VANDERBILT UNIVERSITY

Network Analysis of Freight Diversion and Capacity Issues in Tennessee: Part II

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4/2/2012

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Introduction

This document serves as the final report for phase II of the "Network Analysis of Freight Diversion and Capacity Issues in Tennessee" research project. The first phase of this work took the Tennessee interstate network and determined hotspots based upon segments with high accident frequencies, a history of long road closures, and a great deal of truck traffic. Once these segments were identified, a series of GIS routing routines were deployed to determine if the shortest path route would be feasible for trucks. These routines took curvature, grade, existing traffic, weight limits and vertical clearances into account.

The second phase of this work is a network vulnerability study for waterway and rail freight in Tennessee. The first, and most difficult, step is to identify safety hotspots. The difficulty comes from the availability of accident data for each of the modes. Completing phase one of this project and attempting to gather the operational data, downloading and geocoding safety data proved too time-consuming to attempt anything more than the safety hotspot analysis for the second phase of this work. The results of this analysis are discussed in this report.

Data

This study made use of exclusively publicly available data. This enables other researchers to know what is available, what they would need to fill in the gaps and establishes a benchmark of possible analyses that publicly available can provide. The study was performed using geographic information systems (GIS) and made some use of relational database management systems, such as Microsoft Access, as the datasets were not large enough to warrant the use of Microsoft SQL Server or Oracle. The data sources used in the study are listed described below:

1. National Transportation Atlas Database[1]: several layers were used from this data source, published by the Bureau of Transportation Statistics.
    a. Rail network
    b. Waterway network
    c. Highway-rail crossings
2. Waterborne Commerce Statistics Center[2] (Navigation Data Center, U.S. Army Corps of Engineers)
    a. Waterway mile markers
    b. Waterway network link tonnages
    c. U.S. Coast Guard accident data (archived from 1981-2010)
    d. Port Series – database of over 9,000 terminals and marine facilities in the U.S.
3. Federal Railroad Administration (FRA) – Internet GIS server[3]

[1] Bureau of Transportation Statistics (BTS) and Research and Innovative Technology Administration (RITA) website: http://www.bts.gov/publications/national_transportation_atlas_database/2011/
[2] Navigation Data Center, Waterborne Commerce Statistics Center website: http://www.ndc.iwr.usace.army.mil/wcsc/wcsc.htm
[3] Federal Railroad Administration GIS Mapping Application website: http://fragis.frasafety.net/GISFRASafety/default.aspx

a. Rail mileposts
b. Freight stations
c. Accidents, 2003-2007

4. Federal Railroad Administration Office of Safety Analysis[4]
   a. Highway-rail crossing accident data
   b. Accident summary reports by state (on-demand reporting)

Waterway Safety Hotspot Analysis

There are three major rivers in Tennessee; the Cumberland River, Tennessee River and the Lower Mississippi River. While the Corps of Engineers is responsible for channel dredging and maintenance, the U.S. Coast Guard is tasked with marine safety, including accident reporting. For the purposes of this study, the entire Cumberland and Tennessee Rivers were included (even areas outside the state) as shown in Figure 1.

