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WYOMING COMMODITY FLOW STUDY

FOR JOHNSON COUNTY

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16. Abstract

A hazardous materials (HAZMAT) commodity flow study is a transportation analysis study identifying the types and amounts of hazardous materials being transported through a specified geographic area by analyzing current traffic patterns. Transportation of hazardous material may pose a great danger to the public and environment if an incident occurred. The main objectives of this study were to identify what, where and when hazardous material is being transported in Johnson County. Due to lack of HAZMAT transportation information within this jurisdiction, collecting new original HAZMAT data was needed. Three locations were identified by the Wyoming State Emergency Response Commission (SERC) in conjunction with the Wyoming Office of Homeland Security (WOHS) and Johnson County Emergency Management Agency to collect HAZMAT data from highway segments. Data analysis showed that the most common HAZMAT being transported is class 3 (flammable liquids). It also showed that multi trailer is the most common type used to transport HAZMAT in the study locations I-25 and I-90. Although data collection was scheduled for US 16 also but there was no HAZMAT observed on the location. It is worth noting that manual approach of collecting HAZMAT traffic data is very challenging. In this study, an automatic data collection system using LPR cameras was initially tested. Future work will include developing an automatic placard recognition system. This study provides emergency responders, community planners and organizations information that may aid in

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METRIC CONVERSION FACTORS

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

EXECUTIVE SUMMARY

A hazardous materials (HAZMAT) commodity flow study (CFS) is a transportation analysis study identifying the types and amounts of hazardous materials being transported through a specified geographic area by analyzing current traffic patterns. Hazardous materials are substances that would threaten human safety, health, the environment, or property if released. Hazardous materials are classified into nine classes according to the emergency response guide 2016. Transportation of hazardous materials may pose a great danger to the public and environment if an incident occurred. One HAZMAT incident could affect a circle of diameter ranging from 0.5 to 5 miles. Using the data collected in the commodity flow study, emergency responders and community planners will be able to enhance emergency planning capabilities and continue to support existing emergency response organizations.

The objectives of this study were to identify what, where and when hazardous materials are being transported in Johnson County, identify most likely hazard scenarios that may be expected in that jurisdiction, provide information about the amount of HAZMAT being transported and provide responders, community planners, and organizations information that enhances emergency preplanning.

There is a lack of HAZMAT transportation information in Wyoming. Prior HAZMAT studies in the same geographic area are important as they provide a baseline information for the current situation. Unfortunately, no previous studies were conducted in Johnson County. Although, several studies were conducted in Wyoming in other counties. The first HAZMAT CFS was conducted back in 1986 in Albany County. A large gap separates the first conducted study and the following conducted studies in Wyoming. The Wyoming State Emergency Response Commission (SERC), in conjunction with the Wyoming Office of Homeland Security (WOHS), has identified the need to conduct HAZMAT CFS in Wyoming to fill in this huge gap. In 2015, a HAZMAT commodity flow study was conducted in Campbell and Converse Counties, followed by another two studies in Laramie County and Albany County in 2016 and the latest CFS being conducted in Natrona County and Sweetwater County in 2017. For Campbell and Converse counties two intersections on WY59 were chosen to collect HAZMAT data. For Laramie County, HAZMAT data was collected from four locations around Cheyenne city. The four locations were: 1) US 85

MP 5, 2) US 85 MP 25, 3) I-80 MP 345, and 4) HW 210 MP 18. For Albany the locations studied were: 1) I-80 MP 307, 2) I-80 MP 333 and 3) US287 at MP 405. The Natrona County CFS locations included: 1) US-220 MP 108, 2) US- 20/26 MP 12, 3) I-25 South MP 182.06 and 4) I-25 North MP 192. The Sweetwater County CFS included the following locations: 1) I-80 MP 66, 2) US-30 MP100 and 3) US-191 MP5.

Collecting new original HAZMAT data was needed in this study to achieve the required objectives. Data collection was the major task in this study. In consultation with the Emergency Management Coordinator from Johnson County (Marilyn Connolly), the primary highways chosen for the proposed commodity flow study are: I-25 north and south lanes near Buffalo, I-90 east and west lanes near Buffalo and US-16 east and west lanes through Buffalo. Additionally, the data collection team from University of Wyoming decided to collect data from three other locations on the interchange connecting I-25 and I-90 in Buffalo. In total, six locations were studies and the exact locations were:

1) I-25 MP 295
2) I-90 MP 60
3) US-16 MP 5
4) I-90 west side of the interchange, MP 56
5) I-90 east side of the interchange, MP 56
6) I-25 on the interchange, MP 300

Six graduate students from the University of Wyoming volunteered to carry out the road network HAZMAT data collection. Seven days during the Spring break were selected to collect field data for the selected locations. Field data was collected for the three identified locations and additional three locations on the interchange. Field data collection periods consisted of 3 consecutive days with 12 hours per day of data collection, forming a total of 36 hours of counting for each of the first three locations. For the locations on the interchange 3 hours of field data was collected on different time periods each day forming a total of 12 hours of data collected over the three days. Manual data collection utilizing digital still cameras were used in the study. Automatic data collection using Infra-red (IR) cameras (typically used for License Plate Recognition (LPR) system) was tested in this study similar to the testing carried out in previous two commodity flow

studies in Wyoming. Unlike previous two studies, this study consisted to two cameras pointed towards the same direction with one pointing at the back and another on the side. It was found that the images obtained from the camera pointed at the back are clearer.

Descriptive analysis of the collected HAZMAT data was performed to clarify the distribution of HAZMAT trucks according to its destination and the different types of HAZMAT being transported at the four study locations according to the placard class and ID. Amounts of HAZMAT being shipped were estimated according to the different body configurations, under the assumption that all the counted HAZMAT trucks are loaded with hazardous materials. The HAZMAT amount was calculated according to the minimum and maximum amount of shipment each body configuration can hold. It should be noted that the only way to obtain the accurate amount of shipped HAZMAT, is by checking the shipment documents, which was not feasible to obtain.

Data analysis showed that the most common HAZMAT class being transported is class 3, which is flammable liquids. Accordingly, it would indicate that the most likely HAZMAT incident could happen would involve a class 3 HAZMAT of flammable liquids.

While the exact truck payload of HAZMAT being transported cannot be identified from a field data collection, truck body configuration is a good indication of the amount of HAZMAT being transported. Analysis showed that multi trailers (TT) are the most common types used to transport HAZMATs in the studied locations. The multi-trailer can transport from 9,500 to 19,000 US gallons. The estimated minimum/maximum amounts of the transported HAZMATs were 407,410/776,251 US gallons/day for I-25 and 261,715/497,280 US gallons/day for I-90. There was no HAZMAT truck and very few truck traffic observed on US-16 during the data collection periods. It should be noted that these numbers were estimated without taking seasonal variation into account due to lack of seasonal factors for HAZMAT transportation in Wyoming.

An ongoing effort is taking place to automate the data collection process. An automatic placard recognition system would facilitate monitoring HAZMAT transportation using road network in a more efficient way. In this study, a mobile system was tested for few hours on select days using Infra-red (IR) cameras and a Network Video Recorder (NVR) to capture Placard IDs. Further

processing of the images is undergoing to automatically identify the Placard IDs utilizing image processing techniques.

This study provides responders, community planners and organizations information that could help in enhancing emergency preplanning also to adjust and schedule the resources to support emergency response capabilities for potential incidents to protect the environment and people.

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JOHNSON COUNTY

Final Draft Report
June 2018

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LIST OF ACRONYMS/ABBREVIATIONS

AADT	:	Annual Average Daily Traffic
AC	:	Alternating Current
APRS	:	Automatic Placard Recognition System
CFS	:	Commodity Flow Study
DC	:	Direct Current
DHS	:	Department of Homeland Security
ERG	:	Emergency Response Guide
FHWA	:	Federal Highway Administration
HAZMAT	:	Hazardous Materials
HMCFS	:	Hazmat Commodity Flow Study
HMCRP	:	Hazardous Materials Cooperative Research Program
HRs	:	Hours
HW	:	Highway
I	:	Interstate
ID	:	Identification Number
IR	:	Infra-Red
LED	:	Light-Emitting Diode
LPG	:	Liquefied Petroleum Gases
MADT	:	Monthly Average Daily Traffic
MAWDT	:	Monthly Average Week Day Traffic
MAWET	:	Monthly Average Weekend Traffic

MP	:	Milepost
MT	:	Multi-Trailer
n.o.s	:	not otherwise specified
NVR	:	Network Video Recorder
OCR	:	Optical Character Recognition
PHMSA	:	Pipeline and Hazardous Materials Safety Administration
SERC	:	State Emergency Response Commission
ST	:	Straight Truck
TT	:	Truck Trailer
US	:	United States
V	:	Volts
vpd	:	Vehicles Per Day
WHP	:	Wyoming Highway Patrol
WOHS	:	Wyoming Office of Homeland Security
WYDOT	:	Wyoming Department of Transportation

CHAPTER 1- INTRODUCTION

A hazardous materials (HAZMAT) commodity flow study (CFS) is a transportation analysis study identifying the types and amounts of hazardous materials being transported through a specified geographic area. The CFS clarifies the flow of hazardous materials through a certain area by analyzing current traffic patterns. It provides a reference to match planning programs to existing needs within communities and reduce the occurrence of risky incidents[1].

Hazardous materials are substances that are flammable, explosive, toxic or any substance that would threaten human safety, health, the environment, or property if released. The effect of the increase in transportation of hazardous materials poses safety, security and environmental issues on all the road users[2].

Transportation of hazardous material poses a great danger to the public and environment if an incident takes place. Responding to these danger kinds of incidents should be fast and appropriate in order to contaminate the dangerous effect on public and environment and to reduce the produced risk. Necessary equipment and safety precautions are the controlling rules to adequately contaminate the incident released danger. Dealing with different hazardous materials incidents requires different safety precautions and different equipment. Mitigating the danger requires a previous knowledge regarding the nature of HAZMAT in transit through the roads network.

Hazardous materials are classified into 9 classes according to the emergency response guide 2016 (ERG)[3].

Table 1 shows the different classes and divisions for the hazardous materials.

By using the data collected in the commodity flow study, emergency responders and community planners will be able to enhance emergency planning capabilities and continue to support existing emergency response organizations.

Hazardous Materials Cooperative Research Program (HMCRP) introduced six main steps identifying the commodity flow study process[2]. Figure 1 shows these six steps for the commodity flow study process. This report will discuss the different steps and how they were applied in this study.

Table 1: Hazardous Materials Classes and Divisions (ERG 2016[3])

Class 1 - Explosives
Division 1.1 Explosives with a mass explosion hazard
Division 1.2 Explosives which have a projection hazard but not a mass explosion hazard
Division 1.3 Explosives which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard
Division 1.4 Explosives with no significant blast hazard
Division 1.5 Very insensitive explosives with a mass explosion hazard
Division 1.6 Extremely insensitive articles which do not have a mass explosion hazard
Class 2 - Gases
Division 2.1 Flammable gases
Division 2.2 Non-flammable, non-toxic* gases
Division 2.3 Toxic* gases
Class 3 - Flammable liquids (and Combustible liquids [U.S.])
Class 4 - Flammable solids; substances liable to spontaneous combustion; substances which, on contact with water, emit flammable gases
Division 4.1 Flammable solids, self-reactive substances and solid desensitized explosive
Division 4.2 Substances liable to spontaneous combustion
Division 4.3 Substances which in contact with water emit flammable gases
Class 5 - Oxidizing substances and Organic peroxides
Division 5.1 Oxidizing substances
Division 5.2 Organic peroxides
Class 6 - Toxic substances and Infectious substances
Division 6.1 Toxic substances
Division 6.2 Infectious substances
Class 7 - Radioactive materials
Class 8 - Corrosive substances
Class 9 - Miscellaneous dangerous goods/hazardous materials and articles

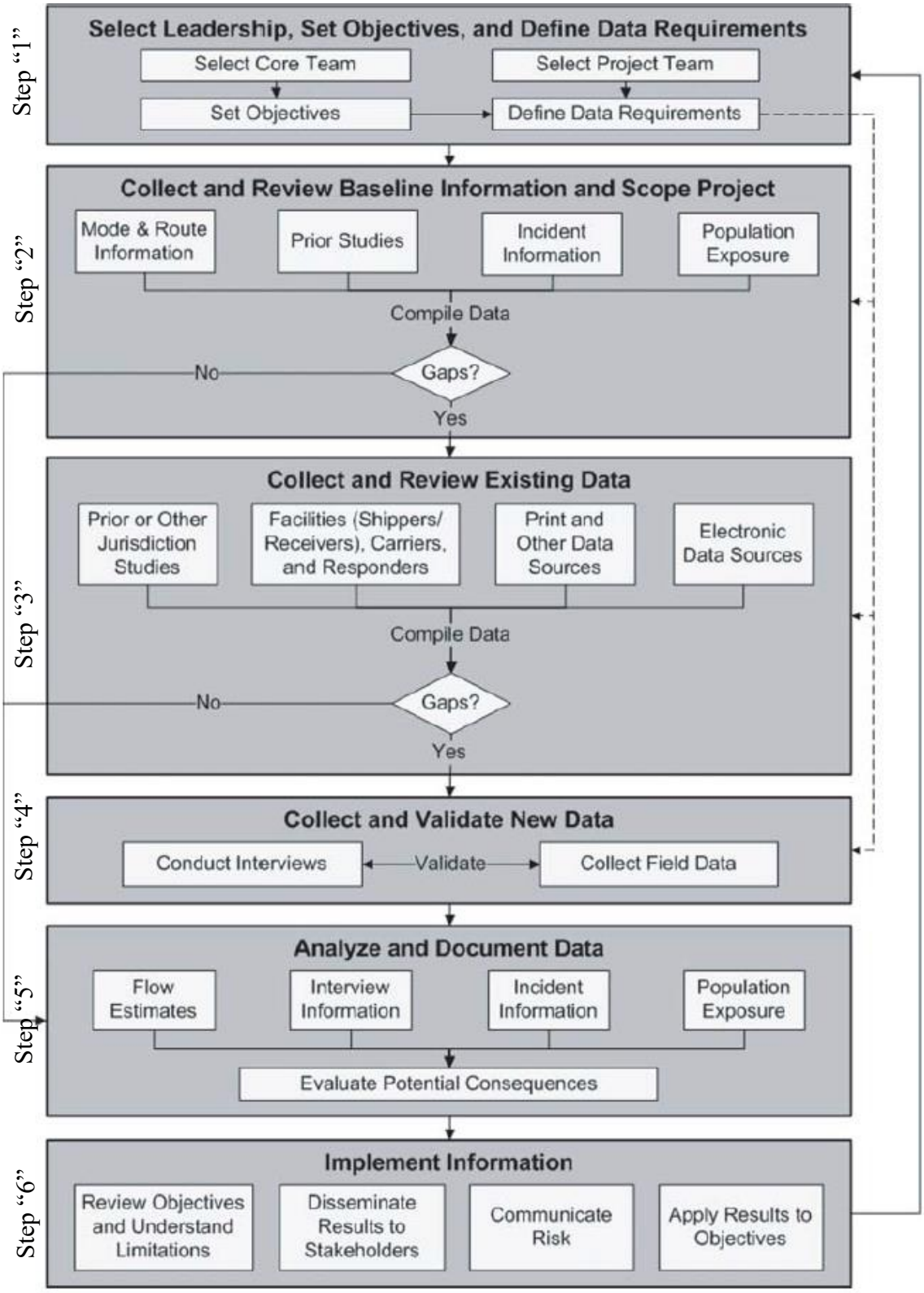


Figure 1: The HAZMAT Commodity Flow Study (HMCFS) Process[2]

CHAPTER 2- OBJECTIVES AND PROJECT OUTLINES

GENERAL

The Wyoming State Emergency Response Commission (SERC), in conjunction with the Wyoming Office of Homeland Security (WOHS) has identified the need to conduct a study of the flow of all HAZMAT commodities in Johnson County. In consultation with the Emergency Management Coordinator from Johnson County, Marilyn Connolly, the following highways are chosen for the commodity flow study: Intestate 25 (I-25) north and south lanes near Buffalo, Interstate 90 (I-90) east and west lanes near Buffalo and State highway 16 (US-16) east and west lanes through Buffalo.

