FREIGHT FLOWS

OF INDIANA

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Preface

Why examine freight flows? It is a reasonable question to ask. Freight is not something that immediately comes to mind when most people think of transportation. It is not like congestion, or potholes, or any of those topics that people discuss around the water fountain soon after arriving at work. It is far more important than most of these topics and to paraphrase a scholar from several decades ago, people don't talk about freight transport because in most cases it works.

You may take any size area you wish from the smallest town to the largest country. These will be economically viable if the value of the products or services they sell in the aggregate to the areas beyond their borders exceed the value of the products they buy from these same areas. It is the exporting of goods that brings new income to the state. Selling goods only to ourselves circulates wealth, and perhaps some regions or counties may benefit from this, but it brings little new wealth to the state in the aggregate.

For the most part we will not concern ourselves with services since this report concerns itself primarily with freight. But one should not dismiss these flows since they often do involve selling something of value to those outside of Indiana. Perhaps one of the best examples of this is the university education sold to a student (or his or her parents) from outside Indiana or in some cases outside the United States. The tuition, lodging, and fees paid by these students represent contributions to the economic base of Indiana and the country. Consulting firms, accounting firms, law firms, and many others often sell their services beyond the borders of the state and are very important economically to the state. Nevertheless, we will focus our concern here on the movement of goods or freight transport.

We will examine freight flows in order to determine what is moving within the state of Indiana and where it is moving. In some cases we want to know this to make sure that the routes being used for these movements are well-maintained. In other cases we want to make sure that many of these same routes are kept in working order so that our manufacturers can get the raw materials that they need to carry out their production processes, which are so important to the state economy.

The routes of primary concern here are made up of rail lines or highway segments, and these receive the lion's share of our attention. We are aware of the use of water modes and the existence of air freight flows, but the former become important when the freight arrives at Indiana ports on the northern (Lake Michigan) and southern (Ohio River) borders, and the latter become important when the air freight destined for Indiana arrives at an airport within or near the state. This view of these modes is not a statement that we view them as unimportant, but rather the recognition that the water routes are maintained by others and the movement of aircraft, freight or otherwise, is not influenced by the state. From the lake and river ports or airports these flows become highway freight movements in most cases and at least the latter are treated as such here. The same is also true in the reverse case when goods are leaving Indiana. Air freight shipments are treated as highway moves until they reach the point when they are moved by an alternate mode.

The freight that we will examine here includes all of the freight that has an origin and a destination within the United States. Exports are generally treated as goods shipped to the point of export; we do not know their final destination outside the country. Imports are also treated as goods arriving at the point where they enter the country in most cases. Once again for these flows we do not know the foreign point of origin. The foreign origins and destinations of goods are discussed here, but they are not a subject of analysis or modeling.

The approach that is taken here in analyzing freight flows of Indiana is a typical 4-step transport planning process: traffic generation, traffic distribution, modal split and route assignment. We begin with a discussion of the areas used (Chapter 1) followed by a discussion of the rail and highway networks (Chapter 2). The commodities examined and their importance nationally and to the state of Indiana as well as the source of these data appear next (Chapter 3).

It is not always apparent why we develop models that enable us to predict data that we already know. The reason for this is that we want to use the models to predict future flows. The primary assumption made is that future flows will be predictable based on the same relationships observed in the first analysis. For example, let us say that each employee in an industry is found to produce 2,000 tons of a commodity that is shipped according to current data. At some point in the future we want to know how many tons of a commodity will be produced in an area that has 100 employees in that industry. The answer would be 200,000 tons. We would use this as our prediction of future flow from that area for that particular industry. However, for many industries we find there are changes in the level of productivity anticipated. If we assume that workers in 2015 will become more productive by a factor of 2 per cent, then each worker will produce 2040 tons of the commodity, and the resulting level of future flow from our area would be 204,000 tons. We will use productivity changes and expected growth factors to estimate flows produced. The methods used for flows produced as well the manner in which flows attracted are handled will be discussed in Chapter 4.

Distributing the flows between origins and destinations will be discussed in Chapter 5. A fully-constrained gravity model and a production-constrained gravity model were evaluated as part of the project. The former model was used in the earlier 1997 study and it was thought that a more realistic replication of flows could be achieved with the production-attraction constrained model. This will be discussed in more detail in Chapter 5.

Modal split analysis attempts to estimate the amount of the estimated flows that will be shipped by different modes moving between an origin and destination. In general it is believed that this is a function of the costs of the different modes, but the type of detailed cost data we would need for this approach is generally not available. Therefore, we will use historical patterns in part. Such an approach would look at the length of the shipment and look at the modes that have been used historically for assigning such traffic. This was the approach used in the previous (1997) study.

Once the modes are known we can proceed with assigning the current and future flows to the modal networks. The principal modal networks of concern here are those of the highway and railroad and the methods used for assignment are discussed in Chapter 7.

Forecasts of future flows are discussed in Chapter 8. For the most part these forecasts are based on procedures derived elsewhere by and for the State.

Chapter 9 discusses implementation of the projections and forecasts derived here. Aside from its value to the state in identifying priority corridors, we know of numerous metropolitan planning organizations that have an interest in the findings derived and the modeling used here. It is for this reason that much of the production and attraction data are included in appendices of this report. This chapter provides a guide as to how different agencies can use these and other data found here.

TECHNICAL *Summary*

Freight Flows of Indiana

Introduction

The transportation of freight is a subject of extreme importance to a state such as Indiana. It is the primary activity that keeps the state from being a subsistence economy in a broader economic sense. If resources were unavailable to the state due to a lack of transportation facilities then many of the goods manufactured here would be manufactured elsewhere. In addition the goods that are manufactured in Indiana would not be sold outside the state.

It is the exporting of goods beyond its border that is essentially responsible for the viability of the state's economy. Such commercial flows to places external to the state result in new money coming into the state and this represents a net income contribution to the state's economy assuming that it does not purchase more from other states than it sells.

As a result of the above the state has a sincere interest in the commodities that flow to, from and through it. There is also a genuine interest in how this is occurring. What modes are used? What routes are used? How much is being moved? What is its value? What are the trends in these flows?

There is not a great deal that the state can do to influence these flows. It does have some policy instruments at its command that can encourage or discourage expansion of industries within its borders — tax policies are a principle technique used in this context. But the state can also influence flows through different employment programs, education, grants, loans, and similar activities. At the same time there are various activities that can discourage economic activities that are here or were planning to move here. Obviously mishandling any of the above policy instruments could do this. However, the primary concern here is with transport facilities.

If the state decides not to make certain investments in its transport infrastructure this will encourage firms to seek locations elsewhere, or discourage firms from locating here. So it is important to make sure that such infrastructure investments are made and to know where these are the most important.

This study seeks to answer the questions raised and to give the state some idea of where these flows will be in the future and what their magnitude might be. As a secondary objective the study seeks to contribute to the modification of the state's travel demand model, which includes other types of travel within the state.

The Approach and Findings

The approach taken here for answering these questions is analogous to an urban transportation planning process. That is, we have compiled information on known freight flows as gathered by the U.S. Census and published in their *Commodity Flow Survey (CFS)* in 1997 and 2002. We have used data from other sources, notably *County Business Patterns*, to develop models of freight traffic generation — both the production of shipments and the attraction of shipments for 41 different commodity groups included in the *CFS*. The study has also examined freight traffic flowing between all the states of the United States and as a result it has examined flows across the state that have neither an origin nor a destination here.

The traffic generation models for production and attraction were evaluated by comparing the estimates from these using updated data to "predict" known flows recently published from the 2002 *CFS*. For the most part these provided good estimates.

Once the traffic generation models were developed the study applied different traffic distribution models to the flows generated. Different approaches were used to evaluate the flows generated since the actual flows were not available for comparison. The model selected as the freight traffic distribution model was the fully-constrained gravity model.

The distributed flows were then assigned to different transport modes. This study used the following modes for this purpose: highway, rail, air, parcel, pipeline and water. Although the modal shares were generated for pipeline and water they have not been treated further here since the state really has little control over investments in those areas.

Assigning the traffic to vehicles was done using a commodity-specific density measure. This enables us to determine how many tons of a given type of commodity could fit into a tractor trailer or rail car.

Highway flows were assigned to the digital highway network of InDOT and rail flows were assigned to the rail network that serves the nation and more particularly the state of Indiana. The highway and rail flows were assigned using an "all or nothing" approach based on travel time minimization in the first case, and an inverse measure of traffic density in the second case.

The assignments to the highways were evaluated by comparing a sample of the flows assigned to the known flows on the network at the sample locations. The level of accuracy was very high for this type of analysis.

Following the modeling above the next objective of the study was to generate flows, distribute these, and assign them to the network for some point in the future. For this purpose two target years were used: 2015 and 2030.

Employment by sector was the primary type of variable used in the traffic generation models. These employment variables were forecasted for 2015 and 2030 by making certain assumptions about the growth in employment and changes in the productivity of employees in different sectors. Both the employment and productivity multipliers were supplied by InDOT.

The models developed earlier in the study were then rerun, but they now included estimates of 2015 and 2030 employment and as a result they generated flows for those future time periods. The same flow models were used with the same parameters and the same assignment models were used to assign the flows to the networks.

There is obviously no way to evaluate how good the future flow estimates are until 2015 and 2030 data are available.

Implementation

The primary users of the output of this study are staff of InDOT and its consultants, and the MPOs of the state of Indiana. The final chapter of this report discusses implementation and in particular explains how to use the results of the study.

This study used a geographic information system named TransCAD to execute many of the steps undertaken here. So the implementation chapter discusses some basic transport questions that can be addressed with the data supplied here and on CD as part of the project. Some of these would involve simply using common spreadsheets with some of the data here and such uses are rather straight forward. Of a little more difficulty are two procedures that the state and its MPOs may find useful.

The first of these is "The Assignment Problem." The chapter presents procedures for how to go about using any of the commodity flow data files provided here to assess the volume of truck traffic on the streets or highways of the state or its urban areas. Maps were not produced for this purpose here because these can not be enlarged to display more GIS details once they are taken off the TransCAD system. The user is shown (using computer screens) how the maps can be produced for the state or any part of it.

The second procedure summarizes how to go about evaluating the effects of re-routing traffic due to construction, disaster, or the desire to remove trucks from central areas. After taking the steps necessary to prevent movement on certain links, the user moves back to the procedure for assigning traffic to see what the impacts of their re-routing would be.

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Chapter 1

INTRODUCTION, STUDY AREA, AND NETWORKS

The primary objective of this project is the forecasting of freight flows for the state of Indiana for 2015 and 2030. The manner in which this is done is to follow a classical transportation planning process. This involves an inventory of facilities, an analysis of what is being moved, the development of models to replicate freight traffic generation, the modeling of flows between places, the separation of traffic between the various modes, and the assignment of that traffic to existing highway and rail networks. In this chapter we will examine the study area and networks used in the study.

The primary study area for this examination of freight flows is the state of Indiana and its ninety-two counties. While the flows to, from, and between each county are of interest, the analysis would be incomplete if it focused solely on intrastate flows. A significant amount of commodity traffic in Indiana has neither origin nor destination within the state's boundaries; instead it represents goods passing through the state. As the state slogan proclaims, Indiana is the "Crossroads of America." The consequence of this overhead traffic on the state's economy is questionable; however its impact on urban traffic congestion, air pollution, highway wear and tear, and rail traffic is decidedly significant. Therefore, the study area goes beyond the state's borders.

A transportation network consists of nodes and route segments. There are 145 nodes of origin and destination. As well as the 92 counties of Indiana, there are 53 major terminals for the other 47 contiguous states (excluding Indiana) and the District of Columbia. All states are represented by one node, with the exceptions of Illinois, Kentucky, and Michigan, which are represented by two nodes, and Ohio, which is represented by three. There were also five nodes added later in the study to represent the five major airports serving the state. For reference a map of Indiana and its counties appears as Figure 1-1.

There are four major route transport networks serving Indiana: the highway system, the railway system, the air transport system, and the waterway network. This study is primarily concerned with the highway and the rail route segments. Flows on the other networks are considered implicitly if motor carriers or rail are used in part of the movement.

Figure 1-1. The Counties of Indiana

The Highway Network

The highway network used in this study is an integrated network consisting of the highway network of Indiana as used by the Indiana travel demand model and the U.S. Interstate Highway network beyond the area covered by the former network. The network is not merely a visual image, but is a connected network to allow for traffic assignment of flows from and to all parts of the nation from locations within Indiana.

In terms of size the network consists of 73,346 segments covering 86,596 miles of highways and roads (see Figure 1-2). The average length of a segment of highway is 1.18 miles. The network is much denser in Indiana than it is through the remainder of the country since the primary concern here are the highway flows within the state (see Figure 1-3). The interconnections between the two networks are shown in Figure 1-4. It will be noted that the network is also dense just beyond the boundary of the state. This is to allow for flows to find their natural path into and out of the state. Confining the dense network only to the area within the boundary of Indiana would result in illogical paths being used by traffic assignment algorithms later in the study.

For purposes of analysis the state's counties are represented by 92 nodes, one for each county. Outside of Indiana each state is also represented by a node, except that contiguous states are represented by two nodes (in the case of Michigan, Kentucky, and Illinois), or three nodes (in the case of Ohio). The District of Columbia is also included and this yields a total of 145 nodes (see Table 1-1).

The Railway Network

The railway network for this study will be similar to the network used for the 1997 flow study. There have been minimal changes in rail line additions and closures and these changes have been incorporated in the network used here based on information supplied by the Indiana Department of Transportation's Rail Division.

The network used consists of 12, 815 line segments covering 148,996 route miles, not track miles. Track miles also include the length of industrial sidings and classification yards. The network used appears as Figure 1-5, with the Indiana portion shown in more detail as Figure 1-6.

As is true for the highway network, the rail network is also represented with network nodes, referred to here as stations. The Indiana nodes appear in Figure 1-7 and all nodes are identified in Table 1-2.

Other Networks

The approach taken here to the water transport and air transport networks remains the same as that used in the 1997 study: they were deemed superfluous and left out of the analysis as

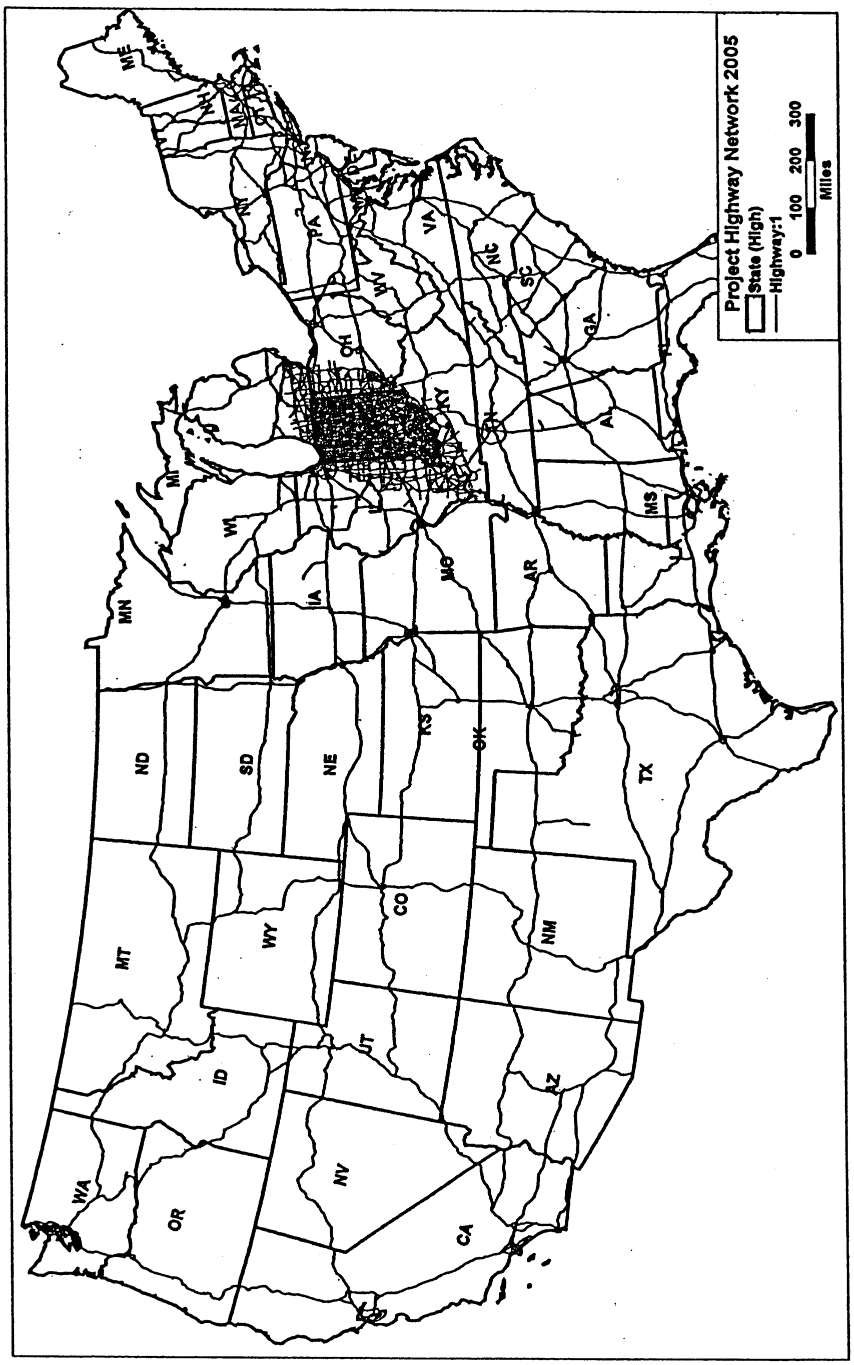

Figure 1-2. Highway Network Utilized

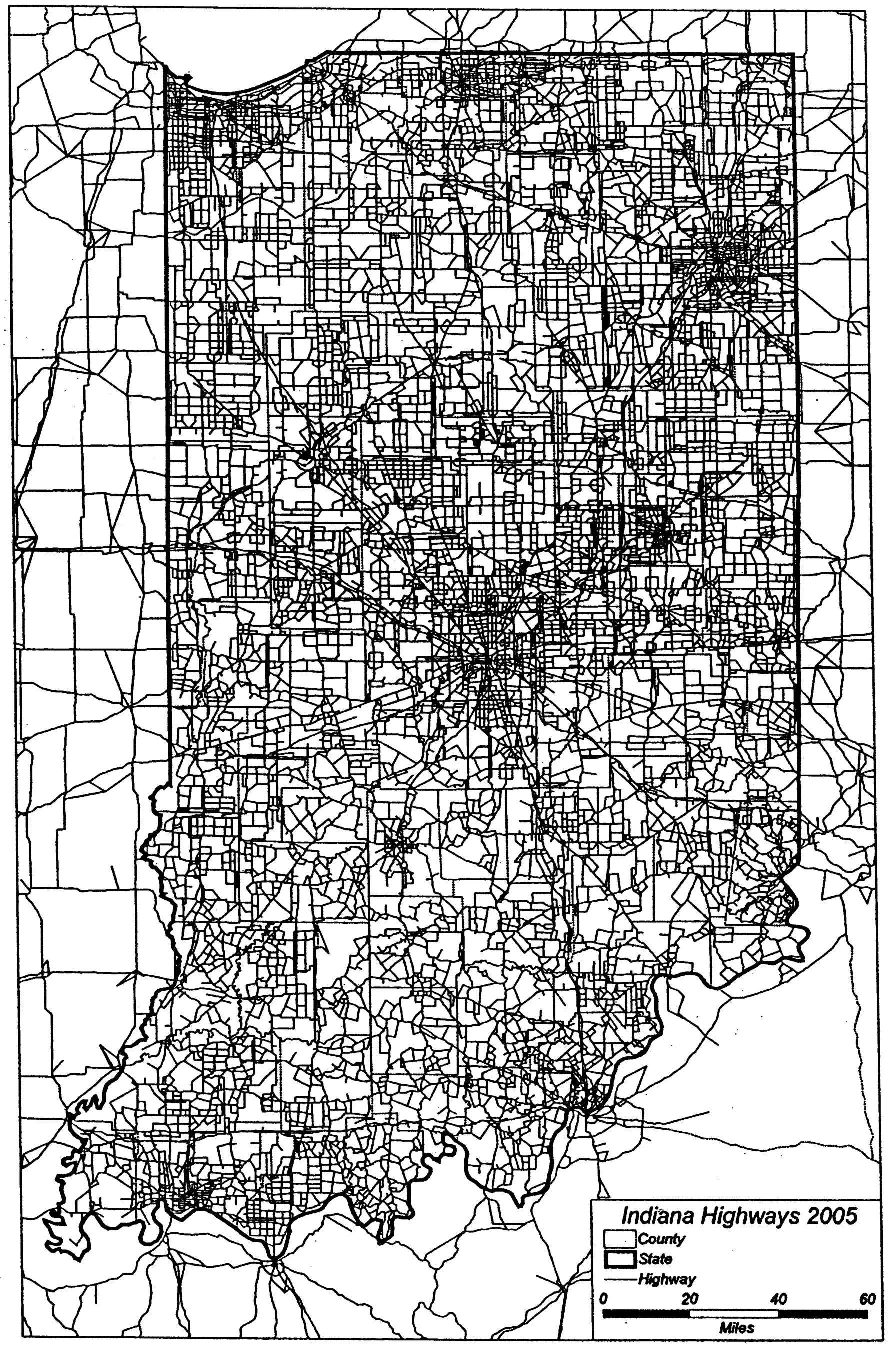

Figure 1-3. Indiana Portion of the Highway Network

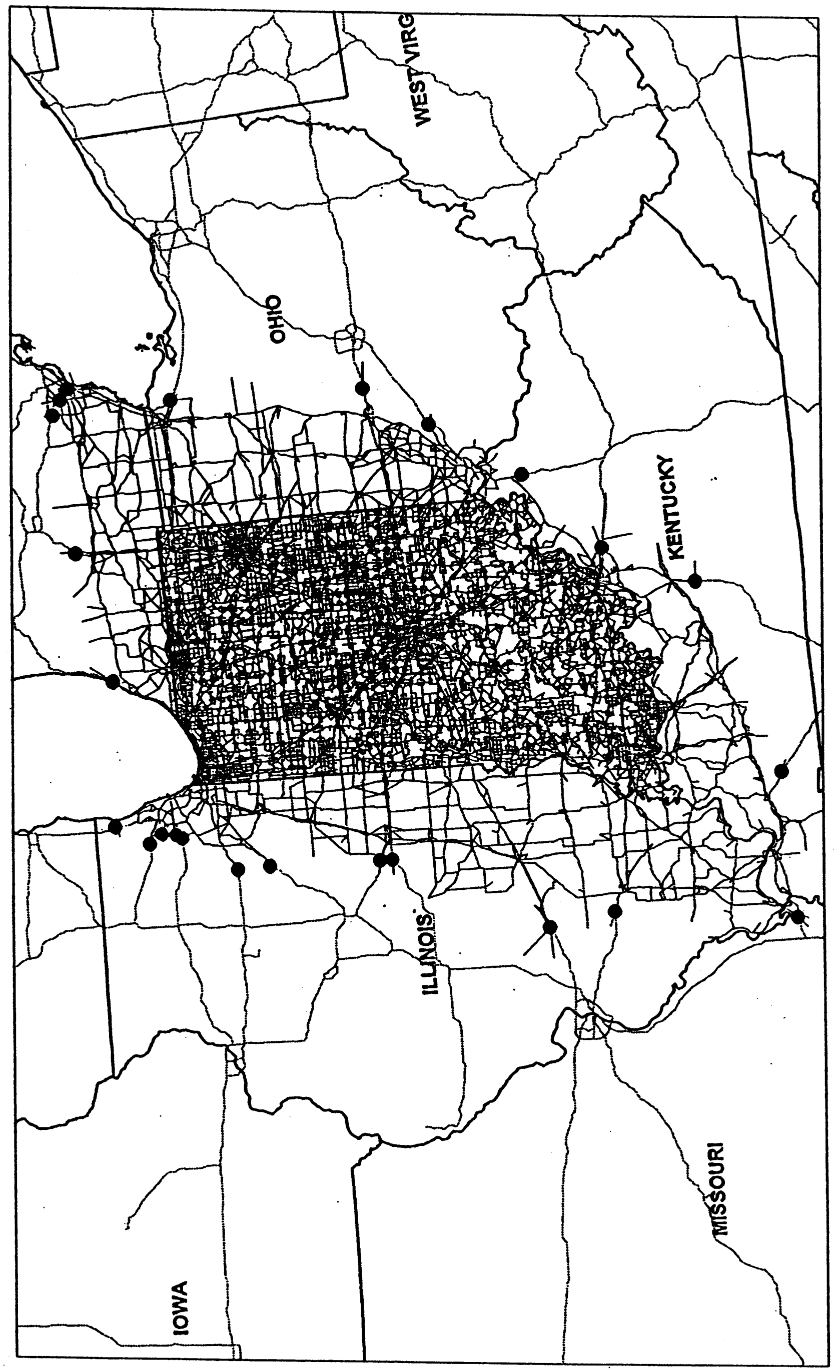

Figure 1-4. Interconnections of the State and Interstate Systems

Table 1-1. Nodes of the Highway Network and Coordinates

	ID	Longitude	Latitude	State	County
1	230218	-86820037	33443494	Alabama	
2	231636	-111966957	33388622	Arizona	
3	243103	-92307369	34799568	Arkansas	
4	232956	-120104507	36079524	California	
5	237253	-105002769	39762338	Colorado	
6	257459	-72814362	41549751	Connecticut	
7	254517	-75740625	39647189	Delaware	
8	254013	-77170502	38894955	District of	
9	241443	-81654805	28228774	Florida	
10	248164	-84332879	33833346	Georgia	
11	236567	-112406986	42833123	Idaho	
12	200286	-87920168	41933007	Illinois-n	
13	246094	-89644442	39732689	Illinois-s	
14	224368	-84947973	40744878	Indiana	Adams
15	226025	-85142641	41079783	Indiana	Allen
16	219760	-85877816	39210716	Indiana	Bartholomew
17	212421	-87318552	40613678	Indiana	Benton
18	222304	-85313342	40471636	Indiana	Blackford
19	215222	-86467969	40046700	Indiana	Boone
20	209588	-86251592	39221586	Indiana	Brown
21	214043	-86544369	40608494	Indiana	Carroll
22	215531	-86373778	40767474	Indiana	Cass
23	10025	-85723950	38440461	Indiana	Clark
24	11012	-87096569	39410856	Indiana	Clay
25	213693	-86487276	40290288	Indiana	Clinton
26	208686	-86471936	38299722	Indiana	Crawford
27	226746	-87061024	38727220	Indiana	Daviess
28	218354	-84945292	39142283	Indiana	Dearborn
29	228865	-85458207	39342636	Indiana	Decatur
30	229559	-85023674	41381355	Indiana	Dekalb
31	223824	-85391868	40200351	Indiana	Delaware
32	227360	-86892542	38355588	Indiana	Dubois
33	225493	-85834268	41584907	Indiana	Elkhart
34	220269	-85136700	39640325	Indiana	Fayette
35	202300	-85890756	38303455	Indiana	Floyd
36	212199	-87243085	40113480	Indiana	Fountain
37	228990	-85049733	39435160	Indiana	Franklin
38	211455	-86240069	41068697	Indiana	Fulton
39	207494	-87574085	38341066	Indiana	Gibson
40	223104	-85662870	40522666	Indiana	Grant
41	205992	-86986146	39029143	Indiana	Greene
42	202425	-86037180	40054579	Indiana	Hamilton
43	219460	-85769890	39814609	Indiana	Hancock
44	31006	-86105365	38182729	Indiana	Harrison
45	209955	-86542622	39760453	Indiana	Hendricks
46	223405	-85381826	39929155	Indiana	Henry
47	215623	-86102831	40476802	Indiana	Howard
48	220796	-85507496	40894927	Indiana	Huntington
49	205480	-86033541	38896113	Indiana	Jackson
50	37019	-87101896	41059717	Indiana	Jasper
51	221075	-84965623	40432540	Indiana	Jay

	ID	Longitude	Latitude	State	County
52	39019	-85366337	38808533	Indiana	Jefferson
53	219865	-85617348	39005641	Indiana	Jennings
54	205059	-86059000	39471207	Indiana	Johnson
55	207138	-87364406	38700598	Indiana	Knox
56	225255	-85852539	41246104	Indiana	Kosciusko
57	226186	-85416623	41633346	Indiana	Lagrange
58	213198	-87364804	41485895	Indiana	Lake
59	216782	-86714144	41608253	Indiana	LaPorte
60	227804	-86494835	38846907	Indiana	Lawrence
61	222379	-85696775	40135183	Indiana	Madison
62	210529	-86171203	39764490	Indiana	Marion
63	216308	-86276287	41343320	Indiana	Marshall
64	208835	-86808774	38706101	Indiana	Martin
65	215676	-86037418	40753536	Indiana	Miami
66	209318	-86533606	39166608	Indiana	Monroe
67	203873	-86901407	40047364	Indiana	Montgomery
68	209685	-86444002	39490714	Indiana	Morgan
69	212654	-87392576	40940527	Indiana	Newton
70	57015	-85379061	41421966	Indiana	Noble
71	217716	-84958239	38952353	Indiana	Ohio
72	208722	-86466330	38536551	Indiana	Orange
73	227771	-86833473	39304481	Indiana	Owen
74	203122	-87236075	39768930	Indiana	Parke
75	205910	-86610269	38109730	Indiana	Perry
76	207896	-87220492	38395125	Indiana	Pike
77	229840	-87082796	41461388	Indiana	Porter
78	207464	-87832984	38063140	Indiana	Posey
79	216102	-86699613	41055440	Indiana	Pulaski
80	209927	-86865922	39653139	Indiana	Putnam
81	222181	-84974353	40172563	Indiana	Randolph
82	219315	-85279495	39104668	Indiana	Ripley
83	220340	-85446370	39608326	Indiana	Rush
84	217078	-86251572	41669097	Indiana	Saint Joseph
85	72004	-85747395	38667739	Indiana	Scott
86	219955	-85783475	39540059	Indiana	Shelby
87	206448	-87016255	38002497	Indiana	Spenser
88	215938	-86639971	41317257	Indiana	Starke
89	220829	-85015205	41635117	Indiana	Steuben
90	208148	-87418958	39082115	Indiana	Sullivan
91	217743	-85065498	38815197	Indiana	Switzerland
92	214830	-86899538	40444761	Indiana	Tippecanoe
93	202535	-86079381	40303494	Indiana	Tipton
94	203499	-84942383	39611086	Indiana	Union
95	226866	-87581795	38022070	Indiana	Vanderburgh
96	211948	-87446011	39893355	Indiana	Vermillion
97	207987	-87413575	39450070	Indiana	Vigo
98	221038	-85818840	40797090	Indiana	Wabash
99	212033	-87347490	40351615	Indiana	Warren
100	207758	-87273908	38060337	Indiana	Warrick
101	209312	-86094090	38609618	Indiana	Washington
102	227273	-84995466	39876434	Indiana	Wayne

	ID	Longitude	Latitude	State	County
103	224062	-85179024	40733401	Indiana	Wells
104	91021	-86844227	40776750	Indiana	White
105	225362	-85485436	41156939	Indiana	Whitley
106	245132	-93625795	41649499	Iowa	
107	244005	-97618105	38737601	Kansas	
108	248286	-84461509	38083662	Kentucky-e	
109	100828	-88366722	36833610	Kentucky-w	
110	238151	-92435321	31074228	Louisianna	
111	258516	-69476868	44684250	Maine	
112	254478	-76641972	39451506	Maryland	
113	257590	-71474012	42299699	Massachusett	
114	249843	-83619247	42885796	Michigan-e	
115	249123	-85707501	42960929	Michigan-w	
116	245934	-93285426	45067452	Minnesota	
117	240372	-90151194	32359372	Mississippi	
118	243046	-92737076	38936512	Missouri	
119	236582	-112628318	46008908	Montana	
120	230184	-99416267	40692745	Nebraska	
121	231953	-116904617	40619709	Nevada	
122	258333	-71533895	43211126	NewHampshire	
123	256124	-74428631	40161577	NewJersey	
124	237070	-106728378	35094742	NewMexico	
125	249550	-75128105	43086742	NewYork	
126	253109	-78983956	35915326	NorthCarolin	
127	230541	-100294382	46836312	NorthDakota	
128	252487	-81757324	41312634	Ohio-n	
129	251974	-82944556	39951533	Ohio-m	
130	218162	-84441939	39289760	Ohio-s	
131	243665	-97527200	35464360	Oklahoma	
132	234350	-123004569	43990692	Oregon	
133	254597	-77530757	41029711	Pennsylvania	
134	257526	-71603735	41650606	RhodeIsland	
135	251082	-81046326	34062847	SouthCarolin	
136	245402	-100051782	43898533	SouthDakota	
137	247850	-86827942	36155684	Tennessee	
138	238642	-97250637	31297776	Texas	
139	235264	-111841802	39679488	Utah	
140	257878	-72610994	44110530	Vermont	
141	253295	-77427674	37552263	Virginia	
142	234657	-122025454	47532033	Washington	
143	252067	-81588158	38391693	West Virgini	
144	248646	-89527193	43517451	Wisconsin	
145	237765	-106282325	42855627	Wyoming	
146	200440	-87763098	41811527	Chicago-O'Ha	
147	218652	-85729640	38190492	Louisville A	
148	217953	-84647423	39001326	Cincinnati A	
149	225647	-85207397	41074554	Fort Wayne A	
150	210243	-86269683	39729598	Indianapolis	

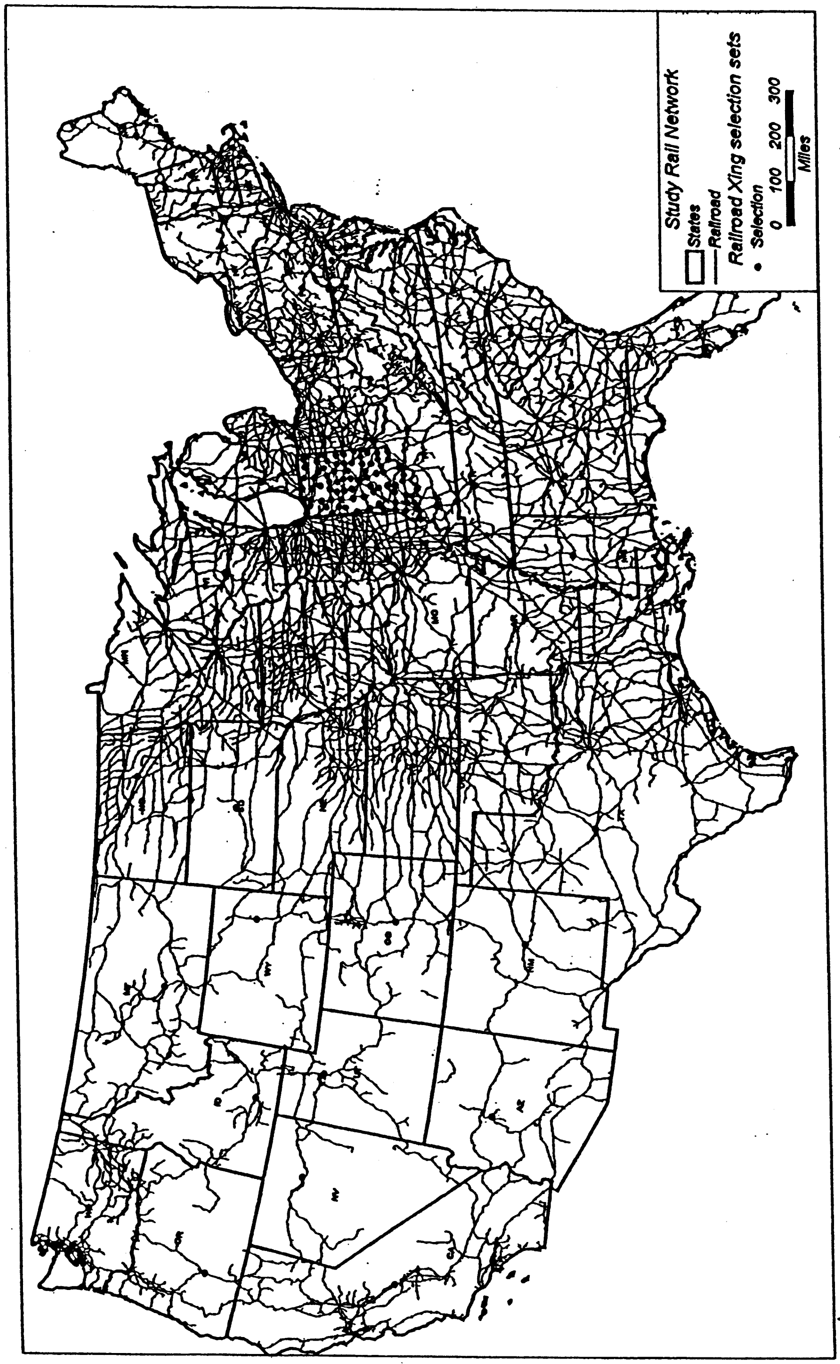

Figure 1.5 Study Rail Network

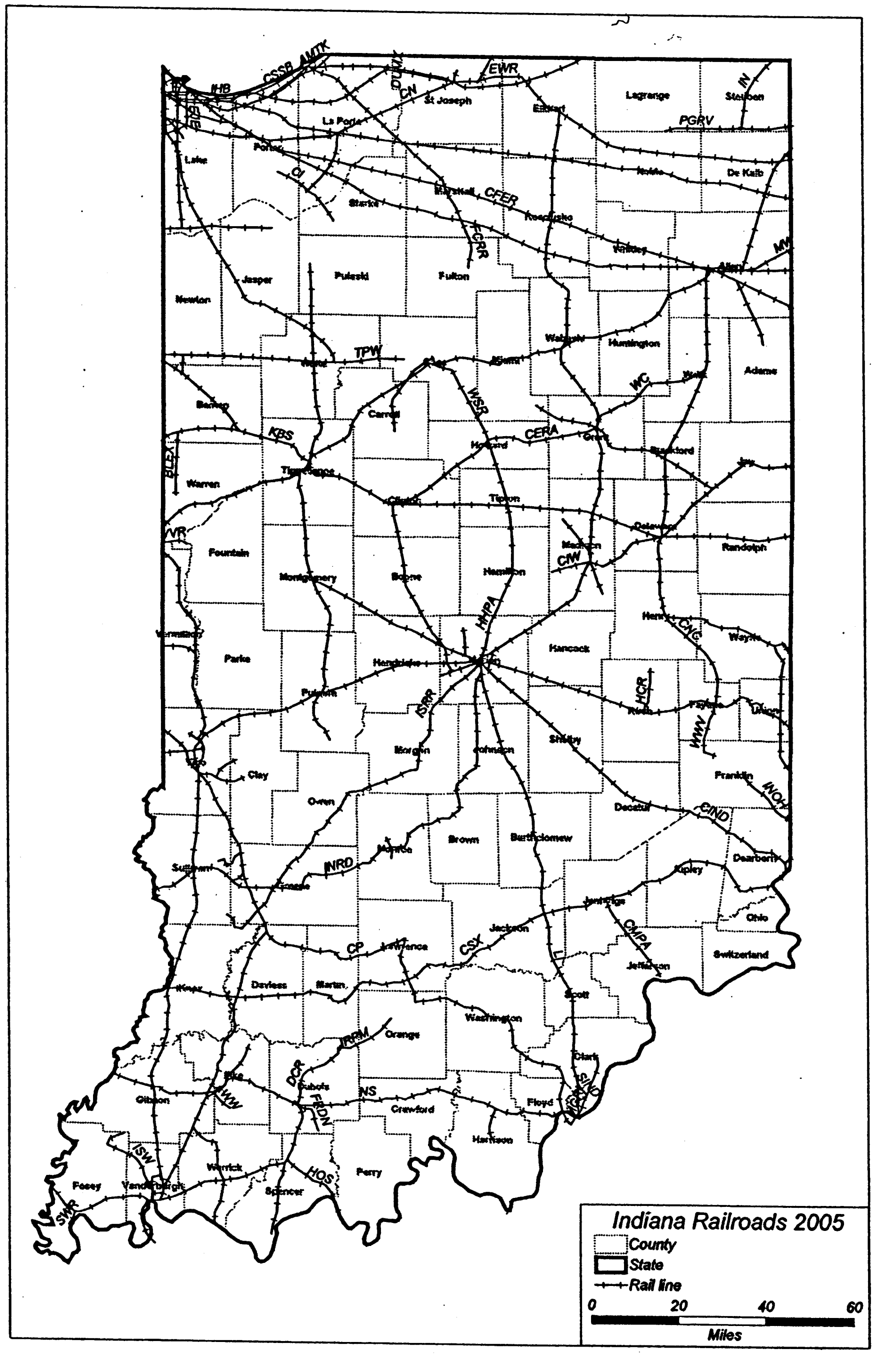

Figure 1-6. Indiana Portion of the Rail Network

Table 1-2. Nodes of the Rail Network and Coordinates

	ID	Longitude	Latitude	State	County
1	832454	-86754144	33129406	Alabama	
2	287311	-112372278	34989207	Arizona	
3	1154620	-92259754	34775464	Arkansas	
4	105441	-120015879	36974614	California	
5	486522	-104809612	38835637	Colorado	
6	2549093	-72631570	41656868	Connecticut	
7	2391830	-75575965	38928557	Delaware	
8	2382821	-77003398	38902120	District of Col	
9	912119	-82430773	29832155	Florida	
10	929464	-83557487	32849301	Georgia	
11	328414	-113478614	42751205	Idaho	
12	1592088	-89083508	39388413	Illinois-n	
13	1775449	-87774828	41804784	Illinois-s	
14	1846978	-84926327	40827592	Indiana	Adams
15	1852740	-85161050	41083426	Indiana	Allen
16	1814690	-85916090	39197325	Indiana	Bartholomew
17	1762637	-87193923	40517290	Indiana	Benton
18	1842508	-85356333	40444524	Indiana	Blackford
19	1790152	-86477502	40057303	Indiana	Boone
20	1814690	-85916090	39197325	Indiana	Brown
21	1790208	-86518057	40523962	Indiana	Carroll
22	1842548	-85368271	39958153	Indiana	Cass
23	1814578	-85751879	38409852	Indiana	Clark
24	1790144	-86528055	40285352	Indiana	Clinton
25	1744271	-86348011	38360123	Indiana	Crawford
26	1732068	-87215582	38658987	Indiana	Daviess
27	1814802	-85067132	39072894	Indiana	Dearborn
28	2644057	-85484267	39324882	Indiana	Decatur
29	1869007	-84888626	41381615	Indiana	DeKalb
30	1838582	-85369661	40188147	Indiana	Delaware
31	1735768	-86947774	38298435	Indiana	Dubois
32	1852556	-85813317	41585929	Indiana	Elkhart
33	1821269	-85135760	39641207	Indiana	Fayette
34	1744343	-85809374	38290139	Indiana	Floyd
35	1762565	-87425856	40146187	Indiana	Fountain
36	1821293	-85014921	39404550	Indiana	Franklin
37	1806118	-86205002	41071754	Indiana	Fulton
38	1731868	-87580879	38354813	Indiana	Gibson
39	1842468	-85651611	40545641	Indiana	Grant
40	1735960	-87230034	39197582	Indiana	Greene
41	1790264	-86013863	40045904	Indiana	Hamilton
42	1756508	-86131639	39806194	Indiana	Hancock
43	1744327	-86097445	38295961	Indiana	Harrison
44	1756508	-86131639	39806194	Indiana	Hendricks
45	1796347	-86385559	40758139	Indiana	Henry
46	1796339	-86122764	40498966	Indiana	Howard
47	1842524	-85474669	40885090	Indiana	Huntington
48	1751092	-85885231	38952889	Indiana	Jackson
49	1781053	-87147545	40948135	Indiana	Jasper
50	1846930	-84978270	40432590	Indiana	Jay
51	1814714	-85386745	38746116	Indiana	Jefferson

