



**CFIRE**

# Transportation Profiles for MAFC Commodities

**CFIRE MAFC-10  
September 2011**

National Center for Freight & Infrastructure Research & Education  
Department of Civil and Environmental Engineering  
College of Engineering  
University of Wisconsin–Madison

**Authors:**

Alan Horowitz, University of Wisconsin-Milwaukee  
Mark Vonderembse, University of Toledo  
David Dobrzykowski, University of Toledo  
Peter Lindquist, University of Toledo  
Kazuya Kawamura, University of Illinois-Chicago  
Jane Lin, University of Illinois-Chicago  
Minyan Ruan, , University of Illinois-Chicago  
Jessica Guo, University of Wisconsin-Madison  
Ernie Wittwer, University of Wisconsin-Madison  
Teresa Adams, University of Wisconsin-Madison

**Principal Investigator:**

Teresa Adams, PhD  
National Center for Freight & Infrastructure Research & Education  
University of Wisconsin–Madison

**Supported by the Mid-America Freight Coalition**



The Mid-America Freight Coalition (MAFC) is a regional organization that cooperates in the planning, operation, preservation, and improvement of transportation infrastructure in the Midwest. The ten states of the AASHTO Mid-America Association of State Transportation Officials (MAASTO) share key interstate corridors, inland waterways, and the Great Lakes. The MAFC is funded by the National Center for Freight & Infrastructure Research & Education and the DOTs of the ten member states.



# Technical Report Documentation

1. Report No. MAFC-10	2. Government Accession No.	3. Recipient's Catalog No. <b>CFDA 20.701</b>	
4. Title and Subtitle Transportation Profiles for MVFC Commodities		5. Report Date <b>August 2011</b>	
		6. Performing Organization Code	
7. Author/s Alan Horowitz, University of Wisconsin-Milwaukee; Mark Vonderembse, David Dobrzykowski, Peter Lindquist, University of Toledo; Kazuya Kawamura, Jane Lin, Minyan Ruan, University of Illinois-Chicago; Jessica Guo, Ernie Wittwer, Teresa Adams, University of Wisconsin-Madison		8. Performing Organization Report No. <b>MAFC-10</b>	
9. Performing Organization Name and Address National Center for Freight and Infrastructure Research and Education (CFIRE) University of Wisconsin-Madison 1415 Engineering Drive, 2205 EH Madison, WI 53706		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. TRJ 03450830	
12. Sponsoring Organization Name and Address Wisconsin Department of Transportation 4802 Sheboygan Ave Madison, WI 53707		13. Type of Report and Period Covered <b>Final Report [1/1/2009-9/30/2011]</b>	
		14. Sponsoring Agency Code	
15. Supplementary Notes <b>Project completed for the MAFC with support from CFIRE and WisDOT.</b>			
16. Abstract  Effective planning for freight in the public sector is often hindered by the difficulty in obtaining reliable estimates of the quantity of freight commodities flowing between points in the planning area. In an effort to address this issue, the states of the Mid-America Freight Coalition (formerly the Mississippi Valley Freight Coalition) initiated a project to develop a profile of commodities flowing through the region.  To address this challenge, CFIRE conducted three separate but related efforts. The University of Toledo conducted the first. It involved developing a case study of the auto industry on the supply chain used. The University of Illinois-Chicago, with help from the University of Toledo, carried out the second. It disaggregated federal Freight Analysis Framework data on commodity flow to yield county-level information. The University of Wisconsin-Milwaukee led the third element, with help from the University of Wisconsin-Madison, the University of Illinois-Chicago and the University of Toledo. It involved the construction of a micro-simulation model the yielded truck-based commodity flow information and route assignments at the county level for key commodities within the region.			
17. Key Words Freight, Planning, Commodities	18. Distribution Statement <b>No restrictions. This report is available through the Transportation Research Information Services of the National Transportation Library.</b>		
19. Security Classification (of this report) <b>Unclassified</b>	20. Security Classification (of this page) <b>Unclassified</b>	21. No. Of Pages 30	22. Price <b>-0-</b>

**Form DOT F 1700.7 (8-72) Reproduction of form and completed page is authorized.**

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# Table of Contents

Technical Report Documentation .....	3
DISCLAIMER .....	4
Abstract.....	6
Background.....	7
A Case Study .....	7
Synthesis Framework for County-Level Freight Data .....	8
Micro-Simulation .....	11
Introduction .....	11
Limitations of the First Generation MVFC Freight Model .....	12
Major Steps in the Microsimulation .....	13
Agricultural Products (Grains) .....	13
Manufactured Products .....	14
Practical Aspects of the Microsimulation.....	15
Lessons Learned to Date .....	15
Sample Results .....	16
Parameters Defining the Scope of Sample Simulations.....	16
Graphical Results .....	18
Time-of-Day Distributions .....	18
Critical Corridors .....	19

## **Abstract**

Effective planning for freight in the public sector is often hindered by the difficulty in obtaining reliable estimates of the quantity of freight commodities flowing between points in the planning area. In an effort to address this issue, the states of the Mid-America Freight Coalition (formerly the Mississippi Valley Freight Coalition) initiated a project to develop a profile of commodities flowing through the region.

To address this challenge, CFIRE conducted three separate but related efforts. The University of Toledo conducted the first. It involved developing a case study of the auto industry on the supply chain used. The University of Illinois-Chicago, with help from the University of Toledo, carried out the second. It disaggregated federal Freight Analysis Framework data on commodity flow to yield county-level information. The University of Wisconsin-Milwaukee led the third element, with help from the University of Wisconsin-Madison, the University of Illinois-Chicago and the University of Toledo. It involved the construction of a micro-simulation model the yielded truck-based commodity flow information and route assignments at the county level for key commodities within the region.

Taken together these three products should help to inform planning efforts within the region.

## Background

Useful freight planning by public agencies requires some understanding of what is being moved from place to place. Private companies typically hold this basic information closely. Commercially available data is typically fairly expensive and has some problems with accuracy. Publicly available information is either incomplete, requiring much analysis and manipulation, or lacking sufficient detail to be useful in a planning process.

In addition, public sector planners sometimes lack a basic understanding of the supply chains that move products. This makes it difficult for them to understand why products move as they do through specific corridors and by specific modes.

In attempt to address these two problems, the ten states of the Mid-America Freight Coalition (MAFC) initiated an effort to develop additional information on the flow of commodities through the region. To do this three separate but related efforts were undertaken. This report outlines the result of the total effort.

## A Case Study

The auto industry is a very important part of the regional economy. Parts suppliers are located in every state. Assembly plants are also in most states. To document the supply chain used by the auto industry, researchers at the University of Toledo used the Chrysler Jeep plant located in Toledo as a case study. Their report outlines how the company works with key suppliers to make the assembly plant operate efficiently. The introduction to the report is reproduced below. The entire report can be found at <http://www.wistrans.org/cfire/research/projects/mvfc-10/>.

**Understanding the Automotive Supply Chain:  
The Case for Chrysler's Toledo Supplier Park and its Integrated Partners  
KTPO, Magna, and OMMC**

The purpose of this document is to describe the supply chain that produces automobiles and light trucks from the perspective of the assembly plant, which controls the tempo of production and coordinates actions of the upstream supply chain beginning with tier one suppliers of chassis and auto bodies and the downstream distribution system that ends at the dealership. The automotive supply chain is a large, complex operation that requires sophisticated management techniques, substantial information technology expertise, and close coordination to reduce throughput time and eliminate non-value added activities. This document specifically examines the Jeep Wrangler which is produced at Chrysler's Toledo Supplier Park.

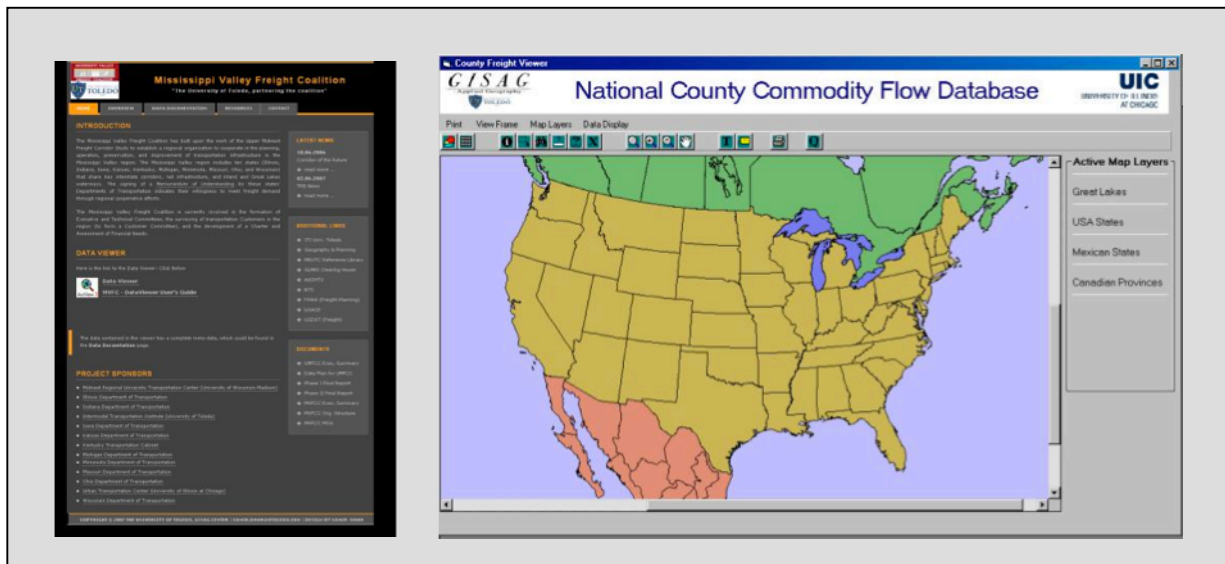


## Synthesis Framework for County-Level Freight Data

Researchers at the University of Illinois-Chicago (Ruan and Lin) developed a set of tools that allows the federal Freight Analysis Framework (FAF) commodity flow data, which is held at FAF regions, to be distributed to counties. This provides commodity flow information, based on the 2002 FAF database, for the entire country.

The National County Commodity Flow Database is the data delivery system for the county-level disaggregated commodity flows generated by Ruan and Lin (2009) for the entire United States. This system was developed to provide a convenient means to retrieve portions of this massive database and to display selected county level flows of interest to individual users.

The system was constructed as a specialized GIS application to be accessed through a web gateway at the University of Toledo (see <http://midwestfreightdata.utoledo.edu/>). Users will reach this site through a link on the project web page as shown on the left in Figure 1. The user interface for the system is displayed on the right hand side of Figure 1. Access to the site will be provided with user Ids and passwords issued by the UIC project team. Potential users will be furnished a link on the project web page to contact the UIC project team for permission to use the site and to download data retrieved from the system.

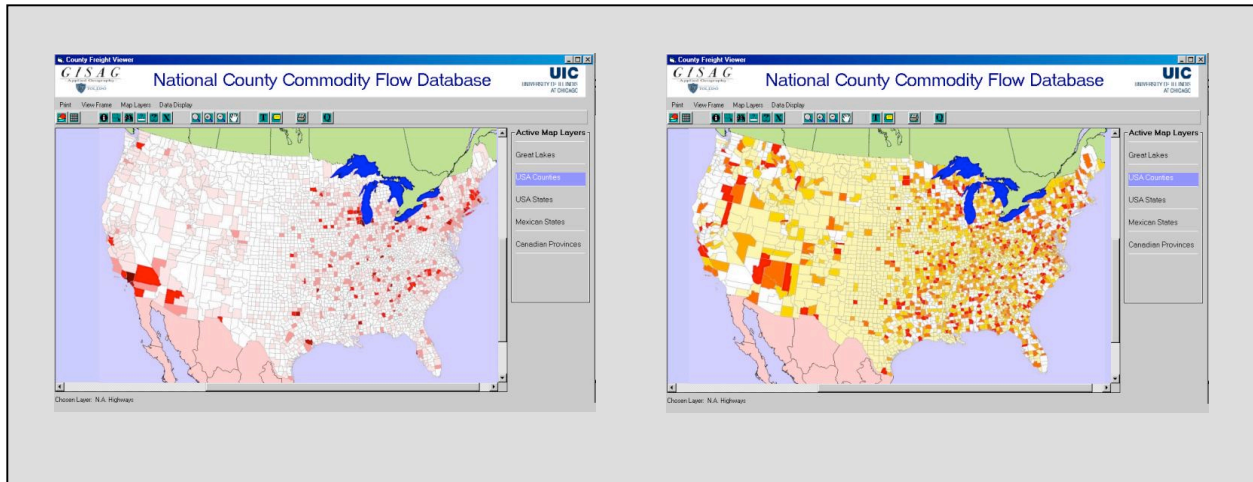


**Figure 1.** Web Gateway for access to the National county Commodity Flow Database and the initial view of the system.

The contents of the database consist of 43 2-digit SCTG (Standard Classification of Transported Goods) categories. Data are stored in the following formats:

- County-level inflow volumes—reported as county tonnage (ktons) totals for all modes
- County-level outflow volumes—reported as county tonnage (ktons) totals for all modes
- County-level combined inflow/outflow volumes—tonnage (ktons) totals for all modes
- County-to-County OD flow volumes (ktons) for trucks only

Users will have the ability to access the data through standard queries furnished through the viewer; data can be displayed both in tabular form and in mapped form. County inflow and outflows can be displayed in mapped form using basic choropleth mapping techniques as shown in Figure 2. Tabular inflow and outflow data can also be downloaded to client computers with designated permissions from the UIC project team.