OBJECTIVES

The main goal of the study is to identify hazardous materials transportation patterns on Johnson County primary highways to provide help for emergency management agencies to allocate resources and enhance the emergency preplanning.

The objectives of Wyoming commodity flow study – Johnson County are as follows:

- Determine the amount of commercial truck traffic moving through certain Johnson County Highways
- Identify the truck and container types in order to estimate the amount of HAZMAT being transported.
- Determine the type of hazardous materials being transported along the roadways designated in the commodity flow study.
- Determine the types and quantities of hazardous materials going through Johnson County.
- Analyze and document the collected data.

DATA REQUIREMENTS

To achieve the above objectives, a sampling framework was adopted. The data requirements should include the data collection plan and the required level of precision of the data. HAZMAT data was collected during March 2018 for seven days from 7:00 am to 7:00 pm forming a total of 36 counting hours per location. Two weekend days and five weekdays were considered for the data collection. For the first location (I-25, MP 295) and second location (I-90, MP 60) data was

collected for two weekdays (15th and 16th of March 2018) and one weekend (Saturday 17th of March 2018). For the third location (US-16, MP 5), data collection was scheduled for one weekend (Saturday 11th of March 2018) and two weekends (12th and 13th of March 2018). More information about data collection plan is provided in "Data Collection Plan" section.

According to the Guidebook for Conducting Local Hazardous Materials Commodity Flow Studies[2], Sampling framework is divided into 6 levels. Table 2 shows the different sampling framework used in HAZMAT Commodity Flow Studies (CFSs). HAZMAT truck survey can be done in seven different methods. It depends on the level of data collected about the HAZMAT trucks. Table 3 shows the seven different methods to conduct a HAZMAT placard survey. According to Table 2 and Table 3, data collection in this study can be classified as directional and intersectional surveys with a representative sampling framework.

Table 2: Sampling frameworks, examples, advantages and disadvantages[2]

Sampling Framework	Sampling Examples	Advantages	Disadvantages
Convenience	As available for data collectors	Easiest for data collectors; minimum scheduling management	Difficult to reliably identify traffic patterns at any one location or timeframe
Representative	One location per major roadway, at different times of day on any given weekday, during any season	Easy to conduct over time for data collectors; moderate scheduling management; moderate degree of information about traffic patterns for roadway; low–to moderate level of data collection resources required	Cannot be used to reliably characterize traffic on different segments of same road or other roads, determine seasonal traffic patterns, or transport patterns throughout a network
Cluster	Multiple locations per major roadway, at different times of day, on multiple days of week, during multiple seasons	High degree of information about traffic patterns throughout a transportation network	High degree of scheduling management; may require high level of time commitment from data collectors or other data collection resources
Stratified or Proportional	Dependent on traffic characteristics on given network segment; less data is required for low traffic volumes, and more data for high traffic volumes	Very high degree of information about traffic patterns throughout a transportation network; focuses effort on high-priority segments	Requires statistical calculations to determine sampling requirements; extremely high degree of scheduling management; may require high level of data collection resources
Random	At random times of day, days of week, seasons of year, for a specific network segment	Very high degree of information about traffic patterns on sampled network segment	Requires statistical calculations to determine sampling requirements; extremely high degree of schedule management; requires high level of data collection resources
Census	All traffic data for all times of day, days of week, and seasons of year, for specific network segment or entire network	Complete information about traffic patterns at sample locations	Nearly impossible to attain with current systems; requires an extreme degree of data reduction

Table 3: Traffic and Hazmat placard survey methods

Survey Method	Description	What It Provides	What It Requires
Total Truck Surveys	A count of the total number of observed trucks	Information about overall truck traffic levels during sampled time periods	Assumptions about hazmat transported on observed trucks (e.g., that hazmat transport conforms to national averages); assumptions about types and configurations of trucks used to transport hazmat
Truck Type and Configuration Surveys	A count of observed trucks by truck type and configuration	Information about truck traffic levels, by type and configuration, during sampled time periods	Assumptions about hazmat transported on observed trucks by type and configuration (e.g., that hazmat transport conforms with national averages)
UN/NA Placard ID Surveys	ID and count of observed hazmat placards	Information about the number and types of hazmat placards present during sampled time periods	Assumptions about truck traffic patterns and the types and configurations of trucks used to transport hazmat
Total Truck Combined with UN/NA Placard ID Surveys	A count of the total number of observed trucks and ID and count of observed hazmat placards	Information about overall truck traffic levels and the number and types of hazmat placards present during sampled time periods	Assumptions about types and configurations of trucks used to transport hazmat; data collectors who can record truck count information and placard information
Truck Type and Configuration Combined with UN/NA Placard ID Surveys	A count of observed trucks by truck type and configuration and ID and count of observed hazmat placards	Information about truck traffic levels by type and configuration and the number and types of hazmat placards present during sampled time periods	Data collectors who can record truck type and configuration and placard information; may require more training of volunteers on data collection process and monitoring of collected data to ensure consistency
Directional and Intersection Surveys	Observation of trucks and/or placards on multiple road directions or at intersections at the same time	Information for more than one roadway lane collected at a single location; may reduce number of data collectors needed	Experienced data collectors; more training of volunteers on data collection process, and monitoring of collected data to ensure consistency
Manifest Surveys	Review of information found on shipping papers and interviews of truck drivers	Highly specific information about hazmat shipment content for both placarded and un-placarded loads	Coordination with local, state, or federal license and weigh stations or patrol units; potentially, a very intensive data collection process for high-traffic roadways

CHAPTER 3- BACKGROUND AND BASELINE INFORMATION

GENERAL

The scope of this study focuses on collecting information on HAZMAT transportation on major highways in and around the town Buffalo in Johnson County, Wyoming. These major highways are Interstate 25 (I-25), Interstate 90 (I-90), and State Highway 16 (US-16). Interstate 25 begins from Las Cruces, New Mexico and ends in Buffalo, Wyoming. In Wyoming, Interstate 25 runs from Colorado state line near Cheyenne to I-90 near Buffalo for 300.53 miles[4] and connects Wyoming's two largest cities, Cheyenne and Casper along with other smaller cities such as Wheatland, Douglas and Buffalo. I-25 intersects with I-90 in Buffalo. Interstate 90 runs through the northeastern part of Wyoming, entering from Montana and passing through Sheridan, Buffalo and Gillette[5]. I-90 meets the end of I-25 in Buffalo and bends to the southeast and intersects US 16 at a diamond interchange in Buffalo. State highway 16, commonly known as U.S. Route 16 (US-16), runs east-west starting from Rapid City, South Dakota and ending at Yellowstone National Park in Wyoming[6]. In Wyoming, US-16 passes through the towns of Newcastle and Upton and joins I-90 near Moorcraft from where it runs concurrently with I-90 and splits off north at Gillette and later intersects I-90 again in the town of Buffalo. Through Buffalo, US-16 runs towards the western part of the state. The interstates are mostly two-lane divided highways while US-16 is a two-lane undivided highway.

According to the Pipeline and Hazardous Materials Safety Administration (PHMSA) Incident Reports Database, incidents in highways in and around Buffalo, Johnson County amounts to 6 HAZMAT incidents from 1990 to 2017[7]. Total losses from the HAZMAT incidents was approximately $ 58,000. Moreover, weather plays a major role in increasing the possibility of having a HAZMAT incident. Adverse weather conditions (rain, snow, fog, and blowing snow) may cause reduction in visibility, which is an important factor that affects the risk of road crashes.

Wyoming's energy industries, oil and gas, uranium, coal and other extracted minerals, are the main sources of HAZMAT materials being transported in Wyoming[8]. It was reported in the Wyoming state emergency response commission report that 58 facilities in Johnson County store HAZMATs[8].

BASELINE DATA

Prior HAZMAT studies in the same geographic area are important as they provide a baseline information for the current situation. However, no CFS was available or carried out previously for the Johnson County. The first HAZMAT study in Wyoming was previously conducted in Albany County, Wyoming back in 1986[9]. The objectives of the study were to:

- Determine the effect of different seasons on truck and railroad traffic volumes.
- Determine the percentage of traffic transporting HAZMAT.
- Classify the HAZMAT being transported.
- Determine the accuracy of the HAZMAT placards.
- Determine the condition of the trucks and trains transporting HAZMAT.
- Determine the amount of HAZMAT being transported in Albany County.

The study identified the major arterials used to transport HAZMAT within Albany County. The data was collected for 48 hours in different weekdays. Data were collected for 3 hours per day in the morning and afternoon. The study showed that 5.25% of the truck traffic contained hazardous materials. It was also stated that 73% of the trucks were out of service, and the remaining were in good condition. The study stated that the accuracy of placard system is approximately 50%, this accuracy was roughly estimated by the Wyoming Highway Patrol (WHP) with no supporting data presented in the report.

It is worth mentioning that in previous year several CFSs were carried out by the Department of Civil & Architectural Engineering, University of Wyoming. The study locations included Campbell and Converse counties in 2015, Laramie County and Albany County in 2016, Natrona and Sweetwater County in 2017. Two intersections on WY 59 were chosen to collect HAZMAT data for Campbell and Conserve counties Commodity Flow Study[10]. The locations studied for the Laramie County Commodity Flow study[11] were: 1) US 85 MP 5, 2) US 85 MP 25, 3) I-80 MP 345, and 4) HW210 MP18 and for the Albany County Commodity Flow Study[12] were: 1) I-80 MP 307, 2) I-80 MP 333 and 3) US287 at MP 405. The Natrona County Commodity Flow Study[13] locations included: 1) US-220 MP 108, 2) US- 20/26 MP 12, 3) I-25 South MP 182.06 and 4) I-

25 North MP 192. The Sweetwater County Commodity Flow Study[14] included the following locations: 1) I-80 MP 66, 2) US-30 MP100 and 3) US-191 MP5.

In addition to the HAZMAT data collected on the roadway sections mentioned above, HAZMAT transportation using the railroad via Union Pacific Railroad was analyzed as well in the Albany County Commodity Flow Study.

CHAPTER 4- COLLECTING AND REVIEW EXISTING DATA

As mentioned earlier, no prior hazardous material commodity flow study was conducted in Johnson County, Wyoming. However, several HAZMAT CFSs were conducted in other counties in Wyoming, as previously mentioned.

Due to lack of information about the HAZMAT transportation in Johnson County, collecting new data was needed to achieve the study objectives. Manual Data collection was the primary method used to collect HAZMAT data in this study. However, other data collection techniques were utilized in data collection. Six graduate students from the University of Wyoming volunteered to carry out the data collection. Raw data for the study is presented in Appendix C.

CHAPTER 5- NEW DATA COLLECTION

An essential task of this study was to collect HAZMAT traffic data from the 3 main locations on Johnson County highways. As previously mentioned, the two locations (I-25, north and south lanes and I-90, east and west lanes near Buffalo) were determined by the Wyoming State Emergency Response Commission (SERC). The other location (US-16, east and west lanes through Buffalo) was identified by Emergency Management Coordinator from Johnson County, Marilyn Connolly. Furthermore, the data collection team selected 3 other locations on the interchange connecting I-25 and I-90 near Buffalo to estimate HAZMAT being transported through the interchange.

Six graduate students from the University of Wyoming volunteered to carry out the HAZMAT data collection. A total of 7 days of HAZMAT data collection were conducted during the period from 11th to 17th of March 2018. Manual data collection in addition to digital cameras were utilized in the study. Moreover, automatic data collection using LPR cameras was also tested in this study.

DATA COLLECTION LOCATIONS

The three proposed data collection locations were on straight segments for Johnson County highways (Figure 2) and the other three locations were on the interchange connecting I-25 and I-90 (Figure 3). Figure 2 and Figure 3 shows general maps of the data collection locations along with the inset maps showing detailed view of the highways. Location 1 and 2 are interstate 2 lane divided highways while Location 3 is a two-lane two-way state highway. Location 4-6 are on the two-lane divided interchange.

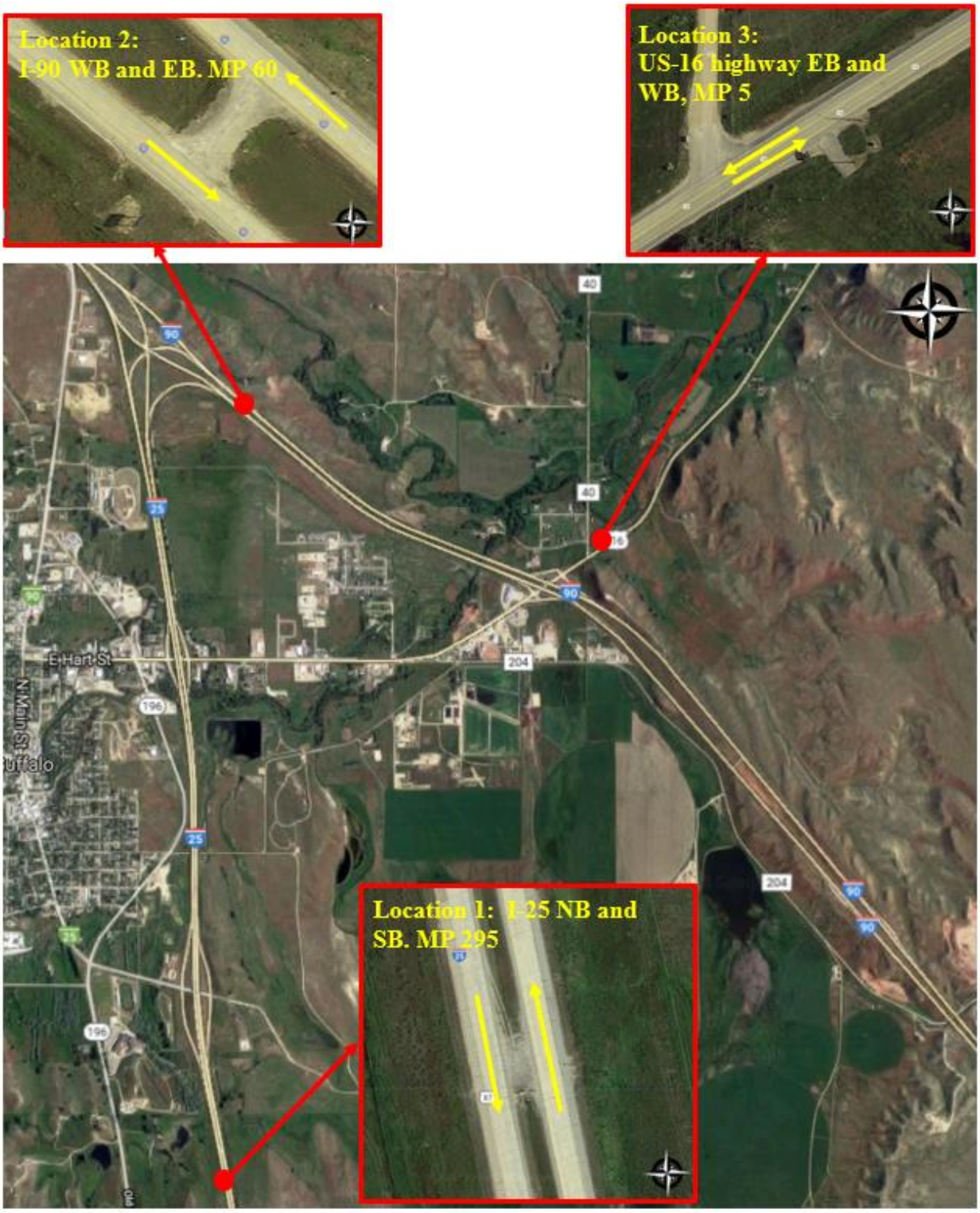


Figure 2 Data collection locations in Johnson County (proposed)