	ID	Longitude	Latitude	State	County
52	1814602	-85623831	39005108	Indiana	Jennings
53	1751148	-86062471	39487599	Indiana	Johnson
54	1731900	-87513090	38684812	Indiana	Knox
55	1806198	-85848876	41230090	Indiana	Kosciusko
56	1852628	-85354402	41524819	Indiana	Lagrange
57	1785363	-87369836	41606245	Indiana	Lake
58	1800242	-86780325	41416473	Indiana	Laporte
59	1744335	-86480813	38866762	Indiana	Lawrence
60	1838486	-85682204	40103210	Indiana	Madison
61	1756508	-86131639	39806194	Indiana	Marion
62	1806142	-86305013	41337591	Indiana	Marshall
63	1744263	-86770551	38648165	Indiana	Martin
64	1796403	-86075264	40752033	Indiana	Miami
65	1750956	-86533887	39165372	Indiana	Monroe
66	1762605	-86872512	40032304	Indiana	Montgomery
67	1751044	-86424708	39419542	Indiana	Morgan
68	1766481	-87440874	40770637	Indiana	Newton
69	1852636	-85261061	41448990	Indiana	Noble
70	1814802	-85067132	39072894	Indiana	Ohio
71	2644056	-86490857	38596124	Indiana	Orange
72	1744391	-86659450	39348423	Indiana	Owen
73	1744103	-87388079	39786465	Indiana	Parke
74	1744239	-86734705	37919284	Indiana	Perry
75	1735736	-87247239	38284821	Indiana	Pike
76	1788113	-87057044	41462716	Indiana	Porter
77	1724066	-87895573	37937319	Indiana	Posey
78	1796451	-86880870	41079248	Indiana	Pulaski
79	1744175	-86837236	39661762	Indiana	Putnam
80	1846906	-84977154	40181201	Indiana	Randolph
81	1814722	-85341034	39083996	Indiana	Ripley
82	1814770	-85448549	39610093	Indiana	Rush
83	1751092	-85885231	38952889	Indiana	Scott
84	1814730	-85773569	39513149	Indiana	Shelby
85	1744391	-86659450	39348423	Indiana	Spenser
86	1806254	-86261405	41675658	Indiana	St. Joseph
87	1800274	-86626982	41301476	Indiana	Starke
88	1856325	-85015156	41537697	Indiana	Steuben
89	1735928	-87399753	39082863	Indiana	Sullivan
90	1814714	-85386745	38746116	Indiana	Switzerland
91	1762621	-86882249	40418130	Indiana	Tippecanoe
92	1790272	-86034693	40286747	Indiana	Tipton
93	1821301	-84859081	39594270	Indiana	Union
94	1729329	-87539512	38003872	Indiana	Vanderburgh
95	1762517	-87459748	39952576	Indiana	Vermillion
96	1741705	-87368100	39504245	Indiana	Vigo
97	1842492	-85806076	40807866	Indiana	Wabash
98	1762597	-87248545	40303088	Indiana	Warren
99	1731972	-87274451	38047592	Indiana	Warrick
100	1744343	-85809374	38290139	Indiana	Washington
101	1831417	-84883253	39835657	Indiana	Wayne
102	1846946	-85175767	40744542	Indiana	Wells

	ID	Longitude	Latitude	State	County
103	1790176	-86865866	40753686	Indiana	White
104	1847034	-85628018	41081761	Indiana	Whitely
105	1250660	-93592647	41660809	Iowa	
106	1053150	-97657012	38376683	Kansas	
107	1680662	-87490279	37327872	Kenetuck-e	
108	1821453	-84180417	37985160	Kentucky-w	
109	1814682	-85044895	38739294	Kentucky	
110	710367	-92434166	31349811	Louisianna	
111	2630042	-69257594	44837910	Maine	
112	2391702	-76641607	39487994	Maryland	
113	2594729	-71688479	42426854	Massachusetts	
114	2558307	-70902019	41871596	Massachusetts	
115	2442298	-83242918	42378966	Michigan-e	
116	1979398	-85792580	43038938	Michigan-w	
117	1415491	-94364172	45976601	Minnesota	
118	1235763	-92290911	39233408	Missouri	
119	396739	-109059215	46306866	Montana	
120	1083504	-97986504	41125308	Nebraska	
121	277265	-116536567	40705654	Nevada	
122	2601835	-71582932	43452103	New Hampshire	
123	2516725	-74445580	40357995	New Jersey	
124	406547	-105214583	34610832	New Mexico	
125	2560517	-74993092	43036527	New York	
126	791241	-89851279	33088870	Nississippi	
127	2285896	-78782512	35791132	North Carolina	
128	1298188	-99128569	47674448	North Dakota	
129	2188395	-81747490	41479822	Ohio-n	
130	2154193	-82947863	39977347	Ohio-m	
131	1831193	-84482502	39181742	Ohio-s	
132	987867	-97507297	35467070	Oklahoma	
133	169375	-121780050	43215263	Oregon	
134	2400417	-77580267	40634032	Pennsylvania	
135	2558123	-71424558	41830201	Rhode Island	
136	2079666	-81049086	33973367	South Carolina	
137	553174	-100349715	44371072	South Dakota	
138	1680798	-86790833	36026512	Tennessee	
139	309972	-111864865	40593786	Utah	
140	2585658	-72964379	43601245	Vermont	
141	2301196	-78338342	37736959	Virginia	
142	230374	-120306809	47426637	Washington	
143	2196653	-80720195	38660199	West Virginia	
144	1940198	-89754693	44583260	Wisconsin	
145	530576	-105348600	43470478	Wyoming	

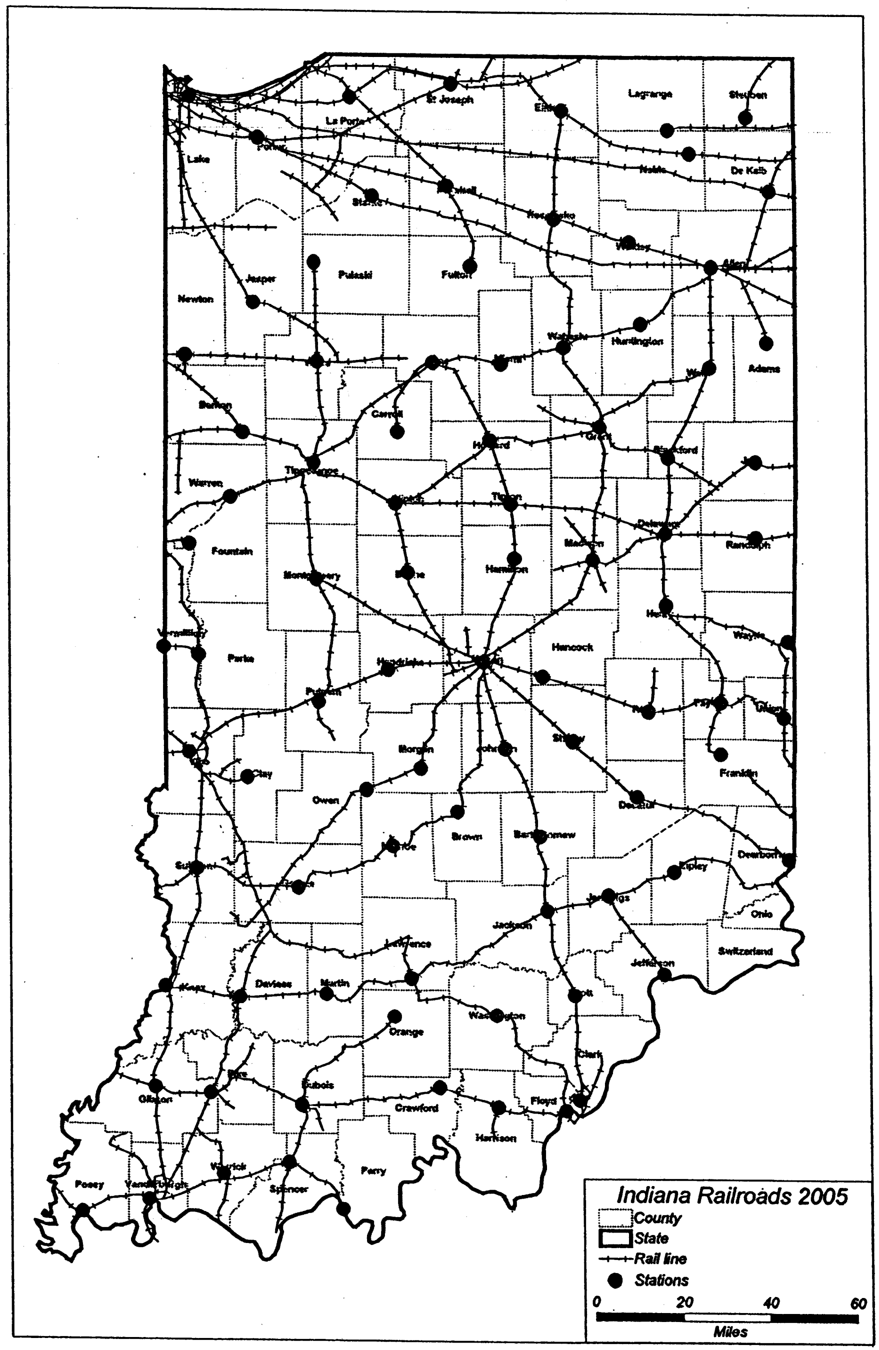

Figure 1-7. Nodes of the Indiana Rail Network

networks (Black, 1997). The great majority of the goods being transported on the water and air networks reached those networks via a transfer from the highway or the railway network.

The goods transported via the waterway network are generally bulk quantities of raw materials whose destination is outside the state of Indiana. With existing data we are unable to assert whether water flows are moving via the Great Lakes or the Ohio River. Even if we could make this distinction it would be hard to know what river ports are used for these flows. As a result we have supplied information on future water flows on CD as part of this research effort, but we have not assigned these to a water network.

The air transport network, though involved in the movement of some freight and express deliveries, is predominantly a passenger transport system. Intercity air travel was not included in the study. Most freight moving by air reached the air transport nodes via the highway network. This is discussed in more detail in later chapters of this report. It will be noted there that both parcel shipments and air freight are handled in a very explicit way. The study design of the project, therefore, has already captured the movement of those goods on the highway network.

Pipeline movement of freight is included in the freight transported. These flows are not examined in any further detail here, but they are included as part of the modal breakdown of freight traffic on the CD.

Summary

This chapter has introduced the objectives of the study, the approach taken in reaching this objective and the networks used for the highway and rail transport sectors. It was noted that the water network was not used as such. In addition to the data problems related to this mode, the waterway network is not maintained by the State of Indiana, but by the U.S. Army Corps of Engineers. The pipeline network is also not examined here. Even though these networks were not examined, there are forecasts of the movement of freight by water and pipeline provided here. In addition, although the air network was not included as such, air freight and parcel movements were viewed as "special" variations of the highway network as will be described later in the report.

References Cited

Black, William R. (1997), *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment: Phase 2.* Transportation Research Center and Department of Geography, Indiana University, Bloomington, IN.

Chapter 2

COMMODITIES EXAMINED AND DATA SOURCES

The 1997 state study sought to have the most detailed commodity grouping possible. For that research it was determined that the two-digit Standard Transportation Commodity Code (STCC) of commodity data provided by the 1993 *Commodity Flow Survey* (U.S. Bureau of Census, 1996) was the most suitable level of specificity. However, since that time the adopted classification methodology for freight movement in the US has evolved to a new system, the Standard Classification of Transported Goods (SCTG).

The level of specification for this research is the two-digit level for the SCTG as presented in the 1997 *Commodity Flow Survey* (U.S. Bureau of Census, 1999). It can be argued, as there are forty-one categories in this study compared to nineteen in the previous, that this study is an increase in specificity. This study, however, runs into the same problem as the 1997 work when trying to look at a higher level of commodity detail: a considerable amount of information is lost at higher levels of detail. To keep from revealing confidential aspects of individual firms operations (salaries, production volume, market areas), flags are placed in the data that can represent an insufficient sample size or simply a notice that data could not be disclosed. In these cases such values were excluded from the modeling and the subsequent models developed were used to replace the missing values. The table on the following page (Table 2-1) describes the commodities used in this study.

Employment and population data were also utilized in the modeling of the commodities. These data are coded by the North American Industrial Classification System, or NAICS, and appear in *County Business Patterns* (*CBP*) (U.S. Bureau of Census, 2004). The year of analysis for the *CBP* was for the year closest to 1997 commodity data, 1998. A three-digit NAICS level was used. However, there is no natural alignment between any level of NAICS data and SCTG data. However, there is a guide for determining the proportion of NAICS data to SCTG data. Symmetry was reached between the two data sets by determining the proportions of each NAICS commodity (the more specific level) within each SCTG commodity (the less specific level).

The study and the modeling here are based primarily on the 1997 *Commodity Flow Survey* (*CFS*). This was the latest version of the *CFS* with data available when the project began; the 2002 *CFS* appeared in 2005 and this was used for commodity discussions and model evaluation (U.S. Bureau of Census, 2005).

Table 2-1 Major Commodity Groups Included in the Study

SCTG	Commodity
01	Live Animals and Fish
02	Cereal Grains
03	Agricult Products Exc. Live Animals, Cereal Grains, and Forage Products
04	Animal Feed and Products of Animal Origin
05	Meat, Fish, Seafood, and Preparations
06	Milled Grain Products and Preparations, and Bakery Products
07	Prepared Foodstuffs, Fats, and Oils
08	Alcoholic Beverages
09	Tobacco Products
10	Monumental or Building Stone
11	Natural Sands
12	Gravel and Crushed Stone
13	Non-metallic Minerals
14	Metallic Ores
15	Coal
17	Gasoline and Aviation Turbine Fuel
18	Fuel Oils
19	Products of Petroleum Refining and Coal Products
20	Basic Chemicals
21	Pharmaceutical Products
22	Fertilizers and Fertilizer Materials
23	Chemical Products and Preparations
24	Plastics and Rubber
25	Logs and Other Wood in the Rough
26	Wood Products
27	Pulp, Newspaper, Print, and Paperboard
28	Paper or Paperboard Articles
29	Printed Products
30	Textiles, Leather, and Articles
31	Non-metallic Mineral Products
32	Base Metal in Primary or Semi-finished Forms and in Basic Shapes
33	Articles of Base Metal
34	Machinery
35	Electronic and Other Elect. Equipment/Components; Office Equipment
36	Motorized Vehicles
37	Transportation Equipment
38	Precision Instruments and Apparatus
39	Furniture, Mattresses, Lamps, Lighting Fittings, and Illuminated Signs
40	Miscellaneous Manufactured Products
41	Waste and Scrap
43	Mixed Freight

References

U.S. Census Bureau (1996), *1992 Census of Transportation, Communication, and Utilities "1993 Commodity Flow Survey."* Washington, D.C.: U.S. Department of Commerce.

U.S. Census Bureau (1999), *Economic Census, Transportation: 1997 Commodity Flow Survey*, Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau (2004), *1998 County Business Patterns*, Washington, DC: U.S. Department of Commerce. Web page, http://www.census.gov/epcd/cbp/view/cbpview.html, various access dates.

U.S. Census Bureau (2005), 2002 *Commodity Flow Survey*, Washington, DC: U.S. Department of Commerce. CD C1-E02-ECFS-00-US1

Chapter 3

GOODS EXAMINED AND TRANSPORT FACILITIES

All Commodities

A discussion of the existing flows of commodities is limited by the nature of freight data collection in the US. The latest available data for comparison are from the 1997 *Commodity Flow Survey* (*CFS*) of the Department of Commerce, released in 1999 and the 2002 *Commodity Flow Survey* released by the same agency in 2005. The project which led to the preparation of this report was initiated with the idea that it would use 1997 data for all modeling. The appearance of the 2002 census led to certain revisions in the study design so as to make use of these newer data. For one thing the discussion of commodities in this chapter makes use of both the 1997 and the 2002 census databases. In addition the 2002 census was used as a target date for modeling the flows using 1997 data. In other words, the models derived were used to estimate values for 2002. This will be described in a later chapter where we evaluate the models.

With each of the last three *CFS*s, the nationwide sample size has shrunk. The original *CFS* included a sample of the shipping practices of 200,000 shippers. In 1997 the *CFS* involved only 100,000 shippers. The most recent *CFS* surveyed the shipping of only 50,000 firms. This means that the quality of the data, and thus the quality of subsequent analyses, is most likely declining in accuracy and specificity. While the precursor to this research, the 1997 Indiana flow study (involving data from 1993), was able to describe the breakdown of shipments to and from individual states with some confidence, the 1997 data had far more missing values that needed to be estimated.

Another limitation has arisen with the change from Standard Transportation Commodity Classification (STCC) codes to the Standard Classification of Transported Goods (SCTG) codes for classification of commodities. This was a consequence of the North American Free Trade Agreement, also known as NAFTA, which necessitated a bridge between Canadian shipment codes and US shipment codes. The result has been a new set of commodity groups that is largely incompatible with the previous set of these commodity groups. While even some names at the 2-digit level have remained the same, the individual subcategories have been drastically altered. Any comparison to flows from the previous study, therefore, would be biased by changes in the subcategories making up each classification code. As mentioned earlier, further specification (at the 3 or 4-digit level) is undesirable due to the smaller sample and impossible due to the reporting restrictions for these data.

Summary tables of the commodities, tons, and values originating in Indiana in 1997 and 2002 appear on the following pages as tables 3-1 and 3-2.

The discussion of the commodities below includes value, tonnage, and average shipment length of goods originating in and attracted to Indiana. This is for the 41 major classes of commodities summarized in the tables on the following pages.

Individual Commodities

SCTG 01: Live Animals and Fish

Most of the information on SCTG 01 is flagged due to sampling and other error in the 1997 *CFS*. The only data available indicate that 926,000 tons of Live Animals and Fish were shipped in 1997. Shipments leaving Indiana averaged 506 miles per shipment. Travel on trucks averaged 197 miles per shipment, while shipments on multiple modes averaged 787 miles. Other and unknown modes averaged 47 miles per shipment.

By 2002 the transport of live animals and live fish had dropped to nothing according to the *CFS*. Although there was a slight drop at the national level, it is more likely that the sampling design simply missed the sector in Indiana. This does not mean that the industry is gone in an absolute sense. It is likely that in the Indiana case there may have been shippers moving cattle, chickens or turkeys to market, and these were simply not sampled in 2002. It should be noted that the data were not withheld due to disclosure requirements or statistically unreliability; the industry is simply not reported and this suggests it may have been missed by the sampling system used in the *CFS*.

The attraction of live animals to Indiana in 1997 was 320,000 tons valued at $348 million. Looking at this sector in 2002 the attractions are not reported primarily due to potential unreliability of the sample size. The problems with this sector are undoubtedly related to the decrease in overall sample size of the *CFS* and this a demonstration of the inherent problems in decreasing the size of the sample.

SCTG 02: Cereal Grains

In 1997 Indiana shipped 12.32 million tons of cereal grains at a value of $1.36 billion dollars; these moved an average of 89 miles. Almost all of these shipments were by single modes. Trucks accounted for 5 million tons (40.6%) of shipments and $528 million of value (38.8%), while distance shipped averaged 52 miles per shipment. Rail accounted for a significant load of cereal grain traffic, with 6.17 million tons (50.1%) worth $705 million

Table 3-1 Value and Tons of Commodities for Indiana, 1997

SCTG Code	Commodity Group	Value (millions)	Tons (thousands)
01	Live Animals and Fish	N/A	926
02	Cereal Grains	$1,362	12,316
03	Agricultural Products Except Live Animals, Cereal Grains, and Forage products	2,323	7,318
04	Animal Feed and Products of Animal Origin	2,443	6,759
05	Meat, Fish, Seafood, and Preparations	2,172	1,018
06	Milled Grain Products and Preparations, and Bakery Products	4,746	3,664
07	Prepared Foodstuffs, Fats, and Oils	7,725	12,856
08	Alcoholic Beverages	1,348	1,315
09	Tobacco Products	561	31
10	Monumental or Building Stone	102	535
11	Natural Sands	27	6,772
12	Gravel and Crushed Stone	456	80 ,944
13	Non-metallic Minerals	204	7,559
14	Metallic Ores	N/A	N/A
15	Coal	552	24,817
17	Gasoline and Aviation Turbine Fuel	4,620	20,031
18	Fuel Oils	2,706	14,141
19	Products of Petroleum Refining and Coal Products	3,273	26,530
20	Basic Chemicals	1,740	7,653
21	Pharmaceutical Products	N/A	83
22	Fertilizers and Fertilizer Materials	626	2,738
23	Chemical Products and Preparations	2,816	1,367
24	Plastics and Rubber	7,732	2,310
25	Logs and Other Wood in the Rough	101	N/A
26	Wood Products	2,911	3,212
27	Pulp, Newspaper, Print, and Paperboard	1,113	1,3 63
28	Paper or Paperboard Articles	1,997	1,553
29	Printed Products	10,893	2,527
30	Textiles, Leather, and Articles	6,216	329
31	Non-metallic Mineral Products	3,510	18,975
32	Base Metal in Primary or Semi-finished Forms and in Basic Shapes	23,929	38,952
33	Articles of Base Metal	6,630	3,077
34	Machinery	17,486	2,540
35	Electronic and Other Electrical Equipment and Components; Office Equipment	17,989	2,062
36	Vehicles	34,975	8,370
37	Transportation Equipment	2,364	N/A
38	Precision Instruments and Apparatus	3,117	62
39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	3,817	676
40	Miscellaneous Manufactured Products	12,838	3,182
41	Waste and Scrap	1,512	8,426
43	Mixed Freight	1,356	481

Table 3-2 Value and Tons of Commodities for Indiana, 2002

SCTG Code	Commodity Group	Value (millions)	Tons (thousands)
01	Live Animals and Fish	N/A	N/A
02	Cereal Grains	$1,948	12,316
03	Agricultural Products Except Live Animals, Cereal Grains, and Forage products	1,911	7,318
04	Animal Feed and Products of Animal Origin	811	6,759
05	Meat, Fish, Seafood, and Preparations	1,774	1,018
06	Milled Grain Products and Preparations, and Bakery Products	N/A	3,664
07	Prepared Foodstuffs, Fats, and Oils	12,356	12,856
08	Alcoholic Beverages	276	1,315
09	Tobacco Products	1,108	31
10	Monumental or Building Stone	N/A	535
11	Natural Sands	62	6,772
12	Gravel and Crushed Stone	402	80,944
13	Non-metallic Minerals	415	7,559
14	Metallic Ores	73	N/A
15	Coal	477	24,817
17	Gasoline and Aviation Turbine Fuel	8,180	20,031
18	Fuel Oils	2,055	14,141
19	Products of Petroleum Refining and Coal Products	3,406	26,530
20	Basic Chemicals	2,354	7,653
21	Pharmaceutical Products	6,063	83
22	Fertilizers and Fertilizer Materials	1,065	2,738
23	Chemical Products and Preparations	7,351	1,367
24	Plastics and Rubber	11,835	2,310
25	Logs and Other Wood in the Rough	N/A	N/A
26	Wood Products	3,877	3,212
27	Pulp, Newspaper, Print, and Paperboard	N/A	1,363
28	Paper or Paperboard Articles	2,857	1,553
29	Printed Products	3,211	2,527
30	Textiles, Leather, and Articles	10,962	329
31	Non-metallic Mineral Products	3,369	18,975
32	Base Metal in Primary or Semi-finished Forms and in Basic Shapes	23,253	38,952
33	Articles of Base Metal	8,328	3,077
34	Machinery	30,097	2,540
35	Electronic and Other Electrical Equipment and Components; Office Equipment	23,158	2,062
36	Vehicles	56,621	8,370
37	Transportation Equipment	N/A	N/A
38	Precision Instruments and Apparatus	4,145	62
39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	4,678	676
40	Miscellaneous Manufactured Products	12,558	3,182
41	Waste and Scrap	1,483	9,883
43	Mixed Freight	29,361	8,782

(51.7%) traveling an average of 577 miles. Water shipments (entirely in shallow draft) accounted for 1.15 million tons (9.3%) and $129 million (9.4%) in goods, average 835 miles per shipment.

Shipments increased in 2002 to 23.85 million tons, nearly twice the 1997 volume, but the value of these shipments only increased to $1.94 billion (an increase of 43%). One could attribute part of this to an export market, however since the shipments in the *CFS* only indicate the domestic destinations, i.e., the point of export, we do not know where the shipments were going outside the U.S. This suggests that the drop in value per unit of weight was most likely related to an increase in production, or possibly a substantial negotiated trade agreement. The length of shipments was up substantially to 354 miles with 81% of the shipments moving by rail and 12% moving by water.

The attraction of cereal grains to Indiana destinations in 1997 was valued at $817 million and represented 7,790,000 tons. This was moved an average of 62 miles suggesting that the grains also originated in Indiana for the most part.

The value of these grain shipments in 2002 was significantly lower with the value dropping to $430 million and the tonnage dropping to 4,325,000 tons, slightly more than half of its 1997 level. Shipment length was 242 miles, representing a significant jump from 1997.

SCTG 03: Other Agricultural Products

There were 7.32 million tons of other agricultural products with a value of $2.3 billion dollars shipped from Indiana in 1997. These products include crops such as soya beans, dried fruit, potatoes, vegetables, and flowers. The average length of these shipments was 149 miles. Among these products, 88.4% of tons (6.5 million) and 89.4% ($2.1 billion) of the value was shipped an average of 101 miles by single modes of travel. Truck shipments were 3.15 million tons (43%) with a value of $1.25 billion (53.8%) and averaged 99 miles per shipment. Rail modes accounted for about 2 million tons (27.2%) and $483 million (20.8%), and averaged 538 miles in shipment length. Water shipments also occurred, most along shallow draft, which accounted for 1.33 million tons (18.2%) and $344 million (14.8%), averaging 817 miles. Multiple mode shipments averaged 763 miles, while unknown modes averaged 226 miles.

These shipments were down slightly for Indiana in 2002. They amounted to 7.17 million tons valued at $1.9 billion, which were shipped an average of 158 miles. Truck modal share had increased to 58.9% of the tonnage and 73.3% of the value, while rail shares had dropped to 23.5% and 15%, respectively. Transfers by water also dropped in an absolute and share sense between 1997 and 2002. There were no shipments by multiple modes in 2002 based on the *CFS* of that year.

The attraction of other agricultural products to Indiana locations in 1997 was at 3,884,000 tons and this was valued at $1.574 million. Contrary to the grain case, other agricultural products saw a significant jump in tonnage and value at the time of the 2002 *CFS*. The value had risen to 2.019 million dollars on 5.252 million tons of products. The 207 mile shipment length would suggest that much of this originated outside of Indiana in 1997, but this was to increase even more in 2002 to 388 miles.

SCTG 04: Animal Feed and Products of Animal Origin

There were 6.76 million tons of animal feeds and similar products, valued at $2.44 billion, shipped an average of 105 miles from Indiana in 1997. This commodity group includes products such as feed for cattle, bird seed, and cat and dog food. Over 99% of this group moved as single mode shipments an average distance of 50 miles. Trucks accounted for 5.56 million tons (82.2%) worth $2.2 billion (90.3%), and moved an average of 43 miles. Rail modes accounted for 1.2 million tons (17.6%), $228 million (9.3%) in value and moved an average of 688 miles. What few multiple mode shipments there were averaged 1,074 miles, while other/unknown modes averaged 835 miles per shipment. By 2002 production had dropped to 3.91 million tons and $805 million. The truck modal share had dropped to 59.9%, and rail had increased to 34.3%.

The attraction of goods from this sector to Indiana destinations experienced a drop between the samples for1997 to 2002. In the former year the tonnage was 5.278 million tons compared to 3.997 million tons in 2002. The value of these shipments also dropped as would be expected; it was $2.1 billion in 1997 and $1.0 billion in 2002. The average shipping distance of 51 miles would suggest most origins were in Indiana.

SCTG 05: Meat, Fish, Seafood, and Their Preparations

A total of 1.1 million tons of meats and poultry, valued at $2.17 billion dollars, originated in Indiana in 1997. Almost all (99.5% of value and tonnage) were single mode shipments. Furthermore, as could be expected, almost all (99% of value and tonnage) was by truck. Shipments moved an average distance of 101 miles.

Shipments from this sector also dropped in 2002. Tonnage had decreased to 871 thousand tons, valued at $1.77 million. All of these shipments moved by motor carrier. The average length of haul was 142 miles.

The goods in this group sent to Indiana destinations increased significantly in value from 1997 to 2002. The values were $2.9 billion and $4.2 billion, respectively. The tonnage changed from 1.1 billion to 1.6 billion tons. The length of these moves increased over the 1997 to 2002 period from 136 miles to 188 miles.

SCTG 06: Milled Grain Products and Preparations, and Bakery Products

There were 3.66 million tons of this commodity group, worth $4.75 billion, shipped from Indiana origins in 1997. The group included products such as baked goods, wheat flour, malt, and pasta, which was shipped an average distance of 134 miles. Over 98% of the tonnage and value moved by single modes averaging 119 miles per shipment. Three million tons (82%) and $4.53 billion (95.5%) in value traveled an average of 116 miles by truck. Rail shipments moved an average of 662 miles and included 452,000 tons (12.3%) that were worth $116 million (2.4%). The minimal amount of water shipments (no exact data available) averaged 1,140 miles per shipment, while multiple mode shipments averaged 708. Changes in tonnages and values in 2002 were not very significant.

The attraction of milled grain products and other goods in this sector to Indiana nearly doubled in value and tonnage between the two *CFS* years. The value of shipments received was $2.4 billion dollars in 1997 and this had increased to $4.8 billion in 2002. Tonnage increased from 2.3 million tons to 4.4 million tons in 2002.

SCTG 07: Other Prepared Foodstuffs and Fats and Oils

This sector includes milk, cheeses, ice creams, juices, fats and oils, among a broad list of other foodstuffs. A total of 12.9 million tons of this group, valued at $7.73 billion, moved an average of 75 miles per shipment. Slightly less than 97% of this tonnage and 99% of the value traveled via single modes an average of 72 miles per shipment. Trucks accounted for 10.4 million tons (81%) and $7 billion (90%) of the group’s value. These shipments moved an average of 69 miles. Two million tons (16%), valued at $607 million (8%), moved an average of 829 miles via rail. An undisclosed amount of air shipments traveled 700 miles per load, while 1.0% ($78 million) of the goods total value was shipped by multiple modes an average of 575 miles.

The volume and value of this commodity group were up in 2002 to 16.1 million tons and $12.36 billion, respectively. The increase was picked up primarily by motor carriers, which increased their modal share to 87.1% of the tonnage and 95.9% of the value. Rail was responsible for most of the remainder.

Shipments of these goods to Indiana destinations were probably to a large extent from Indiana origins since the average shipping distance was only 79 miles. The value of such terminating shipments increased in value only slightly from $8.2 billion to $9.1 billion. The tonnage was 9.5 million tons in 1997 compared with 12.6 million tons in 2002. This suggests a significant drop in the value per ton.

SCTG 08: Alcoholic Beverages

Beers, wine and other alcoholic beverages amounted to 1.3 million tons worth $1.35 billion in 1997. These were shipped an average of 48 miles per shipment. Over 98% of value and tonnage traveled in single mode journeys, averaging 47 miles per shipment. Almost all of this commodity group (1.29 million tons and $1.3 billion of its value) moved 47 miles by truck per shipment. The undisclosed amount traveling on rail moved 1,006 miles per shipment. $16 million (1.2%) traveled 847 miles per shipment via multiple modes.

The volume and value of this commodity group dropped significantly in 2002 according to the *CFS* for that year. Tons were down to 303 thousand and value was down to $276 million, representing decreases of 77% and 80%, respectively, from their 1997 levels. Motor carriers moved this commodity group an average of 64 miles per shipment in 2002.

Shipments of alcoholic beverages to Indiana destinations dropped between 1997 and 2002, both in value and tonnage. In 1997 the value was $1.7 billion and by 2002 this had dropped to $867 million, a drop of nearly 50%. The tonnage of this product also dropped from 1.8 million tons in 1997 to 1.2 million tons in 2002. These shipments moved an average of 61 miles suggesting numerous origins for these shipments in Indiana. On the other hand this distance increased to 241 miles in 2002.

SCTG 09: Tobacco Products

Only 31,000 tons, valued at $561 million, of tobacco products were shipped from Indiana origins an average of 45 miles per shipment in 1997. Over 99% of the value and tonnage were by single modes an average of 40 miles, almost exclusively by truck. Multiple mode shipments averaged 415 miles, almost all reportedly occurring by mail service.

By 2002 motor carriers had captured all of this traffic. Traffic production was up in 2002 to $1.1 billion, while tonnage had dropped to 16,000 tons. Average length of shipment was nearly the same (39 miles).

Tobacco product shipments to Indiana destinations in 1997 were 48,000 tons valued at $948 million. These shipments have dropped significantly to 22,000 tons, but the value of shipments has actually increased to $1.1 billion. The average length of shipment was 179 miles suggesting out of state origins for most of the shipments. This distance value increased to 304 miles in 2002.

SCTG 10: Monumental or Building Stone

There was 535,000 tons of monumental and building stone worth $561 million dollars shipped an average of 45 miles per shipment in 1997. Over 99% of the value and tonnage moved by single modes, and averaged 40 miles per shipment. Almost all of these shipments were by truck. An undisclosed amount of multiple mode shipments averaged 145 miles per shipment.

By 2002 shipments had dropped significantly. In fact the shipments were so low that nothing was reported in 2002 except for the average shipment length of seven miles. We do know that truck remained the dominant mode, but the data collected was considered too unreliable for publication. This probably indicates a loss of market share for this sector of Indiana's economy. It has been under significant pressure from various concrete manufacturers.

The value of monumental and building stone shipped to Indiana destinations was suppressed in 1997 and 2002. We do know that the weight of these shipments was 476 million tons, but once again the smaller sampling rate misses this industry for 2002. The industry continues to be viable for specialized construction needs.

SCTG 11: Natural Sands

A total of 6.7 million tons of natural sands valued at $27 million was shipped an average of 24 miles from Indiana origins in 1997. This would suggest that most of the traffic also terminated in Indiana. No tonnages are disclosed, but $22 million worth moved by single modes for 25 miles per shipment. Of this amount 76.8% ($20.8 million) was shipped by truck an average distance of 25 miles. Water shipments, meanwhile, traveled 237 miles, while multiple modes traveled 474 miles per shipment.

This sector saw some growth and by 2002 the tonnages had increased to 14.7 million tons valued at $62 million. Motor carriers moved 100% of this traffic and average of 15 miles per shipment.

The shipment of natural sands to Indiana destinations nearly doubled in value and tonnage for the two *CFS* years. The value increased from $57 million in 1997 to $103 million in 2002, on tonnages of 8 million tons and 16 million tons, respectively. Average length of these shipments was 59 miles suggesting mostly in-state origins.

SCTG 12: Gravel and Crushed Stone

Almost 81 million tons of gravel and crushed stone with a value of $456 million was shipped from Indiana origins in 1997. The average shipment length was 24 miles so this is also a product group usually destined for Indiana. More than 98% of the tonnage (80 million tons) and 97% of the value ($446 million) were shipped by single modes an average distance of 22 miles. Most of this is by truck (77.5 million tons or 95.7% and $432 million or 94.8%) an average distance of 22 miles per shipment. Shallow draft water modes accounted for 2.6% of the tonnage and 3.1% of the value shipped, averaging 359 miles per shipment. Multiple mode shipments averaged 447 miles.

