopping trips from home to the outlet? Does this increase or decrease VMT?
- For metropolitan areas that include major ports, airports, and distribution centers, does urban form matter?

1.3 Definitions of Freight and Commercial Traffic

Freight is defined to include all goods entering or exiting a metropolitan area and VMT associated with deliveries. Commercial movements include service workers, such as plumbers, repairmen, trash pickup, construction vehicles, and so on. The Quick Response Freight Manual (QRFM) (*4*) states the distinction as follows:

> …many economic analyses…define freight more specifically as the movement of goods from a place of production to a place of consumption in support of manufacturing processes. …this definition of freight specifically exclude goods moving to service establishments, construction, most retail industries, farms, fisheries, foreign establishments, and most government-owned establishments.

Freight trucks as used in this paper include all types of freight movements, which is a broader class than the QRFM definition.

The QRFM goes on to define the principal component of commercial traffic as follows:

> There is a unique segment of truck population that does not carry freight, which also is known as the service sector. This includes trucks that are used in the utility sector and other services related to commercial and residential land uses (i.e., business and personal services). Data on this type of trucking activity is difficult to collect through conventional survey methods because of overlapping nature of these types of truck trips with other industry types.

How do these definitions relate to the truck types reported in highway traffic counts, such as in *Highway Statistics* and Table 1? According to the QRFM service vehicles typically range from 5 percent to 13 percent of total VMT in urban areas, 91 percent of service vehicles are light-duty vehicles, and 9 percent are medium to heavy-duty trucks (*4*). Thus conceptually the vehicle types used in Table 1 equate to freight and commercial trucks as follows:

Combination Trucks	Freight
Single Unit Trucks	Commercial
Other 2 Axle 4 Tire Vehicles	Some Commercial

While there are obvious overlaps between the first two categories (that is, there are single unit trucks used for freight deliveries and combination trucks used in commercial services) the last category is particularly troublesome, since it includes pickup trucks, vans, and sport utility vehicles. Many of these are personal use vehicles, and those that are commercial vehicles have operating characteristics more like those of passenger cars than trucks, and hence are not of as much concern for transportation planning purposes (other than for obtaining accurate forecasts of total vehicular activity). Hence in this paper single unit truck traffic will be used as an indicator of commercial vehicle activity.

1.4 Outline of Paper

The next two sections review the literature on this topic. There has been virtually nothing written directly on the relationships between land use, urban form and truck VMT, so section 2 focuses on evidence presented in various metropolitan planning organization (MPO) and state freight studies. Section 3 investigates ports, airports, and logistics and distribution centers as contributors to freight and commercial truck VMT. Section 4 synthesizes the findings in the form of answers to the research questions posed above. Section 5 concludes the paper with a proposed research plan for resolving the outstanding issues.

2.0 LITERATURE REVIEW: MPO AND STATE FREIGHT STUDIES

2.1 New York

Referencing several recent regional freight studies, the Move NY & NJ Coalition reports (*5*) that trucks are a high percentage of total vehicles on chronically congested roadways in New York City, and occupy 60% of road space. Freight traffic is likely to increase by 50% by the year 2021. Truck VMT is expected to double during the next 20 years. Large commodity carrying freight trucks are forecast to contribute about 20 percent of total regional truck VMT/VHT in 2025. While the projected growth is in line with the national forecast quoted earlier the percentage of VMT due to large trucks is much higher than that shown in Table 1 for all urban highways.

2.2 Atlanta

Atlanta is a major center of freight logistics and supply chain activity in the U.S. Table 2 shows the percentage of truck traffic on Atlanta's principal interstate highways (*6*). Trucks exceed 10% of the traffic on most of this mileage. The breakout between freight and commercial trucks is not reported.