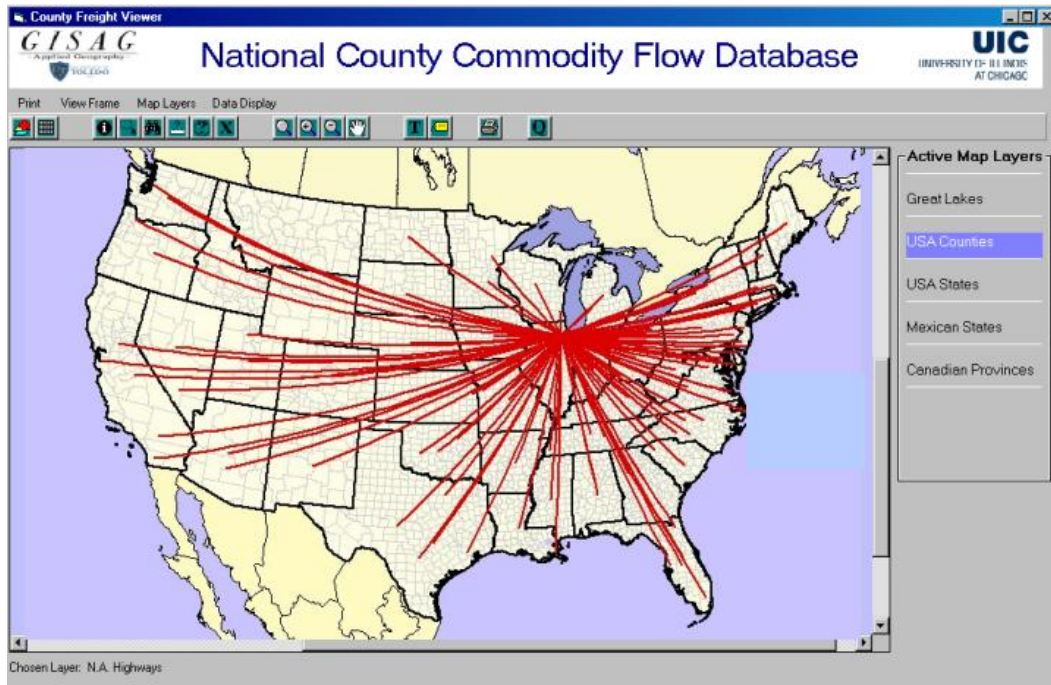
**Figure 2.** County-level inflow and outflow volumes reported in a choropleth map format

OD flow volumes can also be retrieved in tabular and map formats. Data can be retrieved via a series of pull down menus to select counties and SCTG categories. Users have the opportunity to retrieve flows between selected county pairs in several ways: 1) one-county-to-multiple counties by individual SCTG category; 2) multiple-to-multiple counties by individual SCTG category; 3) multiple-to-one counties by individual SCTG category. Multiple SCTG categories can also be summed to display composite flows among several categories between desired sets of counties. Tabular OD data will be provided in an output database format for users to view with their own software.

In addition to tabular output, users will also be given the opportunity to visually examine OD flows using desire line maps furnished through the system. Figure 3 shows a basic approach to desire line mapping of SCTG 35: Electrical Equipment flows from one origin (Chicago/Cook County) to a set of selected destinations. Inbound flows can also be mapped. Users can vary the width of the desire lines in proportion to the magnitude of the flows as a means to increase the explanatory power of the maps.

Additional features of the site include options to print maps on client printers and to export map images to computer graphics files (e.g., bitmap, jpeg, etc.). With the necessary permissions, users also be able to download tabular data retrieved from the database to their local client computer. Geographic data in the form of desire line shapefiles and county boundary files will also be available for download to client computers for use in users' individual GIS and desktop mapping software.

This system was be introduced to the wider freight community at the 2010 Mid-Continent Transportation Research Forum in Madison, Wisconsin. Demonstrations of the software will be provided in a conference presentation.



**Figure 3.** OD Desire Line Map

The paper that summarizes the process used to disaggregate the FAF data was published by TRB and can be found at <http://www.wistrans.org/cfire/research/projects/mvfc-10/>.

# Micro-Simulation

## Introduction

The purpose of the project was to combine information from a variety of data sources and from theory to give a much more detailed picture of commodity flow in the ten-state Mid-America Freight Coalition (Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Ohio, and Wisconsin) than would be possible by relying on a single, aggregated, data source, such as the Commodity Flow Survey or the Freight Analysis Framework (FAF). Emphasis was placed on commodities of particular importance to the Mississippi Valley region (specifically, corn, soybeans, dairy, plastics, and motor vehicle parts) and on the truck mode.

The technique of “microsimulation” (sometimes called “microscopic simulation”) is gaining traction as a method for travel forecasting, in general, and has already seen a few applications for freight forecasting, in particular. Microsimulation generates many random shipments for a given commodity; then it randomly assigns these shipments to random vehicles. These vehicles are deterministically assigned to a road network. A microsimulation can also create random shippers and random consumers, if necessary, to fill in holes in existing data sources. Microsimulation could conceivably involve random driver behaviors in traffic, but this idea was considered impractical for a ten-state region.

Microsimulation was selected as a technique because of the given interest of the Mid-America Freight Coalition (MAFC, a pooled fund of those ten state’s DOTs), in the flow of detailed commodities throughout the region. However, it was unknown whether a microsimulation could work well on such a large scale. Optimism for success was increased by the acquisition of the Dun & Bradstreet establishment database for the whole region. Thus, the amount of generator synthesis could be held to a minimum, and the locations of establishments could be determined with some degree of precision.

Hence, the microsimulation was designed for a high degree of detail. Commodities are identified at the 3-digit SCTG (Standard Classification of Transported Goods); industries are identified at the 6-digit NAICS (North American Industry Classification System); establishments are located to 1/100<sup>th</sup> of a degree longitude or latitude; trips are loaded to the network at individual intersections closest to the actual origins or destinations, not at centroids of traffic analysis zones. The microsimulation is intended to be a description of existing conditions rather than a model of future commodity flows.

The following data sources were used extensively in either calibrating or running the microsimulation.

- Commodity flow tables from the Freight Analysis Framework
- Highway network from the Freight Analysis Framework or from Oak Ridge National Laboratory (as enhanced by University of Toledo)
- Other commodity relationships from the Commodity Flow Survey
- Databases of establishments from Dun & Bradstreet within the ten-state region
- Ontario Truck Intercept Survey
- Census of Agriculture
- County Business Patterns
- Benchmark Input/Output tables



- Agricultural surveys

Farms were synthetically generated within the Mississippi Valley. Super-establishments (for each 6-digit NAICS) were created from macroeconomic data for all FAF zones outside the region, but actual establishments were used inside the region.

## **Limitations of the First Generation MVFC Freight Model**

Given the complexity of the region and the freight system, the first generation of the MAFC Freight Model had certain planned limitations.

- The model is fundamentally descriptive, with only a moderate amount of features for testing transportation system policies.
- Only five indicator commodities are included.
- Path building is based on shortest paths, measured in free flow travel times. Thus, congestion and tolls are not considered. Trucks may be routed in greater numbers to toll roads than in actuality.
- Within the region only establishments within the Dun & Bradstreet database are considered, except for grain elevators, which were given special treatment. However, the synthetic farms, in total, represent the universe of all farms in the region.
- Because only a few commodities were modeled, the model was not “validated” against traffic count data. However, many checks for reasonableness were made.

A second generation freight model would lift these limitations principally in these areas.

- Path building is to be based on a linear function of travel time and travel cost, getting better traffic volumes on toll roads and enabling the analysis of road pricing strategies.
- The number of commodities is to be increased to give a fairer indicator of traffic that will reasonably scale to the whole economy.
- Tour structures are to be calculated with a choice model, which has already been calibrated, instead of by historical shares.
- The model will have mechanisms for growing, shrinking, spawning, or destroying establishments according to changing economic conditions.
- Other key sections of the model, such as destination choice and time-of-day choice, will be made policy sensitive by including time and cost as variable, as well as distance.
- Additional validation checks will be made.

A third generation freight model would incorporate these additional features.

- The model is to include trucks that are empty and trucks carrying waste.
- Background automobile and other commercial vehicle traffic is to be included, which will allow for incorporation of congestion effects. An automobile origin-destination table will be estimated synthetically. Deliveries to households will be included synthetically.
- Capacities will be added to links from existing databases and fine-tuned in critical highway sections.
- Traffic assignments will be upgraded to user-optimal equilibrium DTA.
- Even more validation checks will be made.



## Major Steps in the Microsimulation

Custom software was written to create a very large set of trip records, each trip being identified by its origin location (longitude and latitude), destination location, start time, and truck type. These records are then inputted to traffic assignment software to obtain truck volumes on roads. Both multiclass traffic assignments and dynamic traffic assignments have been tested. Truck trips are built from shipments. The model has two separate sections to handle agricultural products and manufactured products.

### Agricultural Products (Grains)

All agricultural products have their origins at farms or elevators. Destinations are elevators (only if the origin is a farm), feedlots, ethanol plants, biodiesel plants, and food processing plants (HFCS, oils, etc.). All exports (imports are ignored) are assumed to go by railroad, so they are excluded from the list of truck trip records. Elevator-to-elevator shipments are assumed to go by rail only.

**Step 1.** Farm synthesis. Number of farms in a county and the distribution of crops are given. Random farms are generated until the total of farms in the county has been reached. Each farm is identified by:

- Acres of cropland harvested
- Location (state, county and longitude/latitude)
- On-site storage capacity
- Truck (by type) or wagon
- Crop (corn, soybean, other)

**Step 2.** Farm shipment generation, one crop at a time:

p[harvest on this date]	Function of location, crop
p[planting on this date]	Function of location, crop
p[# of shipments]	Function of date, in/out harvest, storage capability, planting

Create shipments. Assume each shipment is in exactly one truck. Then for each shipment:

p[shipment size]	Several size categories, function of truck availability
p[destination type]	Fixed distribution (elevator, feedlot, etc.)
p[destination location]	Logit, function of distance
p[departure time]	Equally space throughout day but with random start time of first shipment

**Step 3.** Elevator shipment generation. Each elevator is given by location and size: p[# of shipments]

Create shipments. Then for each shipment:

p[domestic], p[export]	Fixed shares
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p[this crop] Function of shipments received from farms

Then for each domestic shipment. Number of trucks in shipment is deterministic, once size is known. Calculate:

p[destination type] Fixed distribution (elevator, feedlot, etc.)

p[truck], p[rail] Fixed shares, depends on destination type

p[truck type] Categories (only tractor/trailers at this time)

p[shipment size] Categories (CFS)

p[destination location] Logit, function of distance and establishment size

p[departure time] Uniform, random throughout day

**Step 4.** Assign OD table to network using multiclass, all-or-nothing assignment.

## Manufactured Products

**Step 1.** Establishment selection. There are 3 generalized facility types: producer (P), consumer (C), warehouse (W). Warehouses, as a category, include all transshipment locations. For each establishment determine:

p[producer of product] Associate SCTG with NAICS

p[warehouse for product] , both out and in NAICS, general or refrigerated

The probabilities are functions of primary NAICS for the establishment.

**Step 2.** Shipment generation

p[# of shipments out] Depends on size of establishment, employees

Create shipments out. Then for each shipment, get tour structure (P-C, P-W-C, P-W-W-C, P-W-C-C, etc.):

p[truck], p[rail] Fixed shares

p[tour structure] Categories, 8 different possible tour structures

Then for each trip in each tour:

p[shipment size] Categories (CFS)

p[truck type] Categories (includes the possibility of fractional trucks)

p[destination location] Logit and fixed shares within trip-length categories, number of employees with I/O table weighting

p[LTL], p[TL] From trip length and shipment size

p[departure time]

Uniform throughout day, adjusted for long trips

**Step 3.** Assign OD table to network using dynamic, multiclass, all-or-nothing assignment.

## Practical Aspects of the Microsimulation

*The Economy:* Every non-farm establishments within the contiguous 48 states is represented, either by itself or as part of an external super-establishment. Only a small fraction of these establishments can produce one of the five indicator commodities, but a large majority of them are potential customers. Exports and imports from places except Ontario are ignored; Ontario was included because of its close proximity to the Detroit metropolitan area.