Both the tonnage and value of gravel and crushed stone shipments dropped in 2002. The new values were 73 million tons and $402 million. Trucking continued as the dominant shipping mode with 94.3% of the tonnage.

Shipments of this low-valued product to Indiana destinations dropped between 1997 and 2002 from 82 million tons to 71 million tons, with decreases in total value from $466 million to $418 million. Shipment length was about 34 miles which is consistent with the low value of the product. This distance dropped to 20 miles in 2002 *CFS*.

SCTG 13: Nonmetallic Minerals

In 1997 nonmetallic minerals, which includes limestone, clays, and salt and other such minerals, accounted for 7.56 million tons with a value of $204 million. Of this 98% of the tonnage and value were shipped by single modes an average of 57 miles. Of the total 7.4 million tons (98.2%) worth $189 million (92.5%) were shipped by truck, with an average distance of 56 miles. Undisclosed rail shipments averaged 1,667 miles per shipment, while multimodal shipments averaged 310 miles.

Although the value of these shipments was up in 2002 to $415 million, other data on tonnages and mode shares were considered too unstable statistically to report.

Shipments of non-metallic minerals to Indiana destinations amounted to 10 million tons in 1997, valued at $295 million. These shipments were valued at $411 million in 2002, but the tonnage value was withheld. It is reasonable to infer that the tonnage of these shipments increased in 2002. Most of these shipments would be between Indiana locations as the average shipping distance was about 98 miles.

SCTG 14: Metallic Ores and Concentrates

There is very limited information about the shipment characteristics for metallic ores and concentrates (usually iron ores in Indiana's case) for 1997. We only know that average travel distance shipped by for-hire truck is 396 miles, while multiple modes and other and unknown modes averaged shipping distances of 166 mile and 276 miles respectively. This may very well indicate shipments of foreign origin being counted as originating at an Indiana Great Lakes port.

In 2002 the tonnage shipped was 66 thousand tons, valued at $73 million. Motor carriers control most of this traffic with a 99% share of both tonnage and value. The average length of these shipments was 318 miles.

Shipments of these ores to Indiana destinations come for the most part from outside of the state, except for the port case above. The state really has no indigenous metallic ores except for those it receives from other areas and then may transship from one Indiana location to another. The value of these shipments was $295 million in 1997 and this increased to $558 in 2002. The values also increased from 13.5 million tons in the former year to 17.6 million tons in the latter year. Shipping distances increased substantially from 263 miles to 446 miles.

SCTG 15: Coal

There was 24.19 million tons of coal valued at $552,000 million shipped from Indiana origins in 1997. The average shipment length was 33 miles. Approximately 85% of the tonnage and 87% of the value was shipped by single modes, averaging 33 miles per shipment. There were 3.6 million tons (15%) and $62 million (11.3%) shipped by truck and average of 30 miles per shipment. Coal is a major product moved by rail in the U.S. and in the case of Indiana it accounted for 16.86 million tons (69.7%) worth $416 million (75.3%) for which the average shipping distance was 109 miles. The multiple mode shipments averaged 120 miles, with no disclosed value and tonnage data available.

For 2002 the total coal moved is nearly the same with differences being accounted for by changes in energy demand for heating or cooling. Total tonnage moved was 23.45 million tons valued at $477 million. Rail lost some modal share by 2002. It moved about 52% of the tonnage and trucks picked up 36.5% of this traffic. Average length of shipments was 82 miles by truck and 60 miles by rail, which is counter to the general tendency for these modes.

Shipments of coal to Indiana destinations averaged 76 miles in 1997 (and 94 miles in 2002), most likely representing shipments from the southwestern part of the state to other state destinations. The tonnages of 50.2 million tons in 1997 and 62.2 million tons in 2002 reflect increasing demand in the state. The value of these shipments increased from 1 billion dollars in 1997 to 2.6 billion dollars in 2002.

SCTG 17: Gasoline and Aviation Turbine Fuel

A total of 20 million tons, valued at $4.6 billion dollars, originated in Indiana, with an average shipping distance of 40 miles. Almost all (99.9% of the value and tonnage) were single mode shipments. Of the total, 86.2% of tonnage ($17.27 million tons) and 87.1% of value ($4 billion dollars) were shipped by truck an average of 40 miles. No further data were offered.

By 2002 the tonnage had increased to 30.8 million tons with a value of $8.2 billion. Approximately 43% of the tonnage moved by motor carriers and the remainder moved by pipeline. Average length of shipments in both cases was 29 miles.

There was a substantial increase in the value of these shipments to Indiana destinations between 1997 to 2002 of $5.8 billion to $10.1 billion. Tonnages also increased from 35.4

million tons to 39.5 million tons, but this increase is low compared to the doubling of value reflecting the higher price of these goods in 2002. Shipping distances increased from 29 to 39 miles.

SCTG 18: Fuel Oils

A total of 14.14 million tons of fuel oil, valued at $2.7 billion, originated in Indiana in 1997. Almost all (99.9% of the value and tonnage) were single mode shipments. 68.1% of the tonnage (9.6 million tones) and 70.3% of the value ($1.9 billion dollars) were shipped by truck. The average shipment length by water and air are 2 and 543 miles respectively, and there is no further information available for 1997.

Motor carriers increased their modal share in 2002, but they lost traffic. Tonnages dropped in 2002 to 8.6 million tons and $2.1 billion in total. Trucks picked up 85.8% of this traffic with rail and pipelines sharing the rest.

Shipments of fuel oil to Indiana destinations actually dropped between the two *CFS* years. These were 16.4 million tons in 1997 and 11.3 million tons in 2002. The value of these shipments also decreased from $3 billion in 1997 to 2.6 billion in 2002. Shipment length of 19 miles would suggest these were mostly movements from pipelines in Indiana to Indiana distributors. The value remained low at 26 miles in 2002.

SCTG 19: Coal and Petroleum Products

Indiana shipped 26.5 million tons of coal and petroleum products, valued at $3.3 billion dollars in 1997. This commodity group includes lubricating oils, liquified natural gas, asphalt, and similar products. The shipments for this group averaged 46 miles. Almost all of the value and tonnage (99.6% of value and 99.7% of tonnage) were single mode shipments with an average shipment distance of 45 miles. Among the total shipments of this commodity, 17 million tons (6.9%) and $1.95 billion dollars (59.7%) were shipped by truck. No other number is available for the rail, air or pipeline shipments except the average distance of 157 miles per air shipment.

In 2002 the tonnages were up. A total of 30.8 million tons valued at $3.4 billion was shipped. Trucks handled 63.5% of the tonnage, while rail handled 8.2%. The residual was picked up by air, pipeline, water and multiple modes in small enough amounts not to be reported.

Shipments of coal and petroleum products to Indiana destinations dropped only slightly between the two years. These were valued at $3.7 billion in 1997 and this dropped to $3 billion in 2002. Tonnages dropped slightly from 27.5 million tons to 25.1 million tons. Shipping distances averaged 53 miles and this would suggest primarily internal movement of these products within the state. The increase in this distance in 2002 to 81 miles does not change this conclusion.

SCTG 20: Basic Chemicals

Almost 7.65 million tons of basic chemicals with a value of $1.74 billion were shipped from Indiana in 1997. This commodity group includes a host of chemicals and chemical compounds including among others bases, acids, phenols, and industrial gases. More than 99% of the tonnage (7.6 million tons) and 97.6% of the value ($1.7 billion) were shipped by single modes. About 3.8 million tons (50%) and $1.35 billion dollars (77.4%) were shipped by truck, with an average distance of 43 miles. Another $241,000 (13.8%) was shipped by rail with tonnages and average shipping distances unavailable, but it is know that the average distance for air shipments was 1,180 miles. About $32 million (1.9%) of value was shipped by multiple modes, with undisclosed tonnage or average shipping distance.

Tonnages had dropped significantly by 2002. In that year the total tonnage shipped was 4.3 million tons valued at $2.4 billion. Of these tons, approximately 46% moved by rail, and most of the remainder moved by truck except for a small amount moved by air. Truck shipping distances were an average of 272 miles in comparison to the air average of 1,886 miles.

Shipments of chemicals to Indiana destinations decreased over the two years examined here. Tonnages were 7,505,000 in 1997 and 3,469,000 in 2002; the value of these in 1997 was $2.3 billion and $1.8 billion in 2002. The average shipping distance in 1997 was 189 miles which would suggest that these are coming primarily from out of state. By 2002 this was more evident with an average shipping distance of 482 miles.

SCTG 21: Pharmaceutical Products

Indiana shipped 83,000 tons of pharmaceuticals in 1997 with an average shipping distance of 392 miles per shipment. Shipments going by single mode totaled 67,000 tons or 81% of the total weight shipped, with those shipments averaging 113 miles. Most of these were truck shipments (66,000 tons, 79.6%). The only data available for value reveal 1.35 billion dollars in private truck pharmaceutical shipments. There was also 297 million dollars (2.7% of all value) shipped by air, traveling an average distance of 424 miles per shipment. In addition, 14,000 tons (17.3%), with a value of 965 million dollars, were shipped by multiple modes an average distance of 595 miles.

Traffic in pharmaceuticals was up in 2002. Shipments totaling 235,000 tons, representing a three-fold increase, were reported. Value of these shipments was reported at $6.1 million. Motor carriers remained the dominant carrier with 91.4% of the tonnage moving an average of 323 miles. The remaining tonnage was moved by parcel post or couriers and averaged 363 miles.

The shipments having destinations in Indiana increased substantially between 1997 and 2002. These were 205 thousand tons in 1997 and 751 million tons in 2002. These are low tonnages, but one should bear in mind that we are talking about pharmaceuticals which have low weight. The value on the other hand increased from $4.9 million to $10.2 million. These shipments reflect a national pattern in that the average length of shipments is 728 miles. This distance had dropped substantially by 2002 and was 406 miles.

SCTG 22: Fertilizers

There were 2.74 million tons of fertilizers moved an average shipment length of 447 miles in 1997; its value was $626 million. Single modes accounted for 2.29 million tons, 83.5% of all shipments; these were valued at $562 million, nearly 90% of the total, and averaged 20 miles per shipment. Almost all single mode shipments (82%) were by truck. No further data is available with the exception of shipments made on shallow draft water, which averaged 1,140 miles. This accounts for the multiple mode average of 971 miles, though only 3,000 tons were shipped this way – a tenth of a percent of all shipments.

Tonnages more than doubled by 2002, when 5.86 million tons of fertilizers worth $1.1 billion originated in Indiana. Motor carriers moved 90.6% of this with lesser amounts moved by rail and water.

Shipments of fertilizers to Indiana destinations increased from 5.2 million tons in 1997 to 7.8 million tons in 2002. The value of these also increased from $1 billion to $1.4 billion in 2002. These shipments most likely went from distribution centers to retail outlets in that the average length of these shipments was 61 miles.

SCTG 23: Chemical Products and Preparations

A total of 1.37 million tons of chemical products and preparations, valued at $2.8 billion, originated in Indiana and moved an average of 271 miles in 1997. This commodity group includes products such as paints and varnishes, soaps, pesticides, perfumes and cosmetics, among others. Approximately 1.3 million tons (95.8%) valued at $2.36 billion (83.7%) traveled via single modes an average distance of 174 miles. Almost all of those shipments (94.1% of the total) moved by truck. What little rail traffic there was (values and tons were flagged), moved 2,314 miles per shipment. There were also some air shipments; these averaged 1,119 miles per shipment. There were also shipments involving multiple modes; these shipments averaged 376 miles.

This sector saw significant growth between 1997 and 2002 with the latter year having traffic production of 2.19 million tons, valued at $7.4 billion. Of this amount motor carriers moved 94.2% with lesser amounts moved by rail and some courier services. Average shipping distances overall were 199 miles.

Plastics and rubber shipments to Indiana destinations were 2.7 million tons in 1997 and represented $4.3 billion. In 2002 these numbers were 2.5 million tons and $5.4 billion suggesting an increase in the value of the product, but this could be due to a different mix of chemical products in the category. Shipping distances changed from 261 miles in 1997 to 255 miles in 2002 suggesting a rather stable situation.

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SCTG 24: Plastics and Rubber

In 1997 the total amount shipped of the plastics and rubber commodity group (which includes tires) was 2.3 million tons valued at $7.7 billion dollars; its average shipping distance was 344 miles. For this group 2.14 million tons (92.8%) and $6.5 billion (84.3%) of its value were shipped in single modes, which averaged 172 miles. Almost all of the total single mode shipments were carried by truck; a total of 2.11 million tons and $6.47 billion, averaging 164 miles, were shipped by truck. Rail shipments averaged 899 miles. There was a paucity of air shipments, with 3,000 tons (0.1%) valued at $28 million (0.4%) moving an average of 735 miles per shipment. There were 90,000 tons (3.9%) and $982 million (12.7%) of these products with an average shipping distance of 543 miles shipped via multiple modes, while unknown modes accounted for 3% of the goods shipped and averaged 55 miles in shipment length.

By 2002 the shipments of this commodity group had increased to 3.78 million tons with a value of $11.1 billion. The average length of haul for this commodity was 311 miles with 232 miles being the average length of motor carrier shipments. The latter mode handled 91.9% of the tonnage and 92.8% of the value of these shipments. Additional traffic moved by rail and air, as well as by multiple modes.

Shipments of plastics and rubber to Indiana destinations were fairly stable for the two years examined here. The value of these increased from $9.6 billion to $9.75 billion and the tonnages changed from 3.7 million tons to 3.8 million tons. The average length of shipments was 308 miles suggesting mostly out-of-state origins. The 2002 distance value was 376 miles.

SCTG 25: Logs and Other Wood in the Rough

Total tonnages and shipment lengths are not available for Indiana shipments even though these were valued at $101 million. Most of these shipments (in value at least) were by single mode trips (98.9%) with trucks accounting for $94 million (93.6%) of shipments. There were19,000 tons (4.3%) of shipments with a value of $5 million (5.3%) that moved an average of 878 miles per shipment by rail. There are no further data available for 1997.

The sector appears in the 2002 *CFS*, but except for some shipping distances there are no other data, i.e., there are no data for tonnages, value, or mode use for Indiana, due to the data collected being statistically unreliable.

The shipment of logs and other wood to Indiana destinations is not very significant and the comparative values for shipments are not available. It seems relatively stable based on available information.

SCTG 26: Wood Products

Over 3.2 million tons of wood products, worth $2.9 billion, originated in Indiana and were shipped an average of 242 miles in 1997. Of these totals 97% of the tonnage and 95% of the value traveled by single modes an average distance of 179 miles. Trucks dominated the modal choice; 91% of the value ($2.66 billion) and 94% of the tonnage (3 million tons) moved an average distance of 173 miles by that mode. Rail accounted for 98,000 tons (3% of the total tonnage) and $62 million (2.1% of the value) with those shipments averaging 1,442 miles. There were some air shipments of products and these averaged 935 miles per shipment. A small amount (22,000 tons and $83 million in value) averaged 731 miles per shipment via multiple shipment modes.

For 2002 both tonnages and values were higher: tonnages were 6.34 million tons and value was at $3.88 billion. Motor carrier shipments averaged 106 miles and carried 97.1% of the tonnage. A small amount of traffic moves by the multiple modes of rail and truck.

Shipment of wood products to Indiana destinations is significant with values in the range of $3.5 billion in 1997 and $4.0 billion in 2002. Tonnages for these years were 5.1 million tons and 7.0 million tons, respectively. The average shipping distance of 160 miles suggests a significant amount of out-of-state flow to Indiana destinations. This distance was 162 miles in 2002 suggesting once again a stable situation.

SCTG 27: Pulp, Newsprint, Paper, and Paperboard

A total of 1.36 million tons of this paper area, valued at $1.11 billion was shipped from Indiana origins an average of 529 miles in 1997. About 93% of the value ($1.03 billion) and tonnage (1.27 million tons) averaged 81 miles per shipment on single modes in Indiana. Also, 1.22 million tons (89%) and $977 million (88%) averaged 78 miles per shipment on truck modes. A small proportion of traffic moved by rail; this was 3.7% of the tonnage (51,000 tons) and $55 million (5%) of the value and it averaged 499 miles per shipment. Air shipments averaged 1,337 miles traveled, while multi-modal shipments (4,000 tons, 0.3% and $62 million, 5.5%) moved 870 miles per shipment.

Data from the 2002 *CFS* are withheld in most cases due to their unreliable nature, statistically. We only know that these products moved by truck, rail, and air, but more detailed data for the state is not available.

Shipments of pulp, newsprint and other items in this group to Indiana destinations represented $2.3 billion in 1997 and $2.3 billion as well in 2002. The tonnages for these two years were 3.3 million tons compared to the later value of 3.3 million tons. A fairly stable situation, but the average distances shipped increased from 164 miles to 258 miles.

SCTG 28: Paper or Paperboard Articles

Total tonnage of paper and paperboard articles was 1.55 million tons, valued at $2 billion, with an average shipment length of 253 miles in 1997. Of the tonnage 97% with a value of $1.89 billion) was transported on single modes an average of 117 miles per shipment. The vast majority of this group (96% of tons and 92% of the value) was shipped by truck an average distance of 111 miles. Undisclosed amounts of rail shipments averaged 2,442 miles and air shipments 665 miles. Just 7,000 tons (0.5%), valued at $39 million (2%) were shipped an average of 736 miles by multiple modes.

In 2002 the value of shipments increased to approximately $2.9 billion. Tonnages were withheld, but we do know that motor carriers accounted for 95.9% of the value transported. Additional traffic was moved by rail, air and multiple modes.

Shipments of paper and paperboard products to Indiana destinations increased slightly from $2.4 billion to $2.9 billion. Tonnage values were suppressed for 2002, but the value for 1997 was 1.5 million tons. Even the length of these shipments was rather stable at 168 and 142 miles.

SCTG 29: Printed Products

There were 2.53 million tons of printed products with a value of $10.9 billion dollars that originated in Indiana in 1997; these averaged 601 miles per shipment. Of this total 2.35 million tons (93%) valued at $9 billion (83%) was transported by single modes an average of 590 miles. Motor carriers transported 92% (2.33 million tons) of this category valued at $8.47 billion (77.7%) an average of 377 miles per shipment. Undisclosed amounts of air shipments averaged 1,263 miles. There were 4.7% (119,000 tons) and $1.36 billion (12.5%) shipped 651 miles by multiple modes, and 4.5% of the value ($494 million), shipped by unknown modes.

For 2002 originating flows dropped to 1.02 million tons valued at $3.2 billion. Of this amount, 91.4% moved by truck, a share similar to 1997, but with substantially less tons than the former year. Average shipping distances overall were 717 miles and for motor carriers 308 miles.

Shipments of printed products to Indiana dropped in value and tonnage between 1997 and 2002. The value for the former was $6.4 billion and this had dropped to $3.2 billion in 2002. The tonnages were 2.2 million in 1997 and 1 billion in 2002. It is difficult to assess whether this may be due to a difference in the manner in which these shipments were identified. The average length of these shipments was 358 miles in 1997 and 554 in 2002 suggesting a distribution of national origins.

SCTG 30: Textiles, Leather, and Articles of Textiles or Leather

SCTG 30 includes all of the goods in the title above, which includes textiles, yarns, carpets, luggage, footwear and some clothing. For this group 329,000 tons worth $6.2 billion originated in Indiana, and averaged 701 miles per shipment. Of the total 251,000 tons (76%) and $3.3 billion based on value (53%) moved as single mode shipments an average of 393 miles. Almost all of this was exclusively by truck, with an average distance of 373 miles per shipment. Undisclosed amounts of rail shipments averaged 1,119 miles, with air shipments averaging 699 miles. Multimodal shipments represented 68,000 tons (21%) and $2.75 billion (44%) of shipments averaging 723 miles, all of which appears to be by mail.

Tonnages increased for total traffic produced for this group in 2002. Total tons increased to 649,000 tons valued at $10.96 billion. Trucks carried 81.2% of this traffic and air and multiple modes (parcel, USPS, and courier) were responsible for the remainder. Average length of shipments for trucks was 187 miles, for air 1,790 miles and for parcel and related traffic it was 875 miles.

Shipments with destinations in Indiana were valued at $5.5 billion in 1997 and these increased to $8.9 billion in 2002. The tonnages involved also increased from 422,000 tons to 664,000 tons between these two years. The average length of shipments of 577 miles suggests that this is an industry moving goods from import locations. By 2002 this distance had increased to 595 miles.

SCTG 31: Nonmetallic Mineral Products

There were 19 million tons of nonmetallic mineral products (e.g., cements, glass products, and ceramic products) worth $3.5 billion dollars that originated in Indiana in 1997. It averaged 500 miles per shipment. There were18.9 million tons (99.6%) and $3.3 billion dollars (94%) of this group that moved by single modes, with an average shipment distance of 144 miles. Motor carriers transported 94.4% of the tonnage (18 million tons) and 92.8% of the value ($3.26 billion) an average of 141 miles. Shipments by rail represented 5.2% of the tonnage (990,000 tons) and $50 million of the value (1.4%). Undisclosed amounts of air shipments averaged 1,045 miles. There were also 58,000 tons (0.3%) valued at $172 million dollars (4.9%) transported by multiple modes with an average travel distance of 809 miles.

For 2002 tonnages had increased to nearly 32 million tons valued at $3.4 billion. Of these shipments 98% of the tons were handled by trucks, 1.8% by rail, and the remainder moved by air or multiple modes.

Non-metallic mineral shipments with destinations in Indiana increased from 17.4 million tons in 1997 to 30.8 million tons in 2002. In spite of this significant increase in tonnage the value of these shipments only increased from $3.0 billion to $3.1 billion. The average length of shipments was 243 miles in 1997 and 206 miles in 2002.

SCTG 32: Base Metal in Primary or Semi-finished Forms and in Finished Basic Shapes

There were 39 million tons transported from Indiana origins in 1997. This commodity group, which includes iron, steel, copper, and aluminum forms, was valued at $24 billion, and was shipped an average of 275 miles. Approximately 92% (35.8 million tons) of the commodity valued at $22.4 billion (93.7%) were shipped on single modes that averaged 227 miles. Of these shipments 65.5% or 25.5 million tons woth $17.5 billion dollars (73.2%) were by truck and had an average shipment length of 203 miles per shipment. Rail hauled 10.3 million tons (26.3%) worth $4.8 billion (20.2%) an average of 626 miles. An undisclosed amount of air shipments moved an average of 1,271 miles per shipment, while multiple modes averaged 690 miles per shipment.

By 2002 shipments had increased to 42.5 million tons, but the value had dropped to $23.3 billion. These commodities moved an average of 232 miles. Of this total tonnage, 69% moved by truck, 22.3% moved by rail, with air, water, and multiple modes picking up the remainder. Shipments by truck averaged 191 miles, by rail 692 miles, by water 1,360 miles, and by air 784 miles.

Base metal forms and shapes shipments to Indiana decreased in value between 1997 and 2002; these values were $15.2 billion in the earlier year and $13 billion in the latter year. Tonnages also decreased. It dropped from 22.6 million tons to 19 million tons. Shipment length was 225 miles in 1997 and dropped to 202 miles in 2002.

SCTG 33: Articles of Base Metal

Three million tons of base metal articles worth $6.6 billion moved an average shipment length of 226 miles in 1997. This commodity group includes everything from nuts and bolts to pipes and hand tools. Approximately 96% of the tonnage, valued at $6 billion (90.4%) was shipped by single modes an average of 230 miles, and 94% of the tonnage (2.9 million tons) with a value of nearly $6 billion (89.4%) was shipped an average of 217 miles by truck. Non-disclosed rail tonnages moved an average of 1,773 miles per shipment, and air modes averaged 988 miles per shipment. Multiple modes accounted for only 23,000 tons (0.7%), but $437 million (6.6%) of shipments and averaged 319 miles per shipment. Truck and rail mode shipments averaged 2,135 miles.

By 2002 this group had increased only slightly to 3.1 million tons valued at $8.3 billion.

Of the total tonnage, 91.4% moved by rail, with air, rail, and multiple modes picking up the remainder. Average shipment length by truck was 384 miles per shipment. Shipments by rail were shorter than in 1997 while shipments by air had increased in length.

Base metal articles with destinations in Indiana increased slightly in value and weight between the two census years. The shipments increased from 3.2 million tons to 3.5 million tons and the values increased from $6.4 billion to $7 billion. Shipping distances were high with an average of 280 miles in 1997 increasing to 341 miles in 2002.

SCTG 34: Machinery

This commodity group includes all types of machinery ranging from refrigerating equipment and air conditioners, to dishwashers and power tools, and boilers as well as turbines. There were 2.5 million tons of these goods shipped in 1997 with a value of $17.5 billion; average shipping distance was 461 miles per shipment. Among those, 2.25 million tons (88.6%) with a value of $14.25 billion (81.5%) were transported via single modes, with an average shipping distance of 383 miles. Trucks shipped 88.1% of the tonnage (2.23 million tons) and $14 billion (80%) of the value on average 151 miles. Undisclosed rail shipments averaged 1,331 miles, and multiple modes averaged 585 miles in shipment length. There were 7,000 tons (worth $245 million) shipped by air freight an average of 1,475 miles.

Shipments of this commodity group had increased to 3.5 million tons, valued at $30 billion by 2002. Of this tonnage 84.2% moved by truck, 2.1% by rail, and 3.6% moved by multiple modes. The length of shipments increased for trucks to 249 miles, and for rail it dropped to 829 miles.

Shipments of machinery ending in Indiana increased in value from $14 billion to $18 billion and the tonnages changed from 2 million tons to 2.1 million tons. Shipping distances were about 208 miles in 1997 and 264 miles in 2002 suggesting a Midwest origin for most of these Indiana bound shipments.

SCTG 35: Electronic and other Electrical Equipment and Components and Office Equipment

Two million tons of various types of electronics and electronic equipment worth $18 billion were transported an average of 268 miles per shipment in 1997. Of this 90.7% (1.9 million tons) with a value of $14 billion (78.7%) were transported an average of 150 miles by single modes. Most of transport was by truck, with 1.8 million tons (88.4%) valued at $13 billion (73%) moving an average distance of 129 miles per shipment. Another 30,000 tons (1.5%) were shipped by rail an average of 1,144 miles, while 14,000 tons (0.8%) worth $837 million (4.7%) were shipped on average 1,197 miles by air. Multiple mode shipments accounted for 7.5% (157,000 tons) valued at $3.3 billion (18.2%) with an average shipment length of 406 miles.

Shipment tonnages had dropped to 1.6 million tons as its worth increased to $23.2 billion in 2002. Of the various modes, trucks were dominant with 79.1% of the tonnage and 53.2% of the value. Multiple modes were also important with parcel, USPS and courier moving 10.1% of the tonnage and truck and rail moving 9.2% of tonnage.

Electronics and electrical equipment shipments that had a destination in Indiana increased from 1.564 million tons in 1997 to 1.569 million tons in 2002, practically no change at all. On the other hand the value of these shipments increased substantially from $15.8 billion to $24.8 billion. Shipment lengths decreased from 347 miles to 265 miles suggesting more local origins for these goods in the Midwest.

SCTG 36: Motorized and Other Vehicles

Indiana shipped nearly 8.4 millions tons of motorized and other vehicles valued at $35 billion an average of 278 miles per shipment in 1997. This commodity group includes road-based motor vehicles ranging from bicycles to tractors, including all cars, trucks, and even combat vehicles. Most of the tonnage (85%) and the value (73%) were shipped by single modes an average of 173 miles. Trucks accounted for 6.1 million tons (73%) and $24.2 billion (73.3%) of shipments. These moved an average of 129 miles. Rail shipped 12% of the tonnage but 3.6% of the total value. These moved 603 miles per shipment. Multiple mode shipments occurred for 4% of the tonnage but nearly 10% of the value, while 11% of the tonnage and 17% of the value were shipped by unknown modes an average of 62 miles.

Traffic production increased for this sector in 2002 with 12.2 million tons valued at $56.6 billion. Trucks moved the majority of this tonnage (73.8%) and value (67.1%), but rail was also significant with 11.9% of the tonnage and 5.9% of the value. Average shipment distances for these two modes were 207 and 604 miles, respectively. Multiple modes were important in 4.1% of the moves by tonnage and 9.6% of the moves by value. Truck and rail multiple moves were the most significant of these.

Motor vehicles and the parts for these that were shipped to destinations in Indiana represented $24.6 billion in value in 1997 and $38.2 billion in 2002. The tonnages changed from 4.8 million tons to 6.8 million tons. The length of shipments changed from 162 miles to 186 miles, which is not a significant change.

SCTG 37: Transportation Equipment

This commodity group includes aircraft, spacecraft, and locomotives, as well as parts for these. There was $2.35 billion in transport equipment shipped from Indiana an average of 528 miles in 1997. Single modes handled 62.8% of that value, shipments averaging 528 miles, while the remaining 37.2% was handled by multiple modes and averaged 954 miles per shipment. No data are available on tonnages for 1997.

Data were not available on this group for Indiana in 2002 due to small sample size and statistical unreliability.

Shipments into Indiana are available and these increased in value from $734 million for 1997 to $2 billion in 2002. Tonnage in 1997 was 98,000 tons, but the 2002 value was not reported. The average length of these shipments changed from 503 miles to 724 miles suggesting some of these may be coming from port areas.

SCTG 38: Precision Instruments and Apparatus

The precision instruments included in this commodity group include cameras, photocopy machines, X-ray machines, and scientific measuring equipment. Only 62,000 tons of these instruments accounted for $3.1 billion in freight flow originating in Indiana in 1997. These were shipped an average of 692 miles per shipment. A third of the value traveled 338 miles by single mode, while nearly $2 billion (61.6%) weighing 10,000 tons (16.8%) traveled 780 miles in multiple mode shipments. An undisclosed amount of air shipments averaged 1,007 miles per shipment.

By 2002 the tonnage had dropped to 34,000 tons, but the value had increased to $4.1 billion. Average shipment distance remained about the same at 741 miles. Approximately 95% of the shipments were by motor carrier or parcel, USPS, or courier.

Precision instruments shipped to Indiana destinations were down in terms of tonnage dropping from 123,000 tons to 107,000 tons between 1997 and 2002, but the value of these shipment increased from $3.2 billion to $7.2 billion. Shipping distances increased from 627 miles to 938 miles suggesting shipments from more distant locations, possibly port areas.

SCTG 39: Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs

The title of this group is fairly descriptive of its content. In 1997, $3.8 billion of furniture commodities weighing 676,000 tons originated in Indiana and were transported an average of 409 miles per shipment. Approximately 87% of this tonnage and 92% of this value were in single mode shipments averaging 366 miles. Trucks were used for most of this transport, with $3.5 billion and 586,000 tons (91.8% and 86.7%, respectively) being transported 352 miles per shipment. Multiple mode shipments accounted for 5% of the value and 2.5% of the tonnage, averaging 869 miles in shipment length.

Shipped tonnage remained nearly the same in 2002 at 660,000 tons. The value of these increased to $4.6 billion. Motor carriers increased their modal share to 98.6% of the tonnage and 97.4% of the value in 2002. The little remaining tonnage moved by rail, air, and multiple modes.

Shipments of these goods to Indiana destinations increased from about $2 billion to $3.4 billion. Tonnages increased from 247 miles to 425 miles, which may reflect a further decrease in the furniture industry within Indiana. Tonnages increased from 481,000 tons to nearly 746,000 tons.

SCTG 40: Miscellaneous Manufactured Products

This group of products that doesn't seem to fit anyplace else includes arms, munitions, toys, sporting equipment, clocks and prefabricated buildings. These products accounted for 3.2 million tons worth $12.8 billion and averaged 522 miles per shipment. Of the total tonnage 95% and 83% of the value were transported 345 miles in single mode shipments. Trucks accounted for 2.85 million tons (89.5%) and $9.9 billion (76.8%) of shipments, averaging 324 miles per load. An undisclosed amount of rail shipments averaged 952 miles per shipment, while multiple mode shipments averaging 612 miles accounted for only 2% of the tonnage but 14% ($1.8 billion) of the value.

In 2002 the tonnage was a little less, slightly more than 2.8 million tons, valued at $12.6 billion. Of these totals, 95.5% of the tons and 91.7% of the value was transported by truck. The remainder of this traffic was carried by multiple modes. Average shipping distances were 387 miles by truck and 667 miles by multiple modes.

Shipments of this catch-all group with destinations in Indiana decreased from 2.4 million tons to 1.4 million tons; the value of shipments did not change. The length of the shipments increased slightly from 637 mile to 706 miles.

SCTG 41: Waste and Scrap

Waste and scrap includes slag, ash, sawdust and paper. In 1997 there were 8.4 million tons of this valued at $1.5 billion that originated in Indiana. Of this amount 42.5% of the tonnage moved by truck and 57.5% moved by rail. In terms of value this situation was reversed with trucks handling 61.8% and rail handling 38.1%. Average shipping distances for the two modes were 117 miles for trucks and 130 miles for rail.

This traffic increased in 2002 to 9.9 million tons, but its value remained the same at $1.5 billion. Trucks increased their modal share handling 51.6% of the tonnage and 72.1% of the value transported. Rail continued as the second mode in this area with 38.9% of the tonnage and 21.5% of the value shipped. Average shipping distances were about 120 miles by the two modes combined.

Shipments of waste and scrap destined for Indiana locations increased in value from $2.5 billion to $4.7 billion. Tonnage in 1997 was 10.5 million tons, but not reported in 2002. The average shipping distance dropped from 134 miles to 70 miles.

SCTG 43: Mixed Freight

In 1997 mixed freight was moved almost entirely by motor carriers. It represented 478,000 tons by weight and $1.4 billion in terms of value. They handled 99.2% of the tonnage and 98.0% of the value of these shipments. Shipments by parcel, USPS, and courier picked up most of the remainder. The Truck moves were 66 miles in length on the average and the parcel moves were 246 miles in length.

In 2002 the tonnage had increased to 8.7 million tons, 18 times its value in 1997. Value had increased to $29.4 billion, 21 times its value in 1997. Most of this continued to be moved by truck transport which accounted for 98.7% of the tonnage and 97.1% of the value. Once again parcel, USPS and courier accounted for most of the remainder. Shipments averaged 468 miles in length for this latter group and 78 miles for truck.

Shipments of mixed freight having a destination in Indiana in 1997 represented 1.5 million tons and $2.6 billion. In 2002 these were 7.3 million tons and $20 billion. This is a phenomenal increase by any standard. The length of these shipments dropped from 238 to 208 miles.

Intermodal Facilities in Indiana

The Ports

Indiana has a total of six maritime ports; two along the Ohio River which eventually leads to the Gulf of Mexico by way of the Inland Waterway System, and four on Lake Michigan which gives access not only to the Inland Waterway System, but also to the rest of the Great Lakes, as well as to the Atlantic Ocean by way of the St. Lawrence Seaway. Only three of these ports are intermodal facilities, and these will be examined further in this section. Maritime ports are vital to Indiana’s economy in that they are a major mode of transportation for heavy industrial goods, agricultural products, and stone and other minerals.

The **Clark Maritime Center** in Jeffersonville, Indiana is located on the north shore of the Ohio River across from Louisville, Kentucky. Built in 1985, it is reportedly the fastest growing port on the Inland Waterway System.

This port offers year round access to the Gulf of Mexico via the Inland Waterway System, service for many different general cargo products, and on-site storage for up to 1.6 million bushels of grain. This port is also a site of intermodal transportation with direct linkages to rail and highways, and two airports within fifteen miles. Additionally, on-site switching services for cargo on boats and rail are offered here.

The Clark Maritime Center has 962-acres with 20 tenants, 3,200 linear feet of riverfront access, and is classified as a Foreign Trade Zone. The goods most often handled at this port are steel, iron, grain, fertilizer, salt, and asphalt.

The **Southwind Maritime** Center in Mount Vernon, Indiana is located on the north shore of the Ohio River fifteen miles west of Evansville, Indiana. It is a top port in throughput tonnage, handling an average of more than 2 million tons of cargo each year. This port also offers year round access to the Gulf of Mexico via the Inland Waterway System, including the Mississippi and Tennessee-Tombigbee Waterway Systems.

This port offers storage facilities for general cargo, bulk commodities, and specialized agricultural commodities including a 4.75 million bushel capacity grain elevator, three million-gallon liquid fertilizer storage tanks, and a covered storage facility with the capacity to hold up to 85,000 tons of dry fertilizer. The Southwind Maritime Center also offers advanced material handling equipment such as a 60-ton 760-foot bridge overhead crane, container handling equipment, and a 50-inch 5-ton electromagnet. Additionally, stevedoring, handling, tug, towing, fleeting, and switching services are offered on site.

Finally, the Southwind Maritime Center also has 745 acres with eight tenants, 7,500 feet of riverfront access, and is classified as a Foreign Trade Zone. The goods most often handled at this port are grain, soybean products, coal, fertilizer, cement, and minerals.

Burns Harbor in Portage, Indiana is located on the south shore of Lake Michigan, just 18 nautical miles from Chicago. This port has a 27-foot draft with a special design that allows ships to dock and turn around at the port, and it is capable of simultaneously berthing up to ten ships.

Access to the Gulf of Mexico via the Inland Waterway System and to the Atlantic Ocean via the St. Lawrence Seaway is offered at Burns Harbor. This port also offers twelve modern shipping berths, as well as services for cargo and ships. These services include the capability of handling heavy-lift project cargo, metals, grain, chemicals, fertilizers, and coal. Tenant ship services include tug, barge, fleeting, railroad switching, waste disposal, sanitation, security, and fire protection. Burns Harbor is capable of handling Great Lakes bulk carriers up to 1000 feet in length, as well as saltwater vessels that are capable of transiting the locks on the Great Lakes and St. Lawrence Seaway system.

This port has 530 spaces with more than 30 tenants, and is classified as a Foreign Trade Zone. It is also an intermodal transportation site with service by the Indiana Harbor Belt Railroad, and close proximity to several interstate highways and airports. The goods most commonly handled at Burns Harbor are iron, steel, grain, chemicals, fertilizers, limestone, coal, and heavy-lift project cargo.

Intermodal Rail Facilities

Intermodal rail facilities seem to be very efficient, but there is significant ambiguity in identifying their use and effectiveness due to unclear data. It has been speculated that more of these sites do not exist in Indiana because the majority of the cargo traveling through Indiana originates or terminates in the adjacent states of Michigan, Ohio, Kentucky, and Illinois. This means that traditional intermodal rail facilities are put at a service and cost disadvantage because of the short line-haul distances to adjacent states. However, new bimodal technologies have presented a low-cost structure, and certain Indiana intermodal rail facilities are reaping the benefits.

The Clark Maritime Center in Jeffersonville and Burns Harbor in Portage, as mentioned above, are both sites of intermodal transportation which are capable of handling cargo sent by boat, rail, and truck. Both of these facilities are near airports with cargo handling and shipping capabilities as well.

The Clark Maritime Center provides rail service through the Louisville Indiana Railroad Co. and CSX with interchanges to several other major rail lines, including Canadian Pacific, Norfolk Southern, CN, KCS, BNSF, and Union Pacific. This facility also has an intraport short line capable of allowing on-site switching through M.G. Rail.

Burns Harbor provides rail service through the Indiana Harbor Belt Railroad, Norfolk Southern, CSX, and South Shore Railroad. Indiana Harbor Belt Railroad is the largest switch carrier in the nation. At Burns Harbor, Indiana Harbor Belt Railroad owns 54 miles of main track, as well as 266 miles of yard and siding track.