2.3 Chicago

The Chicago region has 78 rail terminals that move intermodal containers. Even though the traffic at these terminals makes Chicago the world's third busiest container handling port (*7*) it does not show up on traditional listings of large container ports, since those listings are based on containers landed or boarded at their first international/domestic interchange point. Most of the Chicago containers are shuttling between western and eastern railroads, or are destined for the Midwest market area. Truck VMT on urban highways in Illinois is in the 13 to 15 percent range (*7*), which is much higher than the national average. The principal highways serving Chicago's container traffic carry nearly 30,000 trucks per day. In comparison I-710 in California, serving the ports of Los Angeles and Long Beach, carries about 39,000 trucks per day (*7*). These traffic levels highlight the influence of major port and logistics centers in generating truck VMT.

TABLE 2 Truck Traffic on Atlanta Interstate Highways (2005)

Route	Average Daily Traffic (ADT)	Truck ADT	Truck % ADT
I-285	73,833	9,237	14%
I-20	38,095	4,927	15%
I-75	54,322	6,592	12%
I-675	32,275	3,157	10%
I-85	60,501	3,288	6%
I-985	30,718	1,113	4%
I-575	26,285	780	3%

Source: Georgia Dept. of Transportation.

2.4 Houston

Table 3 shows annual VMT in the eight-county Houston region by vehicle type (*8*), although the breakout between single unit and combination trucks is not shown. Light duty vehicles produce most of the VMT for the region. The overall truck share of 9.3% is well above the national average. The top 5 truck freight commodities (in tons) for the region in 2004 were: 1) petroleum and coal; 2) chemicals and allied materials; 3) nonmetallic minerals; 4) secondary traffic; and 5) clay, concrete and glass. Hence it is not surprising that heavy-duty diesel trucks dominate the truck type mix.

2.5 Norfolk

Volumes at the Port of Virginia will increase 100% by 2020 and nearly 300% by 2040 (*9*). Currently the port generates 4000 trucks per day. While coal and other bulk commodities are significant, the container activity is high enough to place Norfolk seventh among U.S. container ports, which accounts in part for the significant port-related truck traffic.

2.6 Metropolitan Smart Growth Concepts

Smart growth concepts (*10, 11, 12*) tend to focus on urban villages, mixed use town centers, higher density residential development coupled with green spaces, walkable communities, and transit oriented development. The typical goal for transportation is lower passenger VMT, due to less urban sprawl. Impacts on freight and commercial VMT are rarely discussed. However it can be asserted with confidence that, other things being equal, higher residential density and mixed-use town centers allow delivery of goods and services to individuals to be accomplished with lower VMT and less in-traffic VHT, as compared with typical suburban residential districts, but the goods delivery impacts are viewed as ancillary effects rather than primary planning goals. At this point there is little research that allows this notional effect to be quantified.

A related concept, city logistics (*13*), is concerned with improving the efficiencies of urban logistics pickup and delivery operations utilizing measures such as cooperative freight transport systems, public logistics terminals, load factor controls, and underground freight transport systems, thereby reducing the urban truck VMT related to goods redistribution. The primary impediments to these concepts are institutional and financial. Cooperative freight transport and load factor controls require vehicle sharing or other means to put more urban freight on fewer vehicles. Public logistics terminals replace or supplement single carrier or firm

TABLE 3 Houston Area Annual VMT by Vehicle Type, 2005 (million)

Light Duty Vehicles		Heavy-Duty Gasoline Trucks		Heavy-Duty Diesel Trucks		Total VMT
VMT	Percent	VMT	Percent	VMT	Percent	
128,862	91%	2253	1.6%	10,862	7.7%	141,978

Source: H-GAC Transportation Department, Air Quality Section, 2007.

urban freight operations with a subsidized third-party service that seeks to reduce truck VMT. Underground systems for urban freight require significant investment in separate special purpose infrastructure, on the same scale as grade-separated urban rail systems. Overall city logistics has mostly been advanced as a research concept and little evidence exists as to its efficacy, let alone its relation to urban form and city type.