*The Network.* The ORNL network contains all major highways in the United States, represented as 112,000 links. For the microsimulation, full detail was retained for the ten MAFC states and a halo of approximately 100 miles just outside those states. The rest of the network was reduced to interstate highways only. The reduced network has approximately 44,000 links. Many attributes were retained from the original ORNL network, but only speed and distance on links have been used in the current microsimulation. Because only a fraction of traffic is being simulated, there was no need to use information on link capacity within the region. Figure 4 shows part of the loaded network in Ohio, which should give a sense of the network's spatial detail.

Traffic analysis zones were defined to be consistent with FAF, but they were used within the region only to tabulate statistics and to rough-check establishment locations. Trips from external super-establishments were loaded at intersections nearest the mathematical centroid of FAF zones; such intersections were usually interchanges on interstate highways.

Dynamic traffic assignments allowed for driver rest periods.

*Computation.* The most computationally intensive parts of the microsimulation are programmed for parallel processing. Runs are being accomplished on a single-processor computer with six cores and twelve threads. Static traffic assignments take only a few hours. Dynamic traffic assignments run at about 0.25 of real time with a 1-hour time slice.

## Lessons Learned to Date

Further work is planned on the microsimulation to fully exploit its dynamic capabilities, to cover all commodities, and to add policy sensitivity. There are major lessons learned so far.

- Microsimulation is practical for a ten-state region. Except for increases in computation time, there are no apparent obstacles for expanding the microsimulation to the full set of contiguous 48 states.
- It is practical to work at the 3-digit SCTG level, given the ability to easily associate 6-digit NAICS codes with the 3-digit commodities and associated 5-digit commodities.
- The major advantage of microsimulation is the ability to integrate numerous databases with varying degrees of aggregation, while still maintaining excellent spatial detail at all steps. The microsimulation also enabled a better representation of the supply chain than found in traditional intercity freight models.
- There are few databases that contain data that can be used to directly calibrate behavioral freight choice models. Most probabilistic relationships within the microsimulation are built from historical percentages from such sources as the US Commodity Flow Survey or the Ontario Commercial Vehicle Survey.

- There is a need to be wary of missing establishments in the D&B database and to take corrective actions, as necessary.
- Because the total tonnages of corn and soybeans on any given harvest day is so much greater than the tonnages from the three industrial products, the band-width plots of link volumes looks distorted. This distortion could be eliminated by including more industrial commodities or by scaling the existing three commodities to match the universe of all manufactured products.

## **Sample Results**

### **Parameters Defining the Scope of Sample Simulations**

Commodities are identified by SCTG and all selected commodities are exactly at 3-digits, with these break-downs to 5-digits for manufactured products:

#### **Plastics**

- Fibers (24211)
- Monofilaments (24212)
- Plastic, flats (24213),
- Plastic, tubes (24221)
- Plastic, coverings (24222)
- Plastic, sanitary (24223),
- Plastic, closures (24224)
- Plastic, household (24225)
- Other plastics (24229));

#### **Motor Vehicle Parts**

- Brakes (36401)
- Gearboxes (36402)
- Wheels (36403)
- Stampings (36404)
- Other motor vehicle parts (36409)

#### **Dairy Products**

- Milk, liquid (07111)
- Milk, solid (07112)
- Milk, other (07112)
- Cheese (07119)
- Ice cream (07130)
- Butter (07130)
- Other dairy(07191)

#### **Corn (02200)**

## **Soybeans (03400)**

Producing industries for the selected manufactured commodities are identified by NAICS at the 6-digit level and correspond closely to these commodities:

### **Plastics**

- Plastics bag manufacturing (326111)
- Plastics packaging film and sheet (including laminated) manufacturing (326112)
- Unlaminated plastics film and sheet (except packaging) manufacturing (326113)
- Unlaminated plastics profile shape manufacturing (326121)
- Plastics pipe and pipe fitting manufacturing (326122)
- Laminated plastics plate, sheet (except packaging), and shape manufacturing (326130)
- Polystyrene foam product manufacturing (326140)
- Urethane and other foam product (except polystyrene) manufacturing (326150)
- Plastics bottle manufacturing (326160)
- Plastics plumbing fixture manufacturing (326191)
- Resilient floor covering manufacturing (326192)
- All other plastics product manufacturing (326199)

### **Dairy**

- Fluid milk manufacturing (311511)
- Creamery butter manufacturing (311512)
- Cheese manufacturing (311513)
- Dry, condensed, and evaporated dairy product manufacturing (311514)
- Ice cream and frozen dessert manufacturing (311520)

### **Motor Vehicle Parts**

- Carburetor, piston, piston ring, and valve manufacturing (336311)
- Gasoline engine and engine parts manufacturing (336312)
- Vehicular lighting equipment manufacturing (336321)
- Other motor vehicle electrical and electronic equipment manufacturing (336322)
- Motor vehicle steering and suspension components (except spring) manufacturing (336330)
- Motor vehicle brake system manufacturing (336340)
- Motor vehicle transmission and power train parts manufacturing (336350)
- Motor vehicle seating and interior trim manufacturing (336360)
- Motor vehicle metal stamping (336370)
- Motor vehicle air-conditioning manufacturing (336391)
- All other motor vehicle parts manufacturing (336399)

Producing industries for crops are either farms or elevators, exclusively.

Almost any industry can be consumers of these products, as given by the Benchmark Input-Output Table. However, crops could be consumed only by a much smaller set of industries:

### **Farm Customers**

- Biodiesel (325199)
- Elevator (424510,493130)
- Ethanol (325193)
- Feedlot (112112, 112210, 112410)
- Corn products (311221)
- Soy products (311222)

Sample results consist of both static and dynamic traffic assignments of commodity flows throughout the region. Static runs we made for each commodity separately and for all commodities together. Static runs span a full 24 hours in a single time slice. One dynamic traffic assignment was created for the three industrial commodities, with a time slice of 1 hour. This dynamic run started at 6 AM on a weekday (e.g., Monday) and ended at 6 PM on a different weekday (e.g., Thursday) 3.5 days later, spanning 84 hours of simulation time. Results are pulled only from the last 12 hours of simulation time (e.g., 6 AM to 6 PM on Thursday). A second dynamic traffic assignment was created for grains. This second dynamic run was shorter, starting at 6 AM on a weekday and ending at 6 PM on the following weekday, for a total of 36 hours of simulation time. Again, only the last 12 hours were considered relevant.

The harvest date parameters were taken from October 29, near the peak of the corn harvest, assuming that day falls on a weekday.

### **Graphical Results**

In Figures 4 to 23 links with few assigned trucks were suppressed. For static assignments only links with 200 or more vehicles are shown. For the dynamic assignment only links with 20 or more vehicles are shown.

Assignment were “multiclass” by separating straight trucks from combination trucks, but Figures 4 to 23 show all classes combined.

### **Time-of-Day Distributions**

Figures 24 and 25 compare time-of-day distributions between the microsimulation of industrial commodities and typical ground count data. The simulated time-of-day distributions come from the 84-hour dynamic traffic assignment. It is important to note that these simulation results were obtained entirely through fundamental and elementary principles of shipper and carrier behavior. Although there are some differences between how the data is displayed, the general patterns are very similar, as are the range in values. There is an odd leveling of truck VMT in the simulation between 5-6 PM and 6-7 PM, which is likely due to the fact that the data for these two hours come from different days in the simulation. That is, these two time periods are actually 23 hours apart, not one hour apart within the simulation. Minor variations are expected between days, especially when only a limited number of hours can be run.

It is logical that the arterial time-of-day distribution is more peaked than the freeway distribution. Arterials are used more often near the ends and the origins, at least, tend to occur during business hours.

## **Critical Corridors**

The microsimulation is able to identify critical highway corridors for each commodity or group of commodities. Here are the critical corridors based on truck volumes over 24 hours.

### **MV Parts**

- I-75 from Detroit to I-80/90 in northern OH and to I-75 S of Toledo
- I-75 Just north of Dayton
- I-275 in Cincinnati to I-75 in northern Kentucky, between Covington and I-71

### **Plastics**

- I-94 from central Chicago to I-90 through Gary
- I-75 from Southern MI to I-80/90 in northern Ohio
- I-75 and I-275 in northern Kentucky

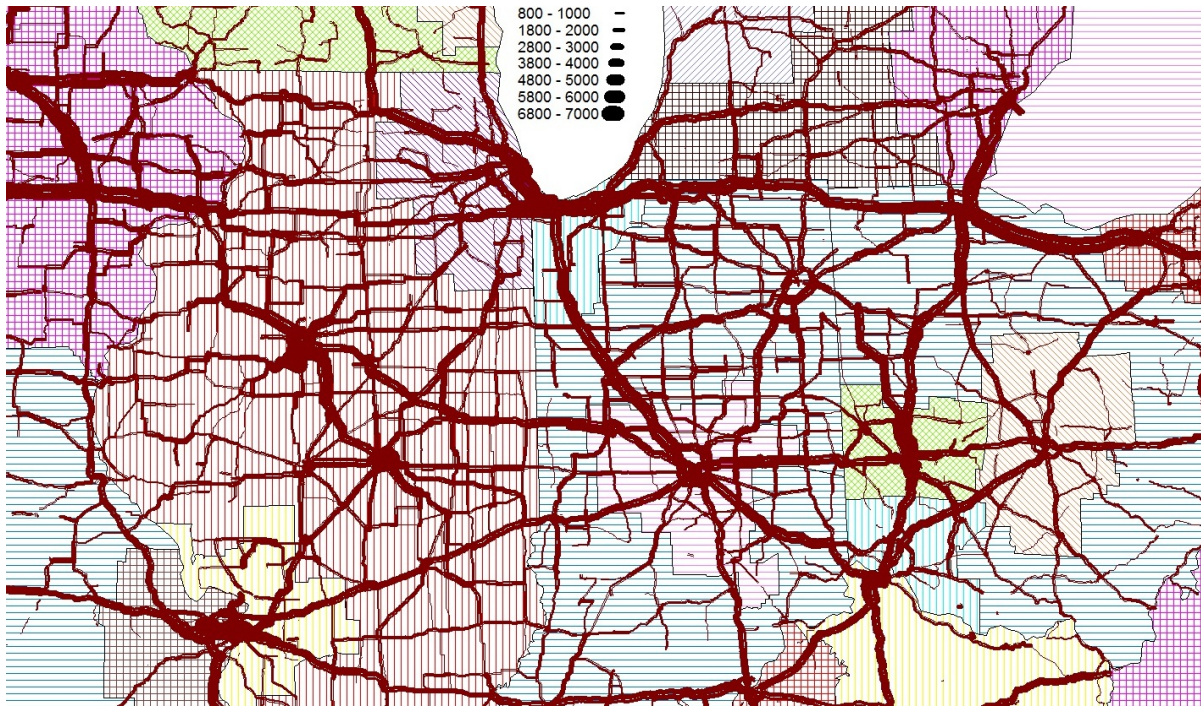
### **Dairy**

- None

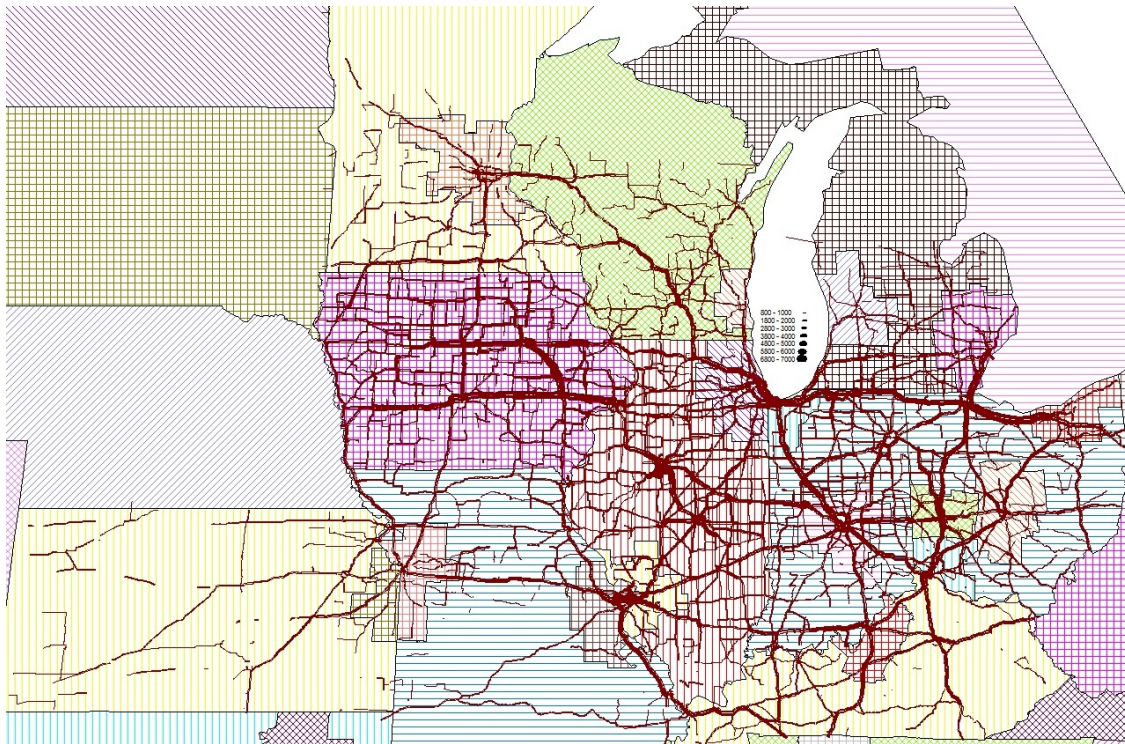
### **Crops**

- I-80 both directions in eastern Iowa
- I-380 between Cedar Rapids and I-80
- US 20 in central Iowa
- Arterial Roads in several states near processing facilities
- I-75 north of Dayton
- I-74 north of Indianapolis
- I-74 and I-155 near Peoria