Several other intermodal rail facilities exist in Indiana which have the capability of handling and transferring cargo between rail and truck only. These sites are the Conrail's Avon Yard west of Indianapolis, the Howell Yard in Evansville, Norfolk Southern Triple Crown Facility in Fort Wayne, the General Motors Roanoke Facility near Fort Wayne, and the Toledo, Peoria and Western Hoosier Lift at Remington. For the most part, these facilities handle containerized bulk cargo. At the GM Roanoke Facility and the Hoosier Lift Facility, intermodal services are generally carried out by contracted third-party companies, such as the Hub Group, Inc.

The intermodal rail facility at **Avon Yard** west of Indianapolis occupies 25 acres of land with room for possible expansion. It has two eastbound and two westbound intermodal trains. Eastbound service dominates, going to Boston and Springfield, MA; Philadelphia, PA; and Syracuse, NY. Westbound service to East St. Louis, however, is minimal. This site offers a total of ten origin-destination pairs, including those just mentioned as well as four in Canada. Avon Yard performed 24,000 lifts in 2001 with its main customer being United Parcel Service sending significant volumes to its Worcester, MA and Little Ferry, NJ sort centers. The equipment split is even at 50 percent containers and 50 percent trailers.

The **Howell Yard** intermodal rail facility in Evansville occupies 17 acres of land with no room available for expansion. It has one northbound and one southbound intermodal train operating between Chicago, IL; Nashville, TN; Atlanta, GA; and Jacksonville, FL. In 2001, Howell Yard performed 23,000 lifts, and the terminal is currently operating at 75 percent capacity. Howell Yard's major inbound customer is water-rail container traffic to Toyota, Inc, and its major outbound customer is Whirlpool, Inc., to the southeast and west coast. The equipment split is 65 percent containers and 35 percent trailers. This site offers many more origin-destination pairs than the intermodal rail facility in Avon, serving a total of 39 origin-destination pairs. CSXI offers service between Evansville and Bedford Park in Chicago, the largest rail hub in the United States, with a line haul of under 300 miles, and no direct Interstate Highway alternative.

The **Norfolk Southern Triple Crown Facility** in Fort Wayne uses a new carless, bimodal trailer technology called RoadRailer®. RoadRailer® combines truck and rail line haul movement. The Triple Crown Service has a fleet that consists of 5,500 trailers that are all 53 feet long and 102 inches wide with slack-free coupling for movement. Typical train size is 73 units, but the Federal Railroad Administration has authorized the operation of trains of up to 155 units. There are a total of eleven origin-destination pairs from Fort Wayne, including sites in Canada and Mexico. The principal commodity market is automotive parts, and the highest to Ft. Wayne is to and from Atlanta, GA; Kansas City, MO; and Harrisburg, PA. Other commodities served by TCS include appliances, paper, and food.

The Toledo, Peoria and Western Railway operates the **Hoosier Lift** intermodal rail facility in Remington, Indiana. In 2001, Hoosier Lift performed only 5,000 lifts with an annual capacity of 35,000 lifts. This intermodal rail facility is underused mostly because it competes with Chicago's 26 rail hubs.

Intermodal rail service expansion in Indiana is possible in the future if the facilities were to use technologies such as RoadRailer® by Norfolk Southern's Triple Crown Services Inc. or *Expressway* by Canadian Pacific which have a significantly higher cost and service advantage than conventional intermodal rail services. It remains to be seen whether Indiana will upgrade its intermodal rail facilities to accommodate these new services.

Air Freight Facilities

Indianapolis International Airport, Indianapolis, Indiana

Indianapolis International Airport was built in 1931. Currently, it covers 7,700 acres and has one terminal with 33 gates. It is owned by the Indianapolis Airport Authority and managed by BAA, the world's largest airport management company. Indianapolis International Airport is the largest privately operated airport in the United States. In 2003, the airport ranked 8th in U.S. all-cargo landed weight, handling over 2.2 million tons of cargo, and ranked 88th in U.S. freight gateway handling of international merchandise valued over $1 billion, trading over $2.6 million in freight. A major user of this airport is FedEx, which has its own terminals on the site.

Fort Wayne International Airport, Ft. Wayne, Indiana

Baer Field Air Base was built in Fort Wayne in 1941 and was used as a World War II military base. After having its name changed several times, in 1991, the Airport Authority changed its name to Fort Wayne International Airport. It is currently owned and operated by the Fort Wayne-Allen County Airport Authority. Fort Wayne International Airport is considered a medium sized airport, and between 2001 and 2003, it handled an average of 360 million tons of cargo. The Air Trade Center at Fort Wayne International Airport offers 450 acres of industrial space. It also has ten T-hangars available to small single or light twin engine planes. In 2003, this airport was ranked 36th in the US in all-cargo landed weight, handling over 374,000 tons of cargo.

South Bend Regional Airport, South Bend, Indiana

South Bend Regional Airport was built in 1929. It is currently operated by the St. Joseph County Airport Authority. In 2003, South Bend Regional Airport handled 7,431 tons of cargo. The majority of the freight traffic handled at the airport is from FedEx, Airborne Express and UPS. Currently, South Bend Regional Airport is working to complete a project to lengthen its runways to allow for increased commercial traffic. It recently acquired 250 acres for this expansion project, which will be finished by the end of 2006.

O'Hare International Airport, Chicago, Illinois

Originally, O'Hare International Airport was a military base named Orchard Field. In 1946, the Chicago Municipal Airport (Midway) bought Orchard Field from the U.S. government and renamed it in honor of naval pilot Butch O'Hare who was killed in World War II. O'Hare Airport was used predominantly by the military until the mid 1950's when it first opened its doors to domestic commercial flights. Today, O'Hare International Airport covers 7,700 acres, has four terminals with 178 gates and 7 runways. It is operated by the Chicago City Department of Aviation. In 2004, Chicago O'Hare International Airport handled nearly 457,000 tons of domestic freight and over 957,000 tons of international freight, totaling over 1.4 million tons of freight. Goods are shipped to and from more than 140 domestic and 30 international non-stop destinations, serviced by 22 airlines. O'Hare is an important hub for Delta and American Airlines, as well as shipping companies. The airport also has a large capacity for storing cargo. The Southwest Cargo Facility dubbed "Cargo City" covers 240 acres and offers 1.2 million square feet of enclosed storage space. The O'Hare Express Center was the first private development on O'Hare property; it covers 50.2 acres and includes five buildings offering a total of 850,000 square feet of storage space. O'Hare International Airport ranked 7th in 2003 for all-cargo landed weight, handling over 2.35 million tons of cargo, making it the seventh busiest cargo moving airport in the United States.

Cincinnati/Northern Kentucky International Airport in Covington, Ohio

Cincinnati/Northern Kentucky International Airport was built in 1943 as an alternative to Lunken Airfield which was prone to flooding. Currently, it covers 7000 acres with three concourses and three terminals, totaling over 100 different flight gates. It is operated by the Kenton County Airport Board. Delta and Comair are the two main passenger airlines servicing the airport. Both of these airlines have over 50 gates each, making Cincinnati/Northern Kentucky International Airport the largest facility of its kind in the world. Not only does this airport handle large amounts of passengers, but it also handles large amounts of freight: over 2 billion tons 2003. In 1984, DHL opened its package-sorting hub at Cincinnati/Northern Kentucky International Airport. Following a series of expansions, DHL opened a new hub on the airfield in 2003 that covers 150 acres. This allows DHL to handle up to two million pounds of cargo nightly with enough ramp space to park more than 60 aircraft. The Bureau of Transportation Statistics ranked Cincinnati/Northern Kentucky International Airport 16th in U.S. all-cargo landed weight, handling nearly 1.1 million tons of cargo in 2003.

Cincinnati Municipal Airport in Cincinnati, Ohio

Originally named Lunken Airfield, Cincinnati Municipal Airport was built in 1925. It currently covers 2,000 acres in Cincinnati near the Little Miami River, and has been prone to flooding in the past. It is owned by the City of Cincinnati and is operated by the Aviation Division of the Department of Transportation and Engineering in conjunction with PB Aviation. Freight traffic to this airport is light, as it serves mostly as a general and corporate aviation facility and as a reliever airport to the Cincinnati/Northern Kentucky International Airport. In 2002, Cincinnati Municipal Airport handled over 500 tons of freight. This freight is primarily comprised of cancelled checks and small packages, flown by AirNet and OnFlight Express. Cincinnati Municipal Airport also offers aircraft engine service and repair, aircraft interior services, aircraft sales, leasing, charter and courier services. The airport also has plans for future expansion to accommodate more passenger and cargo traffic.

Louisville International Airport, Louisville, Kentucky

Standiford Field, a World War II air base, was built in 1941. In 1947 it was sold to its current operator, the Louisville Air Board, and was immediately made into a commercial passenger airport called Louisville Airport. United Parcel Service, the largest private employer in Kentucky, makes up the majority of the airport's cargo. Louisville International Airport has many professional facilities and amenities to handle massive amounts of specialized cargo, including mechanical handling, heated storage facilities, the ability to handle hazardous and dangerous goods. The airport also boasts an Express Courier Centre, and has a limited amount of parking space for large transient aircraft. The Airport Authority began plans for expansion in 1988, including new east and west parallel runways, a new Kentucky Air National Guard Base, a new United States Postal Service air mail facility, new corporate hangars, a new fixed-based operator, a four-level parking garage, and a new control tower. In 2003, Louisville International Airport ranked third in all-cargo landed weight, handling over 4.1 million tons of cargo; four times the amount of cargo handled by Indianapolis International Airport, the country's 8th busiest cargo handling airport.

Intermodal Flows

We have not focused on intermodal flows in the report that follows. It may be a significant proportion of total flows in the United States, but it is not that significant when it comes to Indiana. Let us look at this briefly here.

According to the 1997 Commodity Flow Survey (*CFS*) the shipments leaving Indiana that moved by multiple modes represented 10.7% of the value of all goods. This makes it sound significant, but when we look at the tonnages involved it is about 2.2%. This includes all parcel, courier, and postal moves, truck/rail moves, truck/water moves, rail/water moves, and unknown multiple modes. For the 2.2% of multiple mode moves we know that 0.2% is parcel moves, but the samples drawn of other modal pairs were so small that the data were viewed as unreliable. If we move to flows of specific commodities, there is nothing reported in most cases.

As for 1997 shipments arriving in Indiana we know that 10.9% of the value of the shipments is via multiple modes, but only 6.3% of the tonnage. More specifically the truck and rail moves represent 1.0% of the value and an undisclosed amount of the tonnage, probably something around 0.5% of the value.

In the 2002 *CFS* shipments by multiple modes represented a total of 11.1% of the value of Indiana shipments, but 8.6% of this value was for parcel and similar moves. Truck and rail flows represented 2.2% of the value. The tonnage moving by multiple modes dropped in 2002 from its 2.2% in 1997 to 1.6% of the tonnage in 2002.

Again the 2002 picture is actually less clear. We know 11% of the value of the shipments received arrives by multiple modes, and about 5.3% of the tonnage. The sampling of this area is undoubtedly something that could be improved upon, because the value of the intermodal rail/truck moves is 0.1% of the total. The tonnages, actual or percentage, are not revealed and probably come out significantly less than that.

In effect, we have not looked at the intermodal rail/truck flows originating in Indiana because the sector seems of minor importance based on the data available from the 1997 and 2002 *CFS*. Of course there is always the possibility that the sample used by the *CFS* is not picking up the volumes correctly.

There may be anecdotal evidence that a significant amount of intermodal rail/truck traffic arrives in Indiana. Even if the *CFS* is significantly understating the value and tonnages, we have no way to improve this. The *CFS* is the best data source available. If we were able to work with the general multipliers developed here and discussed later, we would not have sufficient data to work with once this was distributed across 41 different commodity groups.

We suspect that we are picking up some of the intermodal flows in the form of simply rail traffic, we have no way of knowing this for sure and as a result this type of flow has not been treated any differently than rail flows here.

Exports and Imports Related to Freight Flows

Although it is beyond the scope of the present study and clearly beyond the data published by the Commodity Flow Survey (*CFS*) on which this study is based, there is a natural interest in the extent to which exports and imports play a role in the flow of goods to, from, and within the state of Indiana. The way in which such flows are treated in the *CFS*, is worth noting here.

Freight that is being shipped to a port or other site for export appears in the *CFS* as a flow from the state of origin to the state of export. Therefore export flows leaving Indiana by rail and destined for the port of Norfolk, Virginia, and further transshipment to a nation in Europe are treated as flows from Indiana to Virginia. Flows leaving by aircraft from Indianapolis that are destined for a nation in Africa are treated as flows beginning and ending in the state of Indiana. In effect, this is an internal or intrastate shipment. Likewise a container of merchandise from Beijing arriving at the port of Los Angeles-Long Beach in California prior to a West Coast warehouse, followed by its shipment by motor carrier to Indianapolis is treated as a flow from California to Indiana. All of this is rather unsatisfactory if you really care about origins and destinations and Indiana's role in international trade. It is unlikely that we can satisfy all the readers of this document in this matter, but we will try to improve on the situation somewhat. The reader should bear in mind that we will be using estimates for much of what follows.

Export Flows

Of the total goods exported from the United States, Indiana was responsible for 2.4% of the value. This amounted to $21.5 billion dollars in goods in 2005 and this was a 12.4% increase over 2004. Of these exports the dominant commodities were transportation related components and pharmaceuticals and medical-related supplies. The former would most likely move by rail or truck, while the latter might very well be shipped as air freight. These two broad classes of goods accounted for more than 49% of the value of exports.

The major destinations for exports from the state of Indiana are not unexpectedly Canada (44.5%) and Mexico (12.2%) in terms of value. These shipments would be primarily surface moves and would most likely appear in the *CFS* as shipments to Michigan in the former case and shipments to Texas in the latter case.

Other export destinations that comprise the top ten destinations are the United Kingdom (7.1%), France (6.8%), Japan (3.6%), Germany (3.2%), Netherlands (2.0%) and China (1.9%). These countries along with Canada and Mexico represent more than 80% of the destinations for Indiana exports in terms of value.

The heavier exports to European destinations would most likely move from the ports of New York or Norfolk, Virginia, to Rotterdam, Bremerhaven, or Antwerp in container ships. Of course higher value goods (such as pharmaceuticals) would probably be shipped by air.

Those exports destined for Asia would most likely pass through the port of Los Angeles and Long Beach, since they handle 70% of the West Coast transpacific traffic. The other choices are Oakland and Seattle/Tacoma, but these handle only about 20% of the traffic. The receiving port on the Asian side is determined by the final destination of the exports. Hong Kong continues to be very dominant for China, Pusan for South Korea, and Kobe for Japan.

Import Flows

While the export picture is rather clear, the import picture is not. We can speak of the estimated value of goods being imported, but even this requires certain assumptions. If we assume that Indiana consumes goods as a straight proportion of its population to the total U.S. population then we can make some estimates. This is not an all an unreasonable assumption since the state is proportionally quite similar to the U.S. as a whole and it is primarily consumer goods that are being imported in many cases.

In this case the leading source of imports for Indiana would be Canada with 17.2% of the value. China is second with nearly 14.6% of the total value. This would be followed by Mexico with 10.2% of the value, Japan with 8.3%, Germany with 5%, the United Kingdom with 3.1%

and Korea with 2.6%. Let us look briefly at what is being imported from these areas to the U.S.

Our best estimate of the value of these imports (in billions of U.S. dollars) arriving in Indiana (based on 2005 data) is as follows: Canada (6.1), China (5.1), Mexico (3.6), Japan (2.9), Germany (1.8), the U.K. (1.1) and Korea (.9). The increasing dominance of China as an import source is the major change over the last decade.

For Canada the major U.S. imports are transportation equipment (26.9%), energy-related products (23.0%), forest products (9.8%), and minerals and metals (8.9%). China's picture is quite different with electronics accounting for the major share of its exports to the U.S. (35.7%). Miscellaneous products of manufacturing are the second most common import from China (19.1%), followed by textiles (11.1%) and machinery (8.8%). Mexico's leading export to the U.S. is also electronics (23.7%), followed by transportation equipment (20.3%), energy-related products (14.8%), and machinery (11.9%). Japan's exports to the U.S. are dominated by transportation equipment (45.2%), followed by electronics (22.9%), and machinery (13.5%).

Most of above imports would move by motor carrier or possibly rail. Goods coming in from Europe are not very significant in comparison to the Asian trade. The impact of the latter trade on West Coast ports is quite significant and this can impact firms in Indiana in terms of congestion delays preventing ships from being unloaded. The major Asian ports involved in shipments to the U.S. would continue to be the same as those receiving shipments.

Summary

In this chapter we have summarized the attributes and trends related to the forty-one commodity groups examined in this study using a combination of data from both the 1997 and the 2002 *Commodity Flow Survey*s. We can not examine longer term trends since the data for 1993 are not comparable with the newer classification systems.

Also summarized here are the major transportation facilities of the state of Indiana including its port facilities, airports, and intermodal facilities and terminals.

We also examined the intermodal (rail/truck) flows in Indiana commodity productions and attractions. It was noted that in terms of tonnages, in other words traffic, this represents a very small amount of the total volume of goods leaving or entering the state of Indiana. It was also noted that we have no way of improving this situation and as a result this type of flow has not been examined here specifically. Instead this portion of the shipments has been combined with rail shipments.

We closed this chapter with some discussion of the role of exports and imports originating and terminating in Indiana. We have focused primarily on goods based on their value. In the export case Indiana leads with transportation related equipment and pharmaceutical-related products. Imports are being dominated by consumer goods from Asia.

Indiana DOT planners should carefully monitor the development of bridge tables being prepared that will enable one to translate STCC data into SCTG data. If this were available then it would be possible to work with the STCC data of the Carload Waybill Sample and treat it as SCTG data. At present such tables are crude at best and will not provide reliable estimates.

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Chapter 4

THE GENERATION OF COMMODITY TRAFFIC

As noted in Chapter 1, one of the major efforts in the analysis of commodity flows is the identification of variables that influence the production and attraction of this traffic from and to the various state and county origins and destinations. These productions and attractions are referred to collectively as traffic generation. The traffic generation phase of this project was also negatively impacted by the manner in which commodity traffic and employment within industries is now categorized. These problems are worth some discussion at the outset.

Traffic Production

Commodity traffic production, the shipments that emanate from a given area for a given industry, is obviously a function of the amount of production or manufacturing that takes place in that industry within the area of interest. It is of primary interest to determine those factors that are related to this productivity and to model this process so that estimates can be made of future traffic. The usual way of approaching this type of modeling is to relate flow production for a given commodity to employment in that particular industry for the areas of interest.

In the previous flow study commodity traffic was available for the STCC (Standard Transportation Commodity Classification) system. Employment data in that earlier study was available for the SIC (Standard Industrial Classification) system. There were clear linkages between these two systems so that one could be relatively sure that the flows and employees were for the same sectors to a large extent for any given area. The changes in classification systems that occurred in the 1990s weakened this linkage. Flows are now available by SCTG (Standard Classification of Transported Goods) and employment is available for NAICS (North American Industrial Classification System) categories. The linkage between flows and employees is still present to some extent, but it is not as strong as it once was.

One might suggest that we revert to the previous approach and use the older data, but there have been far too many changes in the last twelve years to assume stability in the relationships identified at that time. In addition the models can not be revised because the necessary data are no longer published in the earlier format. If this were not enough, the SIC and NAICS systems are so different that it is not possible to set up a translation of one system into the other at the level at which data are available for planning purposes. One could make such a translation at the five-digit level, but this level of detail is not released to researchers or planners. As a result the project team was required to start from the very beginning and develop entirely new traffic production models for the 41 SCTG commodity flow groups.

The traffic production models developed appear on the following page of this report (see Table 4-1 and Table 4-1a). The data in these two tables as well as the data used in the attraction models are essentially the same. The second table in each case uses acronyms in place of the SCTG codes and the NAICS codes.

These models were derived by correlating each flow group with employment in each of the NAICS industrial groups examined. In addition, population was also examined as were all of the other flow sectors. In the case of population this indicates production occurring in response to consumer demand in the production area. The relationship to other flows would occur when an industrial complex is present and the commodities being shipped are representative of the magnitude of that operation's other related sectors.

The NAICS industrial sectors for which employment was used in the modeling appear as Table 4-2.

It should be noted that the flows used to develop the models are expressed in thousands of tons. Therefore, if one wishes to derive actual tons the decimal point for the regression coefficient should be shifted three places to the right. The N value in the table represents the number of states with data for both the dependent and independent variables that were used to develop the models. These vary from 12 to 46.

The models derived vary significantly in terms of accuracy and in several cases these are hardly what we would want in a research study, but the intent here is not perfectly accurate models. The objective is to get general relationships rather than focusing on the unique aspects of the relationship.

The relationships represented by the models in the table have been forced to have an intercept that runs through the origin. In other words when there are no employees in the industry noted there is no flow for the commodity of interest. This seems like a reasonable assumption. Nevertheless, several of the models are very poor and for this reason some of these were replaced by simply the ratio of employees to thousands of tons produced.

Traffic Attraction

The 1997 *Commodity Flow Survey* published the amount of traffic produced for each commodity in each state for that year. This enabled the project team to develop the traffic production models discussed in the previous section. Similar data were compiled for the traffic

Table 4-1 Production Models Developed

SCTG	Equation	N	R^2
01	0.003 (331) + .007 (337)	22	0.498
02	0.256 (311)	36	0.337
03	0.135 (311)	34	0.647
04	0.149 (311)	41	0.772
05	0.054 (311)	42	0.880
06	0.045 (311) + 0.027 (333)	43	0.853
07	0.000748 (Pop) + 0.141 (335) + 0.083 (311)	46	0.964
08	0.0002188 (Pop) + 0.013 (334)	46	0.882
09	0.009 (313) + 0.005 (337)	19	0.690
10	0.016 (422) + 0.0001118 (Pop) + 0.005 (331)	22	0.919
11	0.087 (421)	28	0.839
12	0.835 (326) + 1.145 (314) + 0.443 (311)	40	0.940
13	0.226 (325)	29	0.507
14	modeled using employment growth and productivity only		
15	7.34 (212)	30	0.604
17	7.812 (324)	44	0.873
18	4.017 (324)	45	0.939
19	3.388 (324) + 0.142 (325)	41	0.918
20	3.151 (324)	43	0.782
21	0.011 (337) + 0.007 (313)	35	0.793
22	0.00081 (Pop)	35	0.304
23	0.025 (332) + 0.017 (325)	44	0.790
24	0.912 (324)	46	0.709
25	0.667 (321)	21	0.518
26	0.544 (321)	44	0.826
27	0.225 (322) + 0.058 (324)	44	0.810
28	0.029 (311) + 0.015 (334) + 0.053 (314)	45	0.931
29	0.024 (422) + 0.040 (322)	43	0.946
30	0.101 (314) + 0.051 (313) + 0.058 (324)	44	0.970
31	0.002 (Pop) + 0.248 (311)	45	0.909
32	0.356 (331) + 0.080 (336)	45	0.911
33	0.030 (332) + 0.266 (324) + 0.033 (327)	45	0.949
34	0.019 (333) + 0.026 (326)	47	0.897
35	0.017 (332) + 0.074 (324)	46	0.913
36	0.061 (336)	44	0.798
37	0.008 (331)	33	0.620
38	0.001 (421)	39	0.826
39	0.020 (337) + 0.004 (336)	45	0.918
40	0.000183 (Pop) + 0.066 (314) + 0.022 (311)	39	0.946
41	0.099 (332)	37	0.931
43	0.0004 (Pop)	38	0.905

Table 4-1a Production Models Developed

SCTG	Equation	N	R^2
(Animals)	0.003 (MetProd) + .007 (Furniture)	22	0.498
(Cereals)	0.256 (Food)	36	0.337
(AgProd)	0.135 (Food)	34	0.647
(Food)	0.149 (Food)	41	0.772
(Meat)	0.054 (Food)	42	0.880
(BakedGds)	0.045 (Food) + 0.027 (Machinery)	43	0.853
(Foodstuffs)	0.000748 (Pop) + 0.141 (Appliances) + 0.083 (Food)	46	0.964
(Alcohol)	0.0002188 (Pop) + 0.013 (Electronics)	46	0.882
(Tobacco)	0.009 (Textiles) + 0.005 (Furniture)	19	0.690
(Stone)	0.016 (WholesaleN) + 0.0001118 (Pop) + 0.005 (MetalProd))	22	0.919
(Sand)	0.087 (WholesaleD)	28	0.839
(Gravel)	0.835 (Plastics) + 1.145 (TexProd) + 0.443 (Food)	40	0.940
(Minerals)	0.226 (Chemicals)	29	0.507
(Ores)	see Table 4-1		
(Coal)	7.34 (MinOres)	30	0.604
(Gas)	7.812 (Print)	44	0.873
(Oils)	4.017 (Print)	45	0.939
(OilProd)	3.388 (Print) + 0.142 (Chemicals)	41	0.918
(Chemicals)	3.151 (Print)	43	0.782
(Drugs)	0.011 (Furniture) + 0.007 (Textiles)	35	0.793
(Fertilizer)	0.00081 (Pop)	35	0.304
(ChemProd)	0.025 (FabMetal) + 0.017 (Chemicals)	44	0.790
(Plastics)	0.912 (Print))	46	0.709
(Wood)	0.667 (WoodProd))	21	0.518
(WoodProd)	0.544 (WoodProd))	44	0.826
(Newsprint)	0.225 (Paper) + 0.058 (Print)	44	0.810
(Paper)	0.029 (Food) + 0.015 (Electronics) + 0.053 (TexProd)	45	0.931
(Print)	0.024 (WholesaleN) + 0.040 (Paper)	43	0.946
(Textiles)	0.101 (TexProd) + 0.051 (Textiles) + 0.058 (Print)	44	0.970
(MinProd)	0.002 (Pop) + 0.248 (Food)	45	0.909
(BaseMetal)	0.356 (MetProd) + 0.080 (TranEquip)	45	0.911
(MetArticles)	0.030 (FabMet) + 0.266 (Print) + 0.033 (Minerals)	45	0.949
(Machinery)	0.019 (Machinery) + 0.026 (Plastics)	47	0.897
(Electronics)	0.017 (FabMet) + 0.074 (Print)	46	0.913
(Vehicles)	0.061 (TranEquip)	44	0.798
(TranEquip)	0.008 (MetProd)	33	0.620
(Instrument)	0.001 (WholesaleD)	39	0.826
(Furniture)	0.020 (Furniture) + 0.004 (TranEquip)	45	0.918
(MiscMan)	0.000183 (Pop) + 0.066 (314TexProd) + 0.022 (Food))	39	0.946
(Waste)	0.099 (FabMet)	37	0.931
(Mixed)	0.0004 (Pop)	38	0.905

Table 4-2 Employment Variables Used in Modeling

NAICS	Description
212	Minerals and Ores
311	Food Manufacturing
312	Beverages and Tobacco Products
313	Textiles and Fabrics
314	Textile Mill Products
315	Apparel and Accessories
321	Wood Products
322	Paper
324	Printing, Publishing and Similar Products
325	Chemicals
326	Plastics and Rubber Products
327	Nonmetallic Mineral Products
331	Primary Metal Products
332	Fabricated Metal Products
333	Machinery, Except Electrical
334	Computer and Electronic Parts
335	Electrical Equipment, Appliances, and Components
336	Transportation Equipment
337	Furniture and Fixtures
421	Wholesale trade, durable goods
422	Wholesale trade, nondurable goods

attracted. While the shipments out from an area are obviously related to industrial activity for that commodity in the origin area, the attraction of traffic is handled somewhat differently.

We know that commodities are shipped in response to demand by markets and that these markets have essentially two components. One of these is a consumer market that is often represented by population. The other market is an industrial market, and this is often represented by related industries. In other words, automobile parts are often sent to an area involved in the assembly of automobiles. Or they are sent to parts distributers who in turn supply these to local dealers. It is reasonable to expect that the models developed should be related to both the industrial market (represented once again by NAIAS employment sectors) and the consumer market as represented by population.

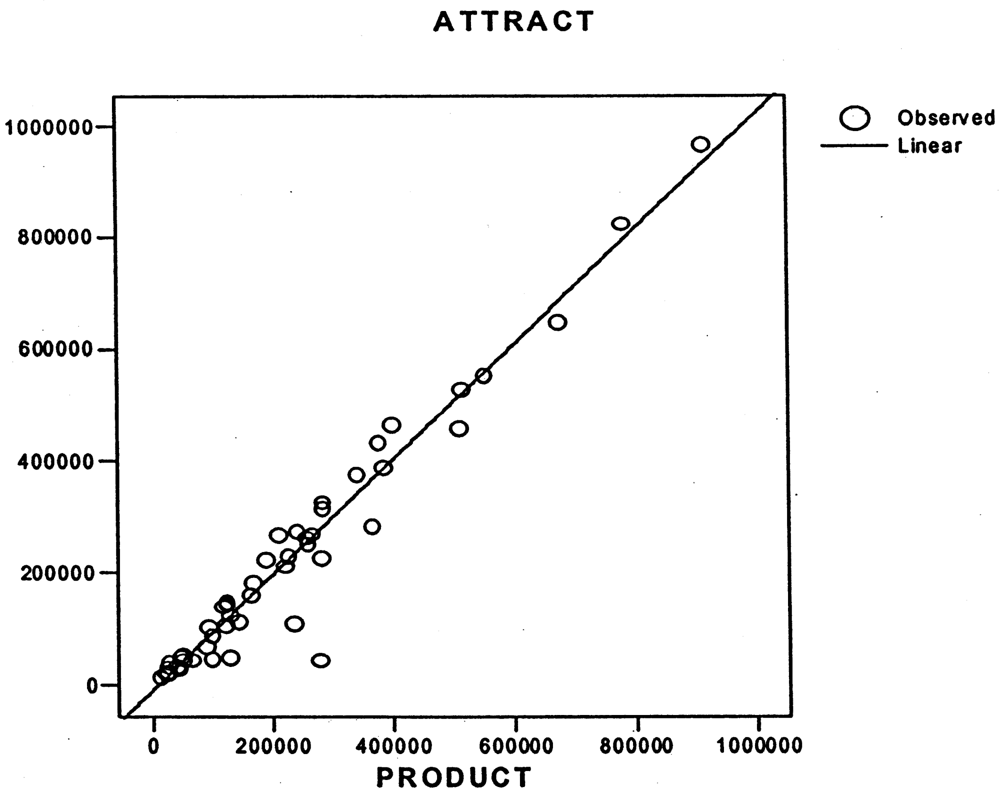
It is also understood that total productions are highly related to total attractions. This is reasonably well represented by the diagram below. This diagram is based on the total flow into each state and the total flow out of each state in tons for 1997. Unfortunately, as nice as this relationship is at the aggregate level, it does not hold with desegregation. For example, the states that are the largest shippers of coal are not the greatest importers of coal. Therefore, we will revert to the use of the earlier relationships between shipments and the industrial and consumer markets.

The models derived for traffic attraction appear in Table 4-3 and Table 4-3a. The estimates derived for all 41 SCAG groups for each of the 145 states and counties of the study can be found in Appendix A.

One technical point worth some discussion is related to the value of the coefficient of determination in the models derived. The models as noted used a zero intercept value in the model developed. This was done for a very practical reason. The value of the intercept could turn out to be negative and this would give an area a negative flow value in some cases. This is something very difficult to explain in a real world situation. Alternatively, the value of the intercept could be extremely large and when we are trying to estimate county flows, this would yield in most cases an unlikely value. So this is the reason for the zero intercept.

Returning to the interpretation of R^2 in these cases, it should be noted that the value of R^2 is not the ratio of an explained variance to total variances in the SASS regression routine. Rather it is a measure of variation about the origin, a notion that has little or no practical meaning. As a result a somewhat different approach was taken in this study. We have measured total variation and then measured how much of this can be explained by our model. This is not an OLS (ordinary least squares) model and therefore it is not a true R^2 value, but it can be interpreted as such. There is one possible flaw with this approach and that occurs when the model derived may be worse than simply using the mean value of the data series. The ramifications of this are that the R^2 value may exceed the normal range of -1 to +1. For the most part this was not a problem here. The modified values appear in Table 4-4 and 4-5.

Figure 4-1 Relationship of Total Productions and Total Attractions



Models Derived Discussion

The production and attraction models derived are not uniformly as good as might be desired. Looking over the production models one notes that the level of explanation on any criterion is not particularly good for those SCTG groups up through 15. These are agricultural or natural resource-based types of goods that are generally produced in states with good agricultural land or other natural resource endowments. Exceptions to this would be for foods and alcoholic beverages which may be for local markets. SCTG groups beyond 15 are often local market-oriented or industrial complex related. The worse models tend to be those where employment is not the best indicator of production or shipping capacity. The best example of this is the fertilizer industry (SCTG 22).

In general the attraction models tend to be much better that are related to consumer or industrial market sectors. Even here the models are not very good at the lower levels of the SCTG groups (1, 2, and 3, or live animals and fish, cereal grains, and agricultural products). Most of the other industrial or commodity sectors do much better, but fertilizer consumption is again low.

There is a clear need for some substantial research on the traffic generation models used in freight analysis. The models used in the earlier study tended to be much better. We suspect this was due to the close tie between the STCC and the SIC systems, which does not seem to be present between the SCTG and the NAICS systems. However, there are other potential sources of error. One of these may be due to the significant increase in the number of SCTG groups as compared to the STCC sectors. We now have nearly three times as many SCTG groups in comparison to the 15 or so STCC groups. This will tend to increase the possible sources of variance as well as error.

In addition to these points it should be apparent that some of the models don't make much sense on the surface. In particular the presence of employment in Print industries (NAICS 324) may bother some. We do not believe that this is a causal relationship so much as it is an associational variable. What this means is that in some cases the flows are clearly a causal function as is the case when we look at the generation of textiles flows as a function of employment in that industry and in the textile products industry. We do not believe the production of gasoline flows are causally determined by employment in the print industry, but we do believe that the Print variable may also be related to some higher level economic functions in an area and this is the basis for the association observed.

It might be desirable to not use such relationships, but that would be difficult to do since we have included all of the data we know of that is available on a county basis in our analysis. In other words there are no better economic variables available for use.Of course if those using these models find them completely unacceptable they could simply work with the data as published in 2002 and apply forecasted growth and expected increases in productivity to those values. This may be seen as being more effective than the approach we have used here although it would not yield estimates at the county level.