2.7 Ohio

According to a 2002 study for the state of Ohio (14) trucks carry 60 percent by weight (566 million tons) and 74 percent by value ($1.3 trillion) of all the freight shipped and received by Ohio business and industry. Additional truck freight moves through the state going to and from other states. Freight-truck traffic is forecast to grow faster than general traffic. Truck traffic in Ohio originates and terminates primarily in its major metropolitan areas. The top 10 counties account for 40 percent of freight-truck tons originating and terminating in Ohio. This pattern is forecast to persist through 2020. This study focused exclusively on freight trucks, and did not present any results related to commercial truck traffic in urban areas. Nor did it investigate land use and urban form as determinants of truck traffic.

2.8 New Jersey

According to information compiled by the Tri-State Transportation Campaign (*15*), freight tonnage in New Jersey will grow by 72 percent, from 409 million tons in 1998 to 703 million tons in 2020. Trucks represent approximately 75% of New Jersey tonnage (around 466 million tons), and provide critical first mile/last mile connections for rail, water, and air cargo. This 75% is relatively evenly divided between inbound (17%), outbound (19%), intrastate (20%), and through traffic (19%) components (*16*). Peak period container truck VMT will grow around two and one-half times; non-container trucking will double; and auto traffic will grow by around 50% (*17*). Some reports suggest that trucks will represent more than 10% of New Jersey's vehicular traffic by year 2020; however, looking just at the peak period, trucks account for 3.3% of the region's VMT. This share is forecast to increase to 4.3% by 2030, unless it can be shifted to off-peak periods. Most of this truck VMT is associated with non-container trucks, indicating that the effect of the major container terminals at Port Elizabeth appears to be minimal from a statewide vantage. However, on highways in the immediate vicinity of the port trucks account for 40 to 55 percent of ADT (*18*).

2.9 Washington

According to the freight portion of the Washington Transportation Plan (*19*) Washington State's population grew from 4.1 million to 6.1 million from 1980 to 2003 (a 45 percent increase), and is projected to grow to 8.3 million (a 34 percent increase) by 2030, but freight traffic is increasing at a much higher rate. Between 1993 and 2003 truck trips increased by 94 percent on the Interstate 5 corridor, and 72 percent on the Interstate 90 corridor. Forecasts indicate that freight volumes in Washington State will increase by 80 percent between 1998 and 2020. Cross-border truck volumes have nearly doubled at western Washington crossings over the past 11 years. This growth has strained border crossing facilities and processes, resulting in queues of trucks both north and southbound.

2.10 I-10 Freight Study

States along the I-10 corridor collaborated on a freight study that was published in 2003 (20). The following states are represented:

California	Louisiana
Arizona	Mississippi
New Mexico	Alabama
Texas	Florida

The corridor was also defined to include important parallel and feeder facilities, such as I-12, California 60, I-710, and many others. This highway corridor crosses the eight southernmost states, covers approximately 2,650 miles, and serves both domestic and international traffic. There are 17 metropolitan areas located on this one highway, including four of the ten largest cities in the country (Los Angeles, Houston, San Antonio and Phoenix). Table 4 lists the number of major freight and intermodal facilities in each state.

Table 5 displays some truck traffic data by state from the I-10 study, and also the total number of intermodal facilities from Table 4. There appears to be no strong correlation between any of the truck traffic data and the number of intermodal facilities. The only noticeable outlier is New Mexico, which has no reported facilities and the lowest truck AADT, and the lowest urban interstate truck VMT and VMT per mile. Conversely they have the highest truck percent of AADT on I-10, which indicates New Mexico's preponderance of through truck traffic. California is at the other end of the spectrum, with the highest levels of all truck traffic values except percent trucks, which are the lowest values reported. California has only the third largest number of intermodal facilities, which contributes to the lack of association of this variable with truck traffic. Texas and Louisiana report the largest number of intermodal facilities, but rank just above the median in urban truck VMT per mile, and not much different than the three

TABLE 4 Major Freight and Intermodal Facilities in I-10 Corridor States

State	Ports	Rail	Airports	Pipeline	Total
California	3	6	5	2	16
Arizona	0	2	2	0	4
New Mexico	0	0	0	0	0
Texas	6	14	8	13	41
Louisiana	13	6	1	0	20
Mississippi	4	0	1	0	5
Alabama	1	2	1	1	5
Florida	4	3	1	0	8
Total	31	33	19	16	99

Source: I-10 Freight Study (*20*).