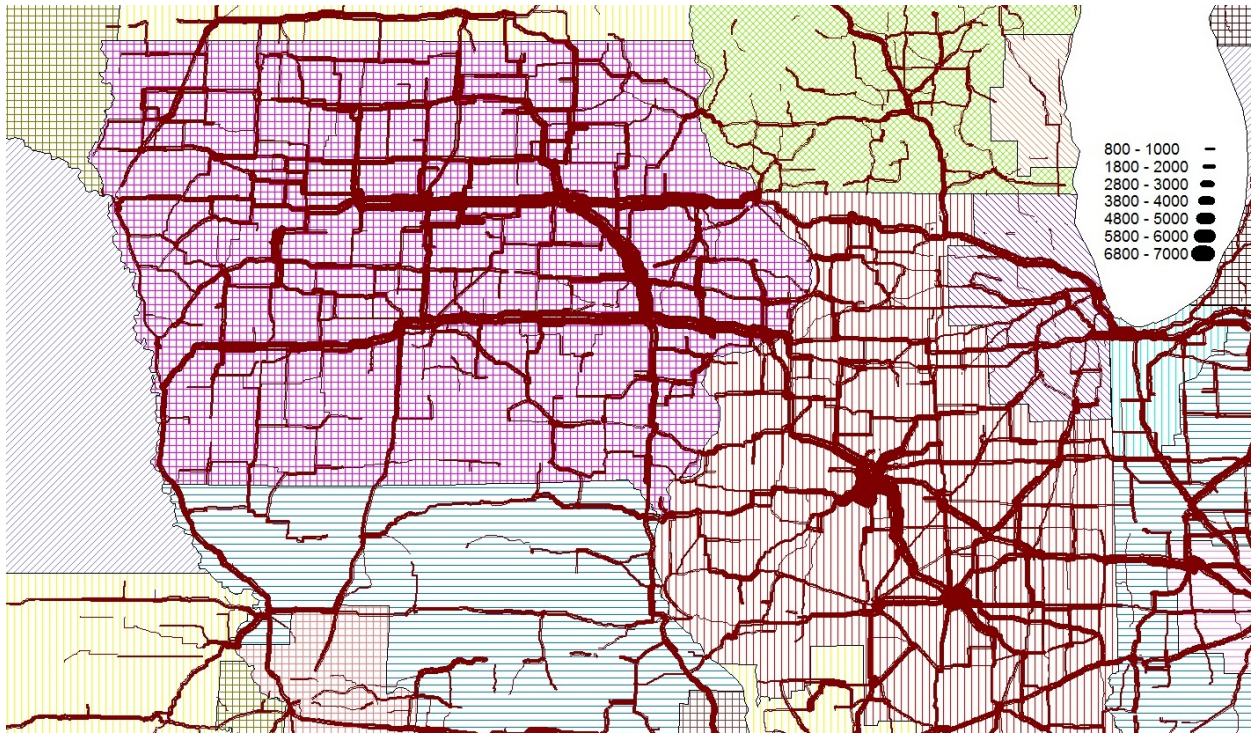


**Figure 4.** Daily Truck Volumes, All Commodities, Central MAFC Region, Only Links with 200 or More Trucks

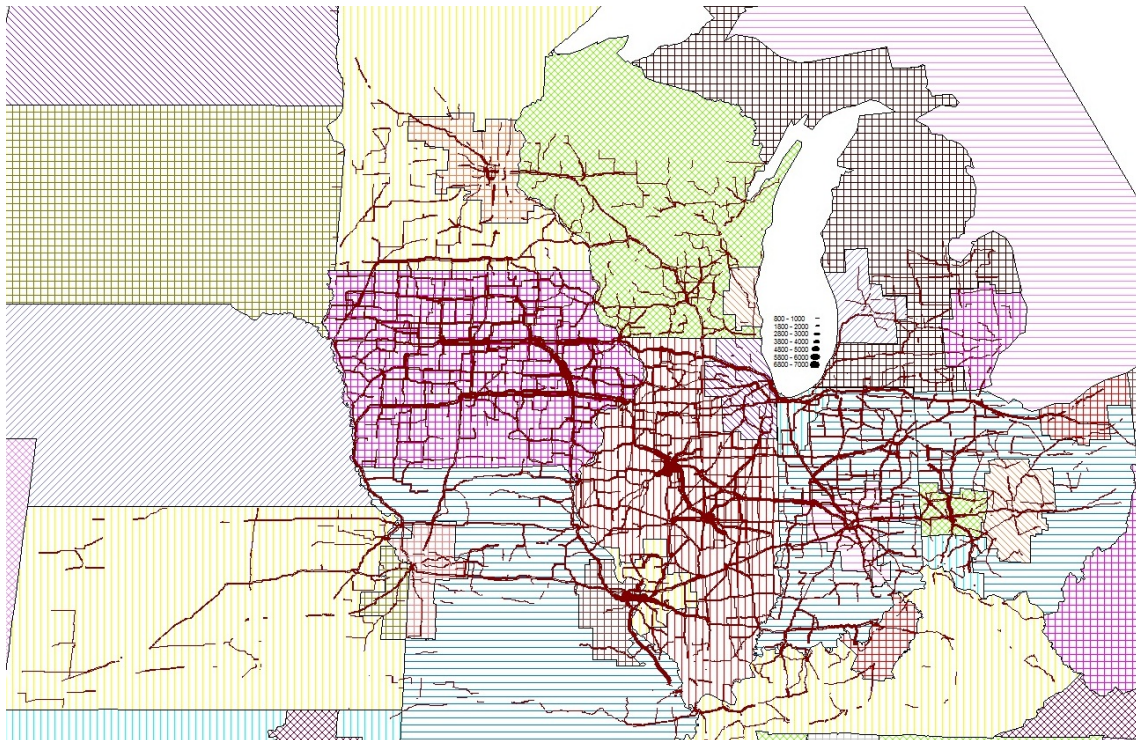


**Figure 5.** Daily Truck Volumes, All Commodities, Majority of MAFC Region, Only Links with 200 or More Trucks



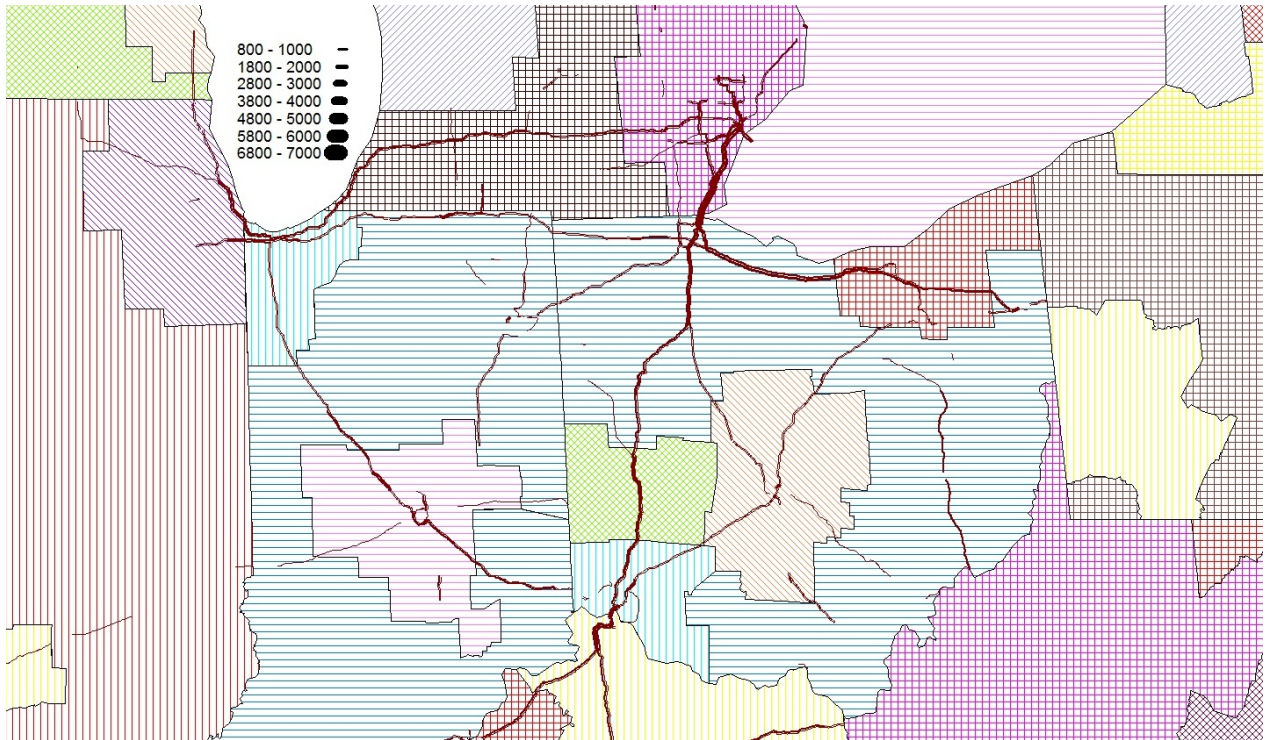


**Figure 6.** Daily Truck Volumes, Two Crops, Corn Belt, Only Links with 200 or More Trucks

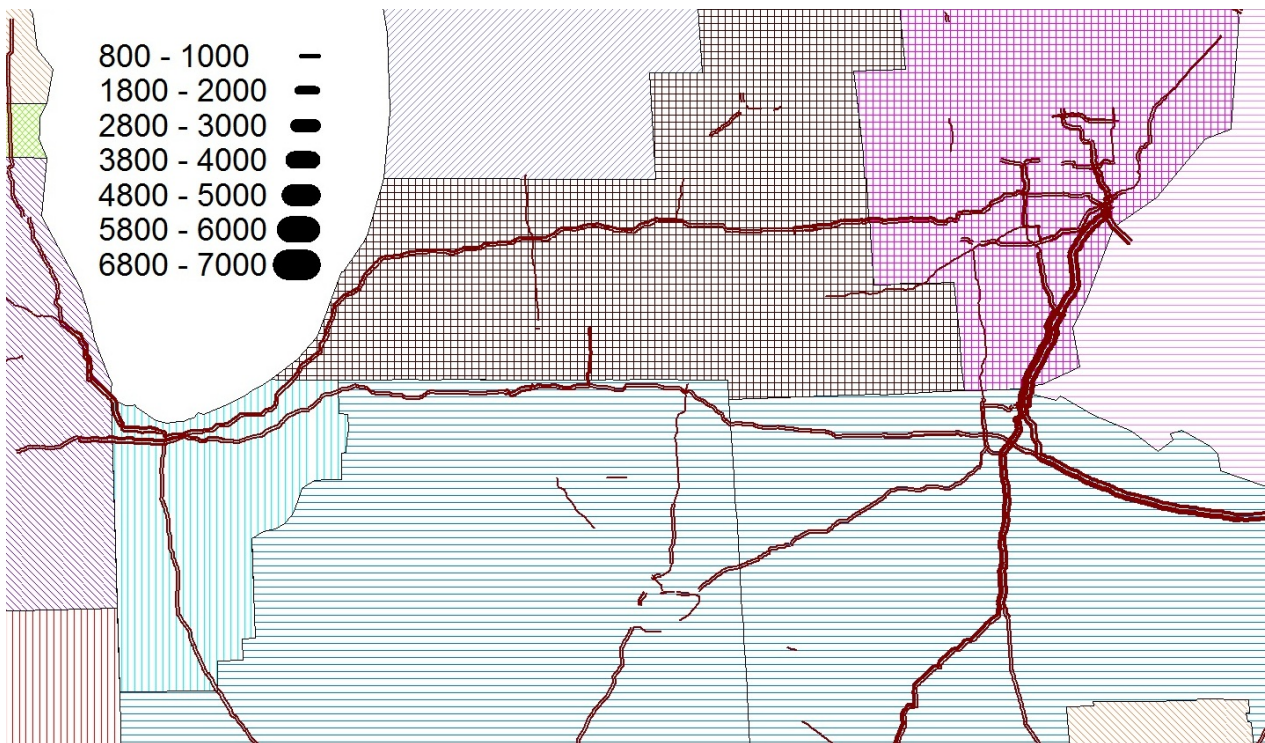


**Figure 7.** Daily Truck Volumes, Crops, Majority of MAFC Region, Only Links with 200 or More Trucks



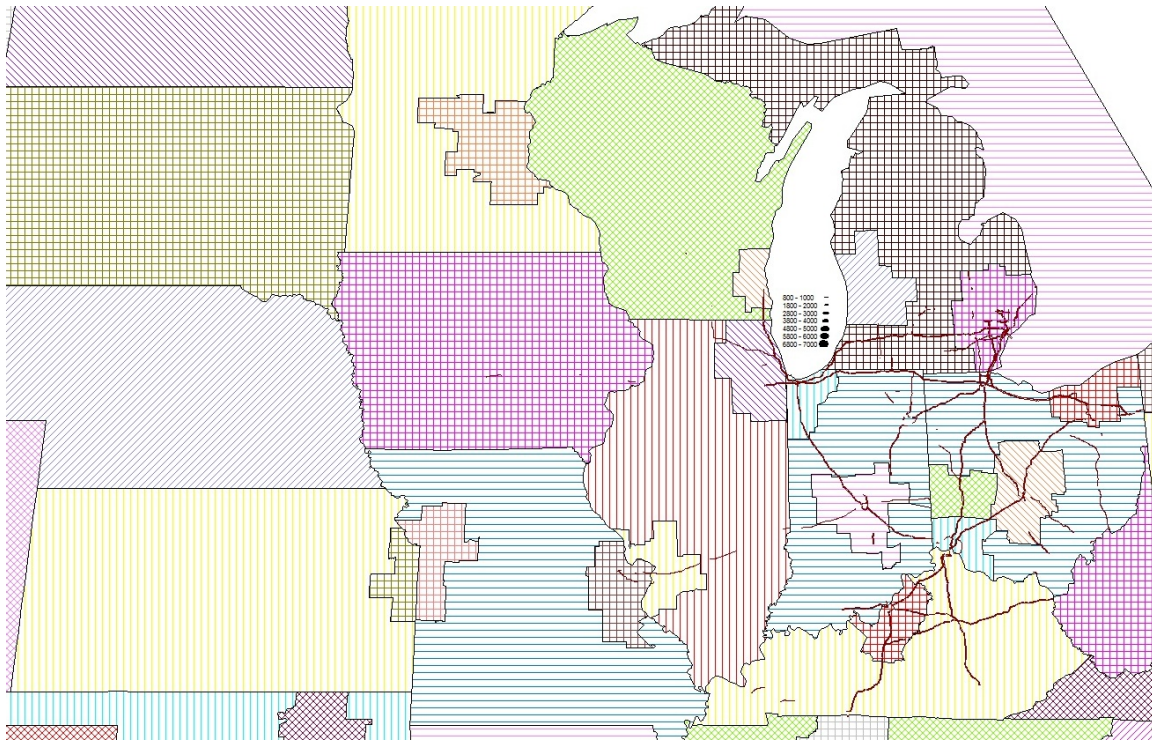


