Original Research Paper

Longitudinal Analyses on Crash Rates of Shale Areas in Texas

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Abstract

The "Fracking Boom", which stimulates Shale Oil & Gas production, in recent years has increased Texas`s roads traffic and hence intensified the risks of crashes for road users` daily operation across corridors that transport liquid bulk products as well as supplies and service materials. In order to prevent or mitigate the risks of the crashes, transportation researchers have to conduct the crash risk analysis to identify hot-spots of the crashes, route their fleet to avoid high-risk locations, and prepare a response plan when accidents happen.

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While the general public holds the impression that higher traffic volumes along Shale Oil & Gas routes lead to higher crash risks, there has not been any research to quantitatively assess the impacts. In this paper, the research focuses on five major areas of Oil & Gas production in Texas, including the Permian Basin, Granite Wash Formation, Barnett Shale, Haynesville/Bossier Shale and the Eagle Ford Shale. In this research, a Geographical Information System (GIS) platform was utilized to collect and analyze roads and vehicle data, and spot the frequency and location of the car crashes. The entire original crash numbers and crash rate data have been input into GIS to generate the maps by six classes ranging from the lowest to the highest.

The data gathered in this research is from roadway crash databases of the U.S. Department of Transportation (DOT) and Texas Department of Transportation. The data includes a total crash number for each county in Texas from 2003 to 2015, and related vehicle miles traveled (VMT) during 2003-2014. In this study, crash rates of each county in Texas were calculated during 2003-2014. Particularly, the crash rates of counties located in the five primary shale plays were analyzed. The results indicate that the overall crash rates display an increasing trend in associated with the increased shale activities. However, crash rates in different shale plays do not all display increasing trends. Those findings provide crucial information for fleet safety and risk management to supply chain operators in Texas Oil and Gas industry. The results also facilitate road users in shale counties to plan for transport routes for accident risk prevention and necessary incident management development, which means they can have target areas to invest the resources.

Keywords:

Crash Number, Crash Rate, Shale Plays, GIS

1 Introduction

1.1 Project background

Texas has played a pivotal role in the U.S. transportation system to support critical industries in the national economy, especially the petroleum, petrochemical, construction, and energy industries. Texas has 313,228 miles by 2013, with more miles of public roads than any other state. The Port of Houston and the Port of Corpus Christi are ranked the second and eighth in the U.S., respectively, and are the two gateways for the world trade to the America, especially the Midwestern states. Texas is also a transit passage for The North American Free Trade Agreement (NAFTA). In 2012 and 2013, Texas was the first state to trade with Mexico. It was the third in trading with Canada.

Texas is known for the strong presence and high density of corporations in the petroleum, petrochemical, natural gas, and energy industries. According to EagleFordShale.com, a business portal of the Eagle Ford Shale companies, the Eagle Ford Shale boundaries include 30 counties in Texas. The recent “fracking boom” has significantly increased the domestic oil and gas production in Texas. This “boom” has drastically mobilized a variety of exploration, production, and transportation activities in the oil and gas supply chain. Unfortunately, one of the impacts of this boom has been an increase in truck traffic and crashes involving commercial vehicles, which hinders economic growth and the benefits from the “fracking boom”.

Regarding traffic risks in the Shale areas, two important factors should be considered. First, Shale Plays are located in mostly remote areas where road transportation infrastructure is not well established. Secondly, shale play products are dangerous by nature. These two factors have increased the probability and severity of the car crashes. Crashes involving large trucks are always a problem for road users that depend heavily on roadway transportation. In Texas, transportation accidents always delay freight transportation, especially for large truck crashes.

Texas has seen more large truck crashes than any other states from 1996 to 2012. According to the Bureau of Transportation Statistics, in 2013, up to 60.8% of NAFTA trucks have done transportation. Currently, more and more large trucks, e.g. single-unit and combination trucks are on the road. Consequently, more trucks are involved in fatal or severe injuries. One possible

reason is the growth of domestic oil & natural gas exploration and production activities, which generate a high demand for truck traffic in Texas.