Table 4-3 Attraction Models Developed

SCTG	Equation	N	R^2
01	0.004 (311)	18	0.488
02	2.724 (324)	37	0.399
03	1.196 (324)	45	0.504
04	0.148 (311)	45	0.839
05	0.030 (311) + 0.00015 (Pop) + 0.0004 (336)	48	0.971
06	0.00018 (Pop) + 0.025 (311) + 0.022 (325)	47	0.980
07	0.000903 (Pop) + 0.068 (311) + 0.104 (322)	48	0.986
08	0.000250 (Pop) + 0.008 (334) + 0.023 (315) + 0.078 (312)	47	0.984
09	0.008 (313) + 0.004 (337)	44	0.732
10	0.015 (325)	22	0.688
11	0.00121 (Pop)	30	0.899
12	0.395 (311) + 1.237 (314) + 0.903 (331) + 2.003 (312)	41	0.966
13	0.338 (322)	37	0.628
14	0.172 (331)	29	0.651
15	3.472 (212) + 0.727 (311)	42	0.847
17	4.60 (324) + 0.00169 (Pop)	44	0.912
18	3.237 (324) + 0.110 (325)	47	0.943
19	2.936 (324) + 0.199 (325)	44	0.899
20	3.218 (324) + 0.050 (334)	46	0.865
21	0.006 (325) + 0.002 (422)	48	0.866
22	0.000653 (Pop)	40	0.372
23	0.000104 (Pop) + 0.208 (324) + 0.067 (314) + 0.026 (326)	47	0.965
24	0.041 (325) + 0.295 (324) + 0.027 (333) + 0.062 (314)	45	0.931
25	0.683 (321)	33	0.555
26	0.494 (321) + 0.391 (324)	47	0.908
27	0.043 (311) + 0.123 (322) + 0.122 (324)	47	0.970
28	.00007030 (Pop) + 0.017 (334) + 0.021 (311)	48	0.951
29	0.000295 (Pop)	45	0.964
30	0.000041 (Pop) + 0.079 (314) + 0.032 (313) + 0.058 (324)	47	0.983
31	0.001777 (Pop) + 0.227 (311)	47	0.918
32	0.315 (311) + 0.079 (336)	47	0.911
33	0.428 (324) + 0.035 (333)	46	0.927
34	0.015 (333) + 0.009 (336) + 0.013(325)	47	0.939
35	0.000076 (Pop) + 0.076 (324) + 0.011 (326)	48	0.957
36	0.053 (336)	48	0.860
37	0.035 (324)	39	0.723
38	0.000415 (421) + 0.001848 (314) + 0.000442 (422)	48	0.959
39	0.000068 (Pop)	48	0.899
40	0.000235 (Pop) + 0.031 (321) + 0.014 (313)	44	0.946
41	0.051 (332) + 0.066 (331) + 0.037 (311)	40	0.941
43	0.000356 (Pop) + 0.036 (314)	46	0.924

Table 4-3a Attraction Models Developed

SCTG	Equation	N	R^2
(Animals)	0.004 (Food)	18	0.488
(Cereals)	2.724 (Print)	37	0.399
(AgProd)	1.196 (Print)	45	0.504
(Food)	0.148 (Food)	45	0.839
(Meat)	0.030 (Food) + 0.00015 (Pop) + 0.0004 (TransEquip)	48	0.971
(BakedGds)	0.00018 (Pop) + 0.025 (Food) + 0.022 (Chemicals)	47	0.980
(Foodstuffs)	0.000903 (Pop) + 0.068 (Food) + 0.104 (Paper)	48	0.986
(Alcohol)	0.000250 (Pop) + 0.008 (Electronics) + 0.023 (Apparel) + 0.078 (BevTob)	47	0.984
(Tobacco)	0.008 (Textiles) + 0.004 (Furniture)	44	0.732
(Stone)	0.015 (Chemicals)	22	0.688
(Sand)	0.00121 (Pop)	30	0.899
(Gravel)	0.395 (Food) + 1.237 (TexProd) + 0.903 (MetProd) + 2.003 (BevTob)	41	0.966
(Minerals)	0.338 (Paper)	37	0.628
(Ores)	0.172(MetProd)	29	0.651
(Coal)	3.472(MinOres)+ 0.727 (Food)	42	0.847
(Gas)	4.60 (Print) + 0.00169 (Pop)	44	0.912
(Oils)	3.237 (Print) + 0.110 (Chemicals)	47	0.943
(OilProd)	2.936 (Print) + 0.199 (Chemicals)	44	0.899
(Chemicals)	3.218 (Print) + 0.050 (Electronics)	46	0.865
(Drugs)	0.006 (Chemicals) + 0.002 (WholesaleN)	48	0.866
(Fertilizer)	0.000653 (Pop)	40	0.372
(ChemProd)	0.000104 (Pop) + 0.208 (Print) + 0.067 (TexProd) + 0.026 (Plastics)	47	0.965
(Plastics)	0.041 (Chemicals) + 0.295 (Print) + 0.027 (Machinery) + 0.062 (TexProd)	45	0.931
(Wood)	0.683 (Print)	33	0.555
(WoodProd)	0.494 (WoodProd) + 0.391 (Print)	47	0.908
(Newsprint)	0.043 (Food) + 0.123 (Paper) + 0.122 (Print)	47	0.970
(Paper)	.00007030 (Pop) + 0.017 (Electronics) + 0.021 (Food)	48	0.951
(Print)	0.000295 (Pop)	45	0.964
(Textiles)	0.000041 (Pop) + 0.079 (TexProd) + 0.032 (Textiles) + 0.058 (Print)	47	0.983
(MinProd)	0.001777 (Pop) + 0.227 (Food)	47	0.918
(BaseMetal)	0.315 (Food) + 0.079 (TransEquip)	47	0.911
(MetArticles)	0.428 (Print) + 0.035 (Machinery)	46	0.927
(Machinery)	0.015 (Machinery) + 0.009 (TransEquip) + 0.013(Chemicals)	47	0.939
(Electronics)	0.000076 (Pop) + 0.076 (Print) + 0.011 (Plastics)	48	0.957
(Vehicles)	0.053 (Plastics)	48	0.860
(TranEquip)	0.035 (Print)	39	0.723
(Instrument)	0.000415 (WholesaleD) + 0.001848 (TexProd) + 0.000442 (WholesaleN)	48	0.959
(Furniture)	0.000068 (Pop)	48	0.899
(MiscMan)	0.000235 (Pop) + 0.031 (WoodProd) + 0.014 (Textiles)	44	0.946
(Waste)	0.051 (FabMet) + 0.066 (MetProd) + 0.037 (Food)	40	0.941
(Mixed)	0.000356 (Pop) + 0.036 (TexProd)	46	0.924

Table 4-4. Adjusted Explanation for Zero Intercept – Production

	SCTG	SST	SSRES	SSR	R2
1	1	1166941	775607	391334	.3354
2	2	9827651819	.	.	.
3	3	1153031012	770009907	383021105	.3322
4	4	1159600556	525666820	633933736	.5467
5	5	115482559	31110802	84371757	.7306
6	6	261104963	72943626	188161337	.7206
7	7	3347582999	239307632	3108275367	.9285
8	8	241101175	45218547	195882628	.8124
9	9	4156889	1414443	2742446	.6597
10	10	5013349	547792	4465557	.8907
11	11	1969509121	699715489	1269793632	.6447
12	12	53519615356	7797626545	45721988811	.8543
13	13	1292370633	959381123	332989510	.2577
14	14	2231103764	.	.	.
15	15	1E+011	64032284853	47888676984	.4279
16	17	50776097062	8915444006	41860653056	.8244
17	18	12442250317	1051040847	11391209470	.9155
18	19	13129166064	1488353040	11640813024	.8866
19	20	10741968486	276164077	10465804409	.9743
20	21	4865579	1442305	3423274	.7036
21	22	3074766229	2576471094	498295135	.1621
22	23	271928515	96279718	175648797	.6459
23	24	810930819	342894005	468036814	.5772
24	25	4517616409	390127271	4127489138	.9136
25	26	2341834550	754931076	1586903474	.6776
26	27	372275553	151924229	220351324	.5919
27	28	290317643	21806771	268510872	.9249
28	29	161513773	15046555	146467218	.9068
29	30	140550424	5238779	135311645	.9627
30	31	14165392706	2553742688	11611650018	.8197
31	32	5583958550	692111193	4891847357	.8761
32	33	309430014	27412385	282017629	.9114
33	34	85550293	13769523	71780770	.8390
34	35	46452607	6926158	39526449	.8509
35	36	747724756	194078542	553646214	.7404
36	37	1094080	656857	437223	.3996
37	38	221691	67529	154162	.6954
38	39	10595057	1594671	9000386	.8495
39	40	119378097	13516673	105861424	.8868
40	41	900314821	106666385	793648436	.8815
41	43	302110283	51264813	250845470	.8303

Table 4-5. Adjusted Explanation for Zero Intercept – Attraction

	SCTG	SST	SSRES	SSR	R2
1	1	.	.	.	.
2	2	121564576	111177105	10387471	.0854
3	3	197409801	141518894	55890907	.2831
4	4	1017483392	334379850	683103542	.6714
5	5	144569195	7922086	136647109	.9452
6	6	224918809	9082367	215836442	.9596
7	7	3154176610	93355445	3060821165	.9704
8	8	162735625	4954435	157781190	.9696
9	9	3050215	467194	2583021	.8468
10	10	4659047	2050195	2608852	.5600
11	11	2030884335	456419418	1574464917	.7753
12	12	52208285031	4266973688	47941311343	.9183
13	13	1134574594	686750896	447823698	.3947
14	14	583546684	273289209	310257475	.5317
15	15	30692834582	10030481693	20662352889	.6732
16	17	36503841716	4943518707	31560323009	.8646
17	18	10423849516	854355944	9569493572	.9180
18	19	12420089498	1732775018	10687314480	.8605
19	20	6889080187	1186847134	5702233053	.8277
20	21	2962599	670852	2291747	.7736
21	22	2655657653	2076398982	579258671	.2181
22	23	214571306	13708176	200863130	.9361
23	24	374735007	47608072	327126935	.8730
24	25	6183589921	4172934398	2010655523	.3252
25	26	2154010191	406623416	1747386775	.8112
26	27	375229029	23913761	351315268	.9363
27	28	270994045	15697566	255296479	.9421
28	29	158941322	10371117	148570205	.9347
29	30	85196165	2171640	83024525	.9745
30	31	13360778680	2205674433	11155104247	.8349
31	32	4378079421	594821297	3783258124	.8641
32	33	293609823	39464420	254145403	.8656
33	34	64782949	7250362	57532587	.8881
34	35	42257428	3252821	39004607	.9230
35	36	482172434	96246183	385926251	.8004
36	37	1077648	471241	606407	.5627
37	38	221533	16181	205352	.9270
38	39	8206145	1664656	6541489	.7971
39	40	137111674	15872566	121239108	.8842
40	41	832359522	63284863	769074659	.9240
41	43	274913997	31460707	243453290	.8856

Evaluation of the Models Developed

During the course of the study the results of the 2002 Commodity Flow Survey were released. Although it was beyond the scope of the project we were asked to take the models developed to that point using 1997 data and use these to estimate the value of the flows for the 2002 data and then to evaluate how close these were. This task was undertaken using the production models developed since these were the only ones available at the time.

The results of that analysis are displayed in Figure 4-2. The values along the vertical axis run from approximately .55 to nearly 1.0 and these reflect the values of the correlations obtained in the initial modeling, i.e., the cases where the models were fitted statistically to the 1997 data. In that case the values for the various NAICS employment variables were used to estimate the flows for the different SCTG groups. There were 36 models evaluated, and sample sizes were too small in the other cases.

The values along the horizontal axis represent the fits obtained when these exact same models were used to estimate the values for 2002. In other words the models derived from analysis of the 1997 data were applied to NAICS data for 2002 to yield estimates of the 2002 flows that were known from the newly released 2002 Commodity Flow Survey.

As one can see the values corresponding to the horizontal axis are not as large and several are quite small. On the other hand the clustering of values in the upper right quadrant of the diagram suggests the models are generally high. We would never expect the estimates to be better than the original fitted model although it does happen in one case here. This involves the estimate of gasoline flows which was .934 in the fitted model and .961 in the estimation of the 2002 data. This is a chance occurrence and should not be expected to occur.

Estimates at the Sub-County Level

The Indiana Travel Demand Model is actually used at the traffic analysis zone level (TAZ). It should be apparent to the reader that the entire analysis of freight traffic generation here was based on models that were derived using state-level data. These models once derived were then used to estimate the tonnages produced and attracted at the county level. We are still some way from the TAZ level since these are considerably smaller than the county level and this raises the question of how the state planners and their consultants can move from the county level to the TAZ level.

During the previous freight planning work in the 1990s the state made use of address-specific Dun & Bradstreet employment data. These data specify exactly what kind of industry is carried out at different locations. The employment in that industry can then be used to allocate a portion of the county's flows to the TAZ where that employment is located. Similarly on the attraction side the allocation can go to that TAZ that has employment in the sector that attracts the

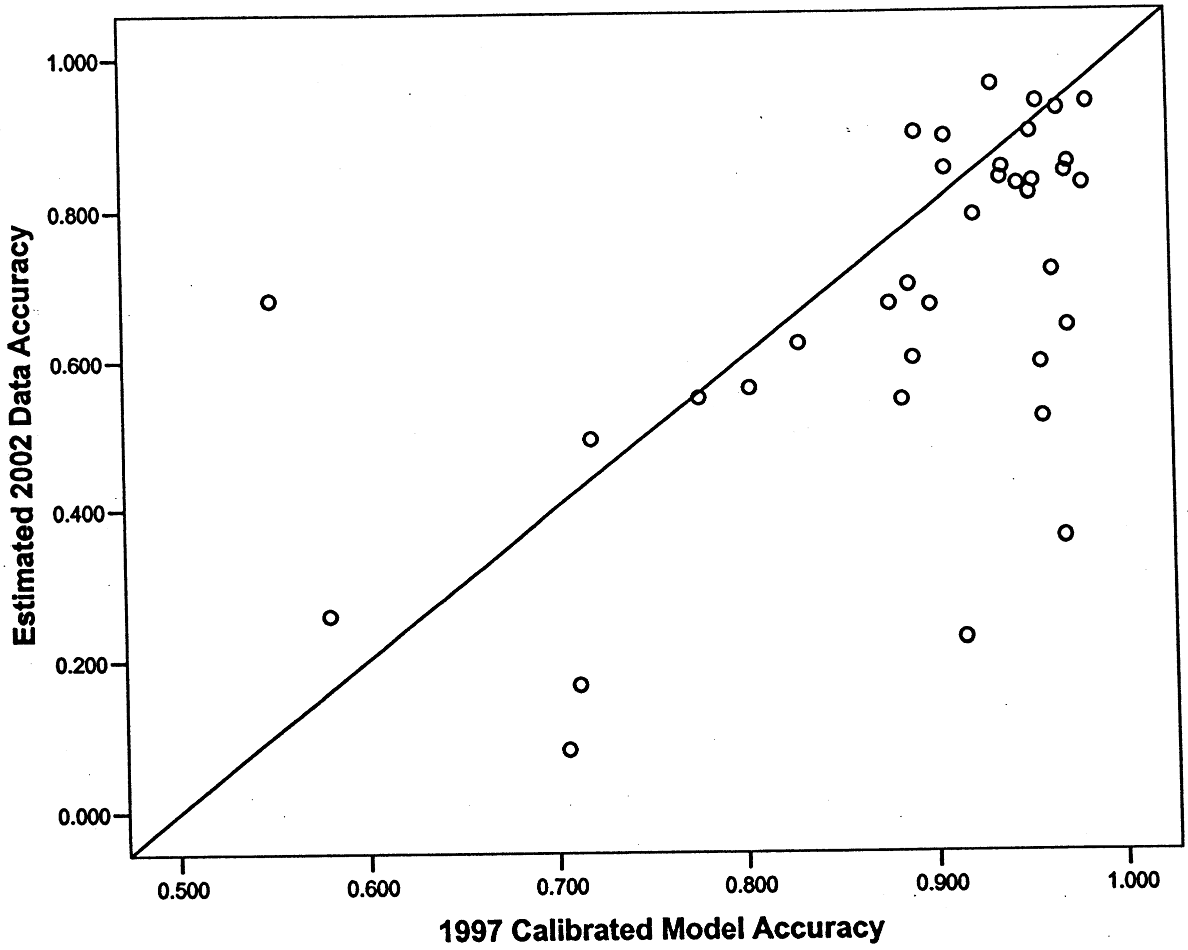


Figure 4-2. Evaluation of the 1997 Models with 2002 Estimates

flows. If the flows are consumer-oriented then the population of the TAZ can also be used to allocate attracted flows to a county to its sub-county TAZ units.

This approach seems to have worked reasonably well in the past so there is no reason to believe that it will fail to work now. Fortunately, those that did this portion of the analysis in the past are still available to the state.

Summary

This chapter has discussed the models developed for the freight traffic generation portion of this study. Production and attraction models developed for predicting the future volume of freight traffic originating or terminating were presented for all of the SCTG classes examined in this study. The independent variables from the NAICS groups were also identified. Attributes of the models and an evaluation of the models for 2002 were also discussed here. The chapter concludes by reviewing the basic manner in which the modeling could be used to estimate traffic production and attraction at the sub-county level.

Chapter 5

THE DISTRIBUTION OF COMMODITY TRAFFIC

Given the level of shipments emanating from the origin or production areas of interest and the level of flow attracted to the different destination or market areas, the next step is to model the volume of flow taking place between all origins and destinations. This modeling takes place for several reasons in this study, but in most studies we model current flows so that we can insert forecasted values into the model for some future time and estimate the volume of flows that should take place between the areas of interest at that point in the future.

This study took the known flows produced by the states of the US and the known flows attracted to a set of states and developed estimates for the remaining states for which data were not released. It also used these same models to estimate the traffic produced and attracted to the counties of Indiana. After addition of several nodes in neighboring states there was a possible 145 x 145 flow matrix to fill with flow estimates. There are different models that can be used for this purpose.

The models that can be used for distributing flows between origins and destinations today are almost exclusively models based on the gravity model. In general, that model states that the level of interaction between two areas is directly proportional to the product of their masses and inversely proportional to the square of the distance between them. Transport planners use the volume of flow produced and the volume of flow attracted as measures of the mass, and usually Euclidian distance as a measure of the distance or spatial separation between the areas. Rather than using the square of the distance, a power function, or in some cases an exponential function, is allowed to vary and the value selected is usually the one that yields the best fit to the data at hand.

In the 1997 study the flow model utilized was a fully-constrained gravity model. This model constrains the estimated flows in such a way that the total flows produced do not exceed the observed flows produced, and the estimated flows arriving at any given destination do not exceed the observed flows received at these locations. In addition, the average length of shipments generated by the model is constrained to be the same as the average length of the observed shipments.

The 1997 study evaluated the model results by looking at selected locations in the state to see if the volume of trucks at those locations were similar to the number of trucks estimated by the modeling and traffic assignment of such vehicles. This is at the very end of the modeling process at a point where the entire flow modeling and traffic assignment process would have to be repeated if it was found to have a large level of error.

At the outset of the modeling process in the present case it was not apparent that similar "actual" flows would be available for comparison with the modeled flows and this necessitated some consideration of how the model could be evaluated. In the urban transportation planning process the actual flows between places are known based on an expanded sample of data received by roadside interviews and home interview surveys. In that case correlation could be used, but it is not. Instead the modeling process is evaluated immediately after the flows are estimated by comparing the trip length frequency distribution of these estimated flows with the trip length frequency distribution of the flows from the expanded sample. This seemed as though it would be a reasonable approach since the trip length frequency distribution of shipments is know for each commodity. As a result it was decided at the outset of the project that a similar approach to evaluation would be utilized here, but if other data became available it would be used as well.

The Initial Model

The first model used in the present study was the fully-constrained gravity model noted above. This was the model used in the 1997 study. The production and attraction of commodities were derived as explained in the previous chapter. The average length of shipments was known from the 1997 *Commodity Flow Survey*. These distance values for different commodities were used in the modeling.

The model used took the form:

$$S_{jk} = A_j B_k O_j D_k \exp(-\beta c_{jk})$$

where S_{jk} = the amount of a given commodity shipped from origin area j to destination area k;

O_j = the amount of a given commodity available for shipment at origin j;

D_k = the amount of a given commodity demanded by destination k;

c_{jk} = a measure of the cost or impedance of moving from j to k.

In addition,

$$A_j = [\Sigma B_k D_k \exp(-\beta c_{jk})]^{-1}$$

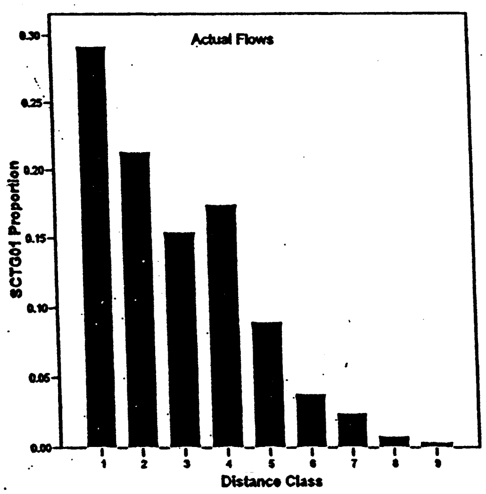
and

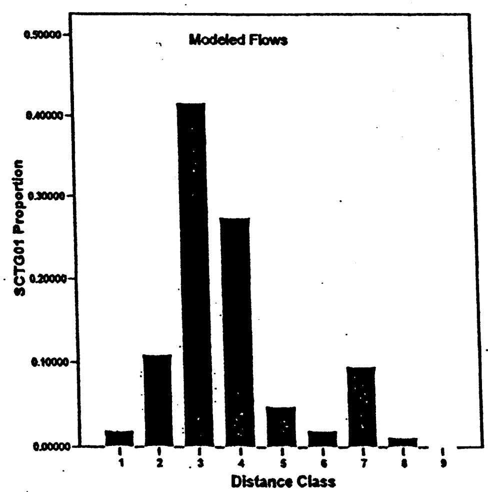
$$B_j = [\Sigma A_j D_j \exp(-\beta c_{jk})]^{-1}$$

The flows of all 41 commodity groups were estimated using this model. This was done even though some of these commodities are not very significant to Indiana. They do nevertheless often move through the state on their way from origins to destinations north, south, east or west of the state.

The next step in the analysis was to evaluate how closely frequency distributions of the generated flows resembled the frequency distributions of the actual flows as published in the volumes of the 1997 *Commodity Flow Survey* (*CFS*). In order to create the model frequency distributions the 21,025 flow estimates for each commodity were examined, along with their distances, and these values were placed into distance classes identical to those in the *CFS*. This was accomplished using a program written for this purpose.

It is an understatement to say that the results were not very satisfactory. The primary problem appears to be that the estimated flows failed to display the expected distance decay in commodity shipments similar to what is found in the actual flows. In part this may be due to the model trying to satisfy the various constraints of this form of the gravity model. In addition there is definitely a problem with the possibility of short range flows (flows up to 250 miles in length), since the only possibility of truly short moves in the database are those between counties in Indiana and between a few small states on the East Coast. The situation is illustrated below for SCTG 01. The actual flows histogram reflects the flow values as published in the *CFS* and the modeled flows are those from the fully constrained model used here.





One possible way of correcting this bias against short trips was to look again at the intrastate distances used as input to the gravity model. The average length of a trip beginning and ending in the same state has traditionally been calculated as one-half the square root of the state's area. This may tend to make the intrastate distances too long in many cases. One way of correcting this figure was to use the average length of an intrastate shipment for all commodities as published in the 1997 *Commodity Flow Survey* report. The new distance values were considerably shorter than the previous values.

The fully-constrained model was rerun, but the new values did not have an appreciable impact on the accuracy of the estimates. A decision was made at this point to try the production-constrained gravity model. One of its major attributes is a tendency for shipments to drop off rather quickly following departure from the origin for nearly every commodity group and it was thought that this would improve the overall quality of the modeled flows.

The production-constrained model used had the form

$$S_{ij} = O_i D_j F_{ij} G_j$$

where $F_{ij} = 1 / c_{ij}^{\lambda}$

and $G_j = 1 / [\Sigma D_j F_{ij}]$

The only problem with this formulation is that we need some way of determining the value of the parameter lamda (λ). The value can not be calculated directly, but it can be determined iteratively by setting the value equal to 0.00 and incrementing it by .01 after each model iteration. Also after each iteration the average length of the shipments for each commodity between the 145 x 145 areas in this study is calculated. The iterative process continues until the average length of these shipments for each commodity as published by the *CFS* is achieved by the model. The corresponding lamda value becomes the value used in the model for that commodity. This solution method could be called a computer intensive solution. The lamda values obtained are in Table 5-1.

This particular model resulted in estimates that tend to have a clear distance decay, i.e., the largest flows are of the shortest length for nearly every commodity examined and they drop off significantly with increasing distance. This is reflected in the lamda value obtained in several cases. For example, several of the most extreme values of lamda in the model are obtained for commodities: SCTG 10, Monumental and Building Stone, SCTG11 Natural Sands, and SCTG 13 Gravel and Crushed Stone. These are nearly ubiquitous materials and it makes very little sense to transport them long distances since they are heavy, of low value relative to their weight, and as noted found

Table 5-1. Production Constrained Model Attributes for 40 Commodities

	SCTG	MeanDist	Modelled	Tons	Tonmiles	Exponent
1	1	253	254	5922001	1503523710	1.52
2	2	410	411	489693024	201222472000	1.26
3	3	400	400	201660960	80581140500	1.16
4	4	213	212	219698944	46605869100	1.65
5	5	458	456	79485000	36217925600	1.02
6	6	472	471	102721008	48370352100	.96
7	7	313	312	396882112	123923538000	1.29
8	8	343	343	81079008	27782098900	1.23
9	9	245	245	4128001	1012662780	1.34
10	10	93	94	15893002	1486681730	2.24
11	11	58	59	442509120	26052460500	3.11
12	12	51	52	1814761090	94263500800	3.40
13	13	222	221	235731008	51991052300	1.60
14	14	526	526	90705000	47667941400	1.03
15	15	446	444	1217037950	540288123000	1.07
16	17	142	141	962814912	136201953000	1.79
17	18	106	107	481681952	51370250200	2.01
18	19	172	172	475105088	81946148900	1.63
19	20	462	459	296055968	135883530000	1.03
20	21	564	562	9896999	5558334460	.71
21	22	243	241	179056032	43098857500	1.58
22	23	489	490	92034000	45072269300	.89
23	24	530	528	130410992	68808646700	.79
24	25	76	77	370686112	28383195100	2.53
25	26	294	291	329118944	95821635600	1.40
26	27	549	545	152290000	82961449000	.83
27	28	299	299	73512992	21994102800	1.29
28	29	292	292	78052992	22764777500	1.28
29	30	538	536	45872000	24567932900	.63
30	31	100	100	910133184	91337072600	2.20
31	32	350	348	335878048	116840858000	1.09
32	33	457	453	106518992	48282214400	.97
33	34	542	539	49914996	26907611100	.72
34	35	683	678	39612000	26869575700	.58
35	36	464	463	98073984	45397053400	.81
36	37	686	686	5477000	3759114750	.55
37	38	738	736	2938997	2161702400	.57
38	39	581	579	19909998	11524856800	.72
39	40	354	352	112491976	39547281400	1.13
40	41	225	225	177823952	40061886500	1.48

nearly everywhere. The lamda obtained for these commodities were 2.24, 3.11, and 3.40, respectively. The lowest value of lamda obtained, .55, was for motorized and other vehicles. This is as it should be. Automobiles are manufactured nearly all over the country, but usually not the same models. In effect, the vehicles shipped are a response to a national market. Also, the buyer of the vehicle usually bears the cost of shipping the vehicle from the plant to the dealership, and within certain limits there is no reason for the shipper to try to minimize this cost.

The frequency distributions obtained using the production-constrained gravity model appear to be much more realistic than they were with the fully-constrained gravity model. We have not subjected these to any statistical analysis because the degrees of freedom for such a test, e.g., the Kolmogorov-Smirnoff (KS) test for comparison of frequency distributions, base their degrees of freedom on the total number of possible observations. In this case with 145 x 145 observations, it would be silly to evaluate the results by testing. This number of observations will nearly always result in a finding that the distributions are significantly different. One must bear in mind that these and similar tests were all developed for much smaller data samples and they become inappropriate here.

The actual and estimated frequency distributions were examined individually and it is believed that the production-constrained model does a much better job of capturing the general pattern of these flows (in terms of frequency distributions) at the national level. Perfect replication was not expected. If this did result there is every likelihood that the model would have over-fitted the data.

Although these frequency distributions are of interest the major test of accuracy would come with a comparison of the generated flow volumes on the highways with previously obtained counts from the Indiana road inventory database. When this comparison was undertaken the results were very poor. More specifically, the correlation between the observed and estimated flows was approximately .40. This meant that the modeled flows were only accounting for about 16% of the variation in the actual flows. This was viewed by the project staff as unacceptable.

Restarting the Analysis

At this point a complete reexamination of the distribution modeling approach was undertaken. Several basic changes were made in the analysis. An estimation procedure for the modal shift analysis developed earlier in the project was discarded. Instead the staff relied more on the published data and taking care to estimate the missing values in that data. A similar approach was taken with the data on attraction. It was known that the fully-constrained gravity model had worked much better in the earlier project so the decision was made to rely on that model in a complete repetition of the distributional modeling.

At the same time it is imperative that we note a couple of general observations about that model. The first of these is that the fully-constrained model does not do a very good job of replicating the published shipment length frequency distributions. The reasons for this seem obvious in retrospect. The actual frequency distributions are based on what the shippers responded in the *Commodity Flow Survey*. Perhaps some of these shipments only go a relatively short distance and this would be recorded as the shipment length. The data available to the project staff would merely state the shipment's destination. It was not possible to replicate short shipping distances because there are far too few of these possible at the scale of the analysis being undertaken here. Even though we know most shipments are short in length, the only possibility of such short shipments would be between some small states in the Northeast, or between some counties in Indiana.

The second point is that although the shipment length frequency distributions are of interest, the primary goal here is to replicate the flows to, from, through and within the state of Indiana. It was known that the fully-constrained model had done this before so it was assumed that this model would work better. If data were available so that the modeling could be between all the counties in the 48 contiguous states, we suspect that the generated frequency distributions would be very similar to the values published in the *CFS*. It is not possible to get that level of accuracy here.

One final point is that the level of disaggregation is much higher than it has been in previous studies. As noted above this study examines 41 different commodity groups in comparison to earlier studies that examined 15 to18 groups. This is bound to have an impact on the level of accuracy since the methods used here tend to work better at the highly aggregated level of the Standard Industrial Classification (SIC) system and the Standard Transportation Commodity Classification (STCC).

The fully-constrained model was run for a second time, disregarding the national picture and focusing more on the Indiana results. The exponential form of this model yields values that are considerably smaller (see Table 5-2) than those from the production constrained model's power function as reflected in Table 5-1. The actual length of shipments was very close to the input values as reflected in Table 5.3.

Modifying the Distributed Flows

The modeled flows were calculated from the gravity model as simply thousands of tons. A subsequent computer program took these flows and converted them to tons, dollars of product value, and truck loads. The first of these was accomplished quite simply by converting the thousands of tons carried to three decimal places to simply total tons. The original production and attraction data are only published in thousands of tons so this may appear to be going beyond the validity of the data, but it was important to get to a level of detail that would have meaning at the level of inter-county flows in Indiana.

Table 5-2. Fully-Constrained Gravity Model Exponents for Indiana, 1997

SCTG Code	Commodity Group	Exponent
01	Live Animals and Fish	-.0510
02	Cereal Grains	-.0031
03	Agricultural Products Except Live Animals, Cereal Grains, and Forage products	-.0030
04	Animal Feed and Products of Animal Origin	-.0070
05	Meat, Fish, Seafood, and Preparations	-.0024
06	Milled Grain Products and Preparations, and Bakery Products	-.0023
07	Prepared Foodstuffs, Fats, and Oils	-.0039
08	Alcoholic Beverages	-.0035
09	Tobacco Products	-.0054
10	Monumental or Building Stone	-.0199
11	Natural Sands	-.0146
12	Gravel and Crushed Stone	-.0140
13	Non-metallic Minerals	-.0067
14	Metallic Ores	-.0016
15	Coal	-.0031
17	Gasoline and Aviation Turbine Fuel	-.0100
18	Fuel Oils	-.0136
19	Products of Petroleum Refining and Coal Products	-.0069
20	Basic Chemicals	-.0022
21	Pharmaceutical Products	-.0014
22	Fertilizers and Fertilizer Materials	-.0050
23	Chemical Products and Preparations	-.0021
24	Plastics and Rubber	-.0018
25	Logs and Other Wood in the Rough	-.0104
26	Wood Products	-.0043
27	Pulp, Newspaper, Print, and Paperboard	-.0016
28	Paper or Paperboard Articles	-.0038
29	Printed Products	-.0040
30	Textiles, Leather, and Articles	-.0013
31	Non-metallic Mineral Products	-.0410
32	Base Metal in Primary or Semi-finished Forms and in Basic Shapes	-.0031
33	Articles of Base Metal	-.0023
34	Machinery	-.0015
35	Electronic and Other Electrical Equipment and Components; Office Equipment	-.0010
36	Vehicles	-.0017
37	Transportation Equipment	-.0010
38	Precision Instruments and Apparatus	-.0009
39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	-.0015
40	Miscellaneous Manufactured Products	-.0318
41	Waste and Scrap	-.0067
43	Mixed Freight	-.0185

The conversion to dollars was relatively simple. The value per ton per commodity was used as a multiplier against the tons of commodities to yield the dollar value of shipments by commodity.

Density

One of the very important topics in estimating the volume of motor carrier and rail traffic after the volume of interaction (in tons) and the modal assignment have been determined is the density of the commodity. In other words, how much of the commodity can fit into a rail car or motor carrier? In the earlier (1997) commodity flow study these density factors were determined by examining flows of rail traffic categorized by the STCC system. These traffic data came from the Carload Waybill Sample, a sample of railroad commodity flow data that presents information on both the number of carloads and the tonnage of each commodity.

Changes in the commodity classification system have rendered the Carload Waybill Sample useless for the present purposes because that sample has continued to use the STCC system and the current study is using the Standard Commodity Transportation Group (SCTG) system. Although these two systems are similar they are not the same and this necessitated a search for new density factors.

It is fortunate that although the United States has not begun to publish data both on tonnage and carriers by SCTG commodity, Canada has. Their monthly *Railway Carloadings* (Transport Canada, 2004) reports give data both on the number of rail cars and the metric tonnes moved, and these are all given in terms of the SCTG system. From the reports consulted there is relatively good coverage in terms of the SCTG sectors included in the present study. There are some exceptions in terms of rail traffic and these are worth a brief discussion.

SCTG 01 Live Animals and Live Fish are not included in the Canadian rail data. As a substitute for this we have included weight estimates based on the recommended number of live animals per railcar derived by the Association of American Railroads. That data is based on the weights of hogs, cattle or sheep. The value of 9.77 tons per railcar was derived for this group.

SCTG 09 Tobacco Products average about 18.30 tons per truck. Rail traffic was estimated as larger by a multiplier of 2.5. Therefore, railcars were viewed as having a density of 45.75 tons.

SCTG 10 Monumental and Building Stone is also not in the Canadian data. It was estimated here as being 100 tons.

Also missing from the *Railway Carloadings* reports were data for SCTG 21, Apparatus. In the first case and the last class these were excluded primarily because rail is not used to move these goods in part because of their higher value. Printed matter simply put is time sensitive and for the most part the railroads are not reliable for this purpose.

The movement of goods by motor carrier in the earlier (1997) study was set at 40% of the railcar tonnage and in nearly every case this proved to underestimate the actual volume moving, and underestimate the number of vehicles involved. An alternative was searched for and found in a Strategic Freight Transportation Analysis (SFTA) report for the State of Washington (Petersen, et al, 2004). The SFTA report derived density figures for motor carriers of freight based on interviews of motor carrier drivers during a survey. It is compiled by SCTG system and gives empirical rather than theoretical values for density. For the most part we have gone with the SFTA values for motor carriers. Exceptions to this statement do exist and these are as follows:

SCTG 01 Live Animals and Live Fish: the empirical data suggest a value of 22.9 tons per truck. This is more than twice the AAR recommended density for a railcar and probably several times what would be recommended for motor carriers.

SCTG 10 Monumental and Building Stone was set at 25.4 tons, instead of 40% of the of the rail car maximum density. It may not be representative of most traffic.

SCTG 15 Coal is used for the thermal generation of electricity and by some manufacturing firms. Although the 100 ton hopper car can be taken as a given, the motor carrier level was less obvious. As a result the rather large trucks that are used to move coal have an average capacity of about 22 tons and this is the value used.

All other values are essentially derived from the SFTA report. The commodity, density and mode of traffic appear on the following two pages as Table 5-4.

Density vs. Payload Factors

During the initial review of a draft of this document a question was raised as to the merits of the density factors discussed above and used in assigning tonnages to trucks and railcars. The earlier study had used density factors derived from STCC data in the railroad Carload Waybill Sample followed by some assumptions regarding the volume that would fit into a semi-tractor trailer. This approach would not work in the present study because the waybill sample continues to use the STCC system. All of this is explained above.

The question raised during the review was to what extent the density factors used in this volume approximate the payload factors derived by Cambridge Systematics (CS) based on their use of the Vehicle Inventory and Use Survey. CS supplied these factors to the IU research team

Table 5-4. Commodity Density Values for Railcars and Trucks

SCTG	Commodity	Railcar density	Motor carrier density
01	Live animals and live fish	9.77	3.91
02	Cereal grains	96.63	30.1
03	Other agricultural products	86.79	22.3
04	Animal feed and products of animal origin, n.e.c.	88.28	25.3
05	Meat, fish, seafood, and their preparations	74.41	18.6
06	Milled grain products and preparations and bakery products	85.50	21.4
07	Other prepared foodstuffs and fats and oils	87.02	21.0
08	Alcoholic beverages	87.31	21.0
09	Tobacco products	45.75	18.3
10	Monumental and building stone	100.00	25.4
11	Natural sands	97.97	25.4
12	Gravel and crushed stone	97.97	24.1
13	Nonmetallic minerals, n.e.c.	100.44	23.4
14	Metallic ores and concentrates	95.91	21.4
15	Coal	109.36	22.0
17	Gasoline and aviation turbine fuel	84.04	28.2
18	Fuel oils	88.22	20.0
19	Coal and petroleum products, n.e.c.	73.66	23.5
20	Basic chemicals	98.66	17.5
21	Pharmaceutical products	[redacted]	13.2
22	Fertilizers	101.81	27.4
23	Chemical products and preparations, n.e.c.	93.96	20.1
24	Plastics and rubber	94.30	13.3
25	Logs and other wood in rough	64.11	29.2

26	Wood products	82.41	24.2
27	Pulp, newsprint, paper and paperboard	82.75	23.5
28	Paper or paperboard products	70.90	17.2
29	Printed products	[redacted]	15.1
30	Textiles, leather and articles of textiles or leather	14.17	13.3
31	Nonmetallic mineral products	98.64	21.2
32	Base metal in primary or semifinished forms and in finished basic shapes	91.47	18.4
33	Articles of base metal	79.66	12.2
34	Machinery	49.77	13.8
35	Electronic and other electrical equipment and components and office equipment	16.69	12.7
36	Motorized and other vehicles (including parts)	21.73	13.3
37	Transportation equipment, n.e.c.	41.36	12.1
38	Precision instruments and apparatus	[redacted]	9.0
39	Furniture, mattresses and mattress supports, lamps, lighting fittings, and illuminated signs	15.00	10.7
40	Miscellaneous manufactured goods	65.22	14.0
41	Waste and scrap	79.86	20.0
43	Mixed freight	32.45	14.2

Sources: See text.

so that a comparison of the two systems could be made. The data used for this test appears as Table 5.5.

There is very little relationship between the two systems and the CS estimates are only able to explain about 14% of the variation in the detailed Indiana density factors. We see no reason to adopt the less precise CS values for the analysis here, although there is sufficient detail here for CS to use their system of payload factors in future applications of the results of this study.

Summary

This chapter has discussed the efforts made to identify the best distribution model for the problem at hand. Two models were evaluated for this purpose. A fully-constrained model was selected over a production-constrained model. Traffic density, the amount of a given product that will fit into a tractor trailer or railcar was also discussed here. The approach selected is commodity specific and based on actual measures used in the U.S. and Canada.

Table 5.5 IU Density Factors vs. Cambridge Payload Factors

	SCTG	Density	Payload
1	1	3.91	.
2	2	30.10	19.48
3	3	22.30	19.48
4	4	25.30	19.48
5	5	18.60	18.35
6	6	21.40	18.35
7	7	21.00	18.35
8	8	21.00	18.35
9	9	18.30	19.20
10	10	25.40	21.40
11	11	25.40	21.00
12	12	24.10	21.40
13	13	23.40	21.40
14	14	21.40	21.40
15	15	22.00	21.40
16	17	28.20	20.61
17	18	20.00	23.03
18	19	23.50	23.03
19	20	17.50	20.61
20	21	13.20	.
21	22	27.40	20.61
22	23	20.10	20.61
23	24	13.30	14.95
24	25	29.20	18.99
25	26	24.20	15.82
26	27	23.50	17.77
27	28	17.20	17.77
28	29	15.10	17.77
29	30	13.30	17.80
30	31	21.20	18.42
31	32	18.40	25.42
32	33	12.20	18.42
33	34	13.80	17.11
34	35	12.70	17.11
35	36	13.30	20.39
36	37	12.10	20.39
37	38	9.00	16.40
38	39	10.70	17.19
39	40	14.00	20.27
40	41	20.00	19.05
41	43	14.20	19.05

References

Petersen, Steven K., Eric L. Jessup, and Kenneth L. Casavant (2004), *Freight Movements on Washington State Highways: Results of the 2003-2004 Origin and Destination Survey*, Strategic Freight Transportation Analysis Report #10, Pullman, WA: Washington State University.

Transport Canada (2004), *Railway Carloadings*, Ottawa, Canada: Transport Canada. Various issues.

U.S. Bureau of Census (2002), *Vehicle Inventory and Use Survey*, Washington, D.C.: U.S. Department of Commerce.

Chapter 6

THE MODES IN THE ANALYSIS

The *Commodity Flow Survey* reports flow movements in several modal categories. This chapter simply notes the manner in which these are treated here. It is not possible to work with all of the various modal categories since flow data are not published for a number of them. It is for this reason that we have aggregated some of these categories.

Motor carriers

Motor carrier flows are often available as for-hire trucks or as private trucks. The former would be represented by a number of trucking companies, while the latter would be represented by those large companies that own a fleet of trucks. If proprietary data would be revealed on either category then the data available would be reported as trucks or would not appear in the data.

Rail

Rail is treated as a single modal category and flows are reported in this manner for the study. As we noted in Chapter 3, the Commodity Flow Survey also reports data as moving by the multiple modes of truck and rail and rail and water. As was also discussed in Chapter 3 truck and rail flows represent such a small proportion of the tonnage moving that we view these as primarily as rail moves and have categorized them in this manner. Rail and water moves were treated as water moves since this would be the manner in which they would tend to arrive in Indiana.

Water

In addition to the rail and water category the CFS recognizes water moves as shallow draft, Great Lakes, or deep draft. We have simply grouped all of these as well as the previously mentioned rail and water moves as water moves. Once again the rationale is that the data are simply not very good at these final modal categories once one leaves the national level. It is true that we could infer the flows that are coming into Indiana through Lake Michigan (the Great Lakes category) or the Ohio River (shallow draft). That is not the problem. The problem is that the data are simply not reported in a sufficient number of cases to merit breaking out the flows in this manner. To use national level estimates of what these should be would be very misleading.

Therefore, the water data are simply all grouped into simply water. We do not break the data down any further than to infer what the origin and destination county of the traffic is. The data are only reported in this manner and are not later assigned.

Air

Air transport of freight even though it may and usually does involve another mode (usually a motor carrier) is often treated as only an air move. Indiana has little to do with air transport infrastructure and as a result it is the motor carrier portion of these moves that are of primary interest here.

Air freight shipments from outside of Indiana were treated as motor carrier moves generated from the nearest large airport to the county that was the final destination of these flows based on the distribution modeling. In a similar manner air freight flows generated by counties in Indiana were considered as motor carrier flows to the airport from which the flows would leave the state. Figure 6-1 is a representation of how these assignments were made for air freight.

Parcels

At one time one could almost disregard the previous air freight category as well as the shipment of parcels in a study such as this. This is no longer the case and moves by various express companies become major components for some shipments between different origins and destinations. There are some counties in Indiana that receive little or no commodity flows as such on a daily basis, but they all receive some goods via FedEx, UPS, the US Postal Service (USPS), and more recently DHL.