**Figure 8.** Daily Truck Volumes, Motor Vehicle Parts, Central MAFC Region, Only Links with 200 or More Trucks

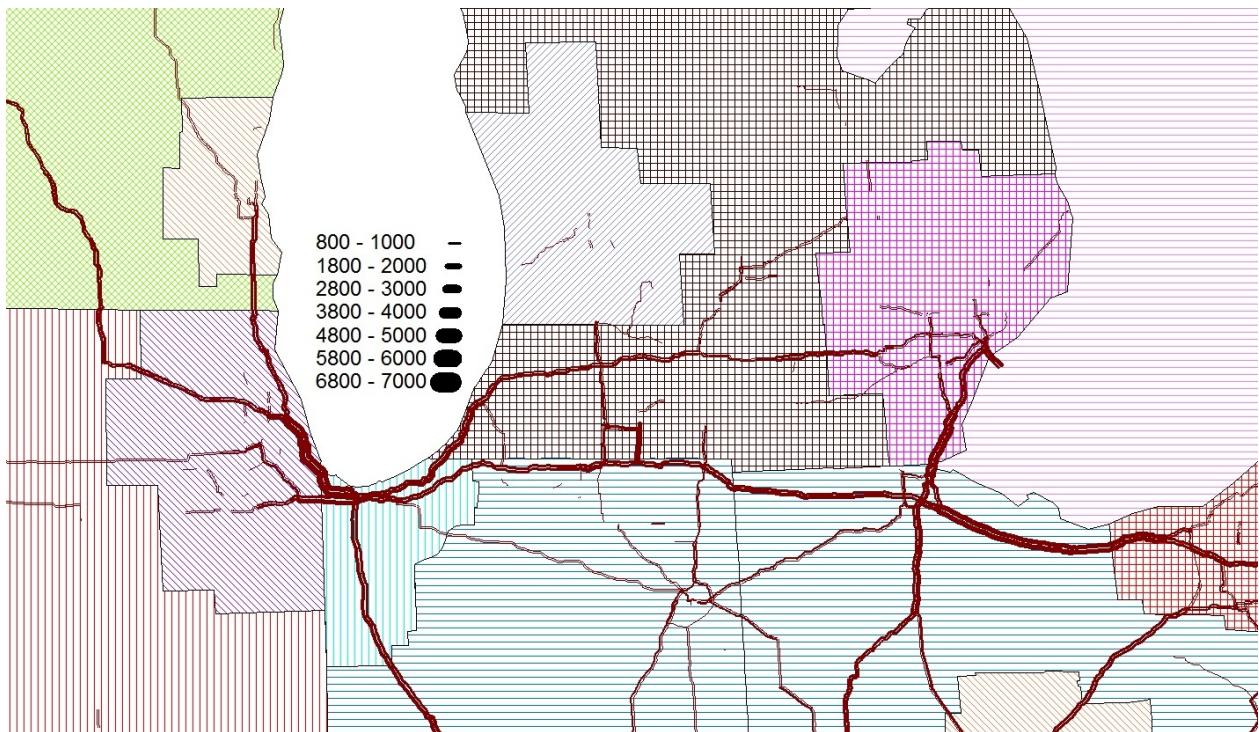


**Figure 9.** Daily Truck Volumes, Motor Vehicle Parts, Southern Michigan, Northwest Ohio and Northern Indiana, Only Links with 200 or More Trucks



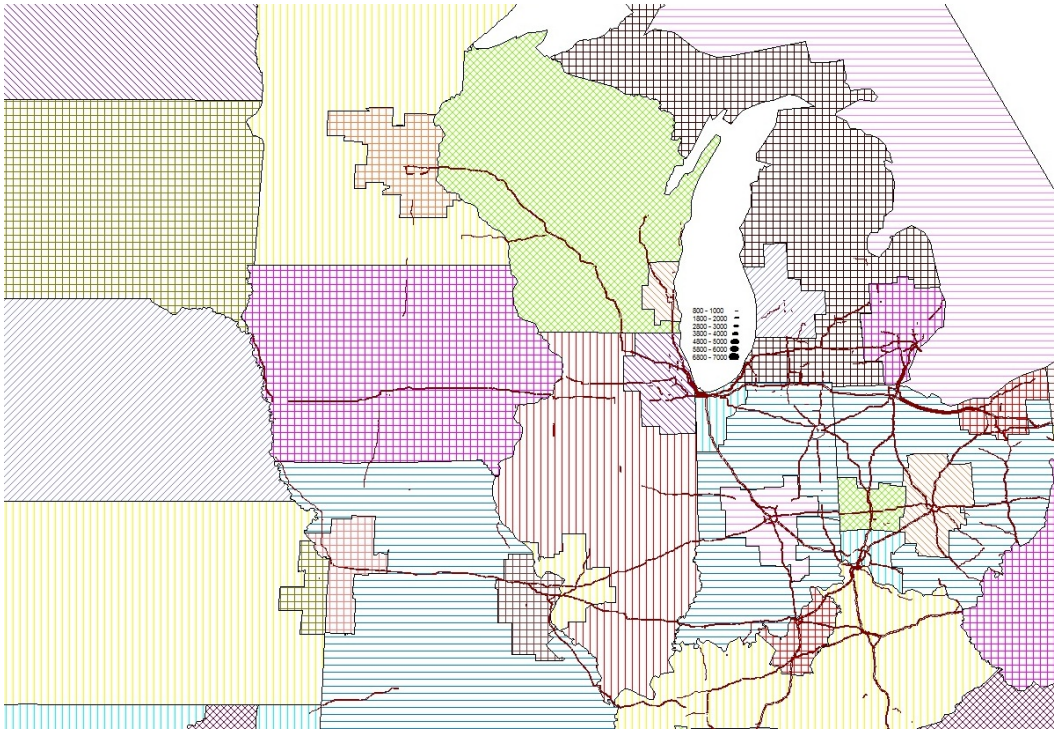


**Figure 10.** Daily Truck Volumes, Motor Vehicle Parts, Majority of MAFC Region, Only Links with 200 or More Trucks

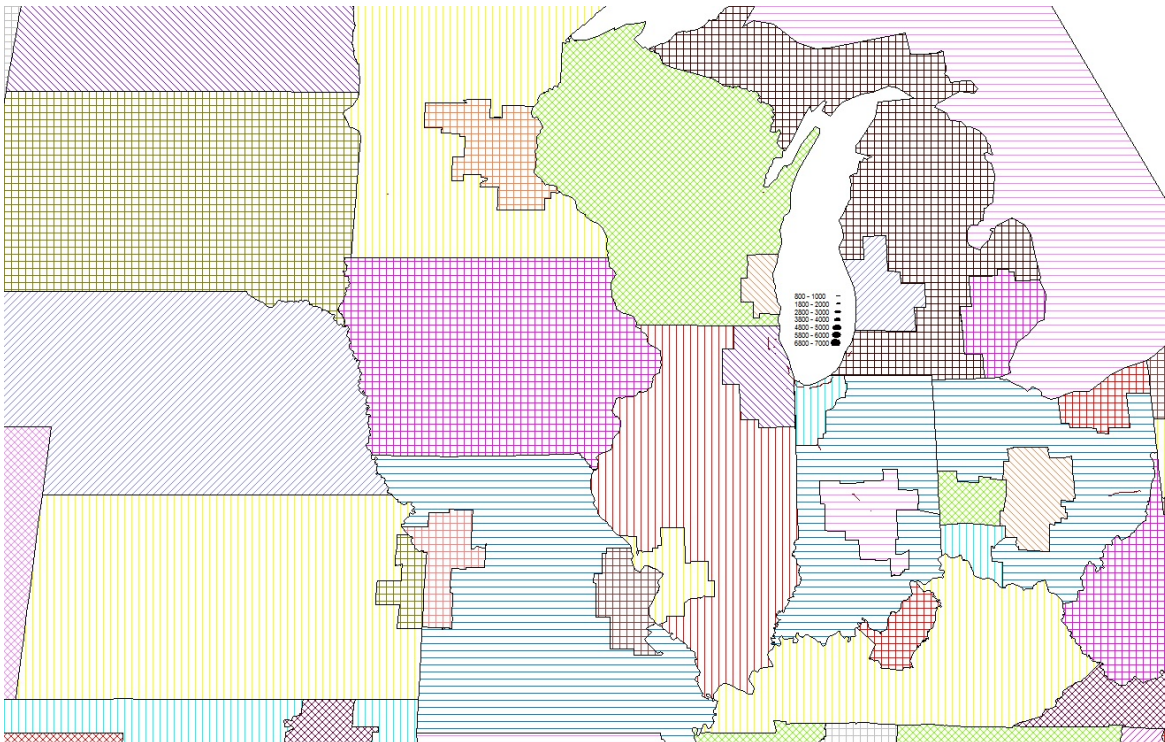


**Figure 11.** Daily Truck Volumes, Plastics, Southern Michigan, Northern Ohio and Indiana and Northeast Illinois, Only Links with 200 or More Trucks