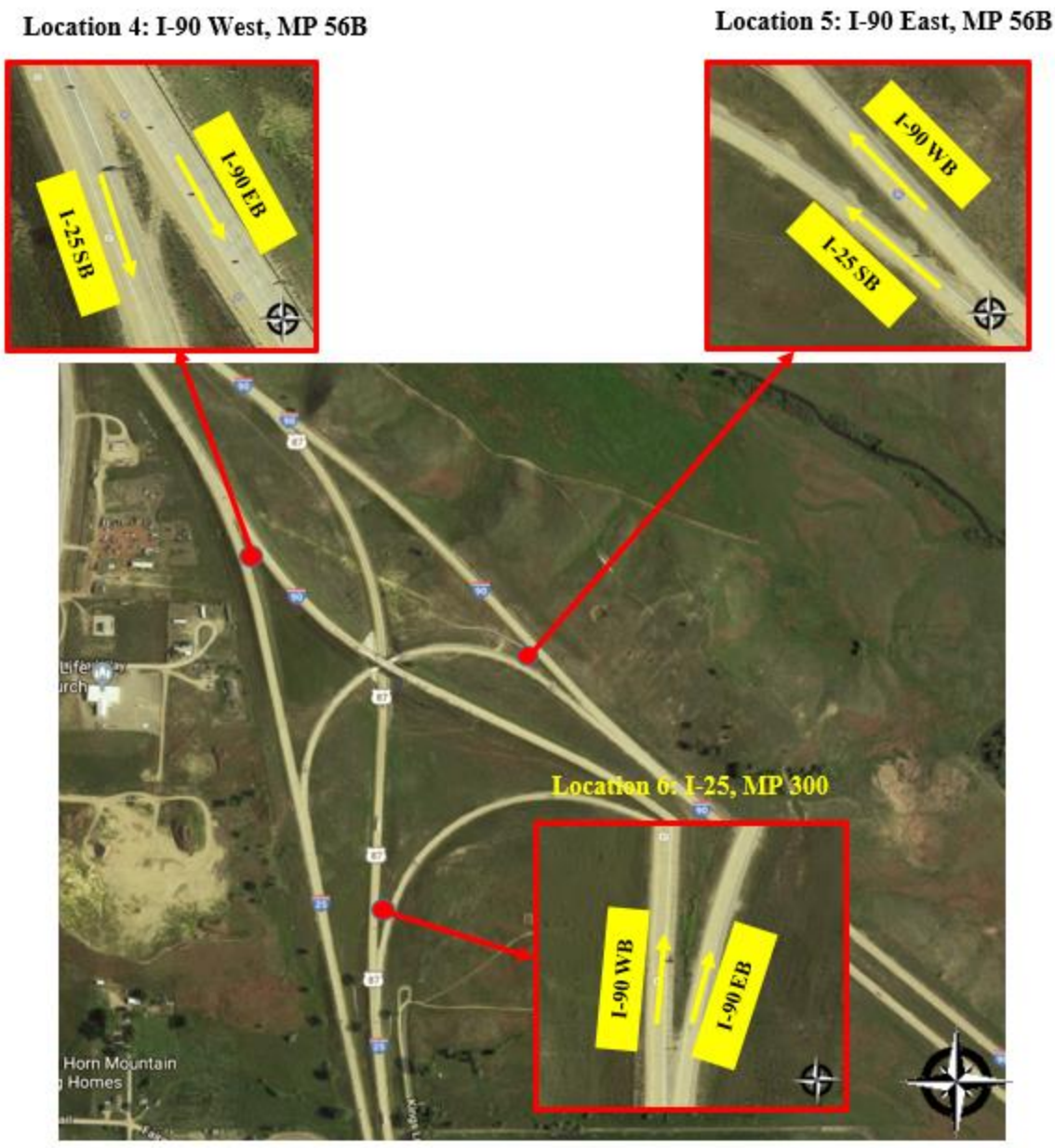


Figure 3 Data collection locations on the interchange

DATA COLLECTION PLAN

Most of the Hazardous Material Commodity Flow Study (HMCFS) use volunteers in order to collect required information about HAZMAT trucks passing at a certain route. In this study, the level of data collection is classified as directional and intersectional surveys with a representative sampling framework[2]. HAZMAT trucks data was collected for the two directions for each of the six locations as shown in Figure 2 and Figure 3 .

A data collection sheet, shown in Appendix "A", was designed to collect Placard ID, Placard Class, Truck Body Configuration, Cargo Type, and Direction. Due to the high speed limit on the study locations, 2 to 3 seconds was the available time to collect all the aforementioned data. Moreover, a truck count was conducted so as to estimate the percentage of HAZMAT trucks passing through each location. Truck count sheets are provided in Appendix A. Another challenge faced during the data collection was the multiple HAZMAT placards posted on the same truck. Moreover, having multiple trucks passing at the same time was a major challenge as well. Due to these issues, volunteers participated in this study received training in order to be able to capture the correct information on the placard and the truck in few seconds.

Initially, 2 volunteers were scheduled to collect data on US 16 on Sunday, Monday and Tuesday (1 weekend day and 2 weekdays) in 4 shifts of 3 hours each. During the first and last shifts on Sunday there was no truck traffic observed. Similarly, on the second day there was no truck traffic on US 16 during the first and last shifts and as a result the data collection on US-16 was cancelled for the third day. Data collection for the other locations were conducted as scheduled (Table 4). For locations 4, 5 and 6 three hours of data collection was carried out each day from Monday to Wednesday to observe the movement of HAZMAT trucks on the interchange in a cumulative 12-hour period. 1 volunteer was assigned to collect data for each location. I-25 and I-90 were the two locations assigned by Wyoming SERC. Six volunteers collected data for the two locations in 4-hour shifts for a total of 12 hour each day from Thursday to Saturday (2 weekdays and 1 weekend day).

Table 4: Scheduled Data Collection Plan for Johnson County

Location		Day	Date	Time		Total Number of (HRs)
				From	To	
1	I 25 MP 295	Thursday, Friday, Saturday	15th, 16th, 17th of March 2018	7:00am	7:00pm	12hr×3d = 36
2	I 90 MP 60	Thursday, Friday, Saturday	15th, 16th, 17th of March 2018	7:00am	7:00pm	12hr×3d = 36
3	US 16 MP 5	Sunday, Monday, Tuesday	11th, 12th, 13th of March 2018	7:00am	7:00pm	12hr×3d = 36
4	I 90 West MP 56	Monday	12th March 2018	7:00am	11:00am	4hr×3d = 12hr
		Tuesday	13th March 2018	3:00pm	7:00pm	
		Wednesday	14th March 2018	11:00am	3:00pm	
5	I 90 East MP 56	Monday	12th March 2018	11:00am	3:00pm	4hr×3d = 12hr
		Tuesday	13th March 2018	7:00am	11:00am	
		Wednesday	14th March 2018	3:00pm	7:00pm	
6	I 25 MP 300	Monday	12th March 2018	3:00pm	7:00pm	4hr×3d = 12hr
		Tuesday	13th March 2018	11:00am	3:00pm	
		Wednesday	14th March 2018	7:00am	11:00am	

AVERAGE DAILY TRAFFIC

Traffic pneumatic tube counters can be used to collect annual average daily traffic (AADT), truck percentage, and vehicle classification. Installing pneumatic traffic tubes on the study locations were impossible due to the high traffic volumes and high operating speeds and accordingly they were not used to collect AADTs for the study locations. The Wyoming Department of Transportation (WYDOT) has several automatic traffic recorders, classifiers and count sites that provide the ADT for Wyoming's highways. A monthly automatic traffic recorder report is published on WYDOT website containing traffic data for Wyoming's highways[15]. Percentage of trucks were calculated from the Vehicle miles 2015 report[16]. Table 5 shows the traffic data for the selected study locations.

Table 5: Traffic Data for the three data collection locations

Location	MADT	MAWDT	MAWET	% of trucks	% of HAZMAT trucks from truck traffic*
I-25	5,832	5,995	5,213	17.9 %	5.5 %
I-90	2,633	2,513	2,644	15.2 %	9.3 %
US-16	697	604	821	4.1 %	0.0 %

* The HAZMAT truck percentages were calculated based on the percentage of HAZMAT trucks collected from the field data collection.

Where:

MADT : Monthly Average Daily Traffic.

MAWDT : Monthly Average Week Day Traffic.

MAWET : Monthly Average Weekend Traffic.

CHALLENGES AND DATA COLLECTION DIFFICULTIES

Many difficulties were faced by the data collection team while collecting the data. Some of these difficulties can be summarized as follows:

- Due to the high operating speed, errors in collecting data might occur.
- Due to the high speed, missing data may be presented when having more than two placards mounted on the same truck.
- In some cases, errors in data collection might happen as more than one HAZMAT truck pass at the same time.
- When trucks or other vehicles are present on both lanes, this might block the vision to collect placard data on HAZMAT trucks.
- There is no fixed location for the HAZMAT placard on the truck body, which represents a challenge to trace its location for each truck as shown in pictures in Appendix B.

CHAPTER 6- DATA ANALYSIS

This section provides descriptive analysis of the collected HAZMAT data. It presents the distribution of HAZMAT trucks according to its destination, and the different types of HAZMAT being transported at the study locations according to the placard class and ID. Moreover, it shows the different amounts of HAZMAT being shipped according to the different body configurations.

HAZMAT TRANSPORTATION USING JOHNSON COUNTY HIGHWAYS

HAZMAT DIRECTIONAL DISTRBUTION

As mentioned earlier, the study locations were at straight highway segments and on the interchange connecting I-25 South of Buffalo to I-90 East and West of Buffalo. Directional distribution provides the information about the percentage of HAZMAT trucks moving in each direction. Table 6 shows the HAZMAT directional distribution for five of the six study locations. US-16 was excluded from this table since there was no HAZMAT observed during the data collection period. From the directional distribution, there is higher percentage of HAZMAT truck movement on I-90 compared to I-25.

Table 6: Directional Distribution for HAZMAT trucks for each study location

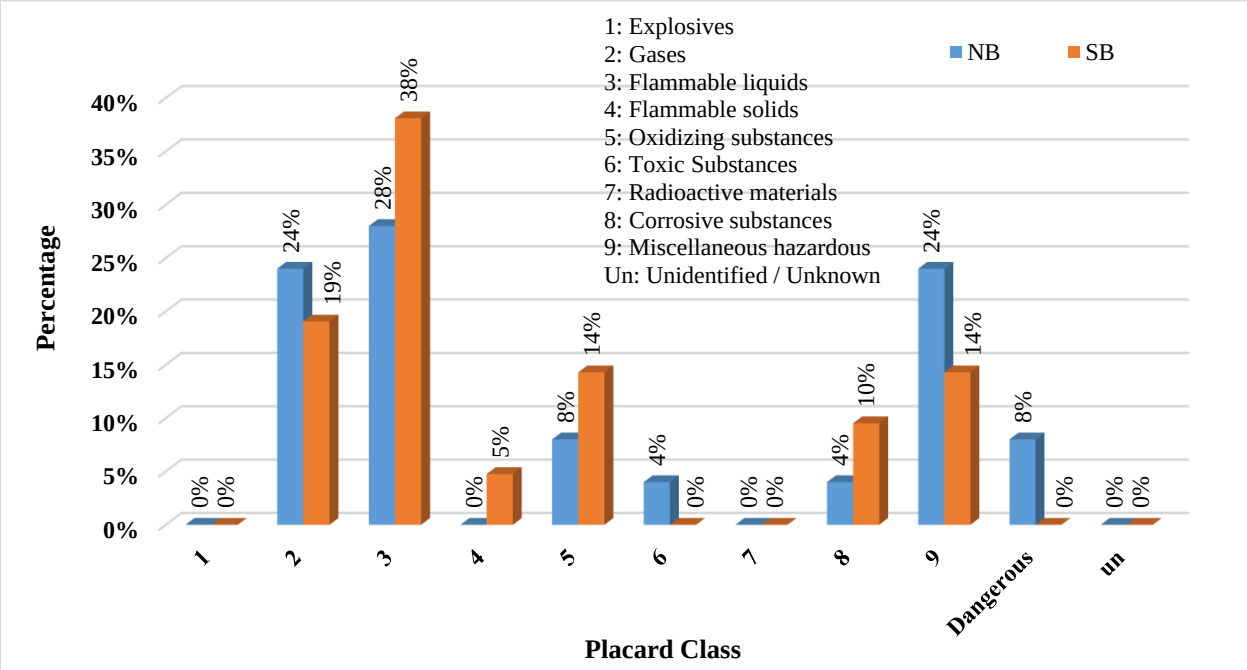
#	Location	Direction	Percentage of HAZMAT trucks for each direction and its count
1	I 25	NB SB	54.35%- 25 45.65%- 21
2	I 90	EB WB	49.37%- 39 50.63%- 40
4	I 90 West (interchange)	I 90 EB I 25 SB	71.43%- 15 28.57%- 6
5	I 90 East (interchange)	I 90 WB I 25 SB	91.67%- 11 8.33%- 1
6	I 25 (interchange)	I 90 WB I 90 EB	45.45%- 5 54.54%- 6

Data represents percentage of total HAZMAT counted for each direction in the study locations and its percentage

HAZMAT CLASS DISTRIBUTION

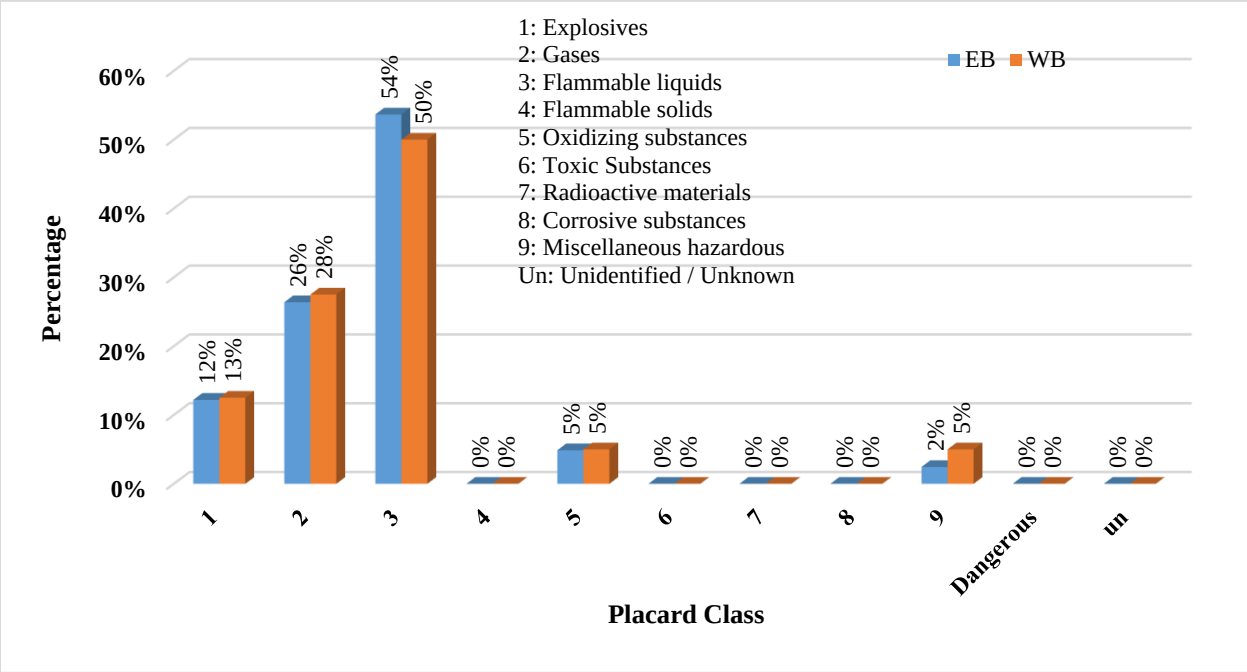
Figure 4 to Figure 8 show how the different percentages of the HAZMAT class being transported in the study locations per direction. Flammable liquids (Class 3) HAZMAT has the highest percentage among the transported HAZMAT classes. It represents 33% of transported HAZMAT

on 1st location (Figure 4), 50% on 2nd location (Figure 5), 51.5% on 4th location (Figure 6), 82% on 5th location (Figure 7) and 38.5% on 6th location, averaged for all directions. There was no HAMAT observed on 3rd location (US-16). It should be noted that about 2.5% and 4.8% of the HAZMAT trucks carried multiple placards of different classes for the locations I-90 MP 60 and I-90 West MP 56 (interchange) respectively.