TABLE 5 I-10 Corridor Truck Traffic (2000)

State	Truck AADT	Truck Percent	Average Daily Truck VMT on Urban Interstate Highways			Number of Intermodal Facilities
			VMT (1,000)	Truck Percent	VMT/mi	
CA	16,000	9.2	3,989	11	17,721	16
AZ	13,000	16.2	1,297	16	15,277	4
NM	6,000	33.3	111	36	6,416	0
TX	8,000	13.6	1,695	11	10,418	41
LA	10,000	17.5	1,471	17	10,583	20
MS	8,000	20.0	190	20	8,716	5
AL	9,000	14.8	202	15	9,224	5
FL	7,000	21.2	360	16	7,423	8

Source: Computed from data in I-10 Freight Study (*20*).

easternmost I-10 states in truck AADT. Even if the pipeline intermodal facilities are discounted these relationships still hold. If the top four states in VMT per mile are grouped they collectively contain 81 of the 99 intermodal facilities. Arizona is a bit of an anomaly within this smaller group, ranking second in truck traffic but having only 4 intermodal facilities. These four states also have the highest urban population, which is likely the more important driver. Hence based on the I-10 data it is difficult to make a case for the primacy of freight distribution activities in explaining observed urban truck AADT and VMT. This is due to the confounding effects of other variables, including the fact that the truck data include commercial vehicles as well as freight vehicles. However a more intensive analysis of the I-10 study data set might be worthwhile, particularly if coupled with other data.

3.0 LITERATURE REVIEW: PORTS AND AIRPORTS

Looking at 2002 data on peak period highway congestion on the National Highway System, Giuliano and O'Brien (*21*) observe that heavily congested roadways are concentrated in the New York-New Jersey coastal area, Southern California, the San Francisco Bay Area, Houston, and Chicago, all of which are major freight traffic interchange points. All of these areas also contain major marine ports and airports.

Table 6 lists the top 12 U.S. container ports, based on twenty foot equivalent units (TEUs) handled in 2005. The port areas noted by Giuliano and O'Brien are all on this list, and several of them are discussed briefly below.

TABLE 6 Top U.S. Container Ports 2005

Rank	Port	Full TEUs (thousand)
1	Los Angeles-Long Beach	9,575
2	New York-New Jersey	3,581
3	Seattle-Tacoma	2,988
4	Oakland, CA	1,561
5	Charleston, SC	1,514
6	Savannah	1,486
7	Norfolk	1,436
8	Miami-Fort Lauderdale	1,369
9	Houston	1,290
10	Honolulu	856
11	Jacksonville, FL	582
12	Baltimore	487
Total, Top 12		26,725
Total, All Ports		30,059

Source: Bureau of Transportation Statistics, *Pocket Guide to Transportation 2008*.

3.1 Southern California Ports

In Southern California (*21*) the ports account for 35,000 daily truck trips, and on major highways serving the ports heavy trucks account for 12 to 14 percent of total daily traffic, versus 2 to 3 percent for other highways in the region. Container traffic at the ports has been increasing by 1 million TEUs per year, with attendant increases in truck traffic. Giuliano and O'Brien (*21*) report on two measures designed to reduce truck waiting times at the terminals, and spread the truck trips over a longer time period. Such measures, of course, do not impact VMT, but may be effective in reducing VHT and hence reducing highway congestion. This attention to port-related truck traffic, which is also seen in other port cities, underscores the belief of local authorities that ports contribute differentially to truck VMT and deserve special scrutiny.