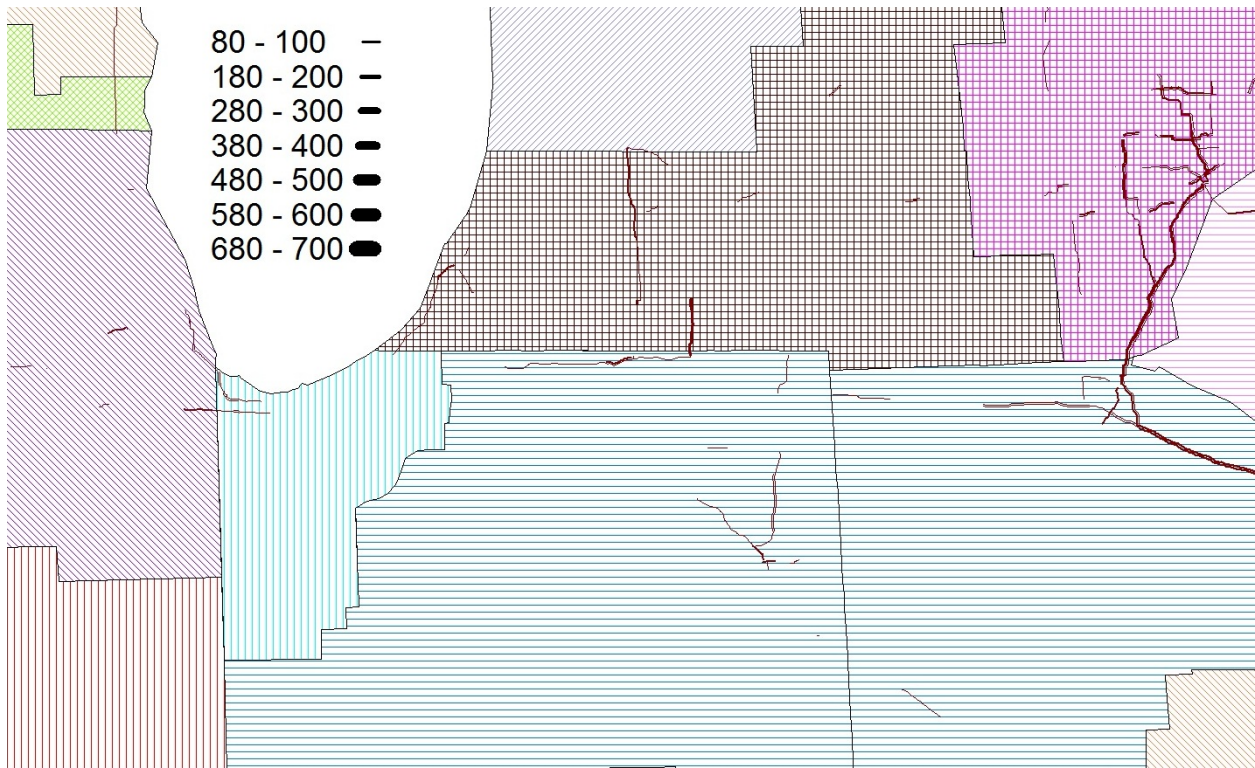




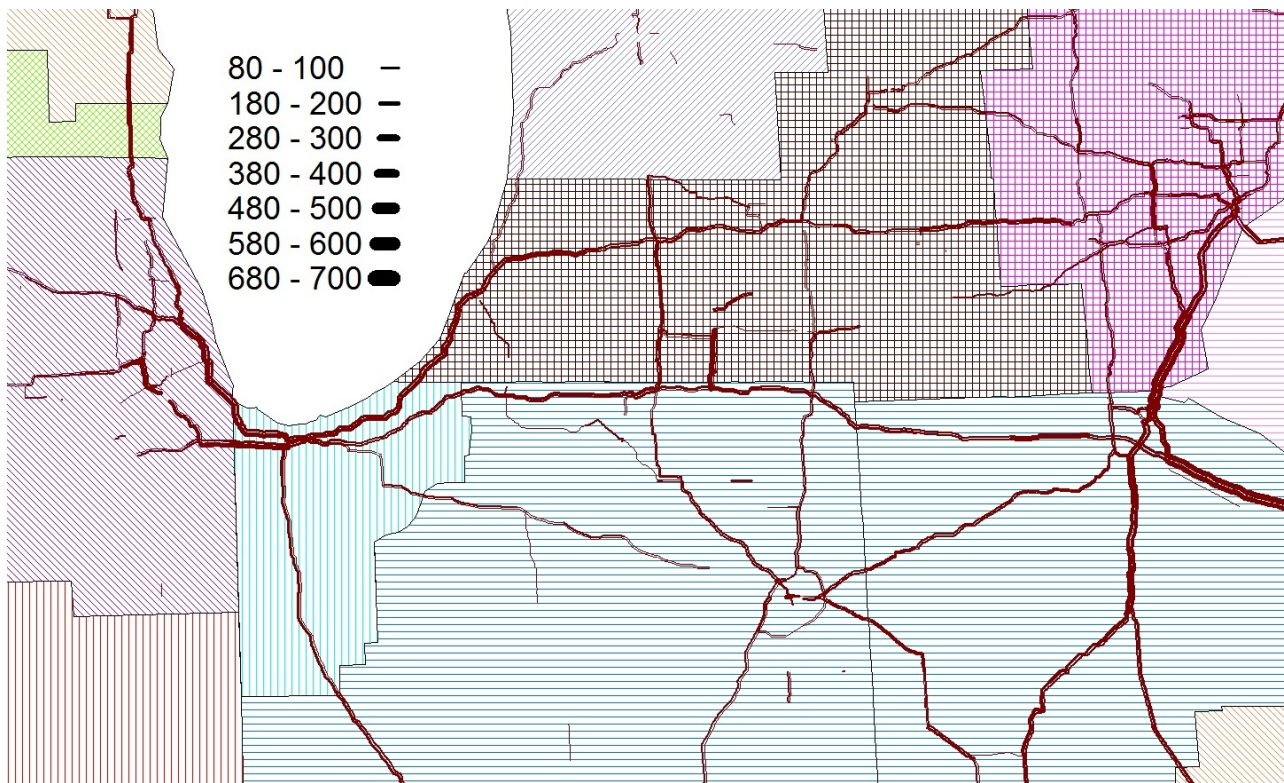
**Figure 12.** Daily Truck Volumes, Plastics, Majority of MAFC Region, Only Links with 200 or More Trucks



**Figure 13.** Daily Truck Volumes, Dairy, Majority of MAFC Region, Only Links with 200 or More Trucks

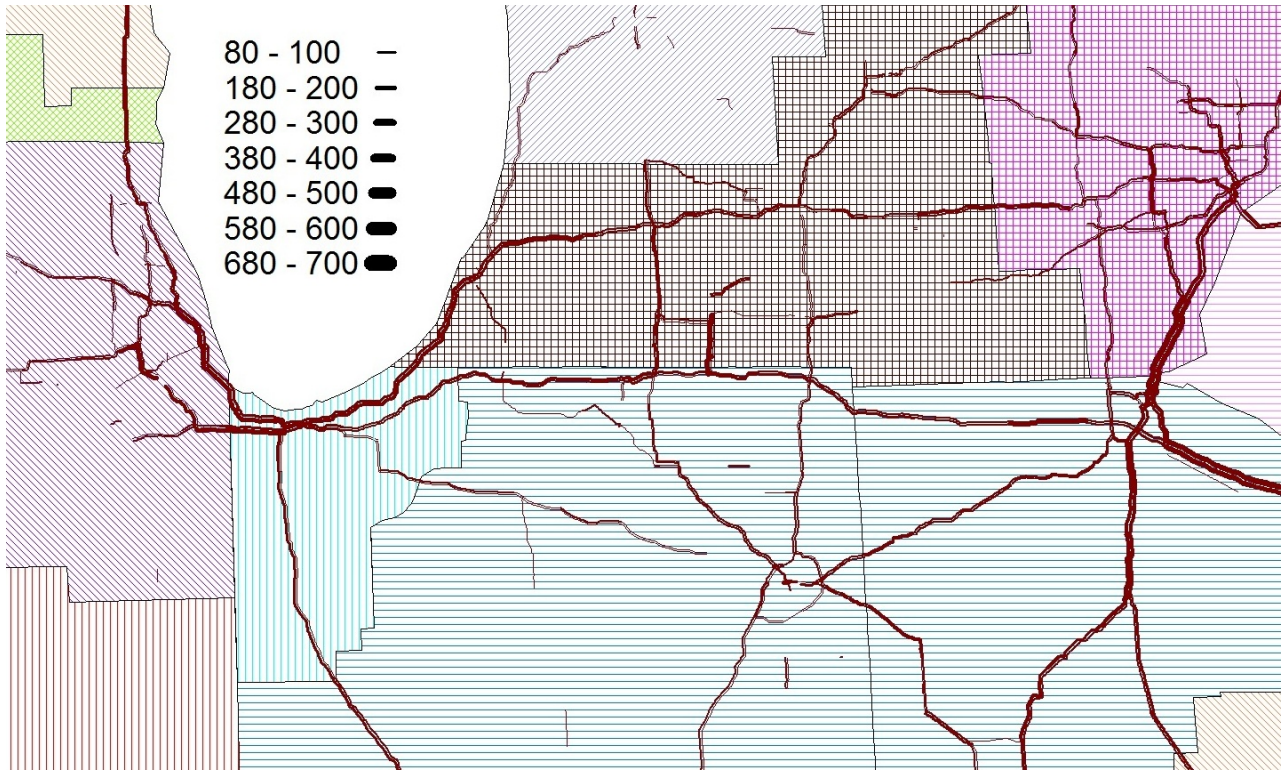


**Figure 14.** Hourly Truck Volumes at 6 to 7 AM, Three Industrial Commodities, Southern Lake Michigan Area, Only Links with 20 or More Trucks

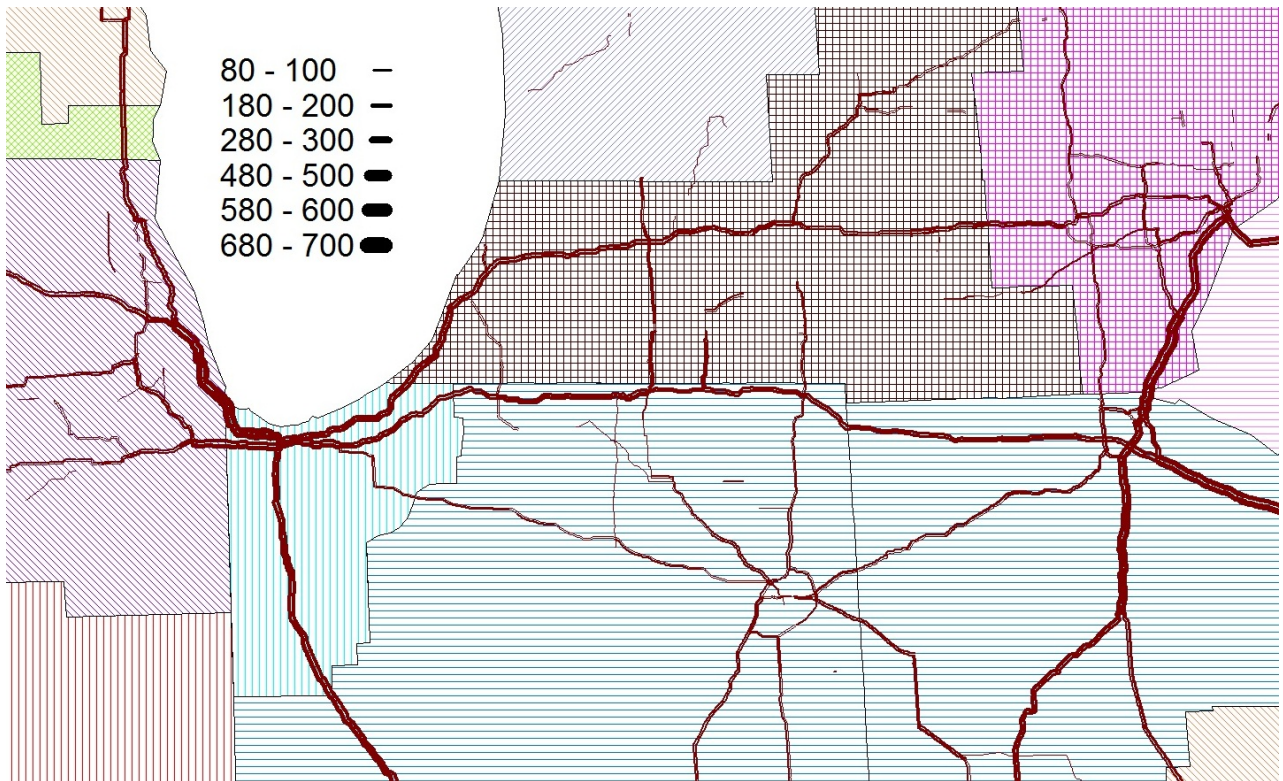


**Figure 15.** Hourly Truck Volumes at 9 to 10 AM, Three Industrial Commodities, Southern Lake Michigan Area, Only Links with 20 or More Trucks



