Conducting Truck Routing Studies from a New Perspective

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ABSTRACT

The era in which transportation professionals could merely conduct analyses of truck traffic volumes, their associated impacts, and routing strategies no longer exists. A much broader and interactive transportation system management approach must be employed, along with innovative analytical procedures and carefully considered recommendations to be compatible with unique situations in each area. Documentation of a recent study of this type that was conducted in Nashville, Tennessee, is presented. This research used visual overlay techniques, sensitivity analyses by computer modeling, and some sketch planning methods to investigate several system alternatives. From these and other analyses, a wide range of innovative recommendations was suggested. This departure from traditional thinking to meeting today's problems innovatively resulted in findings, conclusions, and recommendations that should assist other analysts faced with similar challenges. Increased use of the news media, using nonuniform traffic signs, using available traffic volume data as a surrogate for unavailable origin-destination data, reformatting existing data to increase their utility, studying the evolution of truck terminal operations, and presenting a noise prediction model that local planners can understand and use at public meetings are examples of the innovations presented.

Urban transportation planning is concerned with the safe and efficient movement of both people and goods within an urban area. Heretofore, planning efforts directed toward transporting people within Nashville and Davidson County have received far more attention than planning for the transportation of goods. This disproportionate planning emphasis on the transportation of individuals, however, is certainly not unique to metropolitan Nashville. The movement of people has traditionally received much greater attention in all urban areas throughout the nation.

Urban transportation planners, however, have long recognized basic differences between goods movement and people movement. People make decisions as to how, when, and where they go, whereas goods do not. The parameters, explanatory variables, and associated interrelationships for goods movement are unique, and analysis techniques must be different from those used in passenger transport.

A fundamental and primary reason for conducting this truck route study was to evaluate the performance of future systems, reduce accidents, improve arterial street operations, and minimize harmful environmental impacts by considering the possible designation of truck routes on Nashville and Davidson County highways and streets. Truck transportation handles the greatest tonnage of commodities into and out of Davidson County. Because of the ubiquitous nature of highways and streets, truck routing and truck terminal locations have a significant impact on the performance of these local highways and streets.

BACKGROUND INFORMATION FOR ROUTING STUDY

Nashville and Davidson County have approximately 86 mi of Interstate highways and 267 mi of principal arterials to serve approximately 500,000 county residents and thousands more from neighboring counties (personal communication from Bonnie Brothers, Tennessee Department of Transportation, January 1984).

Nashville is one of only five cities in the entire nation that can boast of having three distinct Interstate highways that both enter and depart from the city. Such a large amount of Interstate mileage is a definite asset to the mobility of metropolitan Nashvillians and to the overall economic viability of Nashville and Davidson County. However, the abundance of Interstate mileage does have some associated drawbacks.

One drawback is that the preponderance of Interstate mileage and frequent interchanges encourage motorists to use the Interstate highways for purposes for which they were not designed (i.e., local trips). This problem, however, is certainly not unique to Nashville. Another drawback is that portions of Nashville's inner loop, the Interstate segments that redistribute traffic near the central business district (CBD), have some significant design problems associated with redirecting higher speed traffic around confined turning radii.

In summary, Nashville and Davidson County have a rather extensive and ubiquitous highway system that combines considerable Interstate mileage with numerous major arterials radiating away from the CBD. Overlay these principal roadways on (a) a CBD grid network, (b) a rather equally distributed network of collectors, and (c) improvements presently being constructed or programmed to start soon, such as the 440 Parkway circumferential and the extension of Briley Parkway, and the results are a highway system that has the potential to meet most of the transportation needs of Nashville and Davidson County. Transportation system management (TSM) improvements (e.g., truck routes, improved intersection design and signalization strategies, ridesharing, curb space management improvements) are just a few of the methods being used by local and state officials to ensure that system capacities satisfy user demands to a large extent.

Turning from the topic of supply to demand, the number of interstate terminals and the number of interstate truck lines serving Davidson County is abnormally large for a city of Nashville's size. This situation is due to (a) the unusually large number of firms and terminals that haul freight exclusively between Nashville and some other city and (b) the regional collection-distribution system of which Nashville is the focus. In addition to the firms and terminals that service general commodities freight, there are approximately 30 additional specialized firms with terminals providing specialized services to Nashville. Specific examples of these items and services are steel, refrigerated goods, household moving, and gasoline (1,p.9).