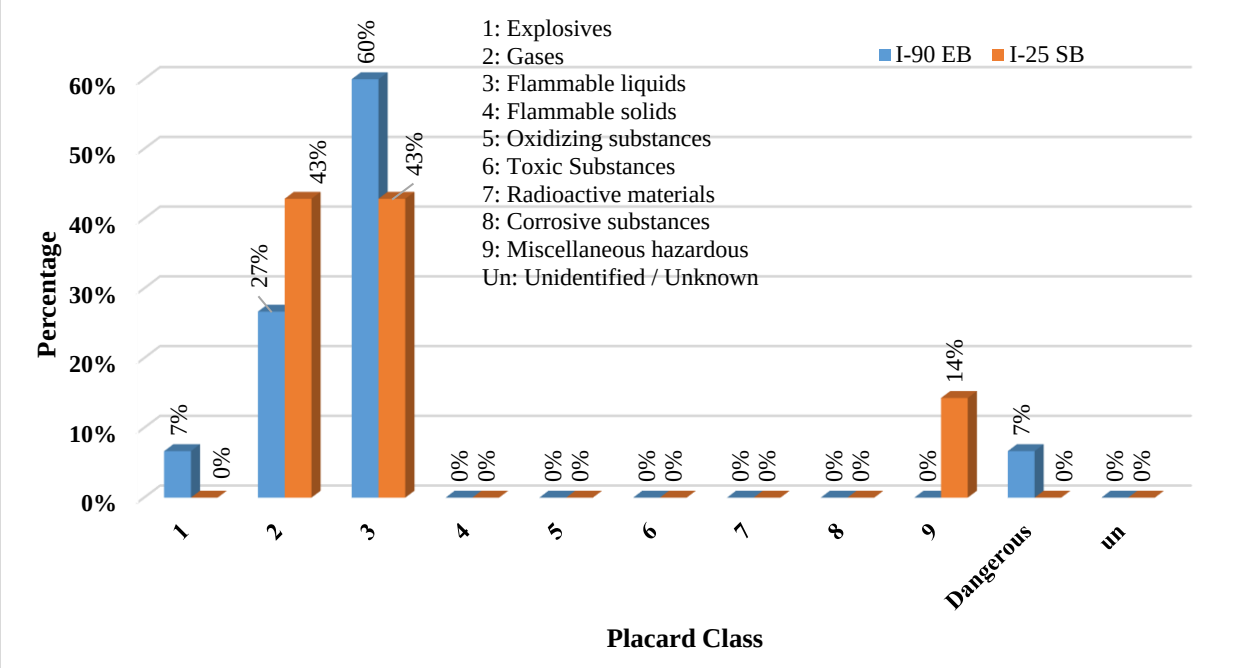
Data represents the percentage of HAZMAT classes from the total HAZMATs shipped in a certain direction

Figure 4: HAZMAT placard class percentages for I-25 MP 295



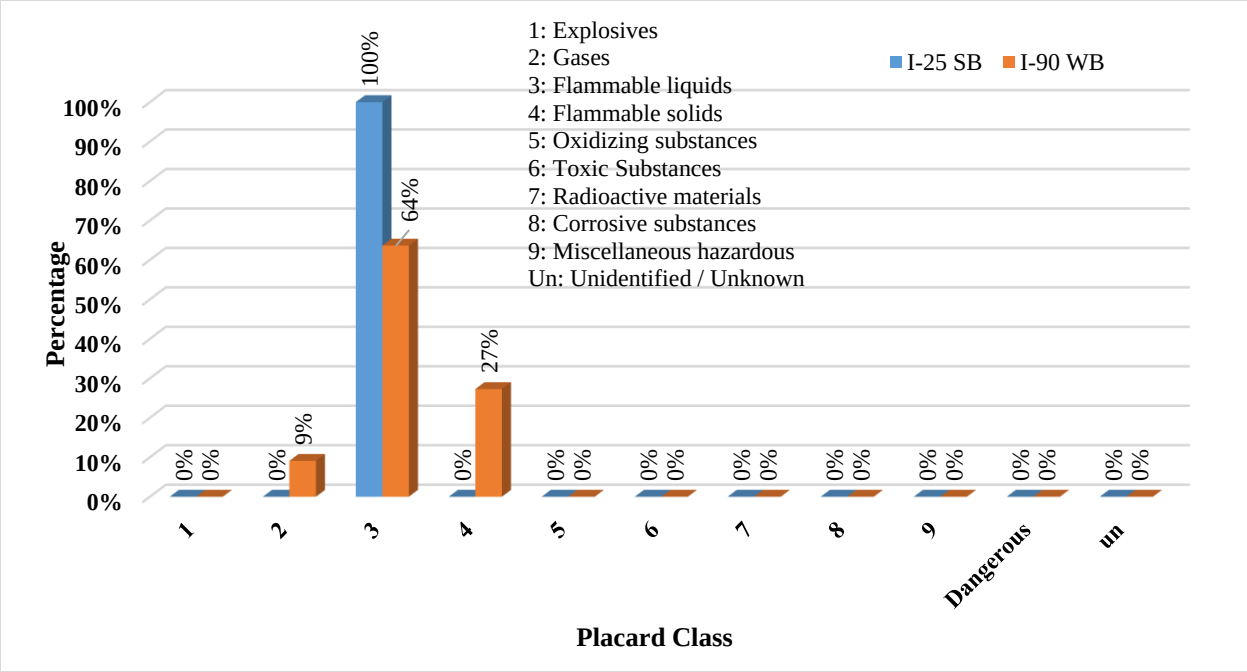
Data represents the percentage of HAZMAT classes from the total HAZMATs shipped in a certain direction

Figure 5: HAZMAT placard class percentages for I-90 MP 60



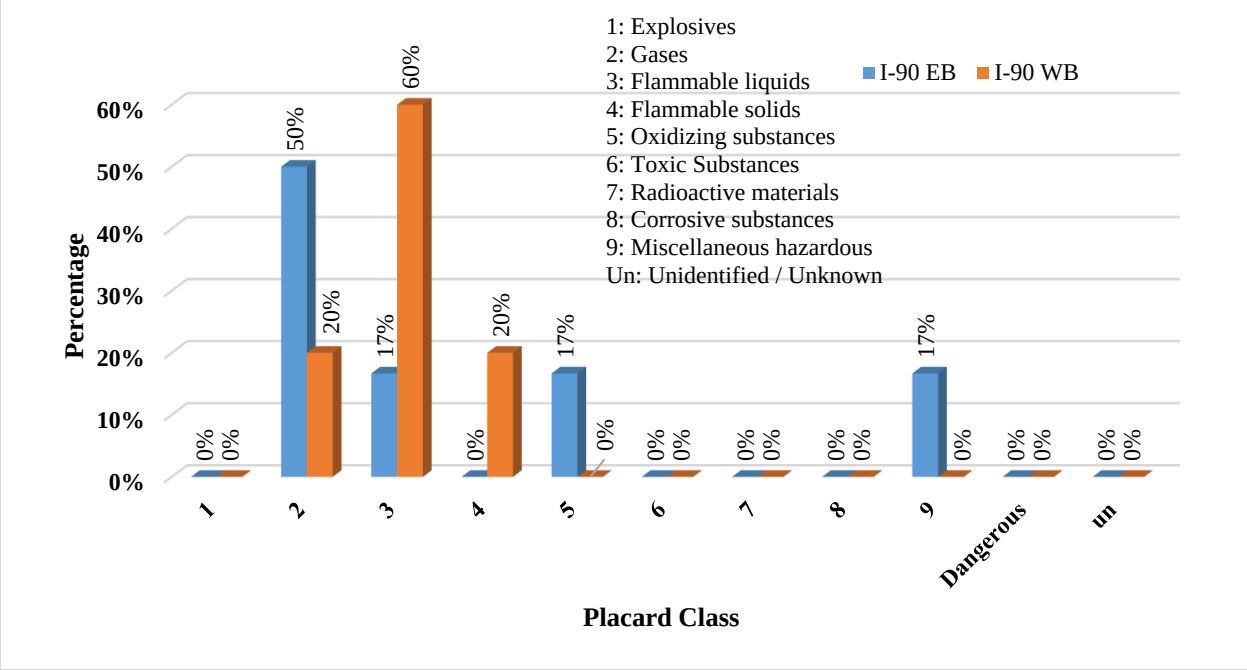
Data represents the percentage of HAZMAT classes from the total HAZMATs shipped in a certain direction

Figure 6: HAZMAT placard class percentages for I-90 West MP 56 (interchange)



Data represents the percentage of HAZMAT classes from the total HAZMATs shipped in a certain direction

Figure 7: HAZMAT placard class percentages for I-90 East MP 56 (interchange)



Data represents the percentage of HAZMAT classes from the total HAZMATs shipped in a certain direction

Figure 8: HAZMAT placard class percentages for I-25MP 300 (interchange)

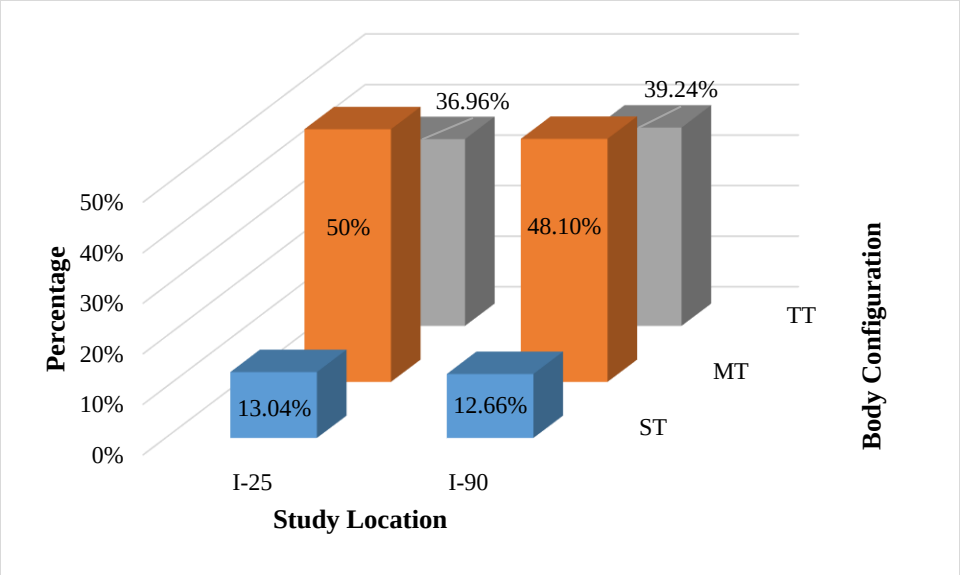
ESTIMATION OF HAZMAT AMOUNT BEING TRANSPORTED

Collecting the body configuration information in the data provides a rough estimate of the HAZMAT amount being transported. Straight truck may have a capacity ranging from 2,400 to 3,900 US gallons. A truck-trailer may have a capacity of 5,500 to 9,500 US gallons while a multi-trailer may have a capacity of 9,500 to 19,000 US gallons. Two main underline assumptions were considered to estimate the amount of HAZMAT being transported in the study locations. The two assumptions are as follows:

1) All the counted HAZMAT trucks, trucks with placards, are considered to be loaded with its minimum or maximum capacity.
2) The estimated minimum and maximum amounts are based on the body configuration not the body type.

According to the two assumptions, partially loaded trucks might be counted and included in the estimated amounts as a fully loaded truck. Also, different body types were not considered in the calculations of the HAZMAT amounts (e.g. a semi-trailer with a high-pressure tank or a mixed cargo were considered as a truck trailer body configuration with the same min/max amount of HAZMAT). It should be noted that the only way to obtain the accurate amount of shipped HAZMATs is by checking the shipment documents, which was not feasible to perform in this study.

The multi-trailer (MT) is the most common body configuration used for transporting HAZMAT in the locations I-25 (MP 295) and I-90 (MP 60). Figure 9 shows the different percentages of body configuration for HAZMAT trucks in the study locations. US-16 is not included in the figure since there was no HAZMAT observed on this location.



Data represents the percentage of different truck body configurations from the total trucks passing at each study location separately.

Figure 9: Percentage of HAZMAT trucks by body configuration for the study locations

Table 7 shows an estimation of the amount of HAZMAT being transported on the study locations in the US gallons per day. The minimum and maximum amounts were calculated using the following equations:

Total min amount = MADT ×% of trucks × % of HAZMAT trucks × body config. × min capacity

Total max amount = MADT ×% of trucks × % of HAZMAT trucks × body config. × max capacity

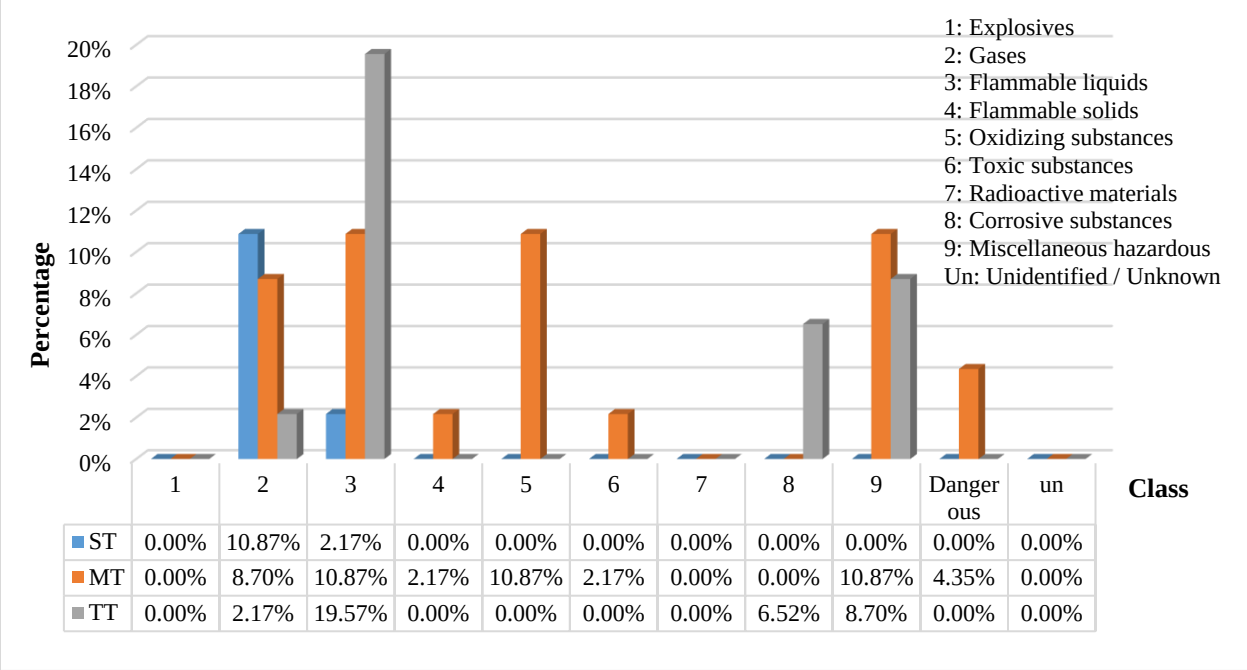
Where:

MADT : Monthly Average Daily Traffic.