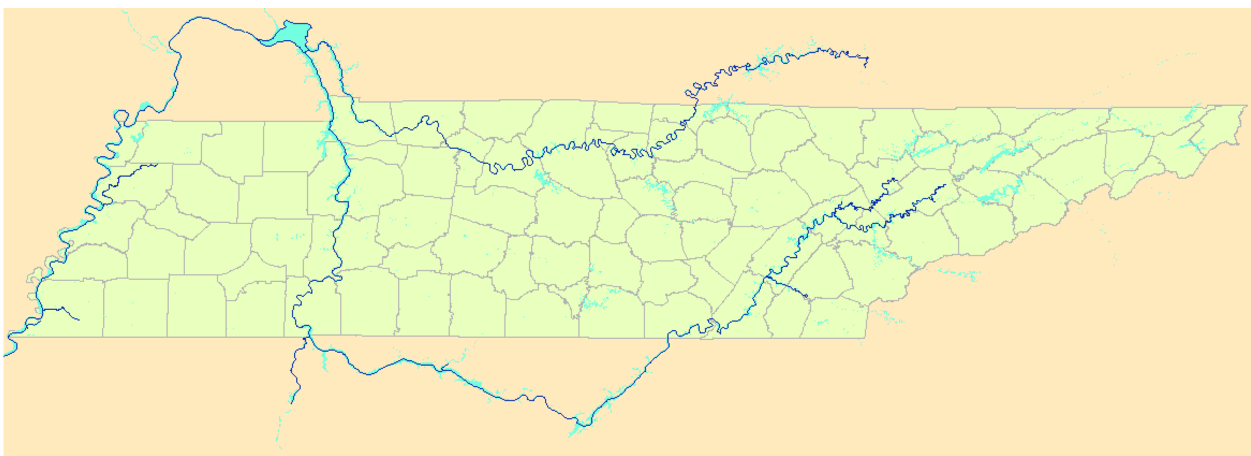

Figure 1. Case Study Tennessee Waterways

The National Waterway Network (NWN), maintained by the U.S. Army Corps of Engineers Navigation Data Center (USACE-NDC), was used to represent the waterways in the case study area. James Dobbins, one of the principal investigators of this project, has compiled an extensive marine casualty database dating back to 1981. Allisions (when a vessel strikes a fixed object, such as a bridge, dock or lock), collisions and groundings are included in this database. Attributes include date, position (latitude and longitude), type of accident and property damage (if reported). A significant shortcoming of the database is that for nearly 60% of the database, the property damage is reported as zero. It is not known whether this indicates no damage or a missing damage estimate. This is why accident frequency is used primarily by this study and less confidence is given to property damage estimates. While the location data is improving, it is not so precise as to indicate which bridge pier is most often allided with, etc. It is sufficient in precision to be used in cluster and density analyses. These were performed using a one

[4] Federal Railroad Administration Office of Safety Analysis website: http://safetydata.fra.dot.gov/OfficeofSafety/default.aspx

square mile mesh overlaid on the marine accident layers. The number of accidents and total damage reported were counted and summed, respectively. Accident frequencies are used as performance measures since sufficiently detailed waterway trip data is not available owing to business confidentiality concerns. Only tonnage information is available. This can be used to estimate ton-miles, but these estimates would leave out empty barge movements. There is trip data produced by the U.S. Army Corps of Engineers, but the reporting segments are too long to enable useful analysis on a mile by mile basis.

Not surprisingly, the top 4 water accident frequency locations are along the Lower Mississippi River (LMR) near Memphis, TN. These are primarily groundings, though there are collisions at river confluences. The 5th location, Pickwick Landing Lock and Dam, has a high number of allisions. Table 1 lists these locations, along with their reported damage (2011 dollars) and general remarks.

Table 1. Most Frequent Waterway Accident Locations in Tennessee (1981-2010)

Location	Count	Damage	Remarks
McKellar Lake entrance	104	$3,791,578	McKellar Lake entrance near fleeting area
Mile 820, LMR	39	$328,349	Obion River entrance
Mile 715, LMR	29	$308,758	LMR at MS-TN state line
Mile 841, LMR	26	$409,182	Above I-155 bridge in Dyersburg, TN
Mile 206, TN River	23	$400,185	Allisions at Pickwick Landing Lock and Dam

When looking at reported damage, the highest reported damage sites from 1981-2010 are listed in Table 2. A minimum of 15 accidents was specified to prevent outlier accidents from skewing the results. Accidents with the most property damage are allisions, resulting to damage to the structure, barge and in some cases, the towboats.

Table 2. Reported Damage due to Waterway Accidents in Tennessee (1981-2010, minimum 15 accidents)

Location	Count	Damage	Remarks
Mile 737, LMR	14	$5,265,571	Groundings near Mud Island in Memphis
Mile 726, LMR	104	$3,791,578	McKellar Lake entrance
Mile 850, LMR	16	$3,419,552	Primarily groundings at bend in LMR
Mile 839, LMR	18	$2,342,099	Allisions with I-155 bridge in Dyersburg
Mile 735, LMR	21	$1,960,186	Allisions with rail and I-55 bridges in Memphis

As far as allisions go, the Donelson Parkway Bridge at Paris Landing, TN on the Tennessee River has been allided with the most (12 times resulting in $453,186 worth of damage since 1981). The two rail bridges and I-55 bridge in Memphis are next, with 11 allisions. This location having a high allision incident rate represents a major vulnerability for Tennessee freight with the importance of the rail bridges connecting Tennessee to Arkansas and the western U.S. Burlington Northern Santa Fe (BNSF) and Union Pacific (UP) own the tracks on these bridges. An interesting fact is that on the Lower Mississippi River, downbound tonnages are approximately three times the upbound tonnages. There are several upbound empty barge movements (to collect the grain, etc.). However, it should be noted that downriver maneuvers are much more difficult than upriver since the water is pushing the tow and it is more difficult to stop.