The intrastate trucking operations resemble the interstate trucking operations in many ways except that they are regulated by the Tennessee Public Service Commission (TPSC) instead of the Interstate Commerce Commission (ICC) and are licensed to haul only inside the state of Tennessee. Intrastate trucking operations provide the primary regional collector-distributor system for Tennessee. Interstate trucks usually deliver local and regional goods at the regional center, in this case Nashville, and smaller intrastate trucks disperse the goods to their final point of termination. Intrastate trucking also provides this distribution service to rail, water, air, and pipeline operations, as requested, because these modes individually do not have adequate collection or distribution systems outside of Nashville.

RESEARCH CONSIDERATIONS

The Metropolitan Nashville Traffic and Parking Commission initiated the truck routing study to

1. Assess the need for designated truck routes,
2. Make more informed automobile-truck planning decisions, and
3. Be more aware of likely consequences resulting from their decisions.

Operational and environmental reasons for conducting a truck routing study showed that

1. Existing terminal areas were heavily congested and the subsequent movements of goods were constrained.
2. Truck volumes represented a significant portion of all interstate traffic (12 to 27 percent trucks).
3. Geometric design deficiencies resulting in congestion, capacity reduction, and safety problems along roadway segments and at intersections were exacerbated at locales where heavy truck volumes exist.
4. Posted speed limits on some roads exceeded design speeds.
5. Commodity transportation originated and terminated in areas already experiencing certain environmental problems (i.e., industrial areas).
6. New truck terminals or expansion of existing terminals, or both, must be carefully studied through proper land use planning and recognition of impacts on residential and commercial development.
7. An excessive number of truck terminals near Interstate interchanges could have significant impacts on traffic operations and land use.
8. Truck traffic, by its very nature and different vehicle operating characteristics, requires special environmental considerations.

Researchers also recognized that a designated truck route system would channelize truck movements along a series of defined paths and thus limit truck access to nondesignated highways. Such a transportation system management (TSM) improvement would reduce automobile-truck traffic interaction on nondesignated highways. Secondary benefits include reductions in roadway maintenance and reconstruction costs from (a) reducing the proliferation of truck traffic on all urban roads while (b) encouraging truck traffic on those streets and roads that are most capable of structurally accommodating heavy-duty, multiaxle trucks.

Important considerations that researchers planned to review in designating truck routes involved the problems of (a) defining the beginning and ending terminals of designated routes (i.e., route access and egress) and (b) evaluating how a somewhat skeletal routing system would affect the economic costs of truck operations (1,p.3).

After these and several other factors were considered, the researchers stated (1) that the primary goal of the study was

> to investigate the feasibility of truck routes for Nashville-Davidson County which will meet the needs of local and through trucks, the general motoring public, and local residents.

RESEARCH RESULTS

During the course of the Nashville truck routing study, Vanderbilt University researchers used a variety of research techniques and discovered certain findings that should be helpful to others who might conduct truck routing analyses. These techniques and findings are reviewed in the following sections of this paper.

The last major analysis and classification of Nashville's truck terminals was performed in 1977. The 1983 research data showed that Nashville and Davidson County had added 84 new terminals and thus experienced a 70.6 percent (from 119 to 203) increase in truck terminals during this 7-year period (1,p.14). This percentage was initially thought to be much higher until careful investigative analyses were performed. When the 1983 data were compared to similar 1977 truck terminal information, an interesting phenomenon was discovered. An original estimate of 110 to 115 new terminals was reduced to the final 84 when it was discovered that what initially appeared to be new terminal operations were often merely variations or outgrowths of earlier 1977 operations. Even though names and often terminal addresses in telephone directories had changed, many 1983 terminal operations were not really "new operations" in the strictest sense.

Researchers discovered that a rather natural evolution was occurring among these terminal operations. The steps might be defined as

1. Creation,
2. Growth and expansion, and
3. Internal reorganization.

The majority of the trackable terminal operations from 1976 to 1983 demonstrated growth and expansion characteristics, followed by a tendency to combine with others to form an even larger operation. Sometimes these combination-expansions resembled partnerships, and others were complete buyouts or takeovers. The combination phase was often followed by internal reorganization leading to further growth or perhaps additional subdividing. Many companies that appeared to disappear were merely restructured organizationally with possibly a new name and central headquarters or mailing address, but little change actually occurred in their original operation.