Table 7: Estimation of the amount of HAZMAT transported in the study locations

Study Locations	MADT	% of trucks	% of HAZMAT trucks	Monthly average Number of HAZMAT trucks per day	HAZMAT trucks body configuration Percentages		Min. Capacity per truck type (US gallons)	Max. Capacity per truck type (US gallons)	Total Min. amount (US gallons / day)	Total Max. Amount (US gallons / day)	Total amount (US gallons / day) Min/ Max
I-25 MP 295	5,832	17.9%	5.5%	57.42	TT	36.96%	5,500	9,500	116,715	201,599	407,410/ 776,251
					MT	50%	9,500	19,000	272,726	545,452	
					ST	13.04%	2,400	3,900	17,969	29,200	
I-90 MP 60	2,633	15.2%	9.3%	37.22	TT	39.24%	5,500	9,500	80,328	138,749	261,715/ 497,280
					MT	48.10%	9,500	19,000	170,077	340,154	
					ST	12.66%	2,400	3,900	11,309	18,377	

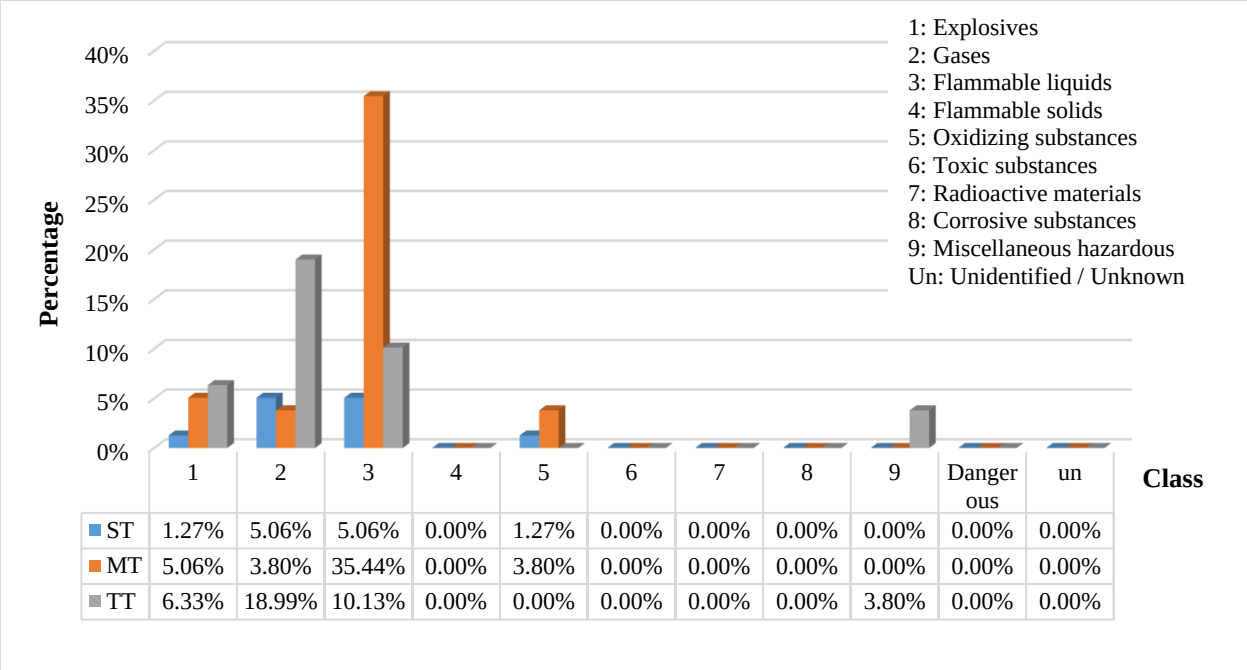
Figure 10 to Figure 14 show the different percentages of truck body configuration used to transport different HAZMAT classes. The percentages provided in the figures are calculated from the grand total of the HAZMAT trucks.



	1	2	3	4	5	6	7	8	9	Dangerous	un
ST	0.00%	10.87%	2.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MT	0.00%	8.70%	10.87%	2.17%	10.87%	2.17%	0.00%	0.00%	10.87%	4.35%	0.00%
TT	0.00%	2.17%	19.57%	0.00%	0.00%	0.00%	0.00%	6.52%	8.70%	0.00%	0.00%

Data represents the percentage of different body configurations transporting different HAZMAT classes from the total HAZAMTs transported at a certain study location.

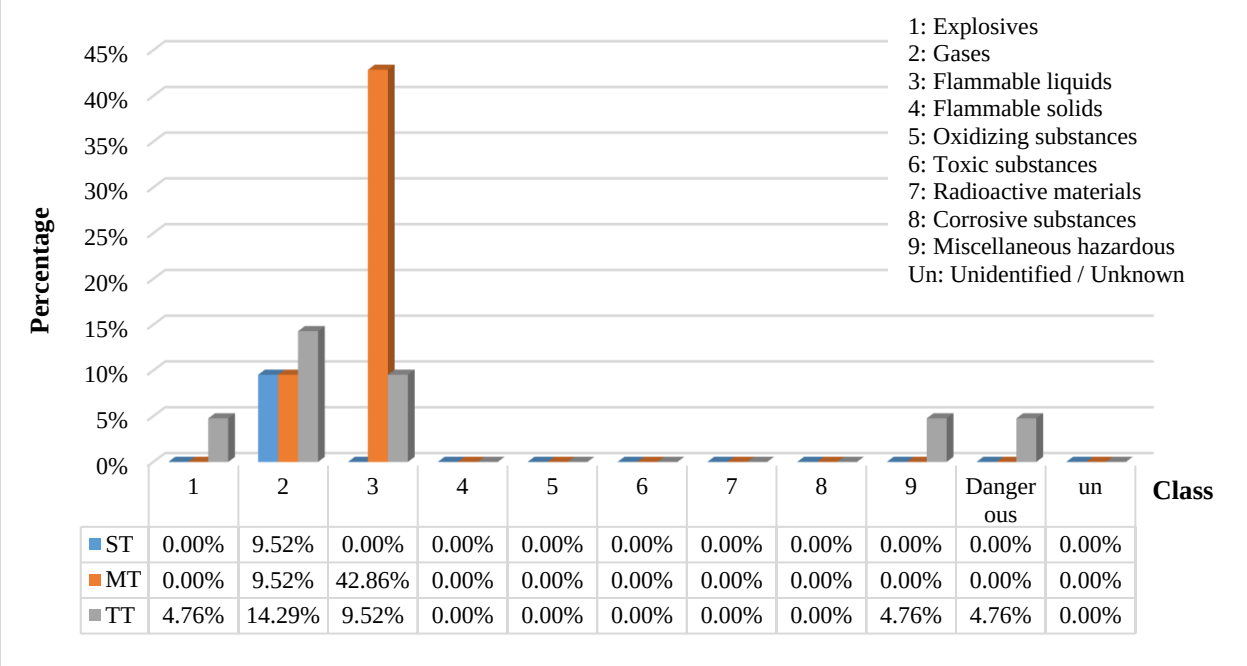
Figure 10: Body configuration percentages by HAZMAT classes for I-25 MP 295



	1	2	3	4	5	6	7	8	9	Dangerous	un
ST	1.27%	5.06%	5.06%	0.00%	1.27%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MT	5.06%	3.80%	35.44%	0.00%	3.80%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TT	6.33%	18.99%	10.13%	0.00%	0.00%	0.00%	0.00%	0.00%	3.80%	0.00%	0.00%

Data represents the percentage of different body configurations transporting different HAZMAT classes from the total HAZAMTs transported at a certain study location.

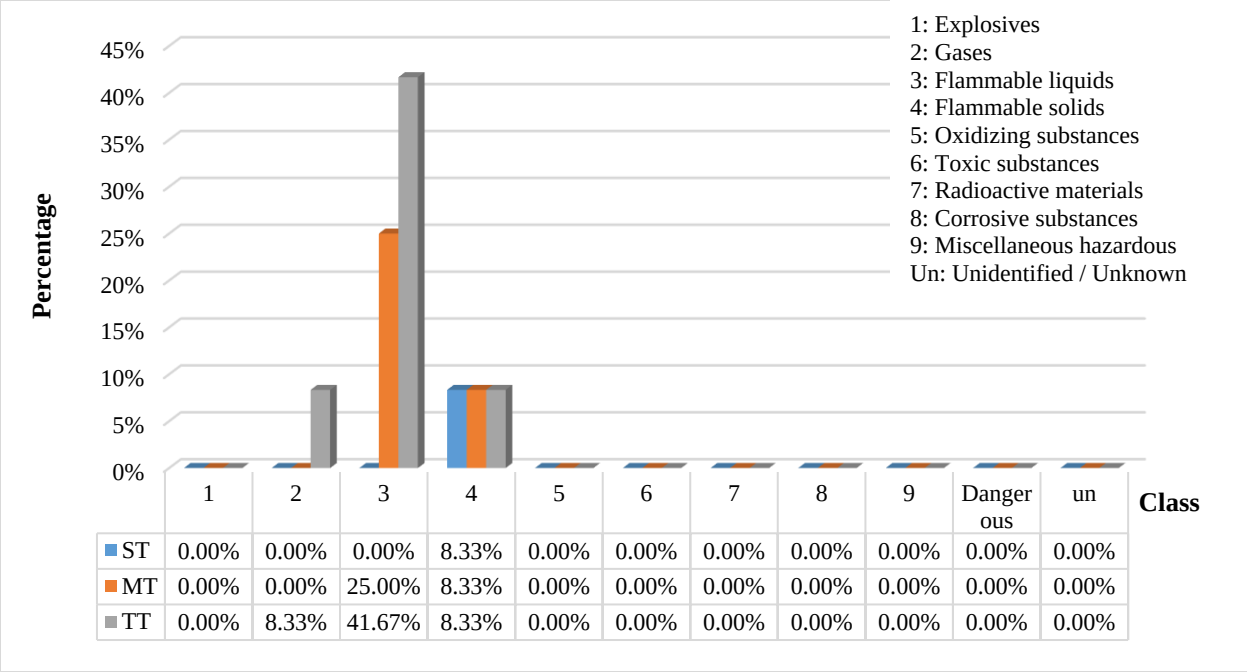
Figure 11: Body configuration percentages by HAZMAT classes for I-90 MP 60



	1	2	3	4	5	6	7	8	9	Dangerous	un
ST	0.00%	9.52%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MT	0.00%	9.52%	42.86%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TT	4.76%	14.29%	9.52%	0.00%	0.00%	0.00%	0.00%	0.00%	4.76%	4.76%	0.00%

Data represents the percentage of different body configurations transporting different HAZMAT classes from the total HAZAMTs transported at a certain study location.

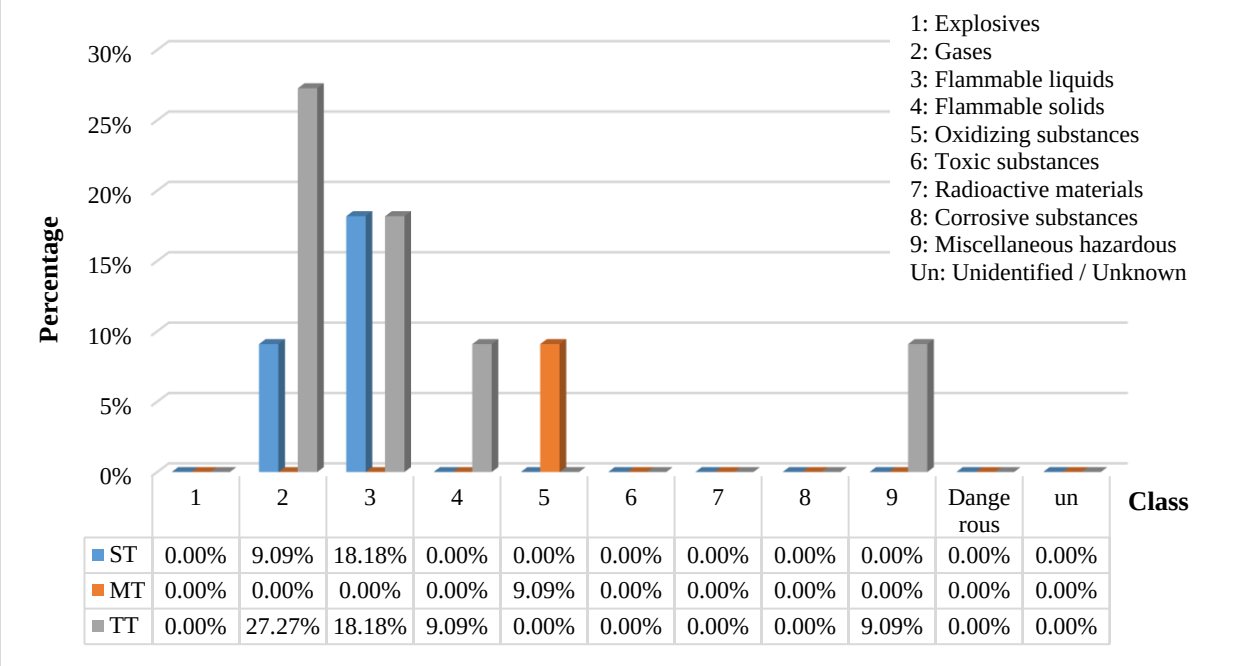
Figure 12: Body configuration percentages by HAZMAT classes for I-90 West MP 56 (interchange)



	1	2	3	4	5	6	7	8	9	Dangerous	un
ST	0.00%	0.00%	0.00%	8.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MT	0.00%	0.00%	25.00%	8.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TT	0.00%	8.33%	41.67%	8.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Data represents the percentage of different body configurations transporting different HAZMAT classes from the total HAZAMTs transported at a certain study location.

Figure 13: Body configuration percentages by HAZMAT classes for I-90 East MP 56 (interchange)



	1	2	3	4	5	6	7	8	9	Dangerous	un
ST	0.00%	9.09%	18.18%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MT	0.00%	0.00%	0.00%	0.00%	9.09%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TT	0.00%	27.27%	18.18%	9.09%	0.00%	0.00%	0.00%	0.00%	9.09%	0.00%	0.00%

Data represents the percentage of different body configurations transporting different HAZMAT classes from the total HAZAMTs transported at a certain study location.