Since these are private for-profit operations in most cases (the exception is the USPS), data are not published on the companies involved in the flows. Research by the project team suggests that the market for such parcel shipments are broken down into proportions as follows:

FedEx	.27
UPS	.53
USPS	.13
DHL	.07

Therefore, total parcel shipments were divided among the various companies using the proportions reported above.

Further research revealed the primary airports used by these different parcel handlers and these were used in a manner similar to what was done with the air freight category above. That is, flows going out of state or coming in state were treated as flows arriving at the nearest airport used by that parcel handler. Flows originating and terminating in the state were treated as ground moves of that carrier. The manner in which these flows were assigned to airports is reflected in Figures 6-2 through 6-5.

Pipelines

Pipelines were the final category reported in the *CFS* and set aside here. These flows were not included in any analysis simply because the state has no responsibility for the infrastructure used by this mode.

A Comment

The modes examined were selected because of their volumes. In a like manner some categories were collapsed into broader categories because their was a lack of sufficient data to do much more with them. We would note that the manner in which air and parcel traffic were treated is a bit more complicated than its volumes would indicate. This was done as much for research reasons as for planning reasons. We wanted to see if this approach has merit. It does and perhaps it might make sense to try and improve on some of the other modal flows n this manner.

Summary

This study has looked at flows by motor carriers, rail, water, pipelines, air freight, and parcels. These six modes were used as the basis for constructing tables of modal use by distance. These in turn were used to allocate the generated flows to such modes. Tables for this purpose appear in Appendix D. We have not assigned any flows to their respective networks beyond the rail and highway case.

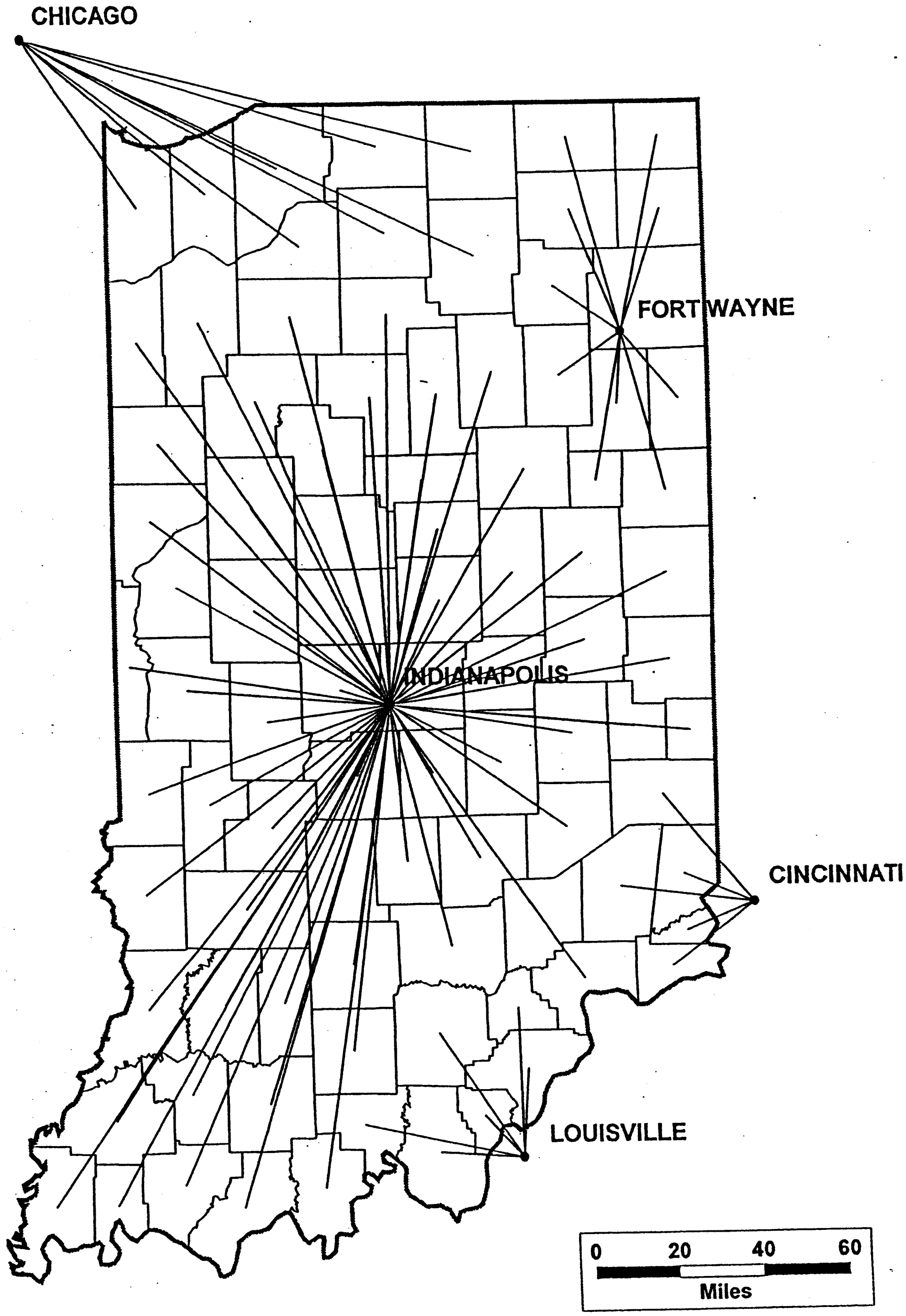


Figure 6-1. Market Area for General Air Freight in Indiana

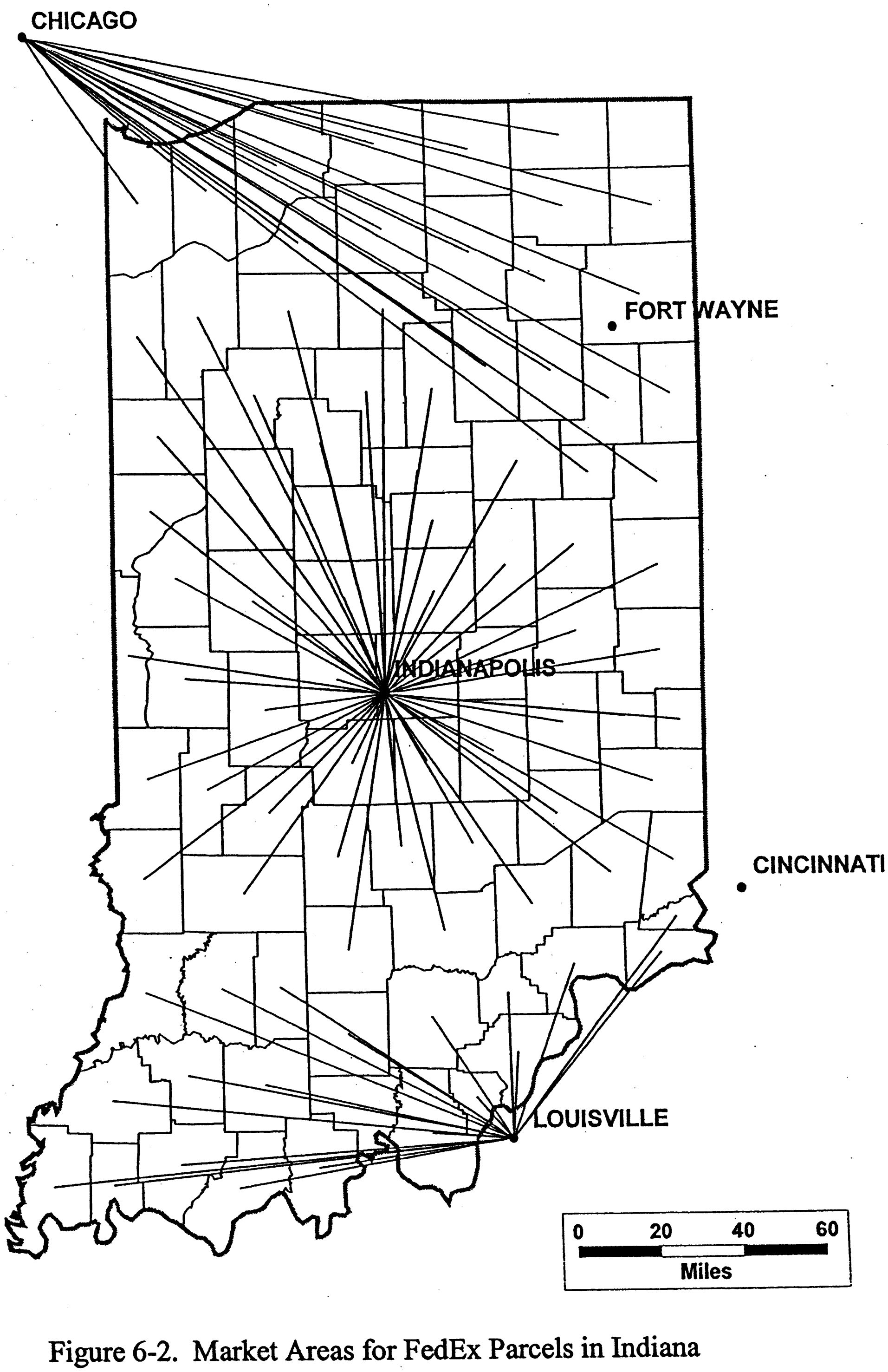


Figure 6-2. Market Areas for FedEx Parcels in Indiana

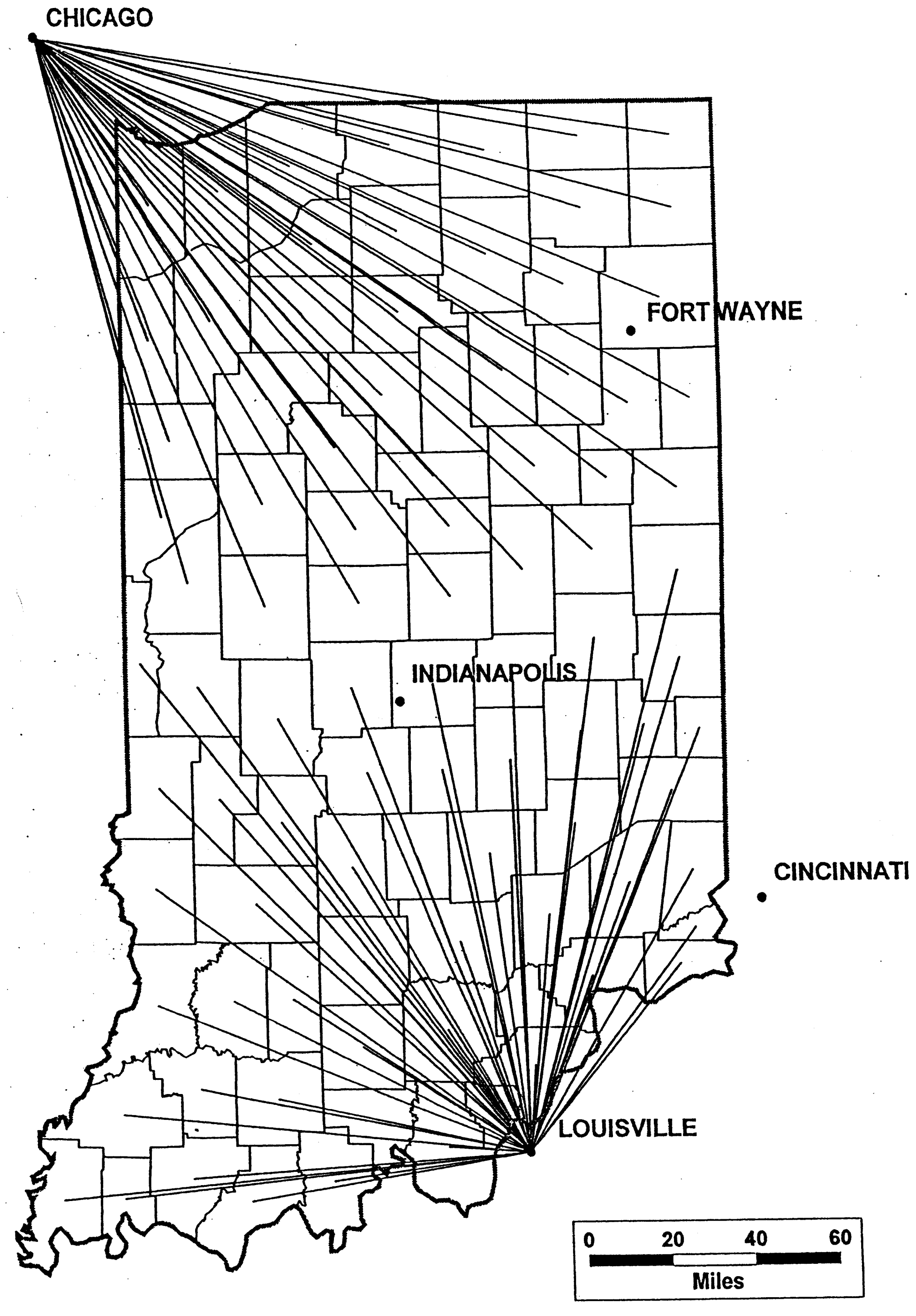


Figure 6-3. Market Areas for UPS Parcels in Indiana

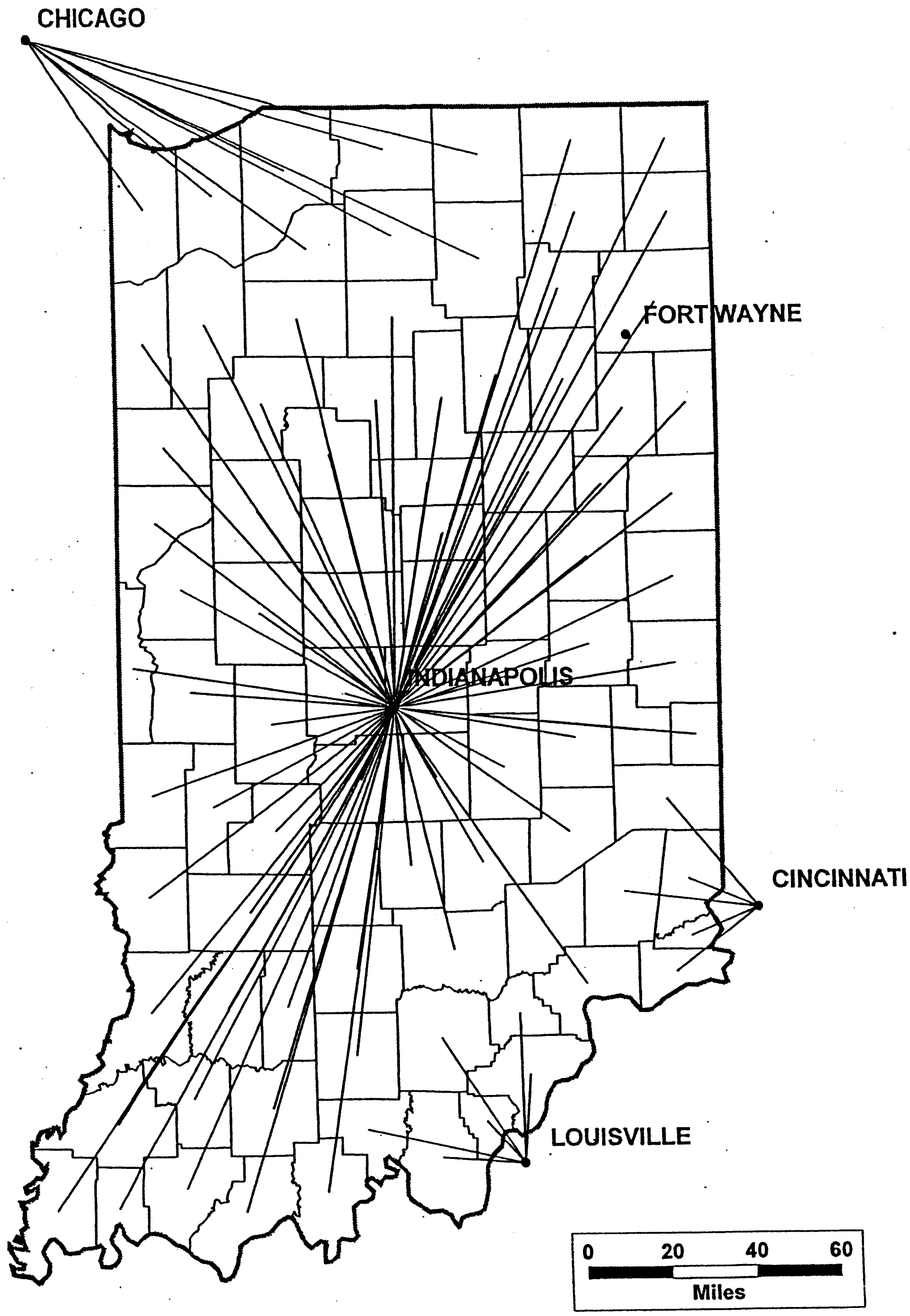


Figure 6-4. Market Areas for the USPS Parcels in Indiana

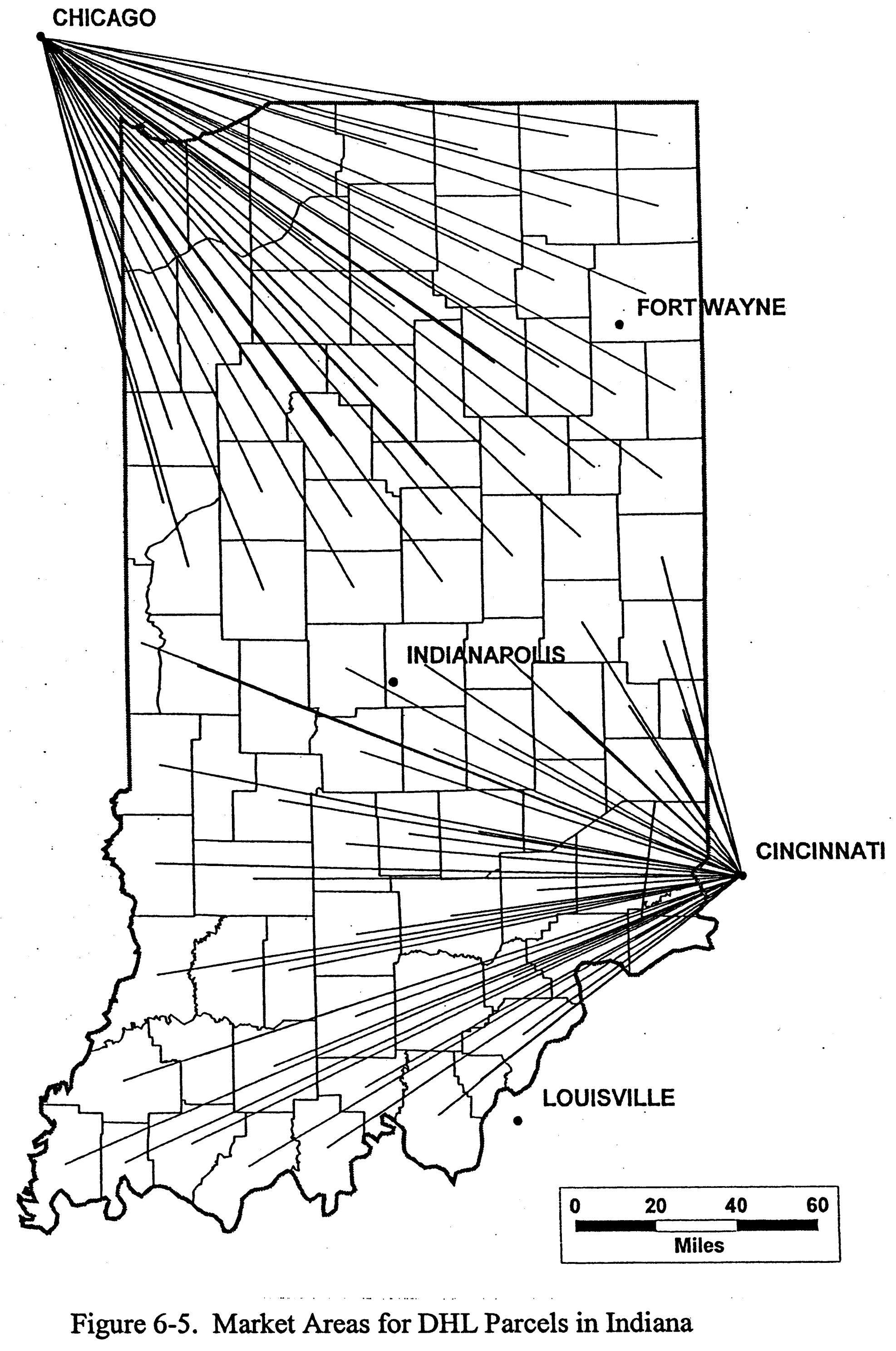


Figure 6-5. Market Areas for DHL Parcels in Indiana

Chapter 7

ASSIGNMENT OF TRAFFIC AND EVALUATION

This chapter describes the procedures that were used for traffic assignment in this study. To place this in the proper context, we have distributed flows to a series of origins and destinations. These are gross estimates of interaction between states and counties without any clear indication of the paths, routes, or highways that these flows would take. Put another way, the flows from our gravity model lack geographic detail. It is the purpose of traffic assignment to provide the geographic detail so that we know those portions of the network over which these flows take place.

There are numerous analytical methods for assigning traffic to a network. The simplest of these methods is referred to as "all or nothing" assignment. This approach assumes that all of the traffic going between any origin-destination pair will travel by the shortest (time, distance, or other metric) path over the network between the two places. Now if we increase this to include all origins and all destinations, and follow the same procedure, then we have assigned our traffic using the "all or nothing" approach to traffic assignment.

This method of traffic assignment has its share of critics. Most of these are concerned with the application of this approach in urban areas where a multitude of possible routes are available. It should be apparent that whatever we use as a metric of spatial separation, e.g., cost, distance, or travel time, this approach will select the route for all flows between an origin and destination for which this is a minimum. Obviously, reality is different and the number of routes that will see some use is a function of the total number of such routes that are available. This is the basis for part of the criticism, although one could also attack the methodology on the grounds that not everyone is attempting to minimize their "friction." Some may want a scenic route, others may want a rural route with less traffic, while others may prefer a bypass that is longer. From a modeling standpoint we can't incorporate the motives of all travelers in our modeling.

When the modeling pertains only to motor carriers functioning over a large area, it is apparent that the "all or nothing" assignment procedure tends to reflect the behavior of those carriers the best. It would be possible to add congestion and capacity effects to the modeling, but the reality here is that these vehicles tend to try to minimize travel time. Even if we added more variables to the assignment modeling, these carriers would still tend to use the Interstate

Highway System whenever they can. If their shipments are originating or terminating off the Interstate, they will try to stay on that system until they are off of it for the least amount of time.

Transport Costs

Traffic assignment requires the construction of a network over which shipments must move. This network connects all origins on the network to all destinations and includes the "cost" of movement over the links or segments of the network. In general, cost studies over the years have tended to use distance, travel time, or traffic flow functions related to distance or travel time for this cost measure. This project used travel time as its initial measure of travel cost. For shipments over very large areas, such as the United States, travel time is rarely known. Instead it is approximated by the use of the following:

Travel time = (link length)/ (posted speed)

Here the length is in miles and the speed is in miles per hour. This results in travel time being measured in hours or parts of hours.

As was true in the earlier study, this study made use of a conversion of the speeds in an attempt to get at user perception of speeds better than the above formulation allows. In other words, drivers generally exceed the speed limit. We therefore modified the previously obtained speeds by taking that value and modifying it as follows:

$$\text{NewSpeed} = (\text{Posted Speed} + (2 * \sqrt{(}70 - \text{Posted Speed})$$

This results in the following changes:

Old Speed	New Speed
70.00	70.00
65.00	69.47
60.00	66.32
55.00	62.75
50.00	58.94
45.00	55.00
40.00	50.95
35.00	46.83

Travel time was redefined as:

Travel time = (Link length / New Speed) * 60

This yields an estimate of travel time in minutes for all links of the network analyzed, and for those links of the interstate and for those in the study area that had no such value in the database. Although travel times are available for segments of the Indiana Road Inventory, the above approach was also used for these segments for consistency.

Highway Assignment Results

The assignment procedure used was "All or Nothing," without any constraint in the form of link capacity. This resulted in the bulk of the traffic being assigned to the Interstate Highway System and only traffic moving toward the counties off of that system using the other highways, in most cases. There are of course exceptions to this statement.

Perhaps the easiest way to discuss this is to refer the reader to the figures on the following two pages. The first of these figures shows the volume of traffic on an annual basis for the entire United States in 1997 (see Figure 7-1). There is a heavy concentration of flows out of Texas reflecting primarily heavy volumes of petroleum and petrochemicals. The heavy volumes between Wisconsin and Illinois reflect not only movement between those states, but also the role of O'Hare Airport in the airfreight and parcel flows in that region. Some of this could also be the result of the modeling attempting to generate the overall short shipping distances that are used as constraints on the flow model.

The distribution of flows within Indiana for 1997 is more clearly displayed in Figure 7-2. As one would expect the flows are heaviest on the Interstate Highway System within the state. The heaviest volumes here are on I-65 between Chicago and Indianapolis. The lowest interstate volume is across the I-64 corridor in Southern Indiana. Volumes are lower than expected on I-69 between Fort Wayne and Indianapolis; this is particularly true for the southern end of that corridor. This may be attributable to the fact that commodity traffic coming into the state from Canada may not be included in the data used here, i.e., only domestic shippers are surveyed.

The accuracy of the generated truck flows is an issue here. The flows in the Indiana map were compared with truck counts for 1997 based on data in the Indiana Road Inventory. The relationship across all segments for which data were available is .65, which means that the models capture about 42% of the variation in the count data. While not as high as might be desirable it should be noted that some of the vehicles counted near urban areas might not be commodity flows as such, e.g., local lumber, stone, brick, and block moves, garbage truck flows, and similar large heavy vehicles would be in any count data.

The Indiana DOT also supplied the project team with vehicle counts for 2002 in a GIS point format. The data were not complete, i.e., only some of the counties have values. A sample of 59 segments appears as Table 7-1 and a map of the sample locations follows that (Figure 7.3). As can be seen the segments range from high volume Interstate links to low volume state highways, and are distributed around the state proportionally to the sampling completed to date.

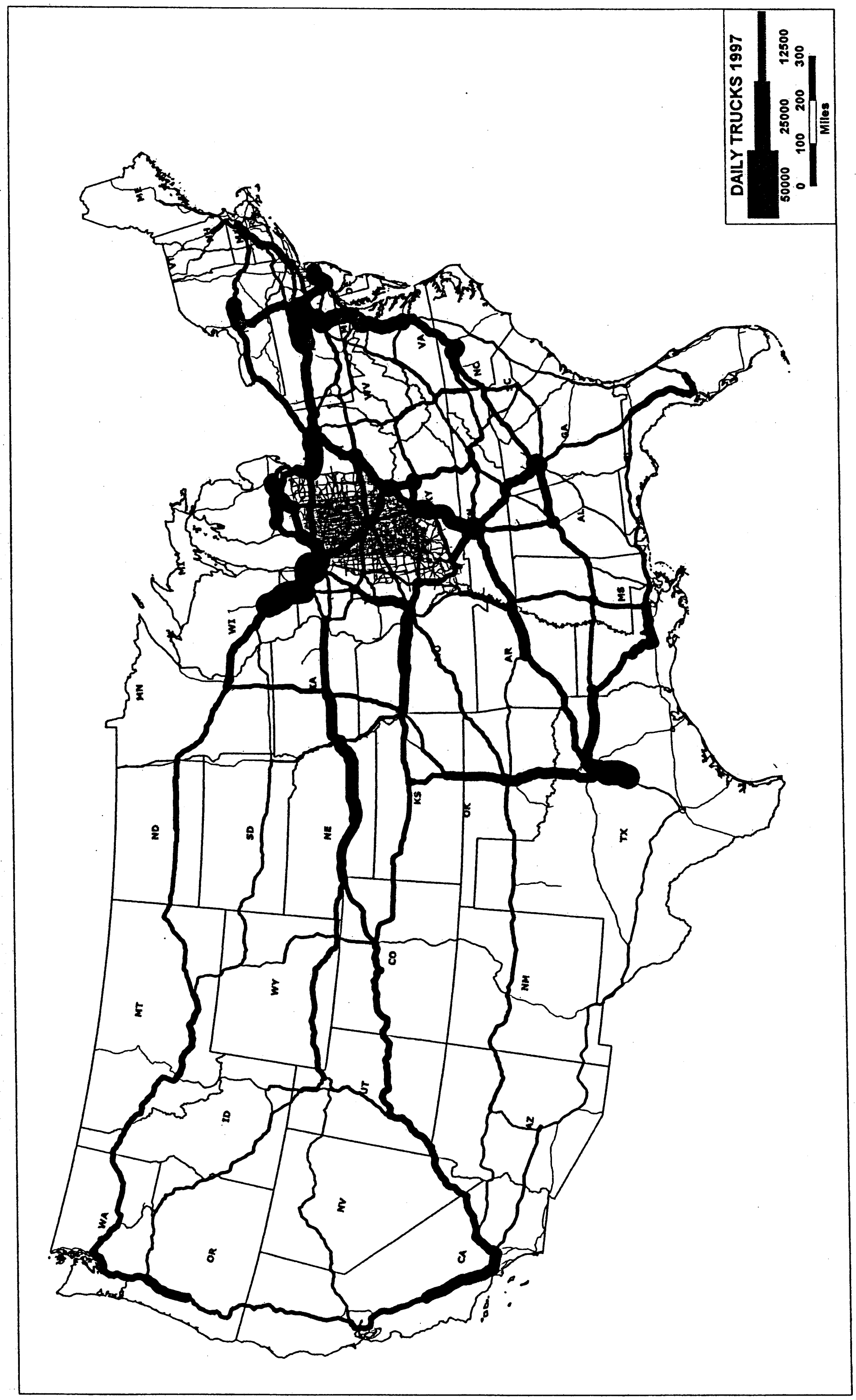


Figure 7-1. US Daily Truck Volumes for 1997

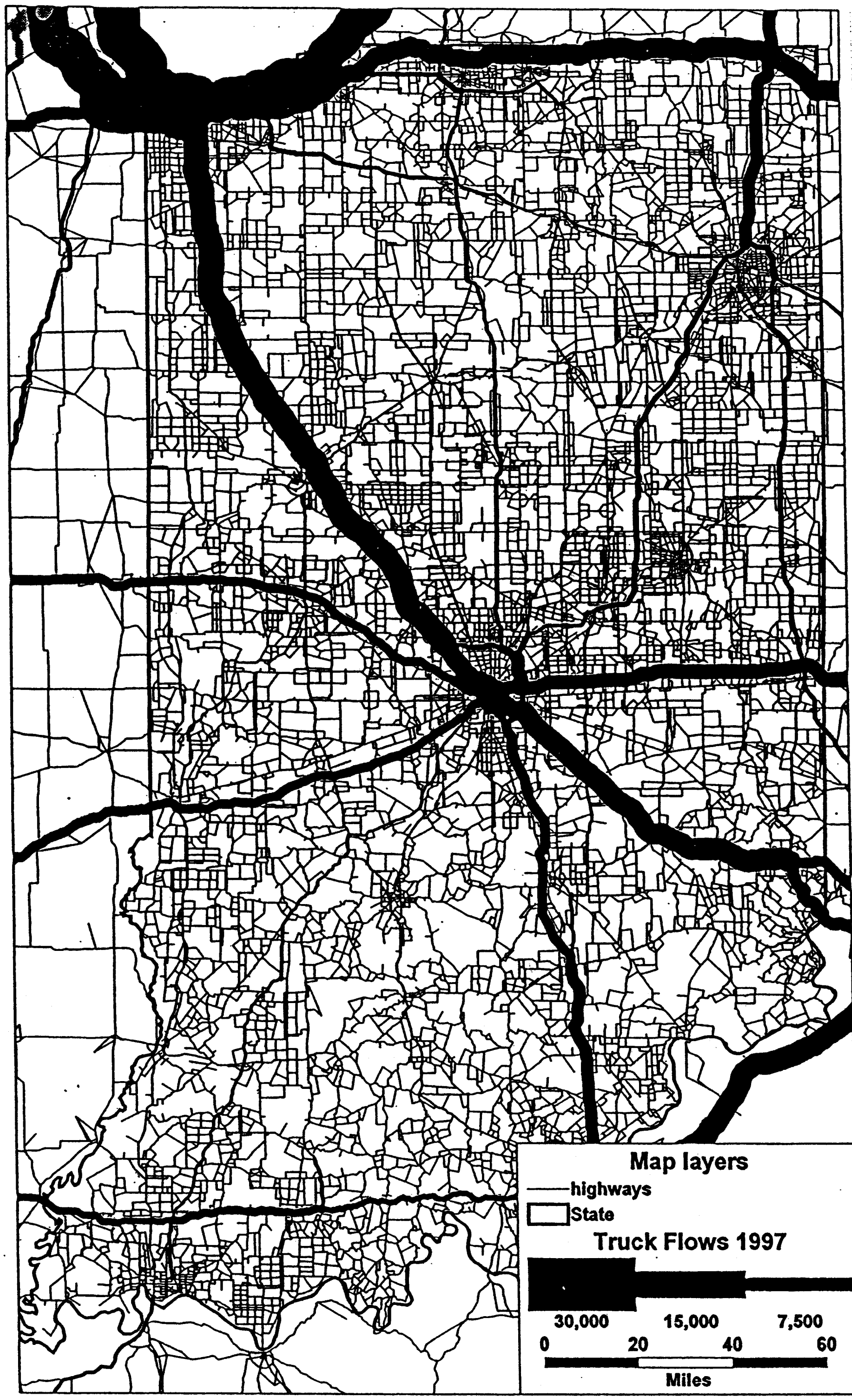


Figure 7-2. Indiana Daily Truck Volumes for 1997

Taking the count data as the dependent variable, the estimated flow volumes based the fully-constrained gravity model followed by an "all-or-nothing" assignment served as an independent variable. The level of statistical explanation was considerably higher than the research team expected. This was slightly in excess of 89 percent (with an r^2 value of .893). The relationship is illustrated in the Figure 7-4.

It is interesting to note that the model developed was of the form:

2002 Counts = 57.8 + 1.125 (1997 Model estimates)

In effect what the model is suggesting is that the values for 2002 have increased roughly 12.5% since 1997. This is a reasonable level of increase given the downturn in the economy in the late 1990s and the subsequent recovery. This difference may also be attributable to empty trucks, which are not incorporated here.

Of course in the sampling process an attempt was made to exclude links with no flow based on the modeling. But there were very few cases where zero flow estimates occurred. In such cases the counts were also very low as represented by some of the segments included here. The major source of variation here is on the Interstate links and for these the level of relationship is reasonably high.

Illustrations of the flow volumes for 2015 and 2030 appear in the following chapter. Although there are substantially higher flow volumes for those future years, the dominant corridors found in the 1997 analysis continue to be the same for the forecast years. This will be discussed in more detail in Chapter 8.

The Rail Flows

The basic network used in the study was described in Chapter 1. It is the 1:2,000,000 rail network prepared by the Federal Railroad Administration as revised to take into account changes due to abandonments and some new construction. It consists of 12,815 segments representing a national network of 148,996 route miles, not track miles.