3.2 New York-New Jersey

Container traffic in the New York-New Jersey port complex generated 13,000 truck trips per day in 2001, 75% of which were destined to local markets (*21*). The New York City and State of New Jersey studies referenced earlier also feature analyses of port-related truck traffic.

3.3 Seattle-Tacoma

In 2003, 7.4 percent of truck traffic headed east on I-90 originated from a marine terminal and 10.9 percent headed west was destined for a marine terminal (*22*). Freight movement in the corridor is growing- with truck traffic showing an increase of 72 percent from 1994 to 2002. Trucks represent from 5 to 28% of traffic on a street in the port area (*23*).

3.4 Airports

Table 7 shows the top 15 air cargo airports in the U.S., ranked by their 2007 air freight tonnage. Several of these airports are highly ranked because of their role as national or regional hubs of major air express operators, such as Federal Express and UPS. These include Memphis, Louisville, Indianapolis, Philadelphia, and Ontario.

Kasarda (*24*) believes that major airports are evolving in form and function. Historically, airports have been understood as places where aircraft operations take place, with runways, control towers, terminals, hangers and other facilities which directly serve aircraft, passengers and cargo. This traditional understanding, according to Kasarda, is giving way to much broader, more encompassing concept known as the Airport City or "aerotropolis." Kasarda's airport city model is grounded in the fact that major airports have developed significant non-aeronautical facilities, services and revenue streams. At the same time they are extending their commercial reach and economic impact well beyond airport boundaries. If this is true major airports should be generators of disproportionately high freight and commercial truck VMT. While Kasarda supports his model with case studies of a number of airports around the world, he provides no data on their related truck traffic.

Appold and Kasarda (*25*) have done some analysis of the relationship between airports and economic activity in their immediate environs. Examining employment and income data centered on the nation's 25 busiest airports as ranked by passenger activity, they found that 2.8 million jobs (2.56 percent of U.S. employment) are located within a 2.5 mile radius of the center of the busiest 25 passenger airports. Over seven million jobs (6.48 percent of U.S. employment) are located within a five mile radius of the center of those same airports while 18.3 million jobs (16.57 percent of the total) are within ten miles.

TABLE 7 Cargo Traffic at U.S. Airports 2007

City (Airport Code)	Total Cargo (tonnes)
Memphis (MEM)	3,840,491
Anchorage (ANC)	2,825,511
Louisville (SDF)	2,078,947
Miami (MIA)	1,922,985
Los Angeles (LAX)	1,884,317
New York (JFK)	1,607,050
Chicago O'Hare (ORD)	1,533,606
Indianapolis (IND)	998,675
Newark (EWR)	963,794
Dallas/Ft. Worth (DFW)	724,140
Atlanta (ATL)	720,209
Oakland (OAK)	647,594
San Francisco (SFO)	562,933
Philadelphia (PHL)	543,357
Ontario, CA (ONT)	483,309

Source: Airports Council International.

Compared with the same data for the central business districts served by those same airports, they found that "the employment surrounding airports is substantial but not yet dominant…Airport-centered employment is, on average, three-fourths as large as CBD-centered employment," but it is growing at a faster rate. Hence major airports are definitely major growth nodes, and contribute substantially to VMT on the surrounding roadways, but this is only partially (perhaps marginally) due to their role in urban freight transportation.

3.5 Impact of Ports and Airports on Truck VMT in Major Metropolitan Areas

Southworth, et al. (*26*), in a recent study for the Brookings Institution, developed a data set on truck traffic in the 100 largest metropolitan areas in the U.S. The Appendix table at the end of this paper provides an extract from that data set for 19 of the metro areas that are listed in Tables 6 and 7 as containing a major container port, airport, or both. The table also includes some computational results produced by the writer, based on the variables presented in columns 2 through 6. The metro area names are abbreviated somewhat in column 1; for the complete names see (*26*). The last two rows in the table provide composite data for the other 81 largest metro areas, for comparative purposes.