Figure 14: Body configuration percentages by HAZMAT classes for I-25MP 300 (interchange)

Each placard ID refers to the material being shipped. Figure 15 show that at the 1st location (I-25) majority of the HAZMATs transported were unidentified (either the placards did not have any ID or they could not be identified). At the 2nd location (I-90), Diesel fuel, fuel oil (HAZMAT placard with ID number 1993) and Gasoline, motor spirit, petrol (HAZMAT placard with ID number 1203) was transported the most as shown in Figure 16. Butane, propane, LPG (1075), Fuel, aviation, turbine engine (1863) and Diesel fuel, fuel oil (1993) were the most common HAZMATs being transported on the I-90 West side of the interchange (Figure 17). On the east side of the I-90 interchange, Fuel, aviation, turbine engine (1863) HAZMAT was most commonly observed (Figure 18) and on I-25 part of the interchange, HAZMAT trucks carrying Butane, propane, LPG (1075) was most commonly observed (Figure 19).

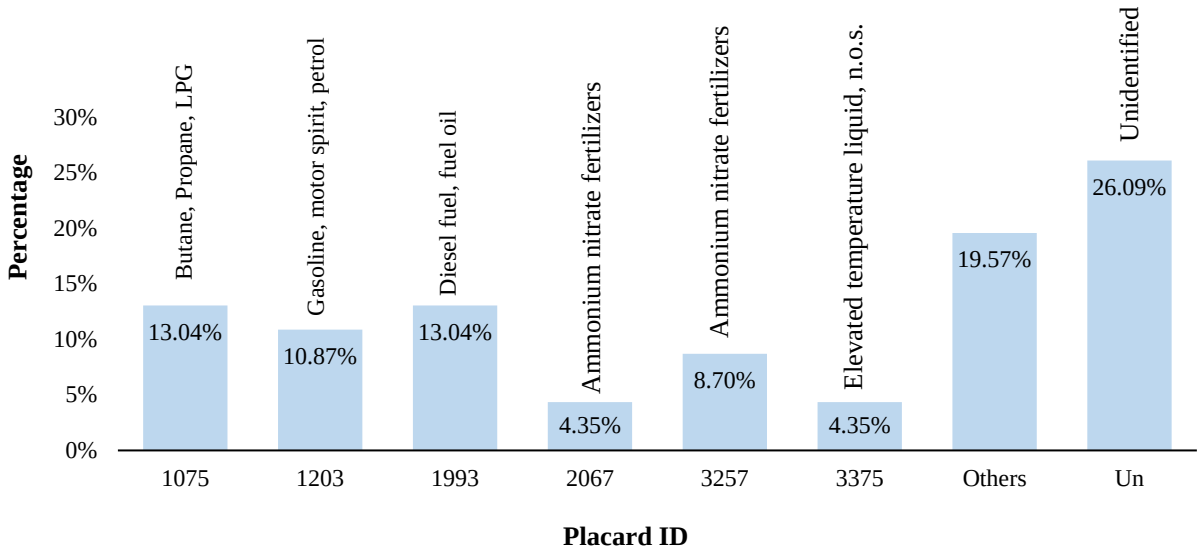


Figure 15: Placard ID number percentages at 1st location (I-25 MP 295)

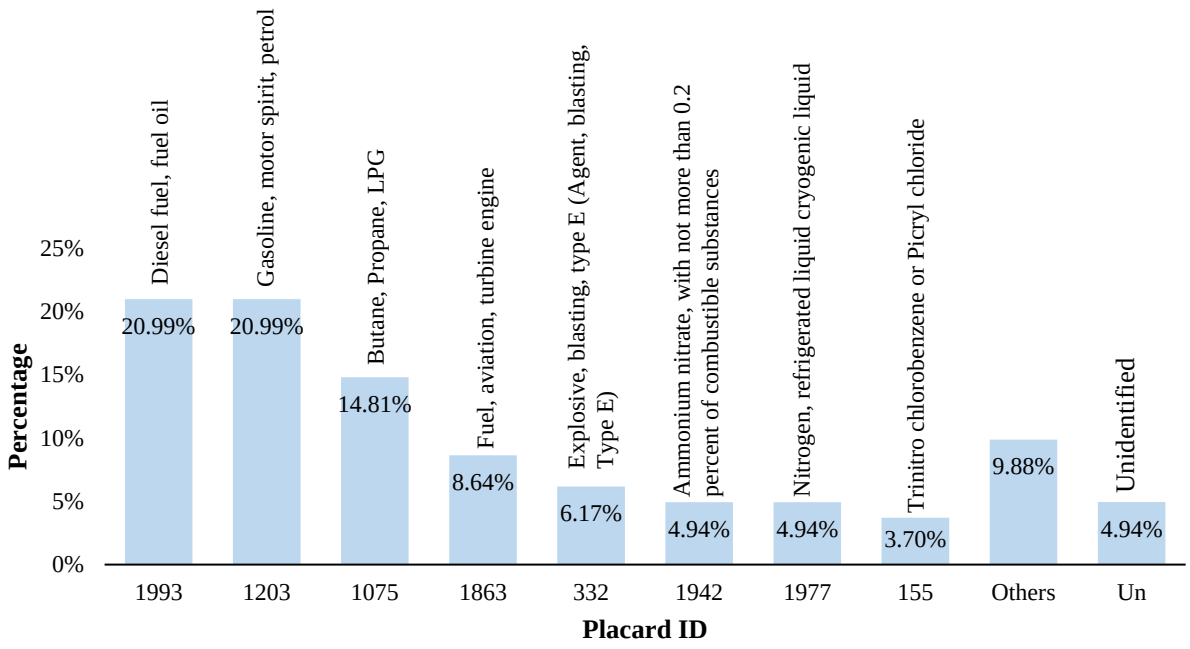


Figure 16: Placard ID number percentages at 2nd location (I-90 MP 60)

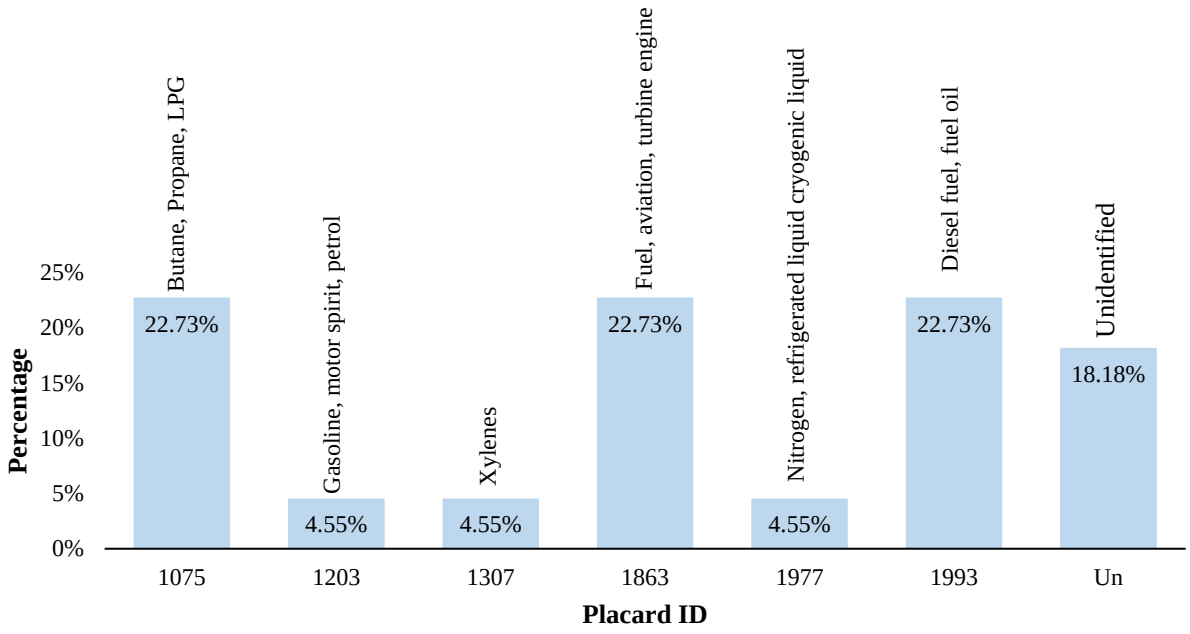


Figure 17: Placard ID number percentages at 4th location (I-90 West MP 56, interchange)

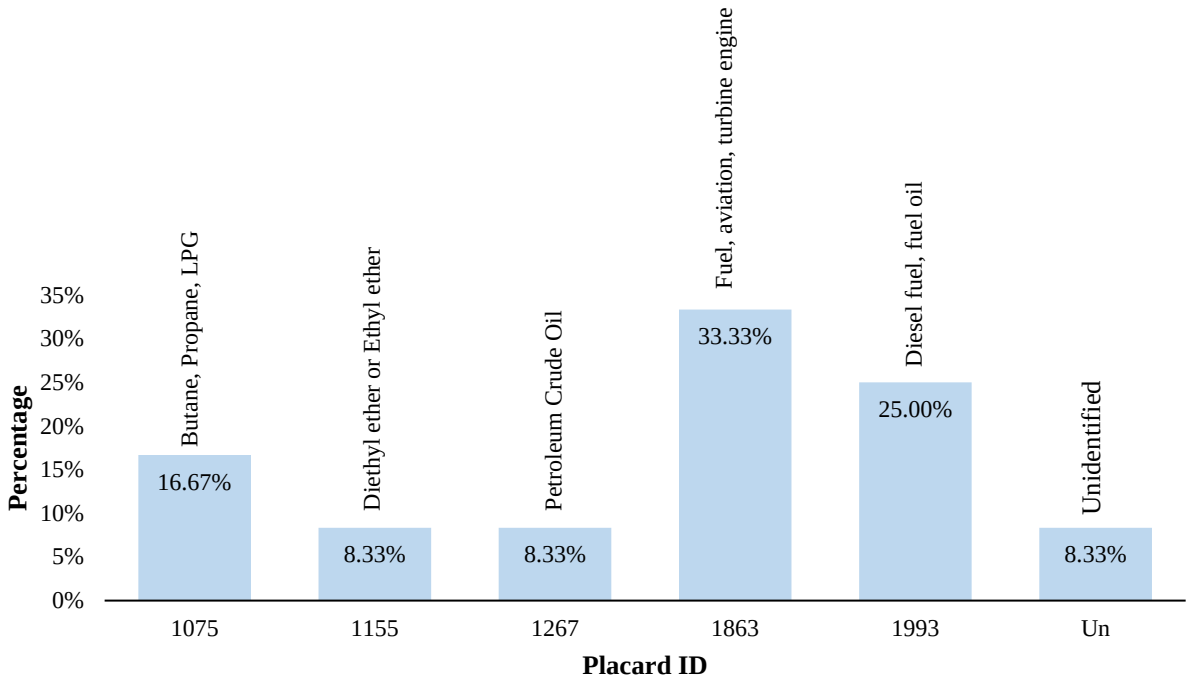


Figure 18: Placard ID number percentages at 4th location (I-90 East MP 56, interchange)

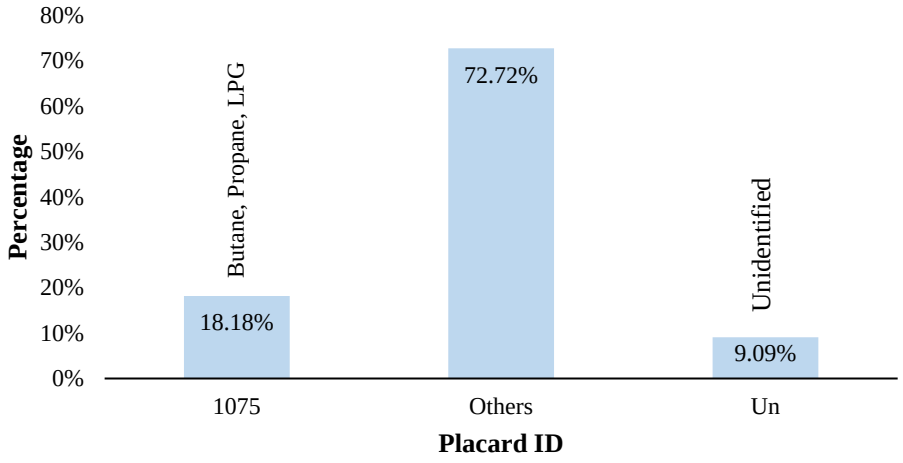


Figure 19: Placard ID number percentages at 4th location (I-25 MP 300, interchange)

CHAPTER 7- AUTOMATIC PLACARD RECOGNITION SYSTEM

All commodity flow studies utilize manual data collection which is mainly based on volunteers to collect HAZMAT data. Manual data collection needs well-trained persons to minimize the errors generated and increase the reliability of data collected. Several other challenges may be faced while conducting HAZMAT data collection as mentioned in CHALLENGES AND DATA COLLECTION DIFFICULTIES section. Weather in cold and windy regions may cause difficulties or termination of data collection plans. Moreover, collecting HAZMAT data at night time is unfeasible due to visibility issues. These challenges raised the need to build up an Automatic Placard Recognition System (APRS).

SYSTEM DEVELOPMENT

The University of Wyoming, Civil Engineering Department has an ongoing effort to develop an APRS. A standalone mobile system utilizing LPR cameras equipped with Infra-Red (IR) diodes are used in developing the HAZMAT data collection system. Figure 20 shows a schematic diagram for the system being tested. The following is a list and description of the components are used in the APRS:

- License Plate Recognition (LPR) – IR Cameras: four black and white high-speed cameras with IR Light-emitting diode (LEDs) for night vision.
- Network Video Recorder (NVR): one Terabyte mobile network video recorder to collect the captured videos and still images
- Switch: eight port switch to connect the cameras to the NVR.
- Modem: Wireless modem connected to the NVR to monitor and control the system remotely
- Traffic Radar: 250ft range Wavetronix radar to collect traffic data

To operate the system, adequate power should be supplied to the different components. All of the previously mentioned components can be operated using an Alternating Current (AC) or a Direct Current (DC) power source. In order to have a completely standalone mobile system, DC is used to power the system. In this study one deep cycle batteries is used to provide the required power to the NVR and the two LPR cameras. The testing was carried out for few hours on selected days.