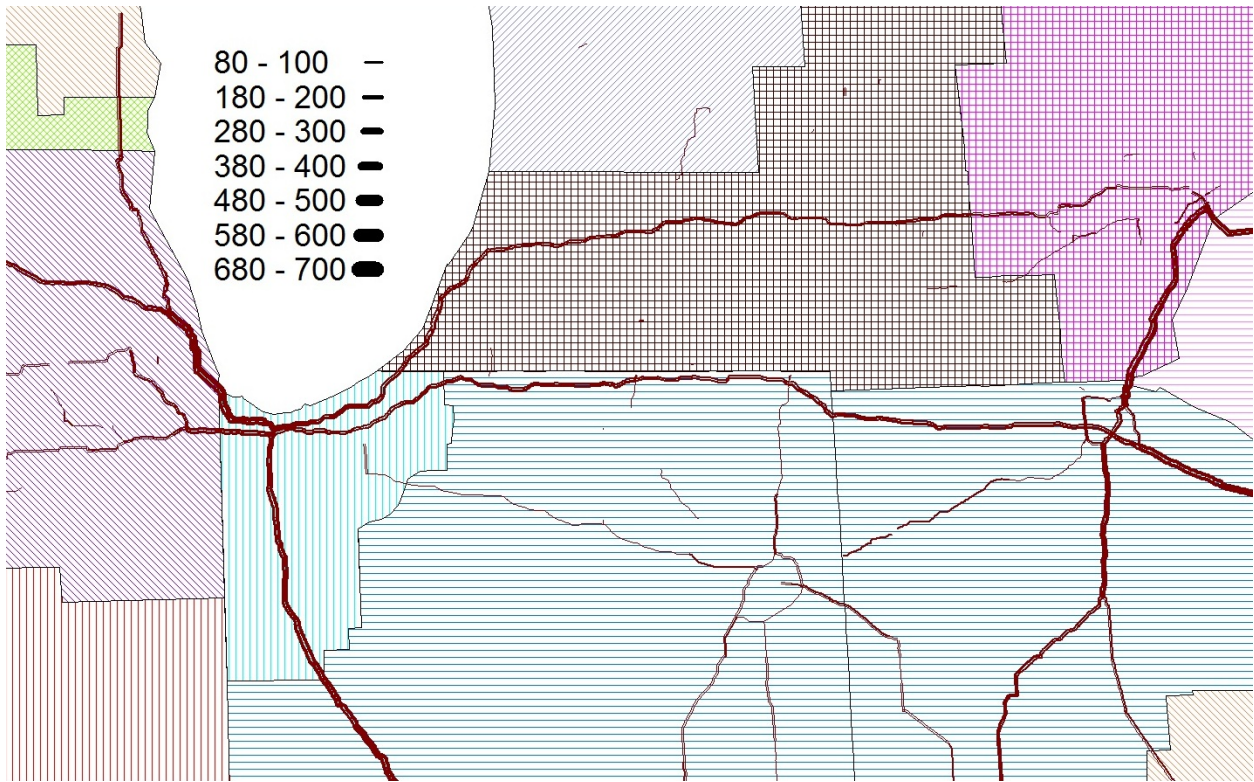


**Figure 16.** Hourly Truck Volumes at 12 Noon to 1 PM, Three Industrial Commodities, Southern Lake Michigan Area, Only Links with 20 or More Trucks

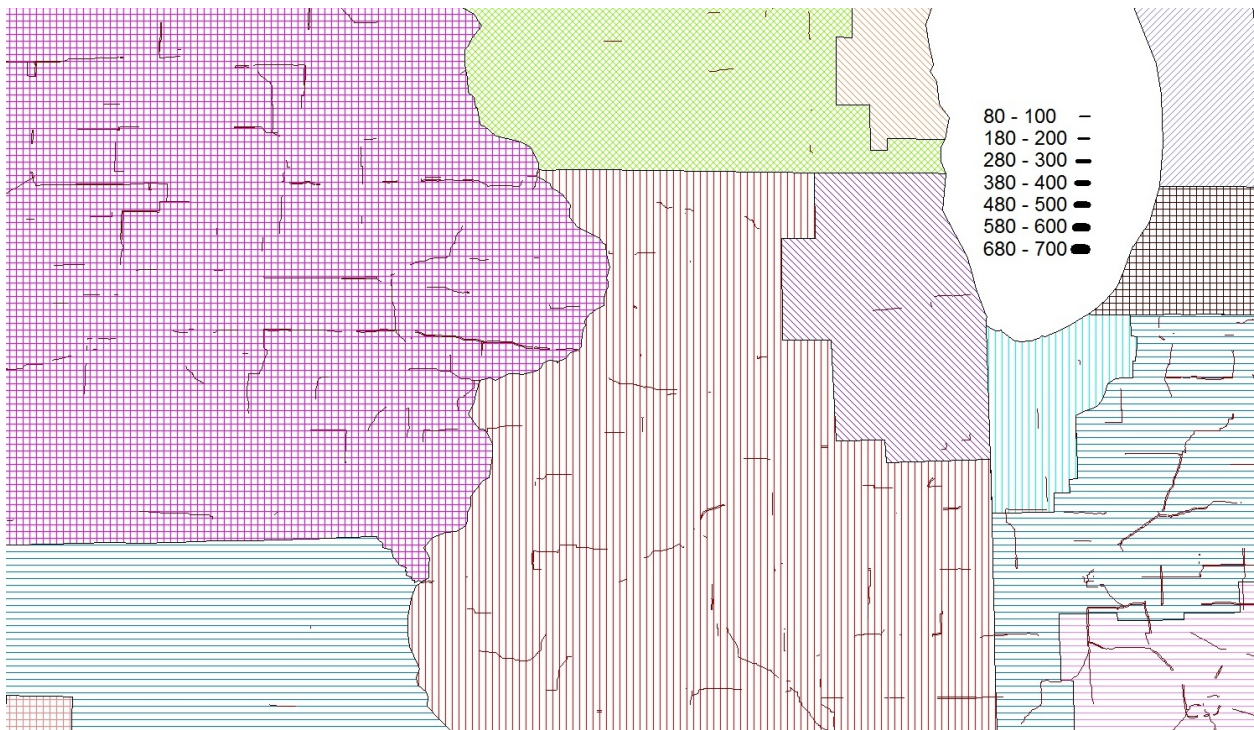


**Figure 17.** Hourly Truck Volumes at 3 to 4 PM, Three Industrial Commodities, Southern Lake Michigan Area, Only Links with 20 or More Trucks



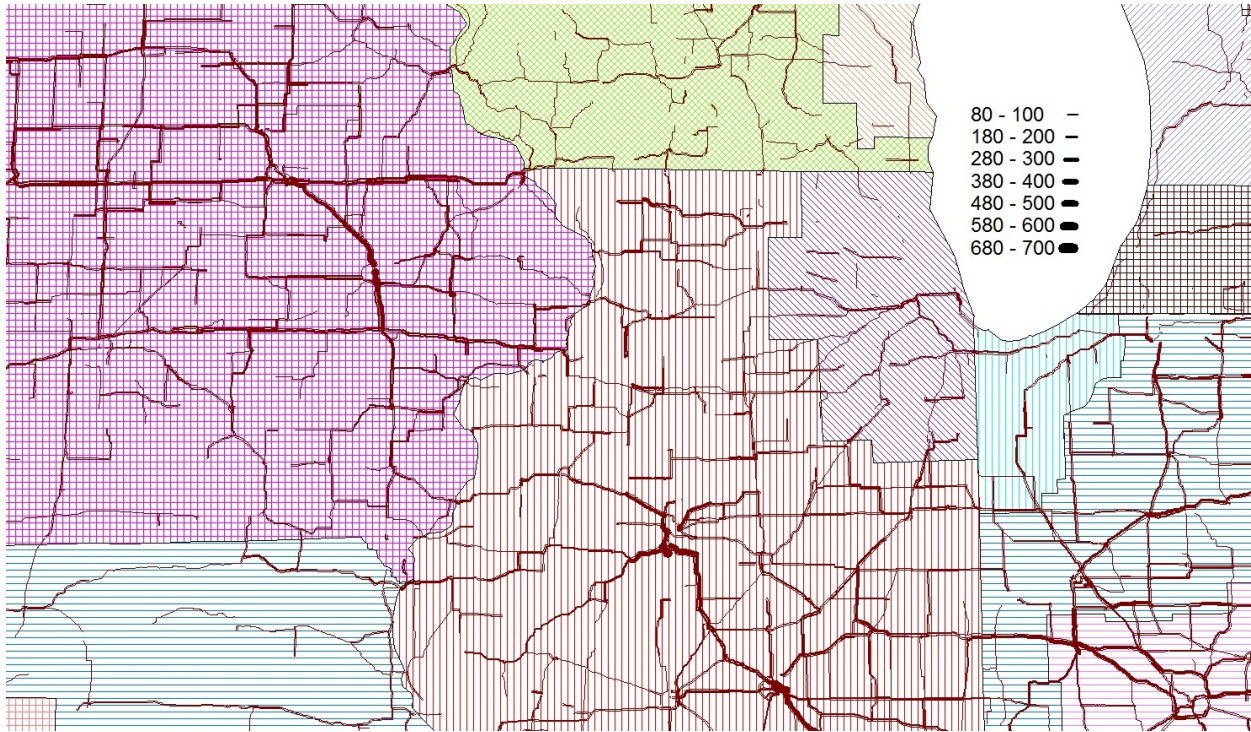


**Figure 18.** Hourly Truck Volumes at 5 to 6 PM, Three Industrial Commodities, Southern Lake Michigan Area, Only Links with 20 or More Trucks