The assumption guiding the three groupings in the Appendix table is that metro areas with both a major container port and air cargo airport should generate the most truck VMT, cities with container ports should be second, and air cargo airport cities should be third because air freight is a very small fraction of all freight shipments in the U.S. Looking at the results, however, this may not be the best way to group the areas. Based on population, Gross Metropolitan Product (GMP, defined similarly to GDP), and total truck VMT areas like Houston, Chicago, Dallas-Fort Worth, Atlanta, and Philadelphia appear to be more similar to the four metro areas in the first sub-group. Perhaps this augmented group of nine areas should be characterized as metro areas with significant freight logistics and redistribution activity. Chicago, for example, while lacking a major container port, handles more intermodal containers than most coastal ports, due to its role as the primary east-west railroad hub in the U.S. It is notable that the average values for VMT, population, and GMP across all of the three groups defined in the Appendix exceed the averages for the other 81 metro areas included in the top 100, often by substantial margins.

The truck VMT per capita data tell a slightly different story. Proceeding from top to bottom, the average VMT per capita for the three subgroups consistently increases, for both single unit trucks and tractor-trailer combinations. The average values for the other 81 areas combined are more similar to those for the last (air cargo airport) subgroup than they are to the values for areas that have a major container port. Another consistent pattern is that for subgroups one and two the average single unit truck VMT exceeds the average combination truck VMT, on both a gross and per capita basis, while for group three the reverse is true. Again the results for the other 81 metro areas match the group three results. Computing truck VMT per dollar of GMP produces similar results.

The results obtained here are similar to the finding of Southworth, et al. (*26*) that per capita VMT tends to decrease as population increases, since large urban areas (as measured by population) tend to have higher densities, promoting shorter trip lengths. In this case the relationship observed is that per capita truck VMT, for both commercial and freight trucks, tends to decrease as container and air-freight oriented supply chain opportunities and activity increase. It is, however, difficult to tease out of the data the exact relationships.

It is entirely possible that the effects noted above are due primarily to the relationship between truck VMT and metropolitan area population. Table 8 shows the R-squared values obtained for simple linear regressions of the various categories of truck VMT against population or the square root of population. (Similar results are obtained regressing VMT against GMP and square root of GMP, with R-squared values roughly 0.10 lower than those in Table 8.) This was not intended to be a comprehensive or definitive analysis, which is beyond the scope of this paper, but rather a quick and simple investigation of what relationships a more exhaustive study employing a wider arsenal of statistical tools would reveal.

As can be seen, square root of population explains about 75 percent of the variation in truck VMT for the 19 logistics-oriented metropolitans areas studied in detail. As might be expected population is more strongly correlated with commercial (i.e., single unit) truck VMT, since freight truck VMT has a substantial through truck component that is not much affected by the population of the cities through which the freight travels. Given this strong relationship correlations of population with freight and commercial trucking activity related variables will confound the analysis of any relationships between land use and truck VMT. Southworth, et al. had some success in analyzing relationships between VMT-related carbon emissions and various measures of population density and urban form (*26*). It would be instructive to attempt similar analyses focused on the land use and truck VMT question. Time and resources did not permit such analyses for this paper.

4.0 SYNTHESIS OF RESULTS AND CONCLUSIONS

This section synthesizes the results presented above in the form of a set of proposed answers to the research questions posed at the beginning of the paper.

4.1 What Have Been the Trends In VMT Growth? What Share of Total VMT in a Typical Metropolitan Area Consists of Freight and Commercial Movements?

Nationally urban VMT grew 30 percent over the past decade, while commercial and freight truck VMT grew 40 percent. Most urban areas are expecting even greater truck VMT growth over the next 20 years. Trucks typically account for between 3 and 10 percent of urban highway VMT, but truck traffic on major freight connectors typically ranges from 15 to 50 percent of ADT, and again is forecast to be even higher in the future. Most urban and statewide freight studies do not differentiate between commercial and freight trucks.