General public holds a perception that the Shale fracking boom caused the growing trends of car accidents, especially truck crashes, in Texas. Given the substantial geographical coverage of Shale plays in the state of Texas, there is a crucial need to pinpoint the high-risk areas of crashes in Texas Shale areas. Therefore, the present research conducts a scientific analysis on the crash trends among Shales counties and proposes solutions to improve safety.

1.2 Objectives of the work

Data on traffic safety of the freight system is essential for the efficiency and safety of the transportation system. This research gathers safety data from sources of state and federal DOTs and identifies high-risk spots associated with large truck crashes in Shale areas of Texas according to the statistics and geospatial findings. The research also recommends risk prevention and mitigation strategy for large truck crashes on Texas road networks.

This research conducts a longitudinal study on car crashes in Texas, especially for large truck crash data. The research presents a first systematic method to study the crash trends in Shale areas, especially about large trucks. The technical objectives associated with the problem are:

1) To identify the hotspots for the crashes and

2) To verify the links between fracking boom and car crashes.

2 Materials and methods

2.1 Literature review

The purpose of the crash rate research is to identify the hotspot locations of road accidents and safety deficiency. Spatial analysis is one of the most important factors in crash rate research while several analysis methods have been proposed in the past. Valverde et al. (2006) conducted a spatial analysis of fatal and injury crashes in Pennsylvania for 1996-2000. The analysis indicated that a full Bayesian model with spatial correlation is more advanced over the traditional negative binomial estimates. Their county-level spatial model provided a method to quantify the

crash rate and mechanism. Deublein et al. (2013) also performed a Bayesian hierarchical approach to analyze and successfully predict road accidents in Austrian rural motorway networks.

Geographical Information Systems (GIS) has become a popular tool to visualize the distribution and trend of road accidents in the recent decades. GIS had evolved by the late 1980s into a widely adopted software application. Liang et al. (2005) described GIS as computerized systems, which comprise a digital map background and layers of additional information, which can be viewed in any desired combination and at any scale. According to Foote and Lynch (2014), GIS can be used as an integrating technology. It is possible to map, model, query and analyze large quantities of data all held together within a single database. Erdogan (2008) performed a GIS aided traffic accident analysis for the city of Afyonkarahisar in Turkey. They used the GIS not only as a visualization tool, but also as a management system for accident analysis and determination of hot spots with statistical analysis methods, such as Kernel Density Analysis (Silverman, B.W., 1986). Liang et al (2005) developed a GIS-based viewing system to facilitate the analysis of road accidents. The users of this system can easily retrieve accident information through the node analysis or the distribution plot, perform the statistical analysis, and thus identify the accident hot spot.

Several studies have been performed to identify the geographic patterns of road accidents. Many area-wide characteristics have been investigated, such as intersection destiny, different speed limits, different functional classifications, junctions, traffic volume and speed, trip generation and distribution, weather conditions, land use, population density, population ages, household income, employment rate, etc. For example, Affum and Taylor (1997) developed a Safety Evaluation Method for Local Area Traffic Management, which is a GIS-based program for analyzing accident patterns over time and for the evaluation of the safety benefits of Land Area Traffic Management schemes.

Xu and Huang (2015) analyzed the crash data pattern in different zones from the county of Hillsborough, Florida. The result suggested that daily VMT (DVMT) reveals an obvious pattern of spatial non-stationarity, and indicates that the increase of DVMT always increases the crash frequency. Based on the EPA document, “Volume IV: Chapter 2, Use of Locality- Specific

Transportation Data for the Development of Mobile Source Emission Inventories," (September 1996) Section 3, "Developing Locality-Specific Inputs from Travel Demand Models," VMT can be estimated by vehicle type with equations: VMT for Single Unit Combined Vehicles (SUCVs), Combinations, and 4-Tire Vehicle Types.

2.2 Data sources

The researcher collected more than 10 years database of crash numbers, and daily Vehicle Miles Traveled (DVMT) in 254 counties in TX. The following sections detail the data sources and the data processing steps.