Rail Safety Hotspot Analysis

The BTS NTAD rail network served as the base network for the case study area. Precise traffic figures, such as trains or carloads per day, are not available for business confidentiality reasons. The next best metric for estimating train volume is density category, measured in million gross tons (MGT), but these ranges are too wide to be useful as the denominator in the “accidents/million ton-miles” accident rate performance measure. The rail hotspot analysis was a bit more challenging to perform since it was more difficult to locate the accidents. The Federal Railroad Administration (FRA) runs an Internet map service (http://fragis.frasafety.net/GISFRASafety/default.aspx), from which accidents occurring between 2003-2007 were imported into the GIS. A large amount of accident data is available through the FRA Office of Safety Analysis on-demand system (http://safetydata.fra.dot.gov/OfficeofSafety/default.aspx). This system has several reports that may be queried by state, county, railroad and accident type.

There is a significant shortcoming with the railroad GIS data in that linear referencing is not possible Linear referencing systems (LRS) are a means to locate events on networks by route and mile marker, interpolating between the mile post information of the segment start and end nodes. The highway and waterway modes make extensive use of LRS, as does rail, but the publicly available mile post database maintained by FRA has shortcomings that preclude its ability to accurately locate accidents. Accident records typically did contain county FIPS code and milepost information. The FRA mile post data had railroad owner, mile post and state/county FIPS. By concatenating the state/county FIPS code with the railroad owner code, the mile posts were still not unique across all counties. When looking at the national network, Cook County, Illinois has up to 14 identical mile posts (having the same state/county code, railroad owner and milepost number).

Before moving on to the accident analysis conducted with data extracted for Tennessee, summary information was pulled from the Office of Safety Analysis website in Table 3.

Table 3. Summary information for Tennessee rail accidents, 2002-2011 (Source: FRA Office of Safety Analysis)

Category	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
TOTAL ACCIDENTS/INCIDENTS	272	298	274	266	243	225	237	200	167	183
---Total fatalities	16	22	17	18	22	13	25	6	10	19
---Total nonfatal conditions	143	156	146	139	118	108	118	107	94	99
Employee on duty deaths	1	1	.	1	1	.	.	.	.	.
Nonfatal EOD injuries	93	103	99	92	69	66	71	68	61	55
Nonfatal EOD illnesses	2	2	1	3	1	.	2	1	2	1
Total employee on duty cases	96	106	100	96	71	66	73	69	63	56
Cases with days absent from work	64	77	75	67	54	50	60	53	44	38
Trespasser deaths, not at HRC	7	13	11	11	13	7	20	4	7	13
Trespasser injuries, not at HRC	18	12	3	8	6	3	9	8	6	10
TRAIN ACCIDENTS	57	70	71	69	70	60	68	53	38	40
--- Train accident deaths	.	.	.	.	.	.	.	.	.	.
--- Train accident injuries	3	4	2	2	2	1	2	1	1	.
> Human factor caused	26	37	24	33	29	27	25	23	15	17
> Track caused	15	15	16	17	22	15	15	11	6	9
> Motive power/equipment caused	4	6	12	7	5	5	12	7	4	8
> Signal caused, all track types	2	2	4	1	1	4	2	1	3	3
> Signal caused, main line track	.	.	1	.	.	.	.	.	1	1
> Miscellaneous caused	10	10	15	11	13	9	14	11	10	3
> Collisions	4	5	6	7	10	10	12	7	3	4
> *** Collisions on main line track	1	2	2	1	2	1	2	2	.	2
> Derailments	40	47	56	45	52	35	40	35	25	28
> Other types, e.g., obstructions	13	18	9	17	8	15	16	11	10	8
Accidents with reportable damage > $100K	10	8	11	11	10	9	13	8	14	8
*** Percent of total	18	11	15	16	14	15	19	15	37	20
> $500K	3	1	3	3	4	1	1	2	1	1
*** Percent of total	5	1	4	4	6	2	1	4	3	3
> $1,000,000	.	1	1	1	1	1	.	1	1	.
*** Percent of total	.	1	1	1	1	2	.	2	3	.
Train accidents on main line	10	11	22	13	22	7	12	11	9	11
Accidents on yard track	41	51	43	51	42	46	52	37	25	27
HAZMAT RELEASES	4	1	1	1	1	3	.	1	1	.
--- Cars carrying hazmat	245	179	197	113	235	211	344	238	248	177
--- Hazmat cars damaged/derailed	37	15	19	9	27	17	29	25	20	15
--- Cars releasing	5	1	1	1	2	4	.	1	1	.
HIGHWAY-RAIL INCIDENTS	82	84	77	79	68	73	63	56	42	54