TABLE 8 Linear Regression R-Squared Values

Dependent Variable	**Independent Variable**	
19 Metro Areas w. Major Container Port/Air Cargo Airport	*Population*	*SQRT Population*
SU Truck VMT	0.695	0.765
Comb Truck VMT	0.495	0.585
SU + Comb Truck VMT	0.655	0.744
Truck VMT Other 81 Metro Areas	0.613	0.623

Based on data provided by Southworth, as used in (*26*).

4.2 Is There Any Evidence That the Dispersal of Employment and Residences in Metropolitan Areas Has Been Contributing to Commercial VMT Growth?

The evidence is somewhat mixed. Large metro areas with high population densities have lower values of commercial truck VMT per capita than newer areas with lower development densities. However the Los Angeles-Long Beach-Santa Ana metropolitan area, which is often held out as one of the worst examples of urban sprawl, has one of the lowest values of commercial truck VMT per capita. On the other hand the San Bernardino-Riverside area in Southern California has one of the highest values. Overall Southern California has higher density than its sprawl reputation might imply, with its high density enclaves spread throughout the region, hence it should be no surprise that its truck VMT per capita values resemble those of areas viewed as being more dense and compact. Low density cities such as Jacksonville, FL and Atlanta also have high commercial truck VMT per capita. So on balance it appears that low density development does increase truck VMT.

4.3 How Does Freight and Commercial Traffic Differ Across Metropolitan Areas?

While most areas are experiencing and forecasting similar growth rates in truck traffic, there are significant differences in the relative shares of commercial and freight traffic. The density effects noted above are also significant. The differences are easily observed, but not as easily explained.

4.4 Would Smart Growth Reduce Freight and Commercial VMT?

As noted above higher development density is correlated with lower truck VMT per capita, so to the extent that higher density (along with many other desired land use qualities) is a product of smart growth it appears that smart growth measures could be effective in reducing truck VMT, with more of an effect on commercial VMT than freight VMT.

4.5 What Is Known About How Big Box Retailing Affects Goods Movement Within a Metro Area, Including Truck Trips from Factories or Distribution Centers to the Outlet and Shopping Trips from Home to the Outlet? Does This Increase or Decrease VMT?

No studies of this phenomenon were found in the literature, so this remains an open question. A principal difficulty in empirical investigation is that big box retailing exists in every major metropolitan area, so it is virtually impossible to find a control group for comparative analysis. Historical data prior to the big box era may be available, but so many other factors have changed over the relevant time period that time series analysis is also difficult. A more fruitful avenue may be to use simulations of urban areas with different postulated retail land use patterns.

4.6 For Metropolitan Areas That Include Major Ports, Airports, and Distribution Centers, Does Urban Form Matter?

Metropolitan areas with significant physical distribution activity centers, such as Kasarda's Aerotropolis areas, do seem to have different levels of gross and per capita truck VMT. Large airports are clearly having an impact on the location of jobs and commercial activity (*25*). The detailed relationships between urban form and VMT and how these differ from other major metropolitan areas needs further study.

5.0 RECOMMENDED RESEARCH

Some of the data sets identified and used in this paper have not been fully analyzed with respect to the relationships between land use, urban form, and freight and commercial VMT in metropolitan areas. In particular, the complete data set built by Southworth, et al (*26*), including the urban density and urban form variables, and the I-10 Freight Study (*20*) could provide the bases for some very informative research. It would also be useful to contact the urban areas and states who have conducted freight studies to see if they have detailed data that could be used.

Second, a series of simulation studies of different urban land use patterns and the resulting freight and commercial truck VMT should be conducted. Given the base data for an urban area (real or hypothetical) it would not be difficult to construct a series of land use scenarios that get at the questions raised above in 4.2, 4.4, 4.5, and 4.6. One could easily envision many graduate student M.S. and Ph.D. theses devoted to such analyses. Finding a way to outline the desired studies and communicate the template to the academic community, and perhaps also assemble some representative base cases, would be a useful first step.