Total crash numbers: The total crash number from 2003 to 2015 is from the Texas Department of Transportation (TxDOT). The basic data is from the Crash Records Information System (CRIS). We choose the item named "Rpt_CRIS_Cnty_ID", which means the county name in which the crash was located. Then the researcher collected the crash numbers in each county of Texas by years using the Pivot Table in Excel.

Crash numbers of large trucks: A historical snap shot of September 25th, 2015 in Motor Carrier Management Information System (MCMIS) provides history report of all reported fatal and non-fatal crashes involving large truck in the period of 2011-2014, which serves as the basis of crash number data in this research.

Vehicle Miles Traveled: The data of daily vehicle miles traveled (DVMT) from 2003 to 2014 is obtained from TxDOT One-Stop online (Demographic Data Analysis Tool). Total DVMT was used as the basic data. According to the introduction of TxDOT, "Total DVMT number means sum of on-system and off-system miles. On-system is a roadway owned by TxDOT. Off-system is everything else (city streets, county roads, etc.)" The data is filtered at the county level with both on the system and off system miles included for the same period mentioned above.

Shales: Based on the outcomes of on-line search and sources from the TxDOT, the researchers identify all the counties of Shales in Texas, including the Permian Basin, Granite Wash Formation, Barnett Shale, Haynesville/Bossier Shale and the Eagle Ford Shale. Table 1 shows the counties associated with respective Shales in Texas.

Table 1 All Shales and their covered counties

Shales	Counties
Barnett	Clay, Cooke, Dallas, Denton, Ellis, Erath, Hood, Jack, Johnson, Montague, Palo Pinto, Somervell, Tarrant and Wise
Eagle Ford	Atascosa, Austin, Bastrop, Bee, Brazos, Burleson, Colorado, DeWitt, Dimmit, Duval, Fayette, Frio, Goliad, Gonzales, Grimes, Karnes, La Salle, Lavaca, Lee, Leon, Live Oak, Madison, Maverick, McMullen, Milam, Robertson, Washington, Webb, Wilson, Zavala
Permian Basin	Andrews, Borden, Cochran, Coke, Crane, Crosby, Dawson, Dickens, Ector, Gaines, Garza, Glasscock, Hale, Hockley, Howard, Irion, Jeff Davis, Kent, Kimble, Lamb, Loving, Lubbock, Lynn, Martin, Midland, Mitchell, Nolan, Pecos, Reagan, Reeves, Scurry, Sterling, Terry, Tom Green, Upton, Ward, Winkler, Yoakum
Granite Wash Formation	Hemphill, Roberts, Wheeler, Gray
Haynesville (Bossier)	Angelina, Gregg, Marion, Nacogdoches, Rusk, Sabine, Harrison, Panola, Shelby, San Augustine

Maps of all Shales: All Shales (the Permian Basin, Granite Wash Formation, Barnett Shale, Haynesville/Bossier Shale and the Eagle Ford Shale) are outlined on the map to visualize the covered counties, which is shown in Fig. 1.