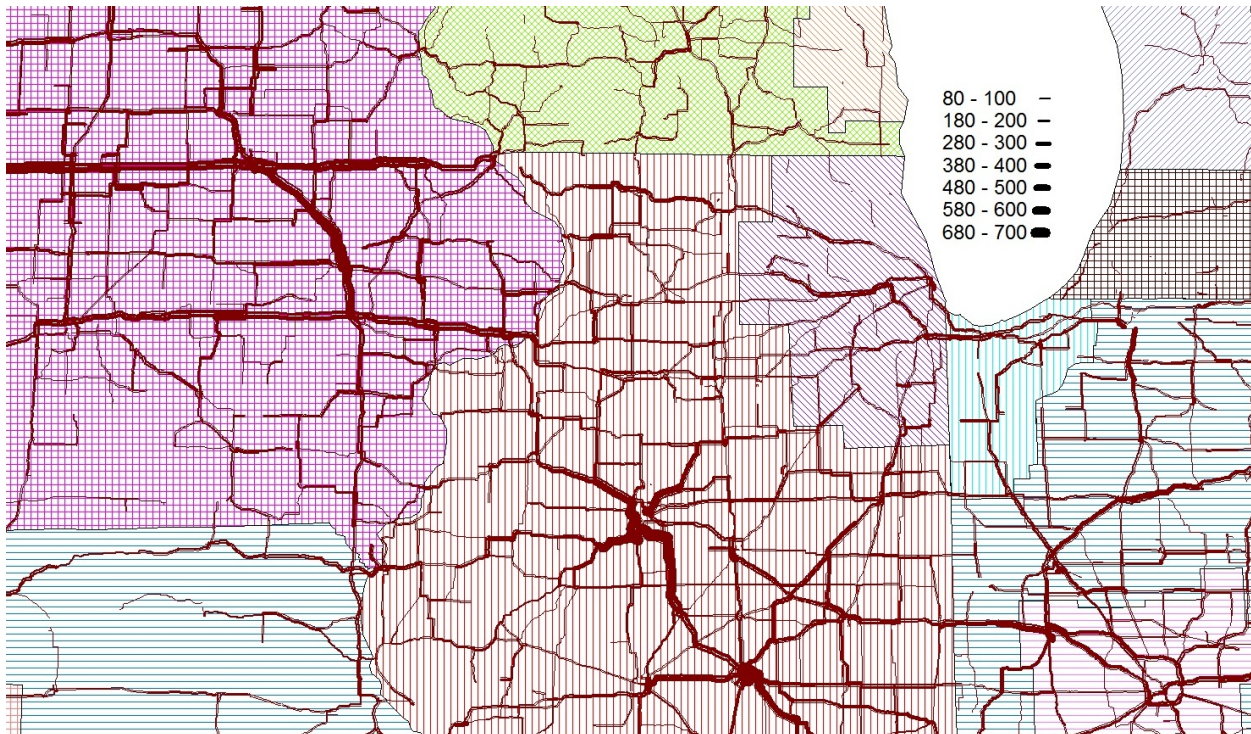


**Figure 19.** Hourly Truck Volumes at 6 to 7 AM, Two Crops, Corn Belt, Only Links with 20 or More Trucks



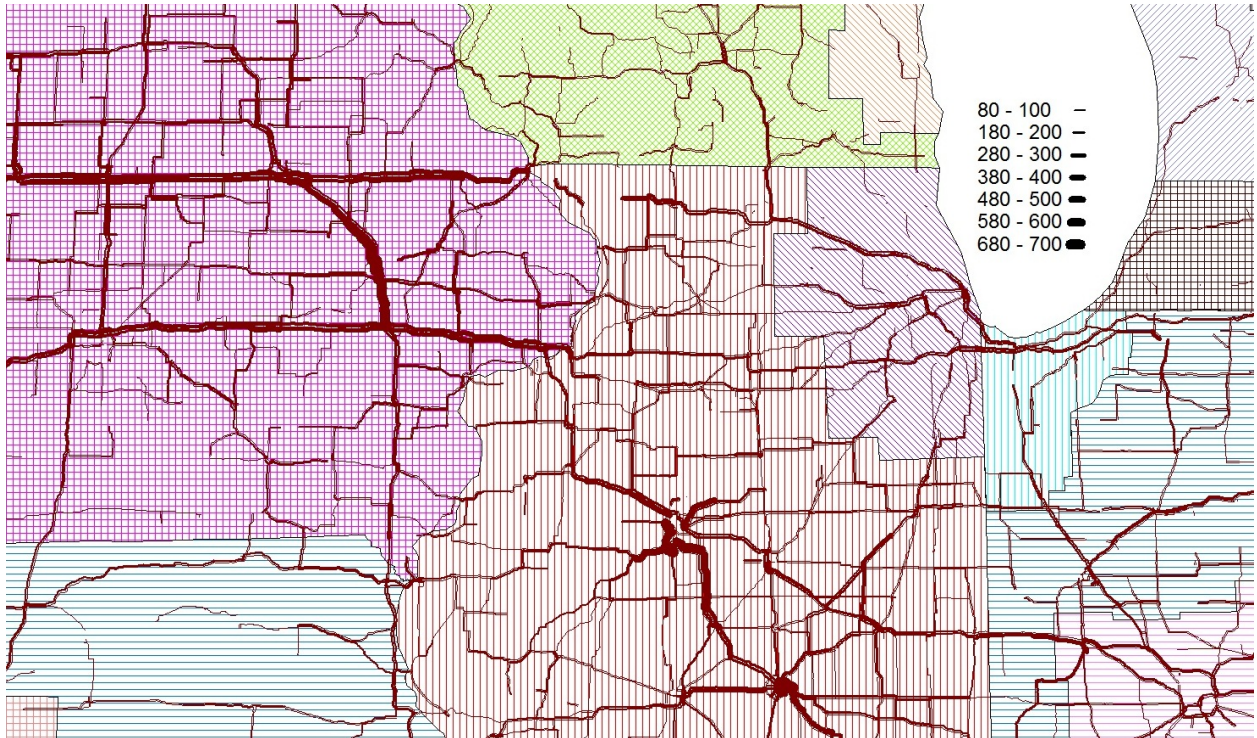


**Figure 20.** Hourly Truck Volumes at 9 to 10 AM, Two Crops, Corn Belt, Only Links with 20 or More Trucks

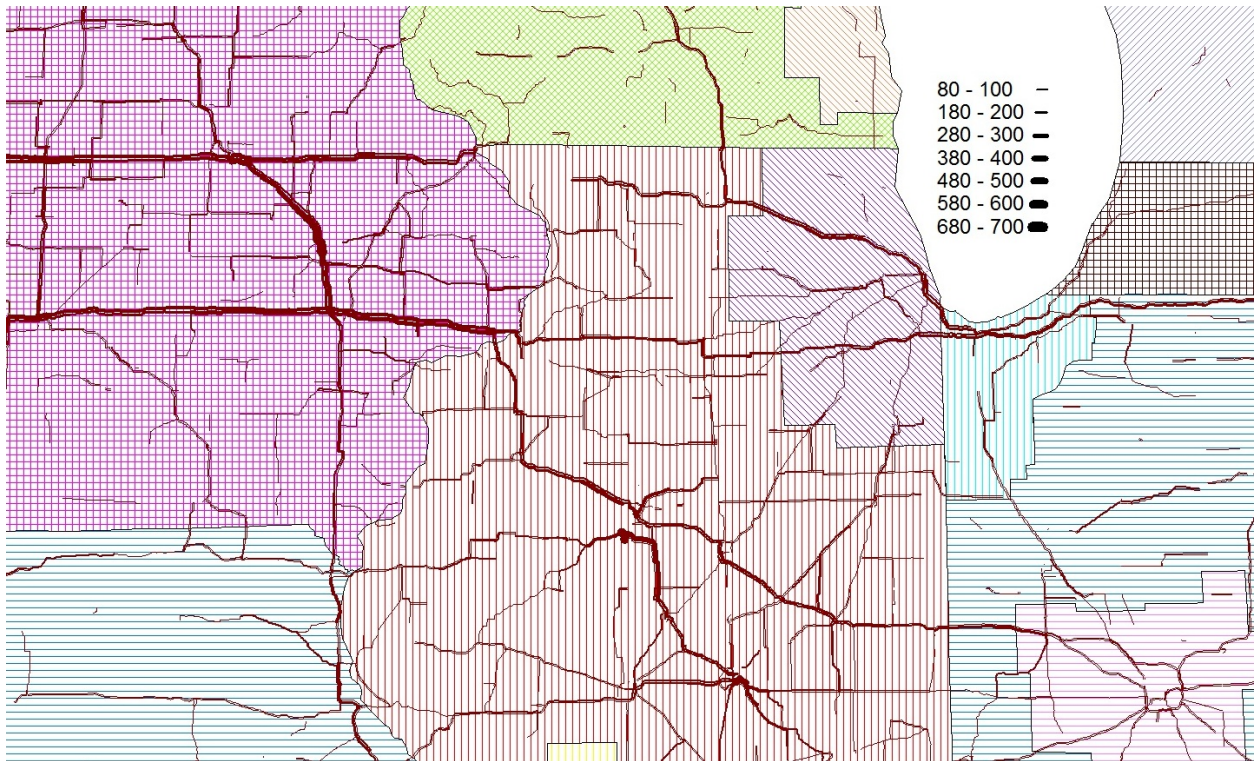


**Figure 21.** Hourly Truck Volumes at Noon to 1 PM, Two Crops, Corn Belt, Only Links with 20 or More Trucks

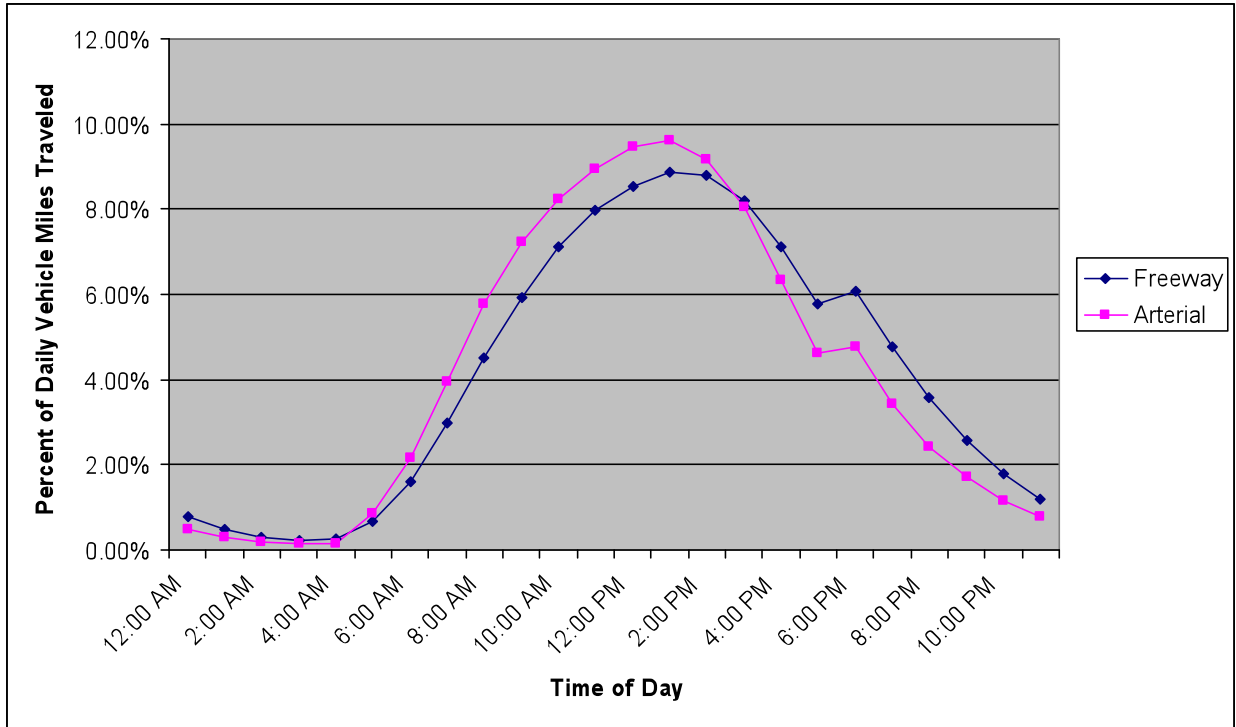




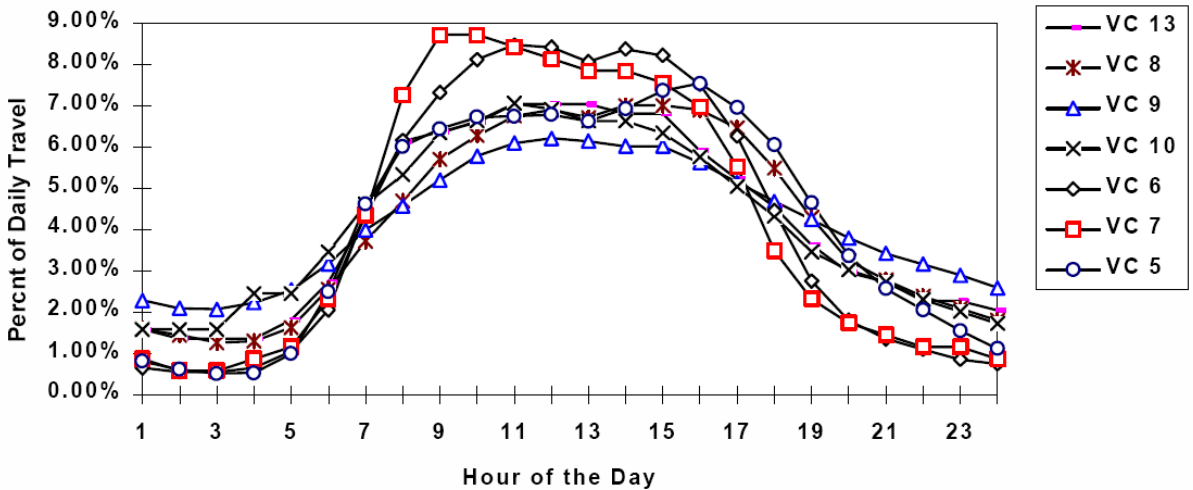
**Figure 22.** Hourly Truck Volumes at 3 to 4 PM, Two Crops, Corn Belt, Only Links with 20 or More Trucks



**Figure 23.** Hourly Truck Volumes at 5 to 6 PM, Two Crops, Corn Belt, Only Links with 20 or More Trucks



**Figure 24.** Time of Day Distributions for Two Highway Functional Classes for All Trucks Carrying Three Industrial Commodities



**Figure 25.** Time of Day Distributions for Vehicle Classes at Sites in 19 US States from a 1997 Study<sup>1</sup>

A longer paper that outlines both the logic of the micro-simulation and a significant expansion of the model can be found at <http://www.wistrans.org/cfire/research/projects/mvfc-10/>.

<sup>1</sup> Mark Hallenbeck, et al., “Vehicle Volume Distributions by Classification”, Chaparral Systems Corporation, July 1997.