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Appendix. Truck VMT and Demographic Data for Major Metropolitan Areas (2005)

Metropolitan Area	Annual Truck VMT (Miles)			Pop.	GMP	VMT per Capita		
	Single Unit	Combination	SU + Comb	(million)	($million)	SU	Comb	SU + Comb
MAJOR CONTAINER PORT PORT & AIRPORT								
Los Angeles-Long Beach, CA	3,043,511,501	2,239,886,269	5,283,397,770	12.934	632,407	235	173	408
New York-New Jersey, NY-NJ-PA	4,650,327,946	3,323,500,070	7,973,828,016	18.814	1,056,381	247	177	424
San Francisco-Oakland, CA	1,238,074,715	1,108,960,383	2,347,035,098	4.158	268,300	298	267	564
Miami-Fort Lauderdale, FL	2,611,122,978	1,534,777,267	4,145,900,245	5.425	231,806	481	283	764
Total	11,543,037,139	8,207,123,989	19,750,161,128	41.330	2,188,894			
Avg	2,885,759,285	2,051,780,997	4,937,540,282	10.333	547,224	279	199	478
MAJOR CONTAINER PORT								
Seattle-Tacoma, WA	1,440,696,420	791,326,519	2,232,022,939	3.208	182,170	449	247	696
Charleston, SC	257,834,598	405,865,485	663,700,083	0.592	22,503	436	686	1122
Virginia Beach-Norfolk, VA-NC	309,367,887	292,903,177	602,271,064	1.642	66,715	188	178	367
Houston, TX	1,553,815,047	2,136,800,001	3,690,615,048	5.353	316,332	290	399	690
Honolulu, HI	139,935,147	50,088,009	190,023,156	0.905	41,111	155	55	210
Jacksonville, FL	918,211,973	726,070,757	1,644,282,730	1.248	52,592	736	582	1318
Baltimore, MD	1,394,118,213	950,927,200	2,345,045,413	2.651	118,063	526	359	885
Total	6,013,979,284	5,353,981,147	11,367,960,432	15.597	799,486			
Avg	859,139,898	764,854,450	1,623,994,347	2.228	114,212	386	343	729
MAJOR AIR CARGO AIRPORT								
Memphis, TN-MS-AR	660,552,499	1,008,140,749	1,668,693,248	1.257	56,694	526	802	1328
Louisville, KY-IN	624,696,907	1,000,946,303	1,625,643,210	1.210	50,108	516	827	1343
Chicago, IL-IN-WI	2,983,466,438	4,462,704,252	7,446,170,690	9.447	461,374	316	472	788
Indianapolis, IN	841,463,867	1,555,062,509	2,396,526,376	1.640	87,645	513	948	1461
Dallas-Fort Worth, TX	1,808,018,220	2,821,841,190	4,629,859,410	5.823	315,544	310	485	795
Atlanta, GA	3,356,395,179	2,193,892,047	5,550,287,226	4.972	242,382	675	441	1116
Philadelphia-Camden, PA-NJ-DE-MD	1,938,196,137	1,490,467,159	3,428,663,296	5.806	295,236	334	257	591
Riverside-San Bernardino, CA	3,477,643,742	3,180,599,081	6,658,242,823	3.910	101,561	889	813	1703
Total	15,690,432,990	17,713,653,290	33,404,086,280	34.065	1,610,544			
Avg	1,961,304,124	2,214,206,661	4,175,510,785	4.258	201,318	461	520	981
OTHER 81 TOP METRO AREAS								
Total	44,364,745,342	47,000,802,383	91,365,547,725	102.013	4,683,376			
Avg	547,712,905	580,256,820	1,127,969,725	1.259	57,819	434.9	461	896