Many truck routing studies face the problem of obtaining reliable truck origin-destination data for use in the traditional transportation forecasting models. Nashville was no exception because reliable truck origin-destination data were not available and would have been extremely costly to obtain. The data that were available consisted of

1. Comprehensive origin-destination travel data (circa 1959) well into its third decade of existence,
2. Aging truck travel forecasts from earlier studies, and
3. Almost yearly traffic volume counts.

The first reactions were that the earlier origin-destination (O-D) information and travel forecasts were too antiquated to be reliable and total traffic volumes, although current, were of little value. After further investigations and analyses, however, a rather innovative solution to developing more useful and current truck trip ends was improvised.

This process of generating updated truck trip ends began by multiplying recent Nashville vehicle classification counts per route by 1982 volume counts, which were the most currently available traffic data, to obtain realistic truck traffic volumes by route. The process continued by updating the 1959 land use data to reflect current land use, investigating the number of truck trip ends produced or attracted per zone for the earlier O-D data, determining the subsequent increases in truck traffic volumes, equating increases in truck traffic to required increases in truck trip ends, and then proportioning the additional truck trip ends among various zonal centroids and external stations using the earlier accumulated knowledge and data for guidance.

The entire process of developing updated truck trip-end projections (i.e., zonal truck productions and attractions) could be viewed as a backward modeling process whereby current, existing truck volumes were used in conjunction with earlier travel forecasts and O-D data to develop reasonable current truck trip-end projections. The resulting trip-end projections were then rechecked against existing land use data for reasonableness. The entire process required several iterations but the resulting truck productions and attractions proved useful in subsequent modeling procedures described later in this paper.

During the data collection phase of this research, three other types of data proved to be noteworthy and will be highlighted. The first set of data consisted of merely reformatting and alphabetizing the results of the combined vehicle classification counts and 1982 traffic volume counts. The result was a summary report in the study that has allowed researchers and local planners to almost instantaneously find the typical daily truck volumes by vehicle type that can be expected on Nashville's roads and streets. An analyst merely identifies the road of interest (e.g., Charlotte Avenue), turns to the alphabetical listing, finds the roadway segment or nearest approximate location, and then reads daily truck volumes and percentages for the three categories of single unit, multiple unit, or total trucks. This simple data reformatting process has proven extremely useful.

A second data set that resulted from this research was a summary of the vertical height restrictions along Nashville's streets and highways. Computer printouts of Tennessee's Roadway Information Management System (TRIMS) were analyzed and vertical height restrictions summarized in the following three increments: (a) 14 ft, (b) 14 to 15 ft, and (c) 15 to 16 ft. These data were compiled for use in eventual truck routing designations. Designating a truck route and then realizing later that it has a vertical height restriction is of little value to anyone.

The third, but perhaps the most useful, result of this research was the discovery of a simplified noise prediction model. Local planners are frequently questioned by local citizens about the changes in noise levels that will be likely to occur as a result of new or revised highway developments, land use changes, truck routings, construction projects, and numerous other activities. Until now, Nashville planners have not been able to satisfactorily answer these questions in a quantitative, yet inexpensive, fashion. Detailed computer modeling procedures are available but are usually not economically justifiable.

During this research, a simplified noise prediction method (2) was discovered. The method greatly simplifies complex mathematical Federal Highway Administration noise prediction models into understandable and easily usable nomographs. Using the nomographs with realistic input assumptions gives local planners a formalized analytical process whereby they can be more responsive to citizen concerns.

RESEARCH ANALYSIS TECHNIQUES

Three primary research techniques using overlays, sensitivity analyses, and sketch planning techniques were used in Nashville's truck routing study. Although these three techniques are not new and have been used before in various capacities, the manner in which they were used in this research should assist other researchers currently performing, or about to perform, additional truck routing studies.

The overlay process was used to identify existing problem areas where further truck traffic could be detrimental. The researchers' original intentions were to identify truck-sensitive areas and then avoid assigning truck routes through these areas, if possible. If truck routes had to include travel through these sensitive areas, special considerations would be studied.

Base maps of Nashville and Davidson County were prepared. Researchers determined that three particularly pertinent sets of data would be displayed on clear transparencies and then overlayed on one another to reveal the "darkened" or truck-sensitive areas. The three types of data selected were

1. Truck terminal locations,
2. Recognized areas of existing traffic congestion, and
3. High truck-automobile accident locations.