We used travel time as a measure of the cost of transport in the highway assignment procedure. This is reasonable in that most users of the highway system are interested in minimizing this metric. That is not the case in the rail sector since, for the most part, the railroads are more interested in maximizing their profits. Although this would also usually involve minimizing some measure of transport cost, this is not done unless the traffic is moving entirely on one rail company's lines. In all other cases the railroads involved in the moves must "divide" the total revenue obtained from the move. These divisions, as they are called, are

Table 7-1. Sampled Locations for Model Evaluation

ID	LONGITUDE	LATITUDE	County	Route_Name Description	Total MU-Trk
15809	-86114336	41173850	Marshall	50-S-331-0-01	81.00
16449	-86433320	41671912	St. Joseph	71-S-002-0-01	2566.00
16641	-86348070	41618607	St. Joseph	71-S-023-0-01	226.00
16777	-86263870	41624870		71-U-020-0-01	5419.00
16929	-86339522	41711237	St. Joseph	71-U-031-0-01	3353.00
17297	-86176822	41566309	St. Joseph	71-S-331-0-01	319.00
17697	-86078323	41662659	St. Joseph	71-S-933-0-01	207.00
18121	-85770500	38498201		10-I-065-0-01	11970.00
18153	-85778462	38545785		10-I-065-0-01	11330.00
18313	-85583875	38707871	Jefferson	39-S-056-0-01	106.00
18409	-85453898	38731948	Jefferson	39-S-056-0-01	378.00
18985	-85944978	39269941	Bartholomew	03-U-031-0-01	726.00
19009	-85864026	39202543	Bartholomew	03-U-031-0-01	496.00
19345	-85516685	38831838	Jefferson	39-S-250-0-01	10.00
19473	-85570786	39309396	Decatur	16-S-003-0-01	754.00
19553	-85731291	39523924		73-I-074-0-01	6712.50
19729	-85479612	39383552	Decatur	16-S-003-0-01	677.00
20233	-85234910	39286934	Ripley	69-S-229-0-01	12.00
20417	-85043078	39019267	Dearborn	15-U-050-0-01	1066.00
21025	-84934179	39124841	Dearborn	15-S-048-0-01	53.00
21953	-85486266	39851750		33-I-070-0-01	12830.00
22393	-85549139	40499488		27-I-069-0-01	10002.00
22401	-85535202	40612790		27-I-069-0-01	7080.00
23961	-84964464	40533707	Jay	38-U-027-0-01	1045.00
25681	-85771890	41667588	Elkhart	20-U-020-0-01	1769.00
26401	-85364647	41395766	Noble	57-S-008-0-01	288.00
26409	-85307693	41205518	Allen	02-U-033-0-01	1086.00
26657	-85014589	40917453	Adams	01-U-027-0-01	1911.00
26793	-85103449	41183165		02-I-069-0-01	8528.00
27393	-85055663	41529974		76-I-069-0-01	6286.00
27417	-85035983	41661540		76-I-069-0-01	7960.00

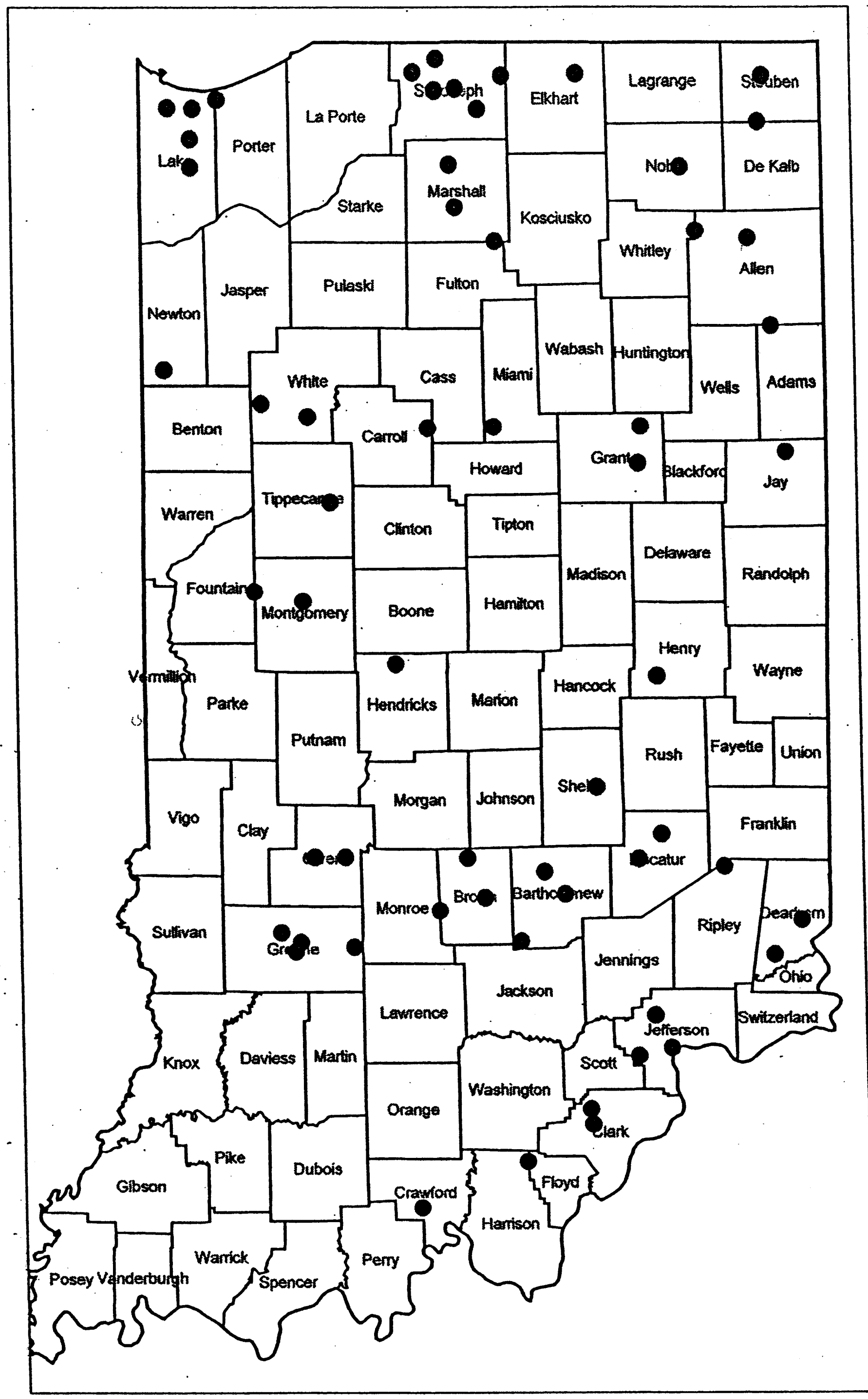


Figure 7-3. Map of Sampled Locations

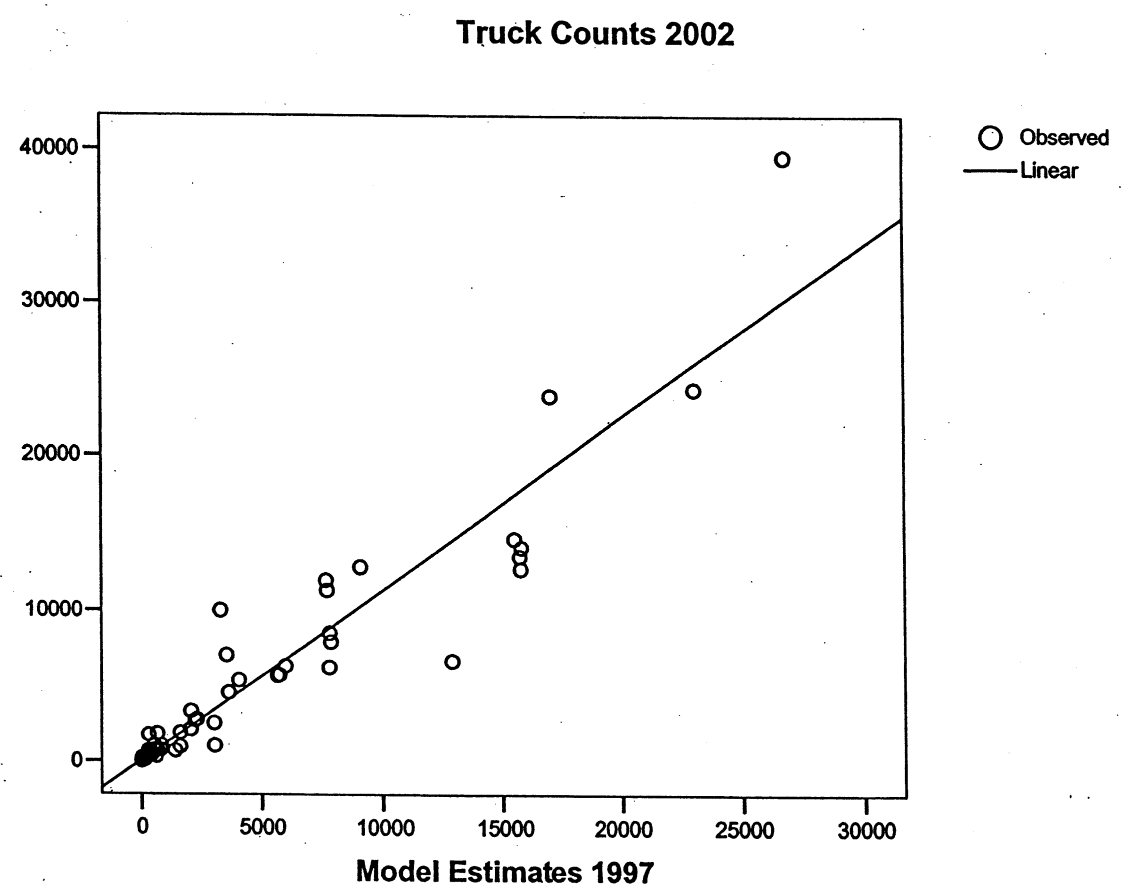


Figure 7-4. Relationship of Counts to Model Estimates

usually based on the respective miles that the traffic is on the various rail carriers' lines. As a result it is to a railroad's advantage to keep the traffic on their system as long as they can accruing more and more miles before transferring it to another rail carrier. One exception to this involves that portion of the traffic that is originating or terminating on short line railroads. In this latter case the short line railroad gets a set fee whether the traffic originated one mile from a junction with a receiving carrier or 50 miles from that location. It is not immediately apparent what type of metric can be used to capture this situation.

It should be apparent that railroad flows would not necessarily follow a minimal path routing and some alternative approach is necessary. In the 1997 report some consideration was given to a procedure that would keep traffic on a rail company's lines as long as possible before passing it off to another carrier. This approach used turning penalties in the assignment algorithm to ensure this type of routing, but problems with the network in the form of duplicate digital lines resulted in failure of this approach.

Instead of that approach the earlier study noted the tendency of railroads to use the same main lines. Although there is some desire on the part of rail carriers to minimize the length of haul, this is minor in comparison to their desire to use mainline trackage even though secondary lines may be more direct. The question was how to represent this tendency with the rail data available on the digital network. Track condition plays a part in such decisions, but this is a very dynamic variable that would change more frequently than the database available. It seemed a new measure of spatial separation was necessary. The new measure would still incorporate an attempt to minimize length of haul, but would also pick those routes that the railroads tend to use.

Short line or regional railroads that originate or terminate traffic are not important in this methodology, since the origin and destination of shipments must be reached. In other words these moves can be replicated by any methodology regardless of the cost attached to it simply because the end nodes of these moves are automatically selected, i.e., there is no alternative.

The measure finally used in the earlier study had the form

$$I = (L\,(1/(D + 1)))$$

where I = the index of spatial separation;
L = the length of the line segment of the network; and,
D = the traffic density of the line in millions of gross ton-miles per year.

The measure diminishes the length of the line segments by dividing the segment by its traffic density, i.e., by gross ton-miles per mile. Typical traffic density values vary from 0 to about six million gross-ton miles per mile of line.

If we have five route segments of 100 miles in length each with traffic density ranging from 0 to 1 to 2 to 3 to 4, the index of spatial separation would be 100, 50, 33, 25, and 20. When used on lines with high traffic density these routes "become shorter" and are always selected. Lines of low traffic density, do not become "longer" since their traffic density always has a unit value added to it. Lines of 0 traffic density would become lines of 0 length, if it were not for the correction factor.

The transport cost matrix used for assigning the rail traffic was defined using the length-density index described above. In the earlier project, it was noted that there was a need for a major research project that would evaluate a broad array of indices and methods for assigning rail traffic to a rail network. Such a study would require the existence of a set of actual flows, referred to in the highway case as target flows, but these are not generally available in the rail case. The carload waybill sample is not available for SCTG commodities so that even if the STCC could be assigned they would not provide a comparable data set for evaluating the accuracy of the rail flow assignments here.

Selection of the Rail Assignment Approach

There is a certain intuitive appeal to the earlier routing method that would keep traffic on a railroad's lines longer in order to maximize their share of the divisions from various moves. On the other hand, the tendency for railroads to use main lines with high volumes (the high density lines) also has some logical appeal.

It has been noted in another context here that we should utilize methods that are flexible to changes in circumstances. If we use the first approach then there is a reliance on the current set of rail carriers. Had we used this approach in the earlier study, the breakup of Conrail would have all but destroyed the flow assignments. We see no reason to assume that the current set of carriers will continue, but more than likely the heavier volume lines will continue to be used even if certain carriers fall out of the system. As a result the assignment process used here is the second approach, i.e., the length-density approach.

A map of the rail flows for the United States as generated by the model here appears as Figure 7-5 and an enlargement of these flows for Indiana appears in Figure 7-6. As is true in the highway case, the major corridors remain the same into the future but the volumes increase. This will be more apparent in Chapter 8.

Flows were also generated for rail and water for the 145 nodes of the original analysis; the five airports included were excluded from this part of the analysis. The flows were generated for rail flows and water flows for all forty-one commodity groups examined here. Digital versions of these are included as part of the deliverables from the project. These files yield the origin, destination and volume of flow for each of these modes by commodity group.

Water flows are not as easy to deal with. Our best estimates are for the tonnage volume moving to Indiana counties by water primarily. In most cases these are most significant when we begin to consider them as highway flows. Unfortunately the data are not so refined as to give the modelers a clear idea of whether these are coming into Indiana via Lake Michigan and the state's ports on that shore, or whether they are coming into the state via the Ohio River ports noted in Chapters 1 and 6. Nevertheless, the estimated 1997 commodity flows to Indiana counties is being provided to the project sponsors in digital format and the forecasted flows for 2015 and 2030 are also being provided. It may be possible for those interested in these flows to infer the Indiana port through which they entered the state.

Pipeline data were collected and treated as one of the modes of interest here, but the State has very little impact on this sector and as a result the data were not treated separately.

A Precautionary Note

It should be noted that while our approach to modal split analysis and assignment discussed in Chapters 6 and 7 have been used in the past, some believe this limits the utility of the models developed. In other words the approach used assumes that modal shares will not change a great deal from historical trends. As a result if the State of Indiana initiates some type of major fuel tax with the objective of diverting truck traffic onto the railroads, the present type of analysis will not enable us to examine such questions. The modal shares are independent of the cost of transport and therefore changes in these costs will not have any impact on the modal shares.

In order to develop an approach to modal split that could evaluate such a question a cost based logistic model would have to be used and this was beyond the scope of the study.

The approach used here would enable state planners to examine the role of changes in employment on traffic, so it still has utility in that regard, although it would not result in a shift of traffic from one mode to another.

The approach used here also has value in examining the impacts of routing as a result of constructing a new highway, or improving an existing highway. It can also be used for various types of economic and policy analysis.

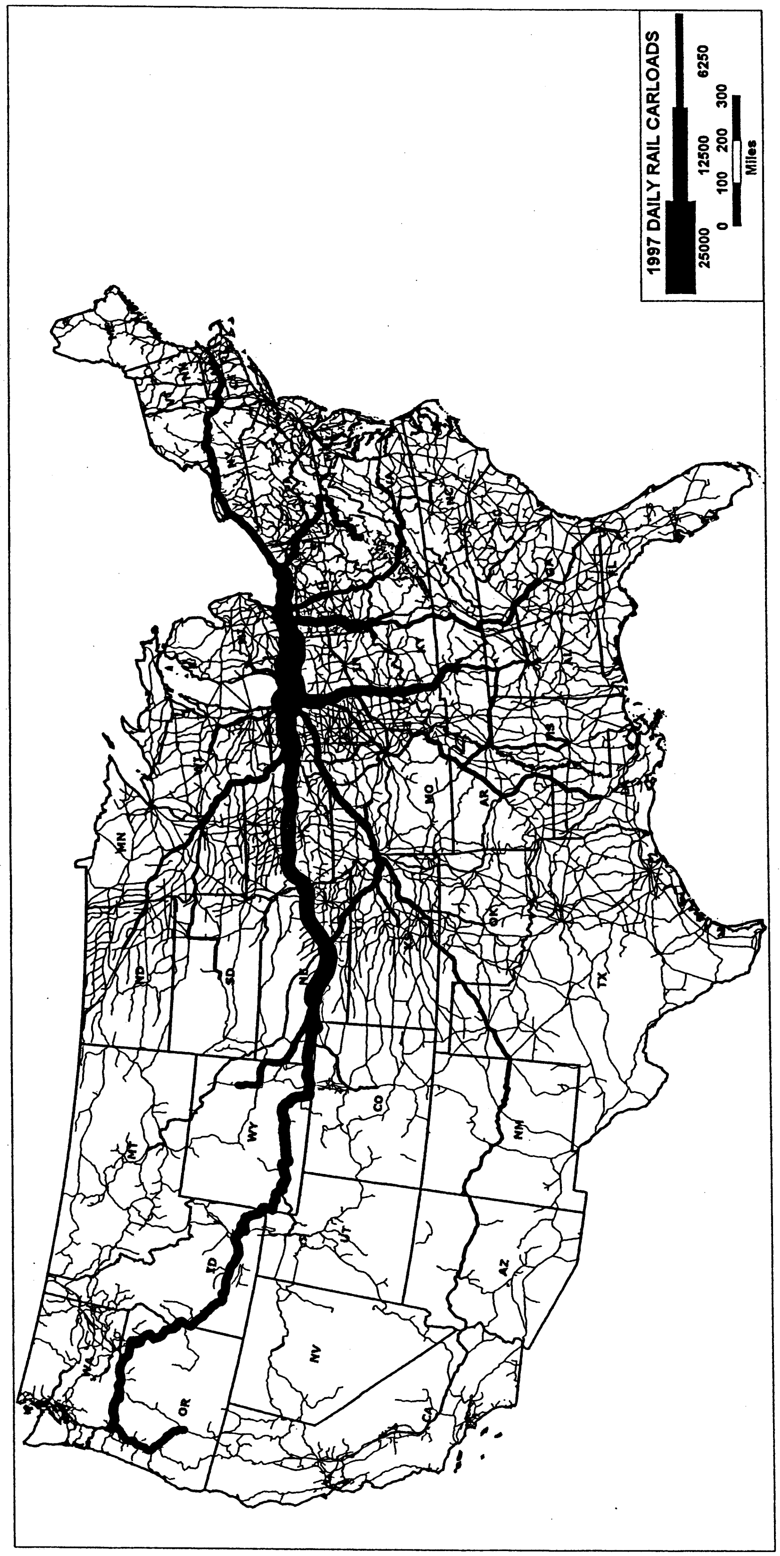


Figure 7-5. US Daily Rail Volumes for 1997

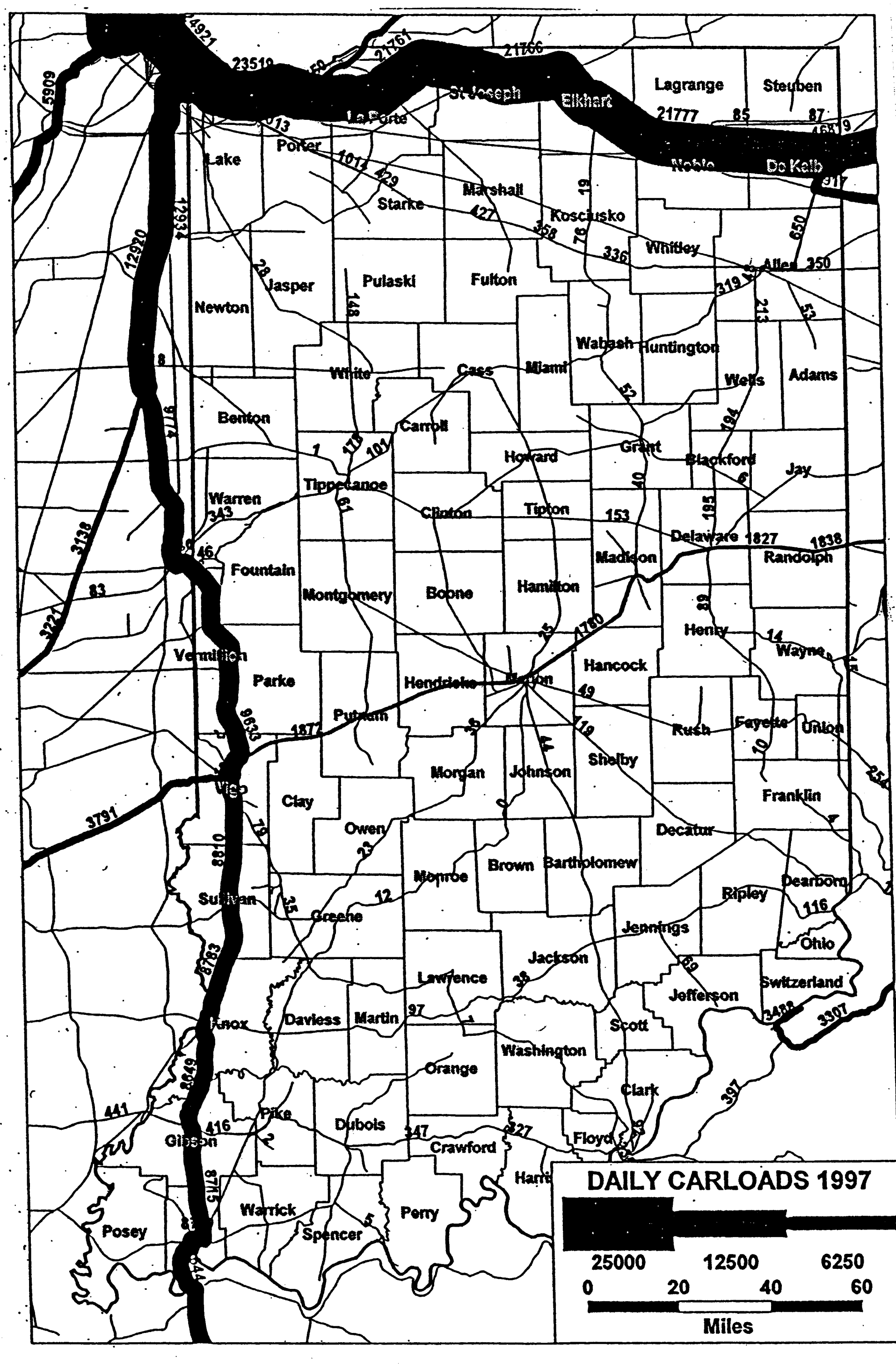


Figure 7-6. Indiana Rail Flows 1997 (modeled)

Chapter 8

FORECASTS FOR 2015 AND 2030

A primary objective of this study was the forecasting of traffic levels for 2015 and 2030. There are numerous ways that this can be accomplished. A standard way of doing short term forecasts involves simply trend extrapolation. This might better be referred to as a projection since one literally projects the trend line into some future time. The projection is sometimes done with a ruler, or more elegantly with a regression model.

In the earlier study that was undertaken we made use of employment projections. In the simplest case let us say that we have found each ton of some commodity shipped appears to be related to .5 employees in some related industrial sector. We project employment using some method and find that the industry at some future date will have 1000 workers in some area of interest. Since we know that one employee will produce 2 tons per year we assume that the 1000 workers will produce shipments of 2,000 tons.

The major problem inherent in the above formulation should be apparent: it assumes that there will be no changes in the productivity of employees over the projection period. Whatever an employee was producing in the base year is the same as what she will produce in the forecast year. This is viewed as unacceptable by many researchers and practitioners in the modeling field. You can look at any one of a number of industries and it is apparent that mechanization, robotics, and computerization have significantly changed worker productivity, so the approach described is unacceptable since it does not incorporate such productivity changes.

In order for this project to incorporate the role of changes in employment the Indiana Department of Transportation supplied the study team with gross county-level employment projections for the year 2015 and the year 2030. By gross we simply mean that the forecasts are not industry specific, but are forecasts of total employment in the county. One could obviously raise some questions regarding the validity of the assumption that employment will increase uniformly across all industries, but this is what we have assumed here. The primary argument against this is due to globalization. We have seen substantial changes in employment levels in the manufacturing sectors and there is no indication that this trend will change in the near future.

Changes in employment for areas beyond the borders of Indiana were not made available. We have no other source for these and we have made the assumption that employment beyond

Indiana will increase or decrease at the same level as the population will change. The source of the population forecasts is the U.S. Bureau of Census.

Future Traffic Production

Table 8-1 on the following page gives the estimates of the change in employment used for 2015 and 2030. For Adams County we are assuming that employment will increase by .1213 or 12.13% between 2000 and 2015. It is expected that the county's employment will increase by 10.81% during the period from 2015 to 2030.

This does not get us around the problem of changes in productivity. For this we have made use of labor productivity changes derived from Indiana's REMI model. That model gives growth factors for labor productivity changes in several employment sectors of Indiana. The values derived cover numerous employment sectors that are not of interest in this study, e.g., the service industries are also included. Therefore the values of interest here appear in Table 8-2.

It may be instructive and clarify the use of the above if an example is provided of the use of these values. Let us assume that we have an industry and SCTG sector for which the relationship between tons moved and employment is as follows:

$$\text{Tons} = 2 * \text{employment}$$

We will assume that employment is 1000 in the area that we are looking at. This would suggest that the current level of this SCTG from this area is 2000 tons (assuming the model is perfect). Now we expect an increase in employment of 20% between now and 2030 or a growth factor 1.20 for this employment sector. So the 1000 employees will be 1200 employees by 2030 and the tonnage shipped will increase to 2400 tons. But we have not yet considered any changes in labor productivity. Let us assume that productivity will increase by 91%, or by a growth factor of 1.91. This means that the expected tons will actually increase from the 2400 tons to 4584 tons.

For the year 2015 we would assume half of the increase in employment to 1100 employees with a tonnage of 2200 without the productivity increase. The total increase of 2,184 tons due to productivity is divided proportionally based on employment and this suggests that 1048 tons accompanied the growth to 2015 (48%) and the remaining 1136 tons (52%) came during the next fifteen years. Therefore, the tonnage of the SCTG for 2015 would be 2200 plus the 1048 or a total of 3248 tons. This should make it apparent that changes in productivity are quite significant in terms of the total amount of a commodity that will be moved at some future point in time. The forecasts of future commodity traffic production for 2015 and 2030 appear in the appendices E and F.

Table 8-1 Proportional Increases in Employment by Area

Locale	2000-2015	2015-2030
Alabama	1.0486	1.0453
Arizona	1.4609	1.4292
Arkansas	1.1105	1.0914
California	1.1846	1.1576
Colorado	1.1740	1.1471
Connecticut	1.0675	1.0146
Delaware	1.1835	1.0919
District of Colombia	-0.1149	-0.1440
Florida	1.3267	1.3528
Georgia	1.2497	1.1747
Idaho	1.2597	1.2083
Illinois-Chicago	1.0546	1.0256
Illinois- Springfield	1.0546	1.0256
Indiana - Adams	1.1213	1.1081
Indiana - Allen	1.1152	1.1033
Indiana - Bartholomew	1.1119	1.1006
Indiana - Benton	-0.0316	-0.0329
Indiana - Blackford	-0.0803	-0.0873
Indiana - Boone	1.3460	1.2570
Indiana - Brown	1.0258	1.0251
Indiana - Carroll	1.0680	1.0636
Indiana - Cass	-0.0054	-0.0055
Indiana - Clark	1.1264	1.1122
Indiana - Clay	1.0302	1.0293

Table 8-1, Continued

Indiana - Clinton	1.0638	1.0600
Indiana - Crawford	1.1917	1.1606
Indiana - Daviess	1.0904	1.0828
Indiana - Dearborn	1.2626	1.2080
Indiana - Decatur	1.0441	1.0422
Indiana - DeKalb	1.1507	1.1310
Indiana -Delaware	1.0596	1.0563
Indiana - Dubois	1.0798	1.0739
Indiana - Elkhart	1.1170	0.1047
Indiana - Fayette	-0.0481	-0.0506
Indiana - Floyd	1.1130	1.1015
Indiana -Fountain	1.0157	1.0154
Indiana - Franklin	1.1356	1.1193
Indiana - Fulton	1.0282	1.0274
Indiana - Gibson	1.1114	1.1002
Indiana - Grant	-0.0934	-0.1031
Indiana - Greene	1.0000	1.0000
Indiana - Hamilton	1.3766	1.2736
Indiana - Hancock	1.3311	1.2487
Indiana -Harrison	1.2538	1.2024
Indiana - Hendricks	1.5767	1.3658
Indiana - Henry	-0.0588	-0.0625
Indiana - Howard	1.0241	1.0236
Indiana - Huntington	1.1117	1.1004
Indiana - Jackson	1.0376	1.0362
Indiana - Jasper	1.0667	1.0625

Table 8-1, Continued

Indiana - Jay	-0.0277	-0.0286
Indiana- Jefferson	1.0790	1.0732
Indiana - Jennings	1.1263	1.1122
Indiana - Johnson	1.3637	1.2667
Indiana - Knox	-0.0501	-0.0528
Indiana - Kosciusko	1.0670	1.0628
Indiana - LaGrange	1.1358	1.1195
Indiana - Lake	1.0189	1.0185
Indiana - LaPorte	1.0127	1.0126
Indiana - Lawrence	-0.0146	-0.0149
Indiana - Madison	1.0338	1.0327
Indiana - Marion	1.0492	1.0469
Indiana - Marshall	1.1088	1.0981
Indiana - Martin	-0.0470	-0.0494
Indiana - Miami	-0.0486	-0.0511
Indiana - Monroe	1.1422	1.1244
Indiana - Montgomery	1.0557	1.0527
Indiana - Morgan	1.2179	1.1789
Indiana - Newton	1.0149	1.0147
Indiana - Noble	1.0842	1.0777
Indiana - Ohio	1.1028	1.0932
Indiana - Orange	-0.0020	-0.0020
Indiana - Owen	1.0856	1.0788
Indiana - Parke	1.0082	1.0081
Indiana - Perry	-0.0413	-0.0431

Table 8-1, Continued

Indiana - Pike	1.0541	1.0510
Indiana - Porter	1.0574	1.0543
Indiana - Posey	1.0657	1.0615
Indiana - Pulaski	1.0526	1.0499
Indiana - Putnam	1.0589	1.0556
Indiana - Randolph	-0.0282	-0.0291
Indiana - Ripley	1.0770	1.0715
Indiana - Rush	-0.0417	-0.0435
Indiana - St. Joseph	1.0545	1.0516
Indiana - Scott	1.0559	1.0530
Indiana - Shelby	1.0186	1.0182
Indiana - Spencer	-0.0062	-0.0064
Indiana -Starke	-0.0165	-0.0168
Indiana - Steuben	1.0527	1.0501
Indiana - Sullivan	1.0522	1.0495
Indiana - Switzerland	1.2387	1.1927
Indiana - Tippecanoe	1.1927	1.1616
Indiana - Tipton	-0.0049	-0.0049
Indiana - Union	1.0363	1.0346
Indiana - Vanderburgh	1.0817	1.0755
Indiana - Vermillion	-0.0457	-0.0481
Indiana - Vigo	1.0351	1.0339
Indiana - Wabash	-0.0294	-0.0304
Indiana - Warren	1.0560	1.0531
Indiana - Warrick	1.1217	1.1085
Indiana - Washington	1.0879	1.0808

Table 8-1, continued

Indiana - Wayne	-0.0601	-0.0640
Indiana - Wells	1.1172	1.1049
Indiana - White	1.0214	1.0208
Indiana - Whitley	1.1150	1.1031
Iowa	1.0342	-0.0235
Kansas	1.0611	1.0306
Kentucky - Louisville	1.0766	1.0468
Kentucky - Lexington	1.0766	1.0468
Louisiana	1.0458	1.0276
Maine	1.0894	1.0160
Maryland	1.0722	1.1311
Massachusetts	1.0645	1.0375
Michigan - Detroit	1.0665	1.0090
Michigan - Grand Rapids	1.0665	1.0090
Minnesota	1.1522	1.1125
Mississippi	1.0597	1.0259
Missouri	1.0848	1.0594
Montana	1.1078	1.0454
Nebraska	1.0451	1.0177
Nevada	1.5304	1.4002
New Hampshire	1.1787	1.1303
New Jersey	1.1000	1.0591
New Mexico	1.1223	1.0285
New York	1.0300	-0.0035
North Carolina	1.2437	1.2215
North Dakota	-0.0110	-0.0450

Table 8-1, continued

Ohio - Cleveland	1.0249	-0.0073
Ohio - Columbus	1.0249	-0.0073
Ohio - Cincinnati	1.0249	-0.0073
Oklahoma	1.0612	1.0687
Oregon	1.1729	1.2046
Pennsylvania	1.0350	1.0045
Rhode Island	1.0870	1.0118
South Carolina	1.1571	1.1091
South Dakota	1.0558	1.0044
Tennessee	1.1429	1.1351
Texas	1.2750	1.2532
Utah	1.2462	1.2524
Vermont	1.1057	1.0575
Virginia	1.1961	1.1604
Washington	1.1792	1.2409
West Virginia	1.0080	-0.0564
Wisconsin	1.0968	1.0456
Wyoming	1.0693	-0.0095

Source: Indiana Department of Transportation

Table 8.2 Labor Productivity Growth Factors for Indiana, 2002-2030

SCTG Code	Commodity Group	Growth 2000- 2015	Growth 2000-2030
01	Live Animals and Fish	1.27	1.54
02	Cereal Grains	1.27	1.54
03	Agricultural Products Except Live Animals, Cereal Grains, and Forage products	1.27	1.54
04	Animal Feed and Products of Animal Origin	1.27	1.54
05	Meat, Fish, Seafood, and Preparations	1.31	1.62
06	Milled Grain Products and Preparations, and Bakery Products	1.31	1.62
07	Prepared Foodstuffs, Fats, and Oils	1.31	1.62
08	Alcoholic Beverages	1.48	1.96
09	Tobacco Products	1.48	1.96
10	Monumental or Building Stone	1.02	1.03
11	Natural Sands	1.02	1.03
12	Gravel and Crushed Stone	1.02	1.03
13	Non-metallic Minerals	1.34	1.68
14	Metallic Ores	1.46	1.91
15	Coal	1.11	1.22
17	Gasoline and Aviation Turbine Fuel	1.60	2.19
18	Fuel Oils	1.60	2.19
19	Products of Petroleum Refining and Coal Products	1.60	2.19
20	Basic Chemicals	1.35	1.71
21	Pharmaceutical Products	1.35	1.71
22	Fertilizers and Fertilizer Materials	1.35	1.71
23	Chemical Products and Preparations	1.35	1.71
24	Plastics and Rubber	1.64	2.29
25	Logs and Other Wood in the Rough	1.30	1.60
26	Wood Products	1.30	1.60
27	Pulp, Newspaper, Print, and Paperboard	1.34	1.68
28	Paper or Paperboard Articles	1.34	1.68
29	Printed Products	1.10	1.20
30	Textiles, Leather, and Articles	1.55	2.10
31	Non-metallic Mineral Products	1.34	1.68
32	Base Metal in Primary or Semi-finished Forms and in Basic Shapes	1.63	2.27
33	Articles of Base Metal	1.63	2.27
34	Machinery	1.82	2.64
35	Electronic and Other Electrical Equipment and Components; Office Equipment	7.95	14.95
36	Motorized Vehicles	2.13	3.26
37	Transportation Equipment	1.58	2.16
38	Precision Instruments and Apparatus	1.43	1.97
39	Furniture, Mattresses and Mattress Supports, Lamps, Lighting Fittings, and Illuminated Signs	1.58	2.17
40	Miscellaneous Manufactured Products	1.43	1.97
41	Waste and Scrap	1.43	1.97
43	Mixed Freight	1.43	1.97

Future Attractions

The same employment increase factors and productivity increases were assumed to influence the consumption side of the analysis. That is it was generally assumed that the increases in shipments produced would be met with an increase in the shipments received. There is nothing seriously wrong with such an assumption except that some of the increased production may very well be exported. We have no way of knowing this with any certainly and therefore we are assuming that the total increase in production is consumed by the domestic market.

Values for productions and attractions for the forecast years of 2015 and 2030 appear in appendices E and F of this report.

The Future Flows

Using the models developed for productions and attractions we next inserted estimates of the employment variables assuming the growth in employment and productivity noted earlier for 2015 and 2030. This was followed by the use of the calibrated fully-constrained gravity model assuming the parameters from the earlier study held. This gave us the distributed total traffic for the two forecast years. The historical patterns of modal choice were again used and the traffic was divided among modes once again for each year.

Maps of the forecasted truck traffic for Indiana in 2015 and 2030 appear as Figures 8-1 and 8-2. Similar maps appear for forecasted rail traffic for Indian in 2015 and 2030 appear as Figures 8-3 and 8-4.

Examining the maps should reveal that the major corridors in 2015 and 2030 in both the truck and the rail case are very similar. This is to be expected since we have done nothing to change the major corridors in a relative sense. Speeds and travel times are assumed to be the same in the truck case and density per unit length is also assumed to be the same in the rail case. In reality the flows are changing more in the highway case than in the rail case as can be seen by comparing the legends on the map. Fine detail can be achieved by using some of the methods discussed in Chapter 9 on Implementation.

We have some confidence in the highway forecasts since the model used has been evaluated on the 1997 data and found to be very good. We have not performed a similar evaluation on any of the rail modeling since we have no actual data set to use for such a test. Therefore, we offer the rail forecasts with this caveat.