--- Highway-rail incidents deaths	8	8	6	7	8	6	5	2	3	6
--- Highway-rail incidents injuries	14	18	27	28	20	21	26	17	10	18
Incidents at public xings	75	75	67	68	56	63	55	52	35	41
*** Percent of total	91	89	87	86	82	86	87	93	83	76
OTHER ACCIDENTS/INCIDENTS 2/	133	144	126	118	105	92	106	91	87	89
--- Other incidents deaths	8	14	11	11	14	7	20	4	7	13
--- Other incidents injuries	126	134	117	109	96	86	90	89	83	81
Passengers killed in train accidents or crossing incidents	.	.	.	.	.	.	.	.	.	.
Passengers injured in train accidents or crossing incidents	.	.	.	.	.	.	.	.	.	.
Passengers killed in other incidents	.	.	.	.	.	.	.	.	.	.
Passengers injured in other incidents	2	1	2	2	.	3	2	1	6	8

Table 4 shows the breakdown of accidents by Tennessee county. Shelby County has the most rail activity, and not surprisingly, the highest number of accidents.

Table 4. Tennessee rail accidents by county and fatal/non-fatal, 2002-2011 (Source: FRA Office of Safety Analysis)

County	CASUALTIES		Total
	Fatal	Nonfatal	
SHELBY	27	449	476
DAVIDSON	19	129	148
HAMILTON	13	114	127
KNOX	15	67	82
MADISON	-	34	34
ROANE	2	30	32
WILSON	2	24	26
MCMINN	4	21	25
RUTHERFORD	7	15	22
HAWKINS	4	17	21
Other counties	75	328	403
Total...	168	1,228	1,396

Railroad tonnage and ton-mile data is difficult to come by, owing to the business-sensitive nature of the information. For this reason, accurate accident rates (e.g., number of accidents per million ton-miles moved) were impossible to calculate, and most of the rail results are accident frequencies only.

Highway-rail crossing accident data is easy to map since data is tracked by the crossing ID number. The top 5 highway-rail crossings in terms of accidents are listed in Table 5.

Table 5. Highway-rail crossing accident frequencies (1975-2011).

Crossing Location	Count	Fatalities	Injured
Castilia Street, Memphis	34	1	11
Chelsea Avenue, Memphis	20	0	5
Concord Street, Knoxville	20	0	10
Kirby Parkway, Memphis	20	1	5
Pendleton Street	18	0	6

Table 6 indicates the accident hotspots in Tennessee based on a one square mile cluster analysis. These accident counts were limited to 2003-2007 since the geographic layer was imported from FRA's GIS server and accurate positioning data (through either route and mile post or latitude/longitude) was unavailable.

Table 6. Top 5 railroad accident cluster locations (2003-2007)

Location	Line Accidents	RRX accidents	Total
Kentucky Street Station (Memphis)	74	18	92
CSXT Intermodal (Nashville)	35	0	35
McDowell Station (Chattanooga)	14	2	16
John Sevier Station (Knoxville)	12	0	12
East Junction Station (Memphis)	11	3	14

Conclusions and Recommendations

The second phase was hampered by limited availability of quality accident and performance data, as well as time to complete the project (due to the time it took to complete the first phase of this research project). However, this research was successful in identifying key gaps in publicly available data that prohibit the completion of accurate safety analysis. The rail accidents could be accurately geocoded if the case study area was much smaller. For example, researchers could go through the accident reports (which are online) for a single county and accurately geocode the location of the accidents. The waterway accidents are improving in quality and precision (latitude and longitude are being reported to 6 decimal degree places now). A significant limitation for performing hotspot analysis for both the waterway and rail freight modes of transportation is the lack of detailed trip data. This prevents the determination of accident rates. Frequencies are only part of the study. For example, with all of the rail activity in Memphis, it stands to reason Shelby County has the highest number of rail crossing and rail line accidents. The same goes for waterway accidents along the western border of Tennessee. What is missing, however, is trip data that would normalize the number of accidents and highlight areas that have unusually high rates. The aggregation of waterway data and inability to route the public version of the Surface Transportation Board's (STB) rail waybill data are two large obstacles to performing this type of analysis. An emerging research topic is the use of other economic indicators and related data that can be used to create a somewhat reasonable estimate of freight activity. This should be explored in future Tennessee freight research activities.