Residential, hospital, and school zone data were also compiled but could not be directly integrated into the final overlay process because their numerous, widespread locations negated the overlay technique. In other words, the entire study area was darkened because of the multiple and diverse location of schools, hospitals, and residential areas. Therefore this information was removed from the overlaying process, but would temper route-by-route decisions later.

The original overlay technique citing truck accidents, traffic congestion, and truck terminal locations revealed that there were seven truck-sensitive areas in Nashville. The overlay technique also dramatically revealed that researchers would have a difficult, if not impossible, task of avoiding all sensitive locations when designating specific truck routes. It is important to note that avoiding existing terminal locations when defining truck routes is not always desirable. Expanding existing terminal areas further instead of creating additional terminal areas may often be the most prudent strategy. Selection of truck terminal locations as one of the three criteria for transparency analyses does not preclude an expansion recommendation; it was merely intended to identify truck-sensitive areas.

Sketch planning techniques of combining Nashville's 248 traffic analysis zones into a more manageable number and use of general routes, instead of specific facilities, were coded into computer networks. Typically, four to seven original traffic analysis zones of similar homogeneous land use characteristics were aggregated to reduce the 248 zones to fewer than 50 zones for each network analysis. To avoid tedious coding of every individual road, comparable parallel roads within close proximity of each other were coded as a single facility.

The downtown street network and the Interstate networks were then tested using the earlier developed truck trip-end data, a gravity model with friction factors changed only slightly from those used in the initial trip distribution process, and an equilibrium assignment model. A model was considered to be "calibrated" when the trip assignments to each existing network link varied no more than ±10 percent from calculated existing truck traffic volumes and the total trip assignments for all links were within ±5 percent of the total estimated truck ground counts for the entire network.

When the sketch planning methodologies had been made final and an existing network assignment had been calibrated, sensitivity analyses testing various operating scenarios were performed on both the Interstate and downtown networks.

For example, Interstate sensitivity analyses were performed by assigning the same truck traffic volumes to different Interstate networks. The Interstate networks differed in the consideration of future major circumferential improvements and in the inclusion or relaxation of operating restrictions due to existing height restrictions on particular Interstate links. The resulting truck traffic volumes for each network assignment were then compared to each other on a link-by-link basis to evaluate the impacts of certain facility improvements and operational height restrictions. These sensitivity analyses resulted in truck traffic routings that were explainable and inherently logical and dramatically showed that completion of the 440 Parkway in approximately 2 years would greatly relieve Nashville's inner loop congestion and many associated problems.

Similarly, sensitivity analyses of truck traffic assignments to downtown street networks were performed. The researchers initially began performing downtown truck traffic assignments by increasing travel times on a few links per computer run to assess the impacts of these restrictions on truck travel patterns and the resulting changes in truck volumes assigned to parallel streets. It became quickly apparent that this rather arbitrary and piecemeal focusing on individual east-west or north-south streets was of questionable value in comparing the results from different networks and that the combinations needed would be almost endless. Nashville's rather symmetrical north-south and east-west grid network of downtown streets allowed the researchers to pursue a different approach.

The researchers decided to constrain all east-west travel or all north-south travel simultaneously in two separate truck traffic assignments. The constraining of truck traffic in the east-west or north-south directions was accomplished by reducing link travel speeds in the constrained directions to 5 mph and increasing travel distances per link approximately tenfold or 1000 percent. Thus a downtown travel link that originally had a travel speed between 15 and 25 mph was reduced to a 5-mph travel speed and an original link distance of 0.1 to 0.2 mi became 1 to 2 mi in the constrained network.

These directional sensitivity analyses revealed the propensity of individual streets in the unconstrained directions to gain or lose truck trips. This information provided valuable insights into a street's proclivity for accommodating truck traffic. Table 1 gives the results of these analyses. The north-south streets displayed much smaller resulting delays when east-west streets were constrained and north-south truck volumes increased. Thus most north-south streets should be considered more appropriate candidates for designated truck routes, when possible.