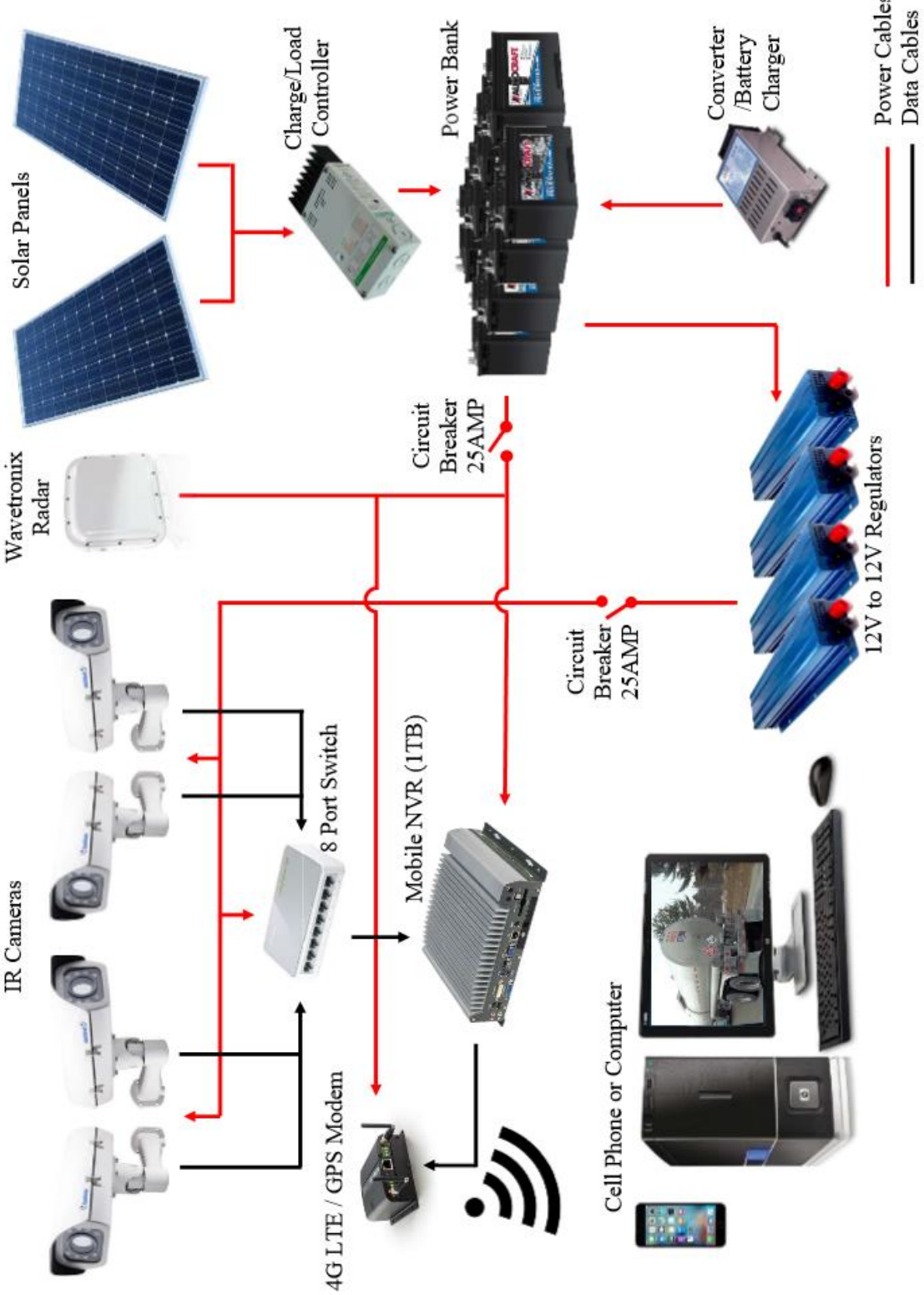


Figure 20: Schematic diagram for the Automatic Placard Recognition System

Deep cycle batteries have a limited capacity of amperage per hour that operated the system for few hours. To increase the operation time, solar panels can be connected to the power banks through a charge/load controller to charge the batteries, which would increase the running time to 5 days. The main use of the solar panels is to extend the operation time. On the other hand, to maintain the power banks lifespan, it can be charged using an AC power source using an AC to DC converter/battery charger once every 6 months.

To ensure the optimum voltage to be provided to the different system components, a 12V to 12V regulator was used. Finally, Ethernet cables was used to transfer data between the different system components, which was accessed on site.

To have a fully mobile system, a trailer-mounted equipment platform was utilized. Figure 21 shows the trailer with the developed Placard Recognition System mounted on it. The trailer has a 32-ft extendable telescopic mast where the LPR cameras were mounted to provide a better angle of view. It is worth mentioning that a Wavetronix radar and an additional IP camera is already mounted and functioning on the trailer.

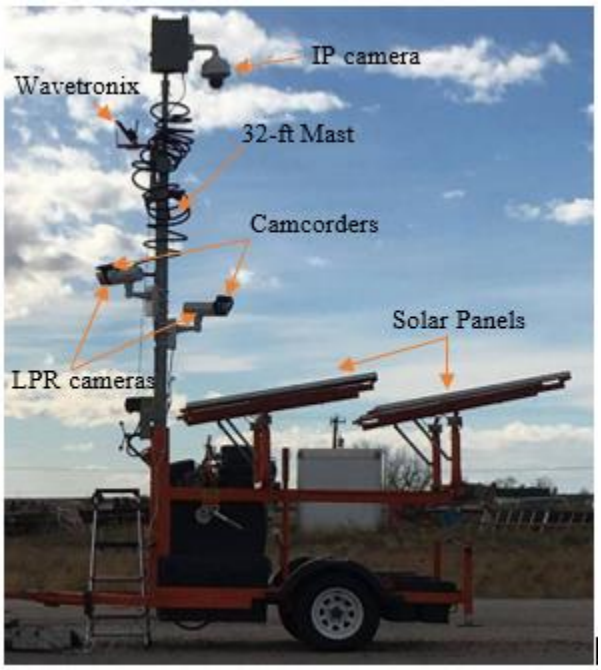


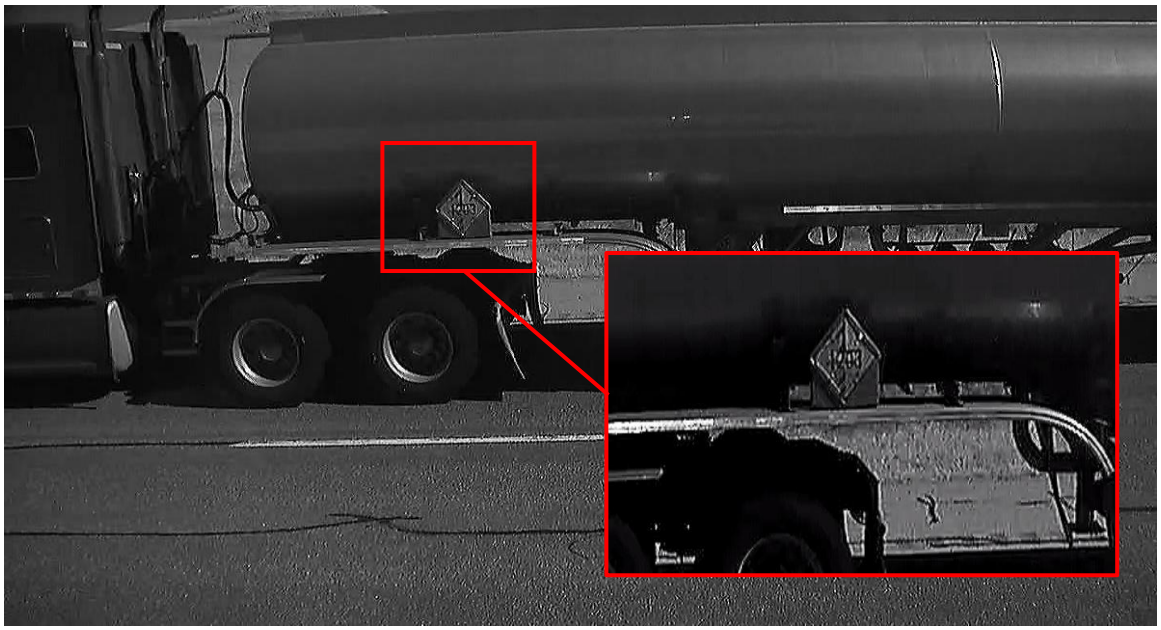
Figure 21: HAZMAT data collection trailer

IMAGES OBTAINED FROM THE LPR CAMERAS

Testing with the LPR cameras to obtain placard images from HAZMAT truck was carried out in previous two studies, Natrona County CFS and Sweetwater County CFS. Similarly, the images obtained from the LRP cameras in this study are provided in Figure 22. According to the placard location synthesis, placards mounted on the back of the truck and on the side were targeted in this study. Images of placards mounted on the back can be recognized better as more time was available to capture them with the cameras.

The images obtained from the LPR cameras depend on the lighting condition and orientation of the cameras facing the Placard IDs. To obtain the clearest placard images, cameras should be placed in a location were the sunlight is behind the cameras and directly reflected on the placard. In addition, at least 2.5x zoomed images should be used. In this study the cameras were placed as close to the roadway as possible and zoomed 3x times. Unlike previous study, this study consisted of two cameras pointed in the same direction with one camera pointed towards the placards mounted at the back (Figure 22a) and another camera pointed towards the placards on the side of the trucks (Figure 22b).

a) Image from the LPR camera pointed at the placards mounted at the back



b) Image from the LPR camera pointed at the placards on the side

Figure 22: Images obtained from the LPR camera

There is an ongoing effort to make the data collection process fully automated where the LPR cameras will capture the Placard ID and store it in the database digitally after post-processing of the image of the Placard ID. The software with the algorithm to recognize Placard ID will be developed in collaboration with electrical engineering department at the University of Wyoming. Optical Character Recognition (OCR) technology will be used to recognize, identify, and digitize the HAZMAT placard IDs automatically.

CHAPTER 8- CONCLUSIONS

Hazardous material commodity flow studies are studies identifying what, where and when HAZMAT is being transported in a certain jurisdiction. In 2011, Hazardous Materials Cooperative Research Program (HMCRP) published the guidebook for conducting local hazardous materials commodity flow studies. Six main steps were identified by the guidebook. One important step is to collect and review existing HAZMAT data. There is a lack of previous HAZMAT commodity flow studies in Wyoming. No commodity flow study was performed in Johnson County, Wyoming previously. One commodity flow study was performed in 1986 in Albany County. In Wyoming, commodity flow studies were conducted in Campbell and Converse Counties in 2015, Laramie County and Albany County in 2016 and Natrona County and Sweetwater County in 2017.

Collecting new data was essential for this study due to the absence of any CFS within the jurisdiction. The purpose of this commodity flow study was to identify and provide information about the different types and amounts of hazardous materials being transported in Johnson County. Providing such critical information will help emergency responders and community planners to enhance emergency planning and capabilities, mitigating the dangerous effect associated with any HAZMAT incident. A comprehensive seven days of data collection was performed to fulfill the study objectives. Manual data collection was performed by six volunteered graduate students from the University of Wyoming. Automatic Data Collection using LPR cameras has been initiated and testing of the system is ongoing.

Three locations determined by the SERC, in consultation with the Emergency Management Coordinator from Johnson County, Marilyn Connolly, were investigated in the study. The three locations were on straight highways segments. The three locations are: I-25 north and south lanes near Buffalo, I-90 east and west lanes near Buffalo and US-16 east and west lanes through Buffalo. Additionally, the data collection team studied the movement of HAMZAT trucks on the interchange connecting I-25 and I-90 in Buffalo.

Table 8 shows a summary for all the data analysis provided in this report for the three highway locations and the additional locations on the interchange studied.

Table 8: Summary of data analysis for Johnson County HAZMAT study

Location	Direction	% of HAZMAT by class		% of Body configuration used to transport Hazmat		Estimated Min. and Max. Amounts of HAZMATs (US gallons/day)		% of most common transported HAZMAT		
		Class	%	Body Config.	%	Min	Max	Placard ID	Material	%
I-25 MP 295	NB	3- Flammable Liquids	28%	TT	36.96%	407,410	776,251	1075	Butane, Propane, LPG	13.04%
		2- Gases	24%							
		Others	48%	MT	50%			1993	Diesel fuel, fuel oil	13.04%
	SB	3- Flammable Liquids	38%							
		2- Gases	19%	ST	13.04%			1203	Gasoline, motor spirit, petrol	10.87%
		Others	43%							
I-90 MP 60	EB	3- Flammable Liquids	54%	TT	39.24%	261,715	497,280	1203	Gasoline, motor spirit, petrol	20.99%
		2- Gases	26%							
		Others	20%	MT	48.10%			1993	Diesel fuel, fuel oil	20.99%
	WB	3- Flammable Liquids	50%							
		2- Gases	28%	ST	12.66%			1075	Butane, Propane, LPG	14.81%
		Others	22%							
I-90 West MP 56 (interchange)	I-90 EB	3- Flammable Liquids	60%	TT	38.10%	-	-	1075	Butane, Propane, LPG	22.73%
		2- Gases	27%							
		Others	13%	MT	52.38%			1863	Fuel, aviation, turbine engine	22.73%
	I-25 SB	3- Flammable Liquids	43%							
		2- Gases	43%	ST	9.52%			1993	Diesel fuel, fuel oil	22.73%
		Others	14%							

I-90 East MP 56 (interchange)	I-25 SB	3- Flammable Liquids	100%	TT	58.33%	-	-	1863	Fuel, aviation, turbine engine	33.33%
		2- Gases	0%							
		Others	0%	MT	33.33%			1993	Diesel fuel, fuel oil	25%
	I-90 WB	3- Flammable Liquids	64%							
		2- Gases	9%	ST	8.33%			1075	Butane, Propane, LPG	16.67%
		Others	27%							
I-25 MP 300 (interchange)	I-90 EB	3- Flammable Liquids	17%	TT	63.64%	-	-	1075	Butane, Propane, LPG	18.18%
		2- Gases	50%							
		Others	33%	MT	9.09%			Others	HAZMAT with other Placard IDs	72.72%
	I-90 WB	3- Flammable Liquids	60%							
		2- Gases	20%	ST	27.27%			Un	Unidentified IDs	9.09%
		Others	20%							

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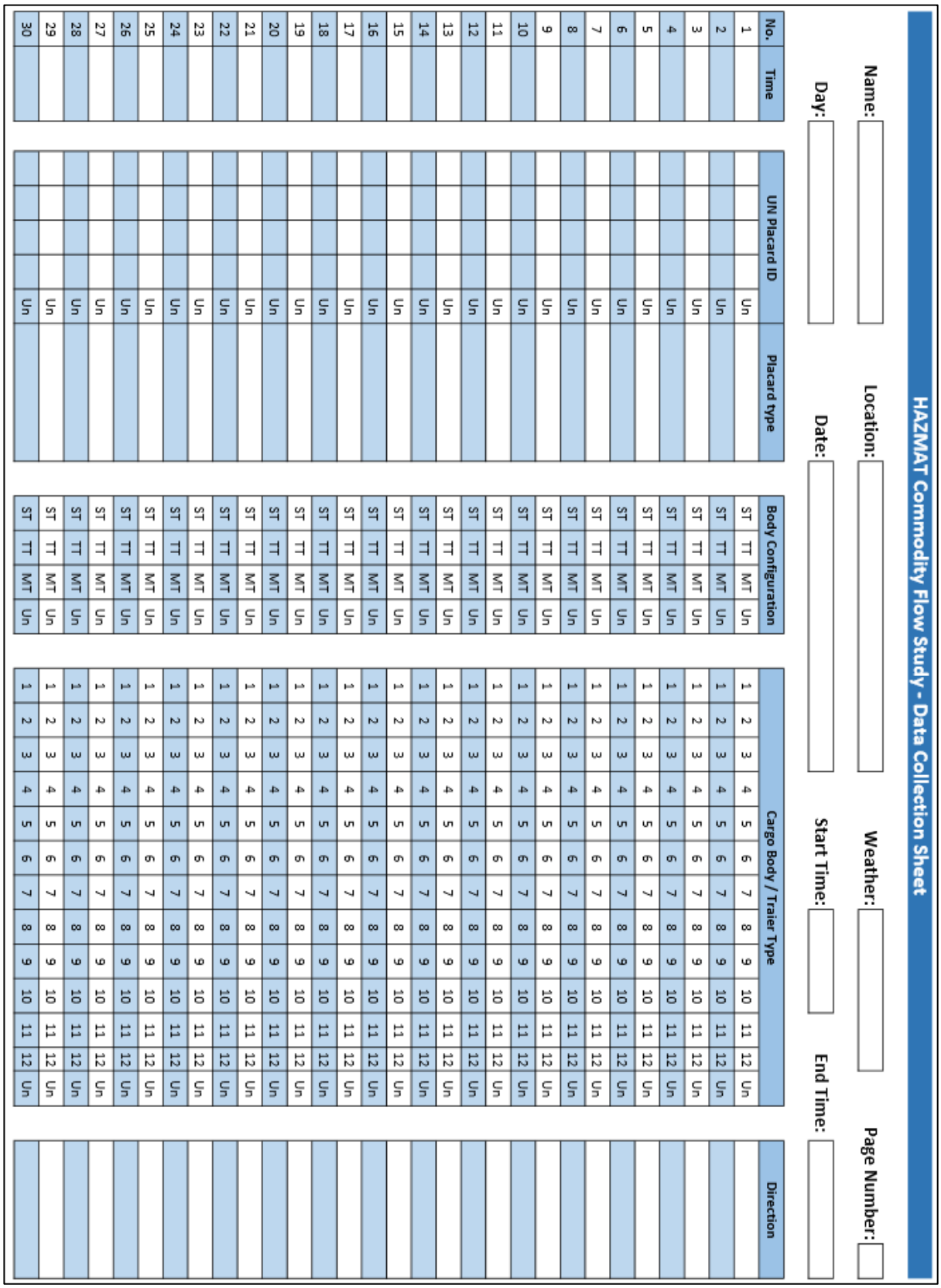
APPENDIX A: DATA COLLECTION SHEETS