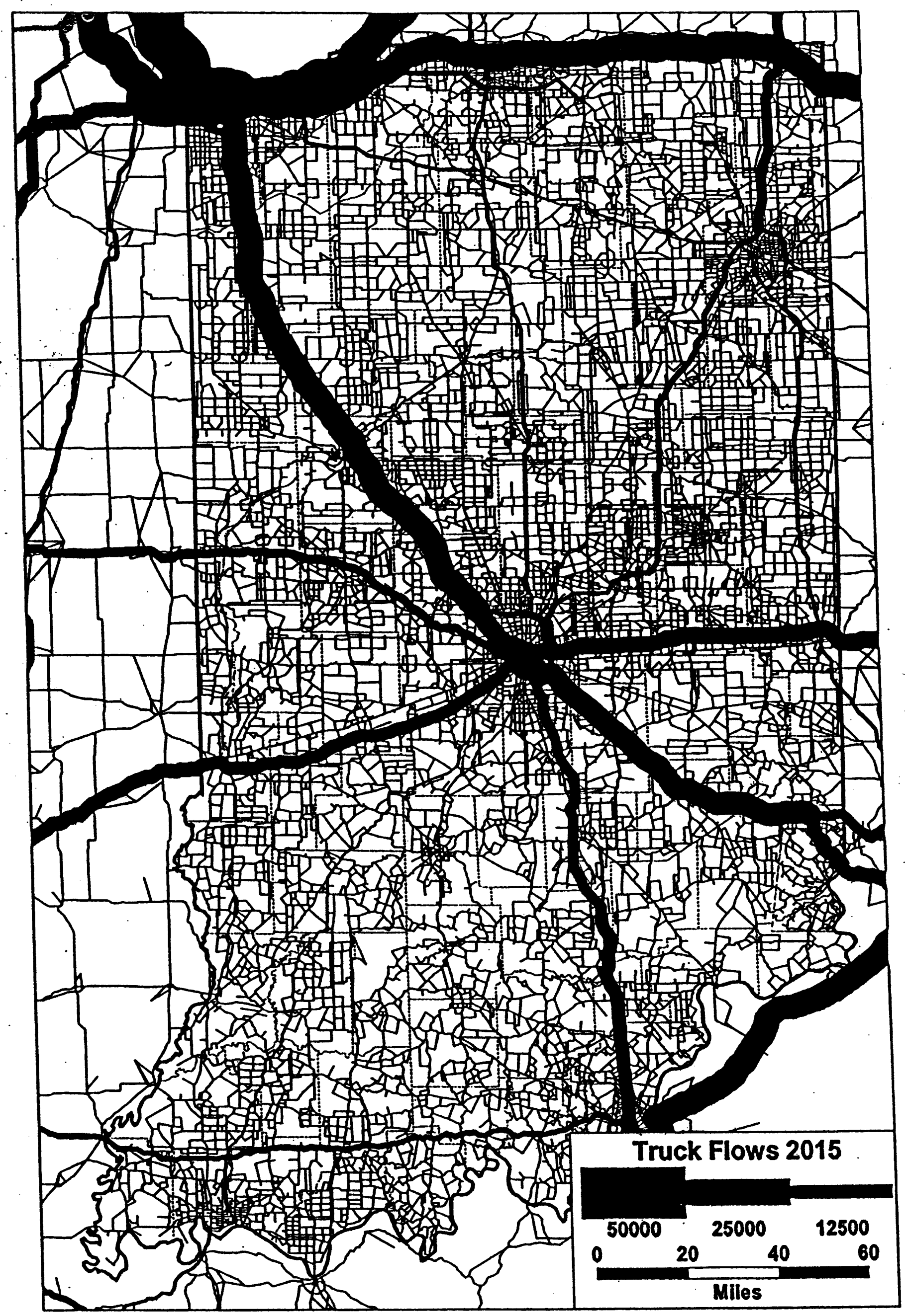


Figure 8-1. Indiana Daily Truckload Freight Volumes for 2015

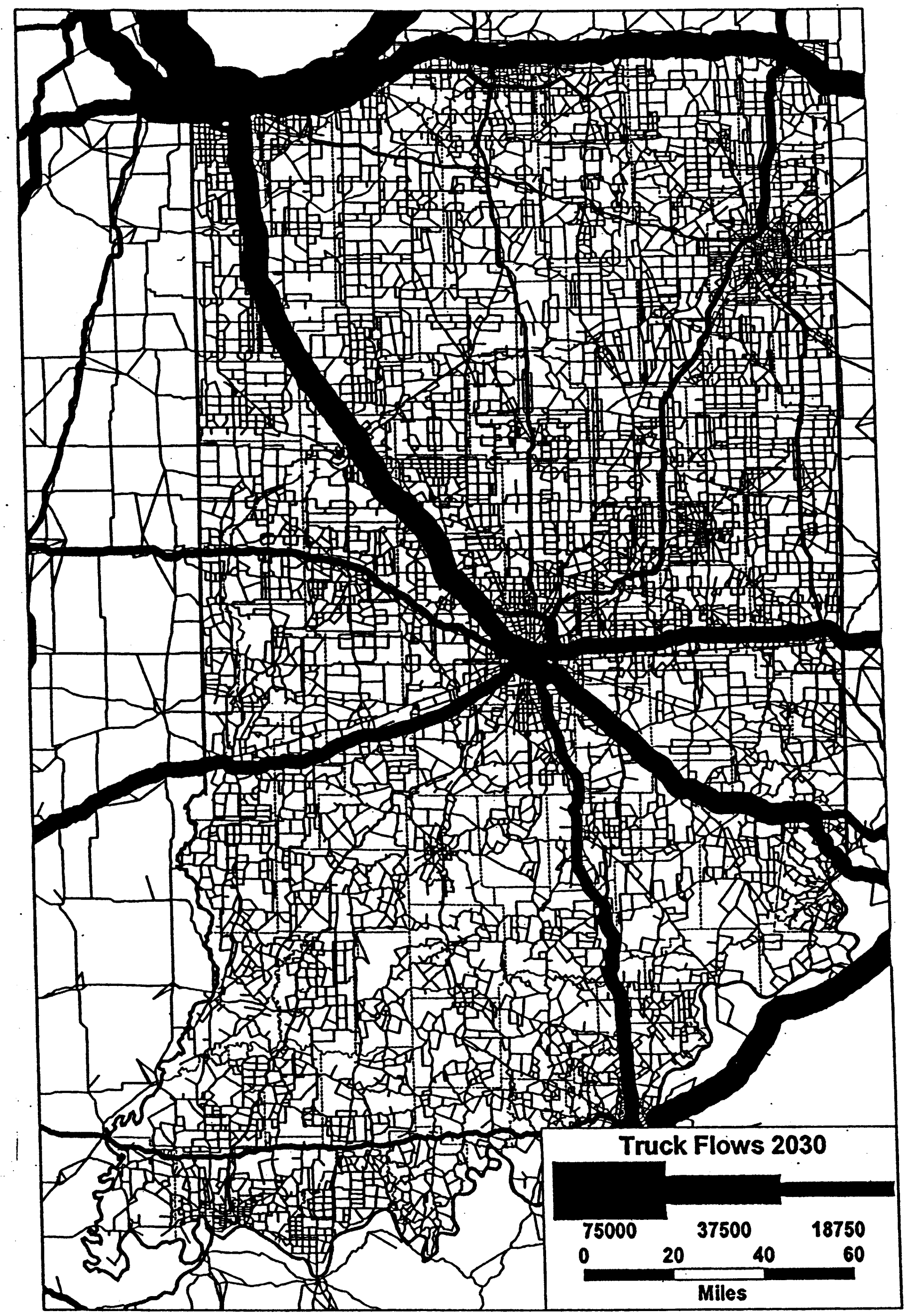


Figure 8-2. Indiana Daily Truckload Freight Volumes for 2030

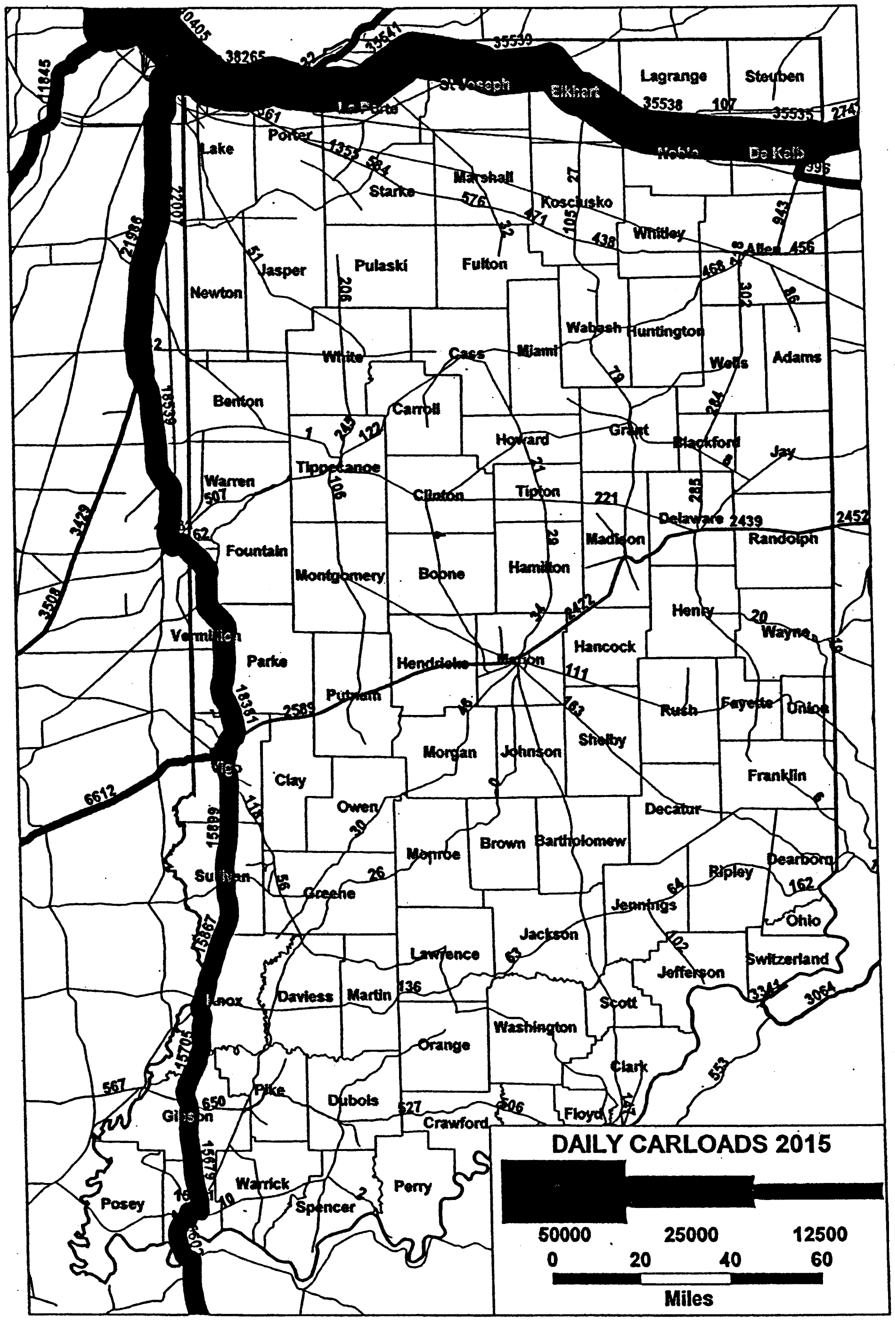


Figure 8-3. Indiana Daily Railcar Freight Volumes for 2015

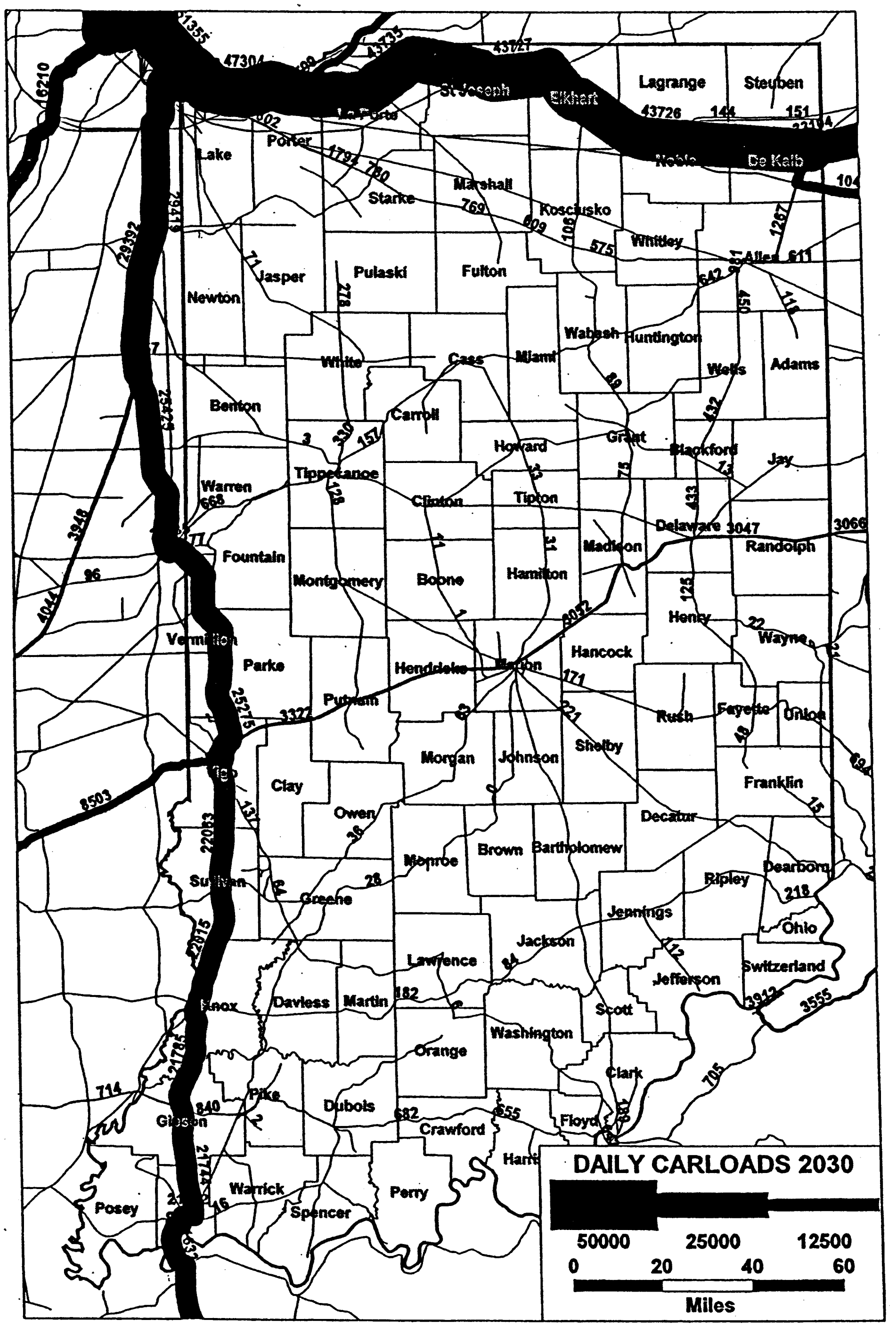


Figure 8-4. Indiana Daily Railcar Freight Volumes for 2030

Possible Improvements

One possible area where improvement is possible in the forecasting area is in the use of more refined estimates of employment growth. As noted above the values used here were county-level specific, but they were not industry-level specific. The assumption is that all of the industries in the county will grow at exactly the same rate. This is perhaps unrealistic. The state may wish to refine these in the future, perhaps using one of the economic models that they already use.

The values used here were supplied by the state and the research team was requested to use these for estimates of employment growth.

Chapter 9

IMPLEMENTATION

This study was undertaken as a planning and analysis project. It should be apparent to the reader that the study also has many of the attributes of a research project. Many of the problems encountered as well as the models used are often found in research papers. We have also evaluated the different models as we went along. The end result is a study that should have value for economic analysis, transport analysis, transport policy formation, and for planning studies conducted by the state or subareas of the state such as metropolitan areas.

In this chapter we will briefly suggest some possible applications for the findings of this study in the areas noted. We will also identify the various deliverables from this project. Beyond this report these consist of computer files that will enable the state to replicate and utilize the models developed here.

Use of the Results for Economic Analysis

The appendices of this report include several project generated databases that should be of use to organizations interested in the flow of goods into, through, and out of counties and urban areas of the state. MPOs (metropolitan planning organizations) have shown considerable interest in the results of this study for such purposes. This would enable these areas to identify which of the myriad of highway projects facing it may have the highest value in terms of local industrial production activities. If an area has an interest in examining its economic base this study will give such areas some information on those economic activities that may wield the greatest impact in terms of the value of commodity flows. This can be done by taking the values from goods for Indiana in 1997 or 2002 (see tables 3-1 and 3-2), and multiplying the tonnage by these values. In this case it should be noted that the values in several of the tables are in thousands of tons.

Using the same procedure a county or metropolitan area can assess to what extent it is an importer or exporter of individual commodity groups. One should bear in mind that the categories or commodity groups used here are indeed groups. That is, these are not individual goods. It may be that a county is importing exactly the same amount of a commodity group as it is exporting of that group. All that this means is that one good of the group may be imported, while another good in the same group may be exported at the same time. Because of these possible idiosyncrasies it might be best to conduct all such analyses in terms of dollars, rather than tons.

Use of Results for Transport Analysis

The type of transport analysis that can be undertaken using the results of this study are probably primarily at the regional corridor level. In that case we might be talking about a major highway link between Indianapolis and Evansville and the concern might be to what extent such a highway link would facilitate the movement of commodities to or from the state. It would be possible to use the results of this study to estimate the net transport cost savings for the state's manufacturers if such a highway were built. Such an analysis needs some reasonably good estimates of the volume of goods currently moving and this study could provide the same.

Use of the study for such a problem would necessitate the use of a transport network similar to the one that was utilized in this study.

We are also reminded of the fact that the oft cited 1997 freight study was used for a couple of major studies after its completion. One of these involved a statewide analysis of intermodal facilities (Booz-Allen & Hamilton, *et al*., 1997) and another looked at the Indianapolis region in terms of freight flows (Cambridge Systematics, Inc., *et al*.,1998).

For county level studies it might be desirable to try and disaggregate the county level estimates provided here to a lower level of geographic detail. This has been done by the state in the past using data from Dun & Bradstreet to estimate the locations of production and attraction of flows.

Use of the Results for Policy Analysis

The state of Indiana could also use the results of this project to evaluate different policy decisions of the state. For example, the state recently decided to increase the speed limit on some of its highways to 70 mph. This was done without any analysis in terms of evaluating what the impact of such a change might do for the state's commodity flows. While there is no reason to believe this decision would result in alternate route selection, such an evaluation could be undertaken here. The reason why little change would be expected is that the leading routes in terms of previous speed limits are for the most part the same ones that received the increase. There is nevertheless the possibility that a 70 mph speed limit corridor could combine with a 50 mph speed limit corridor and completely pull traffic off of an urban 55 mph corridor. By simply changing the speed limits of the network database, such policy decisions could be examined *a priori* the change.

Databases and Deliverables

Aside from this report and the various flow estimates and forecasts, this project will also supply the sponsor with production and attraction vectors developed for the 41 commodity groups examined here. These are all being supplied electronically as well as in published form in the appendices of this report. The values for 1997 appear as appendix A. The forecasts over these same set of commodities for 2015 appear as appendix E and the forecasts for 2030 appear as appendix F.

The last deliverable supplied includes the computer programs used here. One of these was used in the 1997 study, but the others are new. They appear here as Fortran 77 code, but they have also been run on a Fortan 95 compiler. They have not been supplied as executable files. They can easily be made computer-ready by running them through any Fortan compiler, e.g., Microsoft, Lahey, Salford, and so forth. The programs used appear here as appendix B.

There are distance decay curves created from data in the 1997 *CFS* reports that appear in appendix C, and illustrate the manner in which traffic falls with increasing distance from an origin.

A second set of databases are the proportions of each of the commodity groups used in the modal assignments. These are being supplied in electronic form as well as in appendix D of this document.

The project will also provide the sponsor with master data files generated by the project. These will include files for all highway, rail, water, pipeline and air freight traffic. Interaction matrices for 1997, 2015, and 2030 will be provided as well. In order for the state analysts to duplicate the findings here and to use the models derived for evaluating projects and alternatives, we will also supply the state with networks used for highways and rail, the density variable for the railroad traffic assignment, as well as the railroad *.net file. Similarly, the same will be provided for the highway sector, along with any files necessary to run the analyses.

A Guide to Using the Data Files

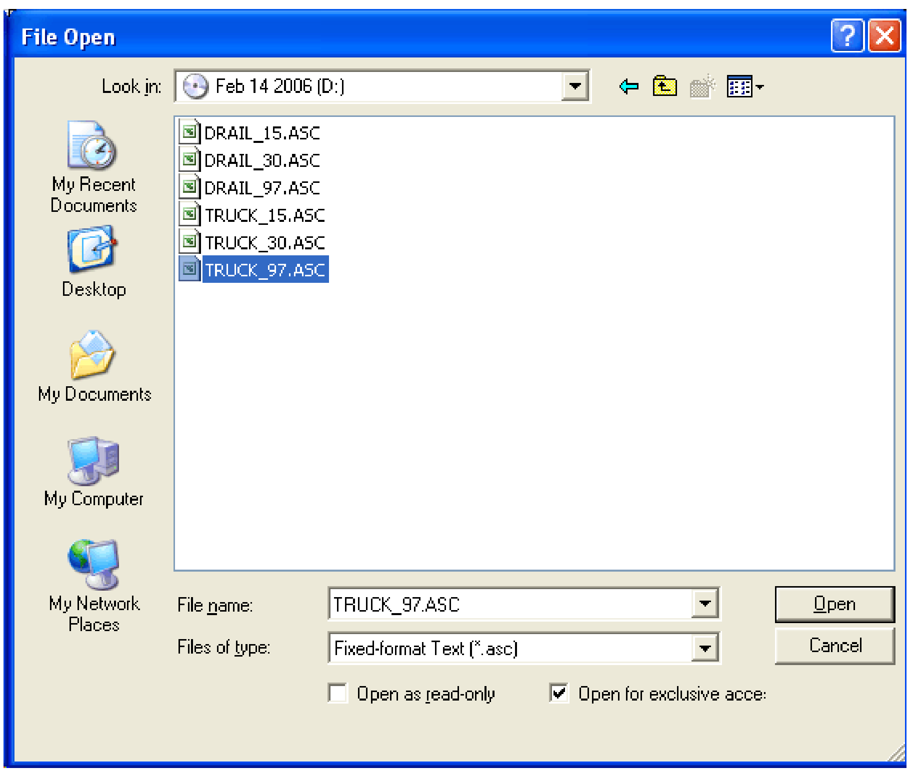
There are numerous uses for the data supplied here and on the CD ROM that will be supplied to the sponsor. As indicated elsewhere we see the users of these as the Indiana DOT and the MPOs of the state of Indiana. We can envision MPOs being interested in the tonnages of goods produced by and attracted to counties within their jurisdiction. This information can easily be obtained by using the appropriate tables of appendix A, E, and F, for 1997, 2015 and 2030, respectively. Appropriate conversions of the data to trucks can be obtained by using the density figures of Table 5-4 in the text of this report. Dividing the tonnages by the truck density will yield the trucks moving these goods in the local area. Conversion of the tonnages to 1997 dollars requires the use of a measure of value for the SCTG groups. These values appear on appendix page B40. The data on that page consists of three columns. The first is the two-digit SCTG code; the second in the motor carrier density, e.g., 9.77, 96.63, and so forth; and the third is the value per ton in 1997 dollars, e.g., $1,042.38.

The other uses of the data supplied here are for evaluating the use of different routes for the movement of goods. This is not nearly so easily done unless the user is skilled in the use of TransCAD, the GIS system used here (Caliper, 2000). We will discuss how this can be done if the user is somewhat familiar with the GIS software.

There are two broad problem areas that the user might want to work on with the data here. The first of these is concerned with the volume of traffic on the local roads of an MPO or other areal unit. In effect the maps prepared here may all be enlarged to reveal such information while the map is resident on the computer, but you lose this ability when the maps appear in print as they do here. So the first thing the user may want to do is create an assignment for the flows distributed. We will call this simply the Assignment Problem below. The second problem seeks to evaluate what the volume of trucks would be on different roads and streets if traffic were prevented from taking some existing link segments in the area under analysis. We will refer to this as the Alternate Routing problem.

The Assignment Problem

We begin by starting TransCAD, and going to File, and then Open. We next find the flow data of interest that we want to assign to the network. In our case the data is on a CD in the D drive entitled February 14, 2006, and it is entitled TRUCK_97.ASC. In order for TransCAD

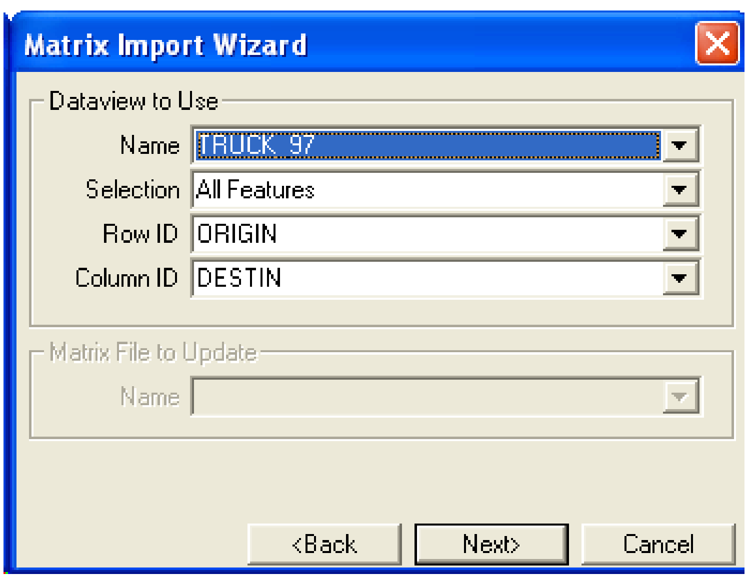


to recognize the data there must also be a dictionary file in the same directory. These files have the extension of .DCT. This file in the case of our flow data has the following form:

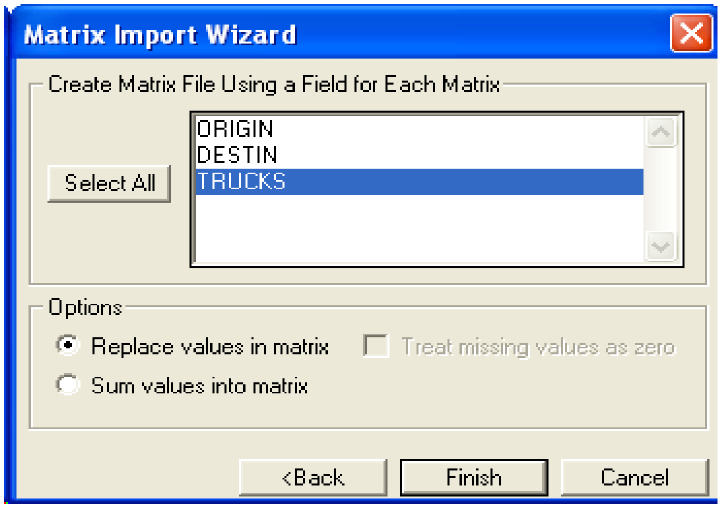
TRUCK_97
41
ORIGIN,I,1,8
DESTIN,I,9,8
TRUCKS,R,17,25

The name of the DCT file must have the same name as the beginning of the flow data file, so the above five line file is named TRUCK_97.DCT. These files are being supplied with the flow data, but the user may have occasion to create a different flow file (e.g., by converting the trucks to dollars). In such a case the first line is a name for identification purposes, the second line gives the total length of data, line three the name of the rows, the type of data (I for integer here), the column where the data begins, and its length. The next line is the same for the columns. The final line identifies what is being assigned, the type of data (R for real or decimal data here), the column where the variable begins, and the length of the variable. Consult the TransCAD manual for further information on this if necessary.

We next want to create an origin-destination matrix from this data. We go to Matrix on the horizontal TransCAD toolbar at the top of the page. Go down the matrix toolbar to IMPORT and press this. This results in the following screen:

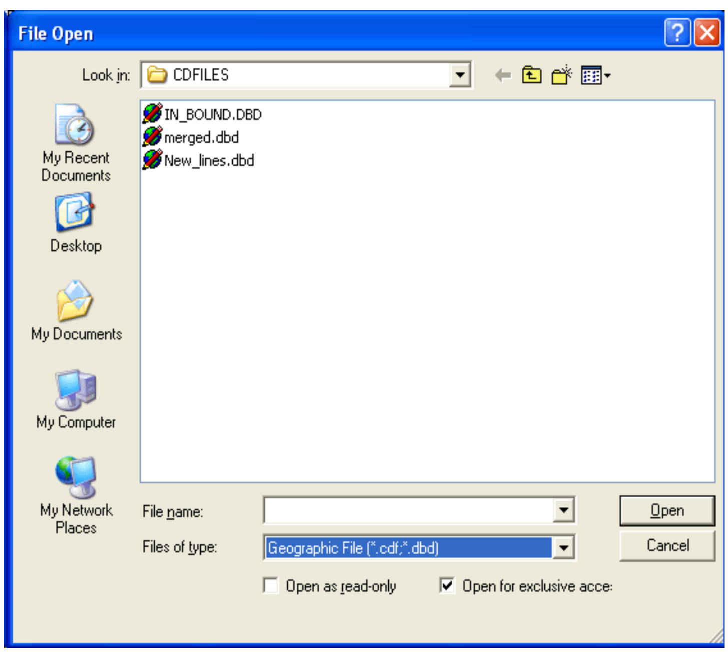


Clicking on Next yields:

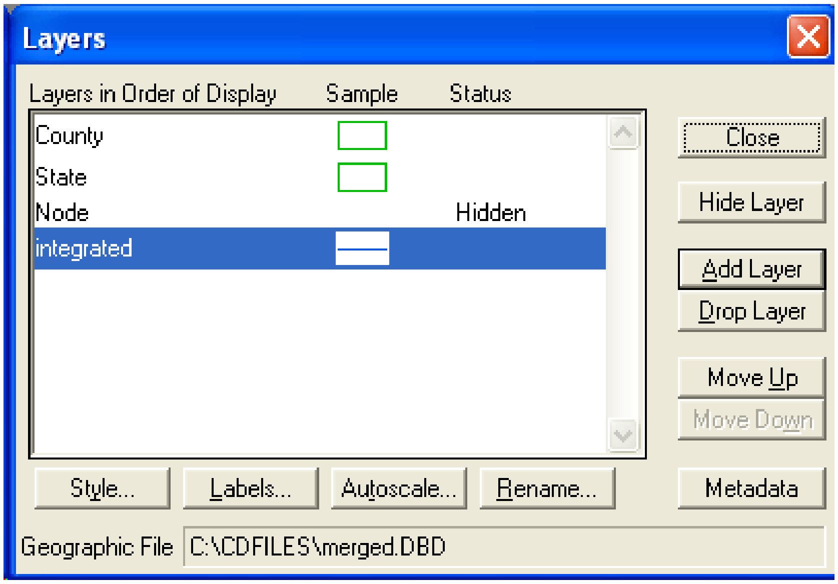


and clicking on Finish yields a screen requesting that you type in the name of the matrix file you are creating. Here we have called it TRUCK__97.MTX. Click on Save and your matrix will appear. Minimize the matrix.

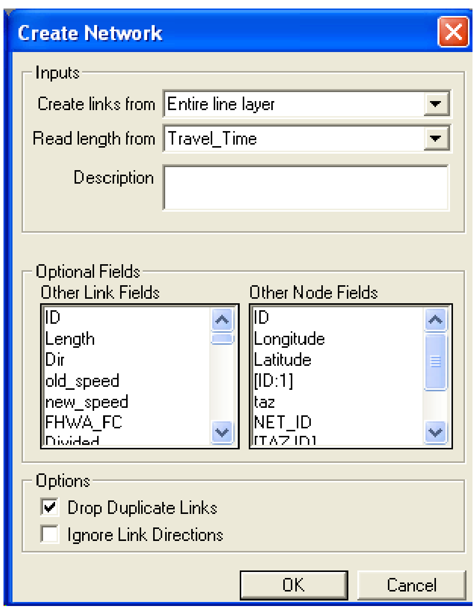
Now that we have the flow matrix, we need to assign these flows to a network. If you have not yet created a network you must do this first. Go to your boundary file directory. This is labeled



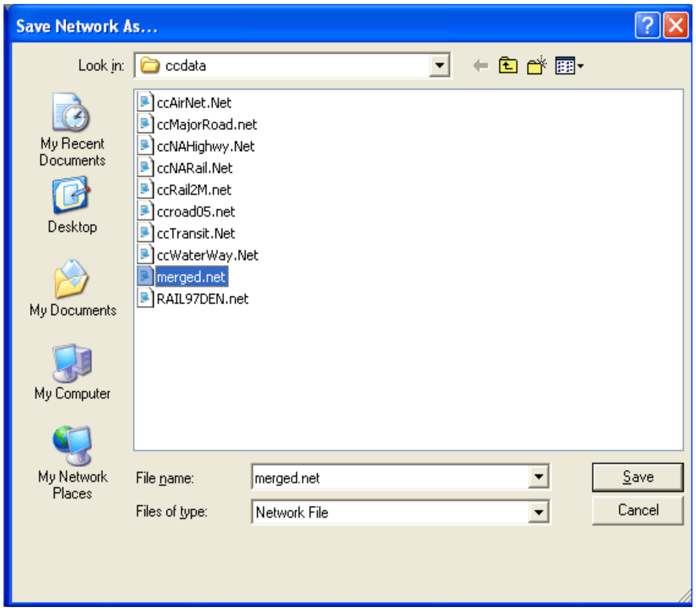
CDFILES here. Make sure the Geographic Files appears and load the IN_BOUND.DBD. This will create a map of Indiana on the screen with counties and the state outlined. Next go to the toolbar at the top of the TransCAD screen. Click on the layers icon. Click on Add Layer and add the merged.DBD. This will yield the display below and create a highway network for the state. Clicking on Close will produce the network on the screen.



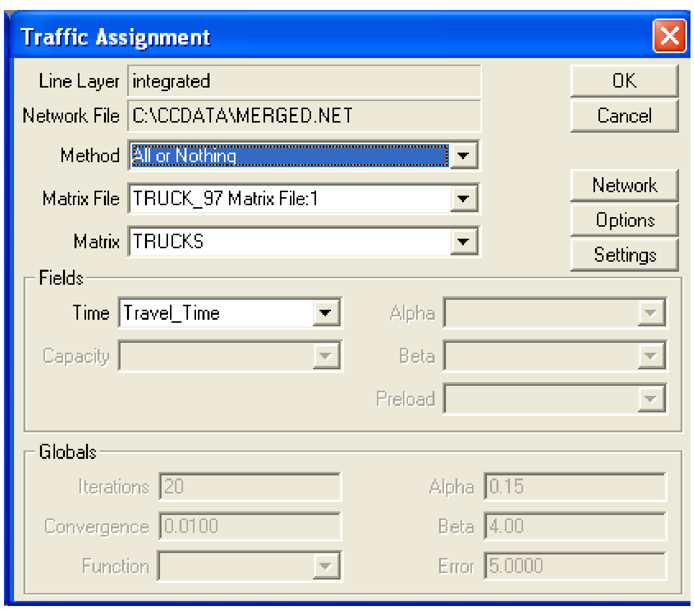
To create a network for assigning flows you next go to the horizontal toolbar at the top of the TransCAD screen. Make sure the active layer is the network (called integrated here). Now go to the Network/Paths icon and click it. From the toolbar produced click Create. The screen below appears.



The travel time we will use is listed as Travel_Time. Select it so that it is displayed in the window. Click on OK. You will be asked for a name for the network file. We have called ours merged.net.

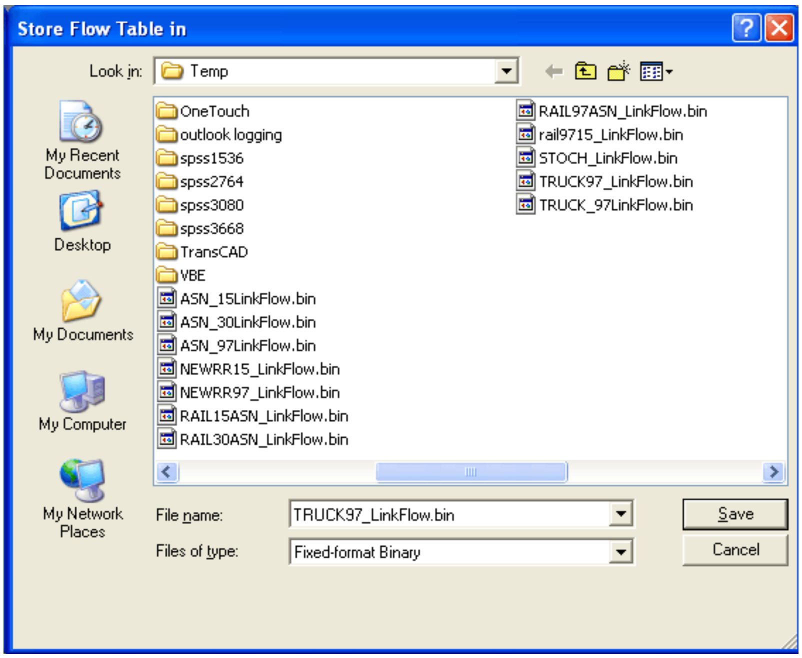


Make sure your flow matrix is active and click on Planning on the horizontal toolbar. Then click on Traffic Assignment. Since we are dealing only with trucks we use All or Nothing as noted in this report. Insert Travel_Time if it does not appear. It is found below.

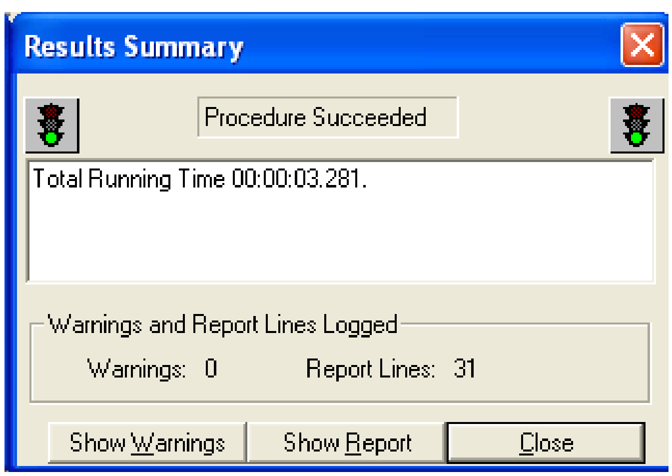


Make sure the TRUCK_97 and merged.net are active. If they do not appear in the above window, try again. As noted above we have selected the "All or Nothing" assignment routine. Other assignment algorithms require a capacity value which is not in the database. Click OK.

We are next asked for a name for the assignment flows. We have used TRUCK97_LinkFlow.bin to store the assigned flows. Click Save.

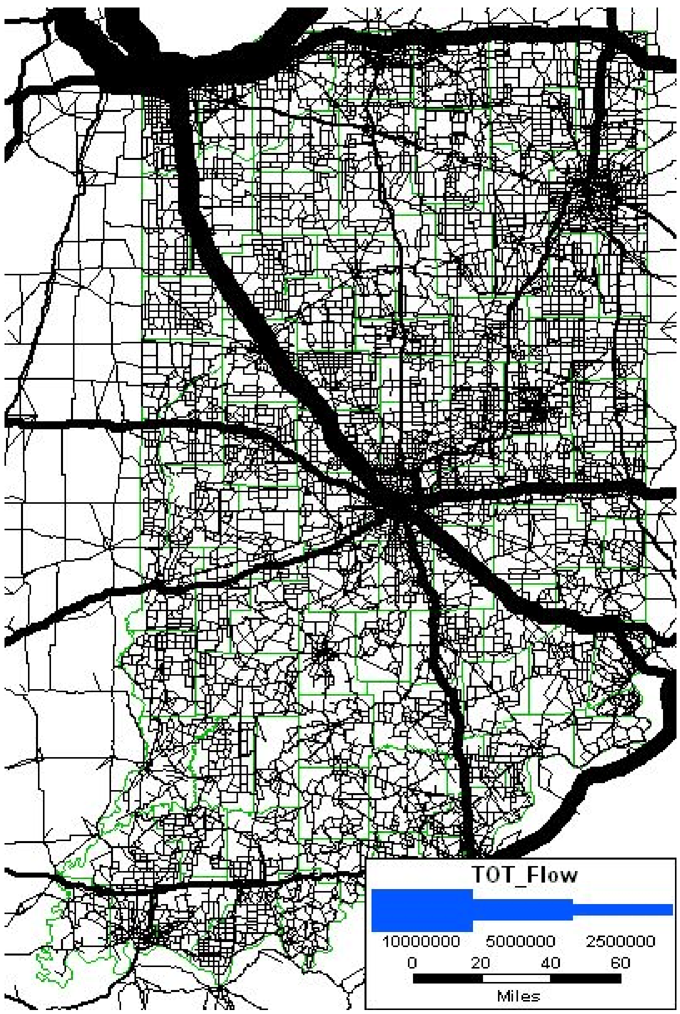


The assignment is executed and a small window appears telling you whether this has been successful.



A new window appears behind the above and this is a dataview that combined the integrated database and the assignments.

If we go back to our Indiana map and click on the TOT_FLOW and the proportional scaling icon (the one with the stars) we will then get a map of the Indiana highway system that displays the volume of traffic on all links Such as the one below:



While in TransCAD you can focus on any part of this network and identify flow volumes for metropolitan area highways, counties, and so forth.

The Alternate Routing Problem

When a road or highway is closed due to an accident, you may want to assess the most likely way that traffic can be diverted to alternate routes; or you may want to evaluate the impacts of building new roads, e.g., a bypass, on truck traffic on local roads; or you may want to evaluate alternate routings if you don't want trucks going through the center of town. All of these are alternate routing problems. Depending on the complexity of the problem at hand, we can evaluate it by dropping one of more links from the network.

At the outset the primary thing you want to do is back up the network file before you begin anything else. You may be tempted to simply go into the network layer and delete links of the system. That is one approach, but I would rather not mess up the network in that way. My preference is to use the side toolbar on the right side of the TransCAD window.

In this approach you enlarge the highway network map and identify the links that you do not want used. Click on the large **i**. Note the link number and make sure this is the link you do not want used in the routing. Go to the Travel_Time variable, and change the travel time to 1000 or any large number. When you run the assignment routine, or the shortest path routine between any two nodes, this is read as a very high cost and the link is not selected. Follow this approach for any other links of interest. You can go back and edit the travel time values for all links changed in the same manner, assuming you have kept a record of the initial values which you changed, or you can click on Edit on the horizontal bar, click on Fill, and have the travel time variable replaced with the initial values as calculated by:

Travel_time = (Length/new_speed) * 60

This will replace any changes with the original values.

Summary

This chapter has summarized the various ways in which this study could be used by the state and by metropolitan planning organization (MPOs). It was noted that the study could be used for transport analysis, economic analysis and for policy analysis. It is important to emphasize that because of the way in which the modal split analysis was carried out here, it would not be possible to examine some of the questions related to this area. In other words, we have used historical patterns to allocate future splits of traffic between the various modes. Such an approach is not sensitive to changes in prices, tolls and the like and this does limit its utility.

In addition this chapter has also provided a guide as to how this report and its databases could be used by planners at different scales (state level and MPO level). We have outlined the various steps that are necessary to use this approach to assign the traffic generated. We have not dwelt upon the various commodities that could be assigned, but if the state and MPOs have an interest in this they can certainly undertake such analyses. The appropriate files are provided here. We have also provided some direction on how the data could be examined at the county level in terms of productions and attractions. Finally we have suggested the manner in which this study could be used to examine the problem of alternative routes could be examined. This would be very useful in the event that planners wanted to examine a number of different transport questions.

References

Booz-Allen Hamilton, Inc., Bill Black (Indiana University), Professional Data Dimensions,Caliper Corporation and GIS/Trans, Ltd. (1997), *Intermodal Management System*, (San Francisco: Booz-Allen Hamilton, Inc.), October.

Caliper (2000), *TransCAD: Transportation GIS Software, User's Guide*, Newton, MA: Caliper Corporation.

Cambridge Systematics, Inc., Dyer Environmental Services. URS Greiner, Inc., and William R. Black (1998), *Indianapolis Intermodal Freight System Plan*, Final Report, prepared for the Indianapolis Department of Metropolitan Development, (Cambridge, Mass.: Cambridge Systematics, Inc.), June.

APPENDICES

APPENDIX A - PRODUCTIONS AND ATTRACTIONS, 1997

APPENDIX B - COMPUTER PROGRAMS DEVELOPED

APPENDIX C - DISTANCE DECAY CURVES

APPENDIX D - MODE CHOICE/DISTANCE TABLES

APPENDIX E - PRODUCTIONS AND ATTRACTIONS 2015

APPENDIX F - PRODUCTIONS AND ATTRACTIONS 2030