TABLE 1 Directional Sensitivity Analysis of Downtown Truck Routes

Street	Percentage Change[a] in Travel Propensity
North-South Travel Constrained[b,c]—Resulting East-West Assignments	
Jefferson	+18
James Robertson Parkway	−45.8
Charlotte	+3.8
Church	+54.6
Broadway	+28.7
Demombreum	−62.5
East-West Travel Constrained[b,e]—Resulting North-South Assignments	
Thirteenth	+32.7
Twelfth	−9.0
Eighth	+9.6
Hermitage	+9.4
First	+29.0

[a]Change is in terms of the "unconstrained, calibrated" base truck volume assignments by link.
[b]"Constrained" constitutes a reduction of link travel speeds to 5 mph and approximate travel distance increases of 1000 percent for links in the indicated constrained directions.
[c]Increase[d] in vehicle-miles of travel (VMT) = +10,157 vehicle-miles, increase[d] in travel times = +631,803 min., total VMT = 38,096 vehicle-miles, and total travel time = 2.37×10^6 min.
[d]Each "increase" is from a comparison with similar statistics from the original "unconstrained, calibrated" base truck volume assignments.
[e]Increase[d] in vehicle miles of travel (VMT) = +3,670 vehicle-miles, increase[d] in travel times = +226,270 min., total VMT = 33,373 vehicle-miles, and total travel time = 2.07×10^6 min.

Overall, the overlay, sensitivity analysis, and sketch planning techniques were useful and informative. They were also quite cost-effective in developing final recommendations.

RESEARCH RECOMMENDATIONS

As a result of field investigations, data analyses, and the modeling procedures previously described, this research resulted in several rather unconventional or perhaps surprising recommendations.

The first recommendation (1,p.57) prescribed truck prohibitions instead of truck routings:

> Because of the economical and temporal hardships a skeletonal truck routing system would impose on the trucking industry, improved system facilities that will open in the near future, and the scarcity of comparable parallel facilities; designating an entire system of truck routes for general trucking operations is not recommended at this time.

Requirements associated with this first recommendation include

1. Evaluating the impacts (hopefully improved truck-automobile operations) as new and improved highway facilities are implemented,
2. Improving the current operating conditions in the seven identified sensitive areas,
3. Restricting trucks from selected areas where their presence is not critical to their continued operational stability but where their operation could definitely be detrimental to the existing quality of life, and
4. Investigating the feasibility of designating specific truck routes for hazardous materials transport because these movements have more defined origins and destinations.

The remaining study recommendations more specifically addressed these four requirements. For example, the other recommendations identified various types of improvements, specific locales, and actual Nashville locations where prohibiting trucks might be appropriate.

Specifically, the second recommendation adopted a transportation system management philosophy that improvements to the seven identified sensitive areas were better than merely diverting traffic away from these areas. These site-specific recommendations involved improvement such as adding left-turn lanes, removing utility poles restricting right turns, constructing raised medians, and improving signalization along with simple improvements such as merely repainting intersection stoplines and other line restriping.

Recommendation 3 identified the fact that posted speeds on portions of Nashville's inner loop sometimes exceed design speeds and should be reduced. The fourth recommendation cited specific locations where better upstream signing was needed.

Recommendation 5 adopted the innovative approach of suggesting that nonstandard speed limit signs be adopted in addition to conventional standard ones. Only a few nonstandard signs were deemed appropriate at specific design-deficient inner loop locations. The basic rationale for this recommendation was that these "different" signs would better inform and possibly cause truck drivers and other motorists to reduce their speeds to safer levels as a result of the increased "shock effect" of these nonstandard signs. Limited use of such signs should maintain this shock effect, and having duplicative information on both uniform and noncompliance signs appears to be the most prudent action from a legal liability viewpoint.

Other study recommendations urged that

1. Truck traffic on north-south downtown streets was more appropriate than east-west traffic.
2. Public officials should make better use of local media and other communication techniques to fully inform the public of increased police efforts to ticket speeding and traffic signal violators, and
3. A specific study to investigate the movement of hazardous materials was needed.

EVALUATION OF RESEARCH RESULTS

Although the recommendations of this recent research are still being reviewed, general review comments have been favorable. Some intersection improvements have already occurred. Local officials concurred with the recommendation not to designate specific truck routes, and some of the resulting data and analyses generated from this research have been of immediate benefit to local transportation professionals and other public officials. The researchers fully intend, and expect, that implementation of the study recommendations will be instituted in conjunction with input and guidance from trucking industry representatives.

By looking beyond traditional analysis techniques and typical recommendations, it is hoped that sharing the lessons learned and the techniques used in this research will foster further innovativeness in forthcoming truck routing studies.

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Publication of this paper sponsored by Committee on Urban Goods Movement.