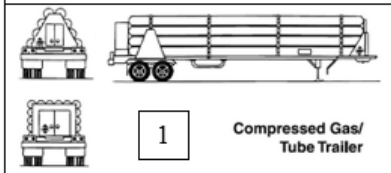
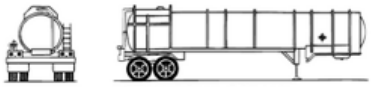
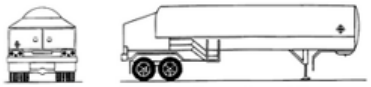
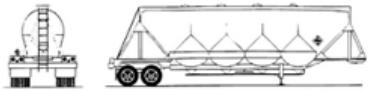
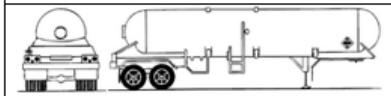
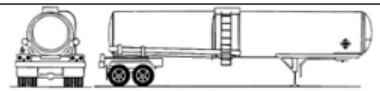
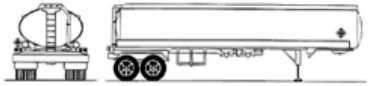
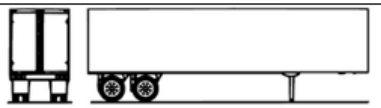
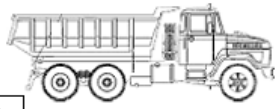
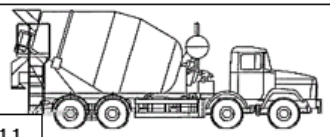
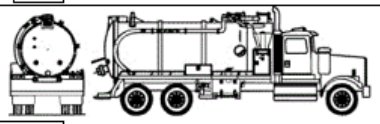
HAZMAT Commodity Flow Study - Data Collection Sheet

Name: Location: Weather: Page Number:

Day: Date: Start Time: End Time:

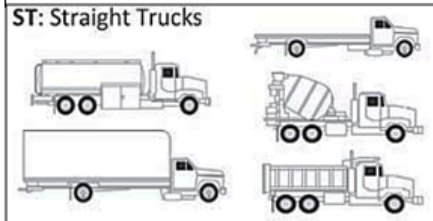
No.	Time	UN Placard ID	Placard type	Body Configuration	Cargo Body / Trailer Type	Direction
1		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
2		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
3		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
4		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
5		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
6		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
7		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
8		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
9		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
10		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
11		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
12		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
13		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
14		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
15		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
16		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
17		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
18		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
19		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
20		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
21		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
22		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
23		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
24		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
25		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
26		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
27		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
28		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
29		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	
30		Un		ST TT MT Un	1 2 3 4 5 6 7 8 9 10 11 12 Un	

Cargo Body / Trailer Type

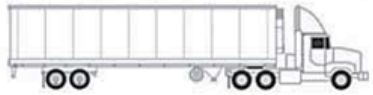
 1 Compressed Gas/ Tube Trailer	 2 DOT412, TC412, SCT-312 Corrosive Liquid Tank (MC312, TC312)	 3 MC338, TC338, SCT-338 Cryogenic Liquid Tank (TC341, CGA341)	 4 Dry Bulk Cargo Trailer
 5 MC331, TC331, SCT-331 High Pressure Tank	 6 DOT407, TC407, SCT-307 Low Pressure Chemical Tank (MC307, TC307)	 7 DOT406, TC406, SCT-306 Non-pressure Liquid Tank (MC306, TC306)	 8 Mixed Cargo
 9 Low Bed Trailer	 10 Dump Truck	 11 Cement Mixer	 12 Vacuum loaded tank

Body Configuration

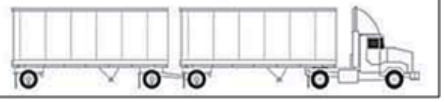
ST: Straight Trucks



TT: Tractor-Trailer
(also includes straight truck with trailer)



MT: Tractor with Multiple Trailers



Placard type

1 

2 

3 

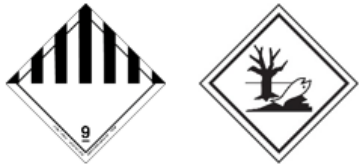
4 

5 

6 

7 

8 

9 

10 

Truck Count Sheet

Name: Location: Start Time:

Day: Date: End Time:

卌	卌	卌	卌	卌	卌				

APPENDIX B: PHOTOS

APPENDIX C: RAW DATA FOR HIGHWAY MODE OF TRANSPORTATION

LOCATION 1: I-25 MP 295

Serial	Time	Date	Day	Direction	Placard #	Class	Body Config	Cargo Type
1	7:35	03/15/18	Thursday	NB	1075	2	ST	5
2	7:35	03/15/18	Thursday	NB	1075	2	ST	8
3	8:10	03/15/18	Thursday	SB	1203	3	ST	8
4	8:30	03/15/18	Thursday	NB	1075	2	ST	5
5	8:35	03/15/18	Thursday	SB	3057	2	MT	6
6	8:55	03/15/18	Thursday	SB	1075	2	ST	8
7	9:02	03/15/18	Thursday	SB	1075	2	ST	6
8	9:35	03/15/18	Thursday	NB	un	2	MT	6
9	9:37	03/15/18	Thursday	NB	un	9	TT	6
10	9:55	03/15/18	Thursday	NB	1097	3	TT	2
11	10:03	03/15/18	Thursday	NB	3257	9	MT	6
12	10:41	03/15/18	Thursday	NB	3257	9	MT	6
13	10:46	03/15/18	Thursday	NB	un	9	TT	8
14	10:48	03/15/18	Thursday	NB	1993	3	MT	7
15	12:02	03/15/18	Thursday	SB	3375	5.1	MT	4
16	12:27	03/15/18	Thursday	SB	1993	3	TT	7
17	11:35	03/15/18	Thursday	SB	un	9	TT	8
18	13:50	03/15/18	Thursday	SB	2067	5.1	MT	7
19	13:55	03/15/18	Thursday	NB	1075	2	MT	7
20	15:12	03/15/18	Thursday	NB	3075	6.1	MT	6
21	15:16	03/15/18	Thursday	SB	un	4	MT	8
22	17:18	03/15/18	Thursday	NB	1863	3	TT	7
23	17:39	03/15/18	Thursday	SB	un	2	MT	8
24	7:39	03/16/18	Friday	NB	1203	3	TT	7
25	8:24	03/16/18	Friday	SB	1867	3	TT	7
26	9:55	03/16/18	Friday	NB	2067	5.1	MT	4
27	9:56	03/16/18	Friday	SB	1203	3	TT	7
28	15:30	03/16/18	Friday	SB	1203	3	MT	7

29	15:30	03/16/18	Friday	NB	un	9	TT	8
30	15:36	03/16/18	Friday	NB	un	Dangerous	MT	8
31	15:40	03/16/18	Friday	NB	1993	3	MT	8
32	15:57	03/16/18	Friday	SB	1942	5.1	MT	4
33	16:07	03/16/18	Friday	NB	3257	9	MT	6
34	16:26	03/16/18	Friday	NB	un	Dangerous	MT	8
35	16:44	03/16/18	Friday	SB	1203	3	MT	7
36	16:54	03/16/18	Friday	NB	3375	5.1	MT	4
37	7:40	03/17/18	Saturday	SB	un	3	TT	9
38	8:20	03/17/18	Saturday	NB	un	8	TT	8
39	9:45	03/17/18	Saturday	NB	un	2	TT	8
40	11:28	03/17/18	Saturday	NB	1993	3	MT	7
41	12:14	03/17/18	Saturday	SB	1760	8	TT	6
42	12:38	03/17/18	Saturday	NB	1993	3	TT	8
43	14:11	03/17/18	Saturday	SB	3082	9	MT	6
44	14:11	03/17/18	Saturday	SB	1993	3	TT	7
45	14:28	03/17/18	Saturday	SB	1052	8	TT	6
46	15:32	03/17/18	Saturday	SB	3257	9	MT	6

LOCATION 2: I-90 MP 60

Serial	Time	Date	Day	Direction	Placard #	Class	Body Config	Cargo Type
1	7:10	03/15/18	Thursday	WB	1203	3	MT	7
2	7:18	03/15/18	Thursday	WB	1263	3	MT	7
3	7:32	03/15/18	Thursday	WB	1863	3	MT	7
4	8:22	03/15/18	Thursday	WB	155	1	MT	6
5	8:31	03/15/18	Thursday	WB	155	1	TT	6
6	8:37	03/15/18	Thursday	EB	1075	2	TT	5
7	8:44	03/15/18	Thursday	EB	1203	3	TT	7
8	8:54	03/15/18	Thursday	EB	1977	2	ST	5
9	9:06	03/15/18	Thursday	EB	1075	2	MT	5
10	9:21	03/15/18	Thursday	EB	1203	3	MT	7
11	9:25	03/15/18	Thursday	WB	1203	3	TT	8
12	9:43	03/15/18	Thursday	EB	1977	2	TT	6
13	9:56	03/15/18	Thursday	EB	1203	3	TT	7
14	10:11	03/15/18	Thursday	WB	1075	2	ST	5
15	11:02	03/15/18	Thursday	WB	1863	3	MT	7
16	11:26	03/15/18	Thursday	WB	1863	3	TT	7
17	11:50	03/15/18	Thursday	WB	1993	3	ST	un
18	12:08	03/15/18	Thursday	WB	1203	3	ST	7
19	12:25	03/15/18	Thursday	EB	1993	3	TT	7
20	12:27	03/15/18	Thursday	EB	1075	2	ST	5
21	12:29	03/15/18	Thursday	WB	3077	9	TT	8
22	12:37	03/15/18	Thursday	EB	332	1	ST	un
23	12:54	03/15/18	Thursday	EB	1993	3	MT	7
24	12:59	03/15/18	Thursday	EB	332	1	MT	un
25	13:08	03/15/18	Thursday	WB	1063	2	TT	5
26	14:39	03/15/18	Thursday	WB	1075	2	MT	5
27	14:41	03/15/18	Thursday	EB	155	1	TT	8

28	14:42	03/15/18	Thursday	EB	1203	3	ST	7
29	14:53	03/15/18	Thursday	WB	1977	2	MT	6
30	15:05	03/15/18	Thursday	WB	1967	2	ST	8
31	15:05	03/15/18	Thursday	WB	1203	3	MT	7
32	15:22	03/15/18	Thursday	EB	8002	2	TT	6
33	15:32	03/15/18	Thursday	EB	1203	3	MT	7
34	15:34	03/15/18	Thursday	EB	1956	2	TT	8
35	16:48	03/15/18	Thursday	EB	1203	3	MT	7

LOCATION 4: I-90 WEST, MP 56

Serial	Time	Date	Day	Direction	Placard #	Class	Body Config	Cargo Type
1	15:25	03/12/18	Monday	EB	1203	3	MT	7
2	15:44	03/12/18	Monday	SB	1075	2	TT	5
3	16:35	03/12/18	Monday	EB	un	2	TT	un
4	16:40	03/12/18	Monday	SB	un	9	TT	8
5	17:48	03/12/18	Monday	SB	1075	2	MT	6
6	18:08	03/12/18	Monday	EB	1863	3	MT	7
7	18:17	03/12/18	Monday	SB	1993	3	MT	7
8	18:18	03/12/18	Monday	EB	1863	3	MT	7
9	18:33	03/12/18	Monday	EB	1993	3	MT	7
10	18:48	03/12/18	Monday	EB	1863	3	TT	7
11	11:10	03/13/18	Tuesday	EB	un	10	TT	5
12	11:38	03/13/18	Tuesday	EB	1075	2	MT	5
13	11:42	03/13/18	Tuesday	EB	1993	3	MT	7
14	12:43	03/13/18	Tuesday	SB	1993	3	MT	6
				SB	1307	3		
15	12:58	03/13/18	Tuesday	EB	un	1	TT	6
16	13:08	03/13/18	Tuesday	EB	1863	3	MT	7
17	13:16	03/13/18	Tuesday	SB	1977	2	TT	un
18	13:36	03/13/18	Tuesday	EB	1075	2	ST	5
19	14:00	03/13/18	Tuesday	EB	1863	3	TT	7
20	14:27	03/13/18	Tuesday	EB	1993	3	MT	7
21	14:32	03/13/18	Tuesday	EB	1075	2	ST	5

LOCATION 5: I-90 EAST, MP 56

Serial	Time	Date	Day	Direction	Placard #	Class	Body Config	Cargo Type
1	13:18	03/12/18	Monday	WB	1993	3	TT	7
2	13:57	03/12/18	Monday	WB	1863	3	TT	2
3	15:11	03/12/18	Monday	WB	1863	4	TT	7
4	8:22	03/13/18	Tuesday	WB	1863	3	TT	7
5	8:31	03/13/18	Tuesday	WB	1863	3	MT	7
6	8:52	03/13/18	Tuesday	WB	1155	3	TT	6
7	8:52	03/13/18	Tuesday	SB	1267	3	TT	2
8	9:06	03/13/18	Tuesday	WB	1993	3	MT	7
9	9:33	03/13/18	Tuesday	WB	1993	3	MT	7
10	9:51	03/13/18	Tuesday	WB	1075	2	TT	10
11	10:22	03/13/18	Tuesday	WB	1075	4	ST	5
12	10:49	03/13/18	Tuesday	WB	un	4	MT	8

LOCATION 6: I-25 MP 300

Serial	Time	Date	Day	Direction	Placard #	Class	Body Config	Cargo Type
1	8:37	03/12/18	Monday	WB	1202	3	ST	7
2	8:48	03/12/18	Monday	WB	1075	2	ST	5
3	8:57	03/12/18	Monday	WB	un	4	TT	9
4	9:13	03/12/18	Monday	WB	1203	3	TT	7
5	9:31	03/12/18	Monday	WB	1993	3	ST	7
6	15:38	03/13/18	Tuesday	EB	3082	9	TT	6
7	16:19	03/13/18	Tuesday	EB	1002	2	TT	8
8	16:21	03/13/18	Tuesday	EB	1075	2	TT	8
9	17:16	03/13/18	Tuesday	EB	1971	2	TT	2
10	17:49	03/13/18	Tuesday	EB	1992	3	TT	8
11	18:03	03/13/18	Tuesday	EB	3375	5.1	MT	un