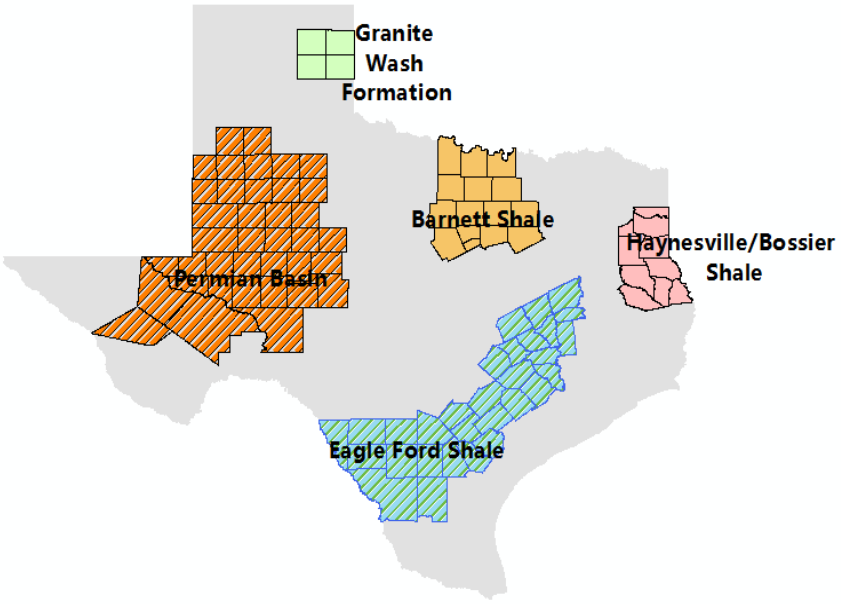


Fig. 1 Maps of all Shales

2.3 Methodology for crash data analysis

The methodology for data analysis is longitudinal studies. The techniques the researchers applied are data collection, data processing, variable operationalization, and visualization of outcomes. The variables in the present research include: total crash numbers of each county in Texas, large truck crash numbers of each county in Texas, DVMT, and crash rates of each county in Texas and all the Shales in Texas.

This project designed an equation for crash rate calculation according to the literature review. Specifically, crash rate is obtained by dividing the crash number by the VMT. It reflects the possibility of a crash per VMT in the specific county during 2003-2014 periods.

The foundation of this research is the following:

$$\text{crash rate} = \text{crash number/VMT (number/mile)} \quad (1)$$

The formula mentioned above is applied to calculate crash rate per U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA, 2011) study.

Crash rate raw data is then fed into the ArcGIS system and plotted on a county map of Texas. Six color categories were used to visualize different rate ranges. In addition to graphical inspections,

a total of the crash rate from each area was calculated and plotted against time to visualize the annual trend for the purpose of analysis.

All the crash numbers and crash rate data have been entered into the Geographical Information System (GIS) to generate the maps by six classes ranging from the lowest to the highest.

3 Results and discussion

3.1 Crash Trends in Shale Counties in Texas

As shown in Fig. 2, we can see that both the total crash numbers and crash rates in TX increased steadily year by year since the year 2011, even though there has been a downward trend from the year 2003 to 2011.

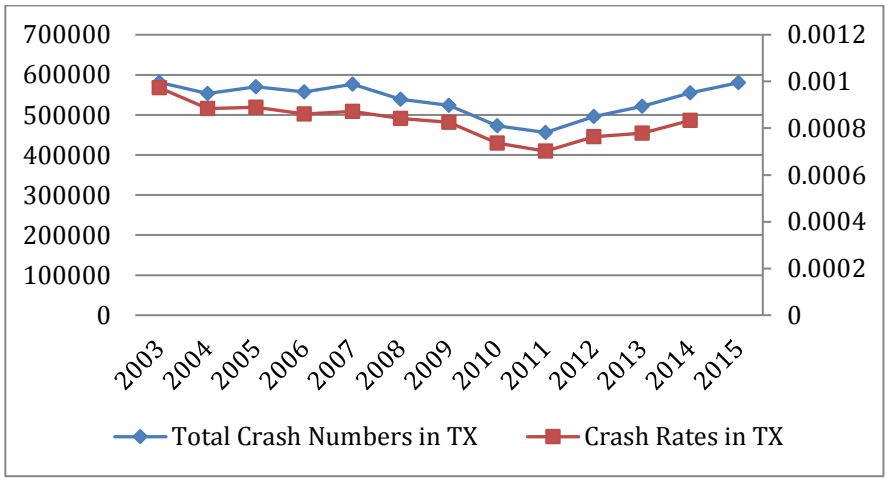


Fig. 2 Total crash numbers and crash rates in Texas

All Shales cover 97 counties in Texas. According to Fig. 3 below, the crash rates of all Shales in TX start to increase from the year 2013. Before the year 2013, the trends of the Shales are different. The crash rates of Permian Basin, Bossier and Eagle ford decreased a little on the whole despite fluctuations in the middle. However, the crash rates of Barnett Shales increased since the year 2011 and the crash rate of Granite Wash Formation has no obvious trend.

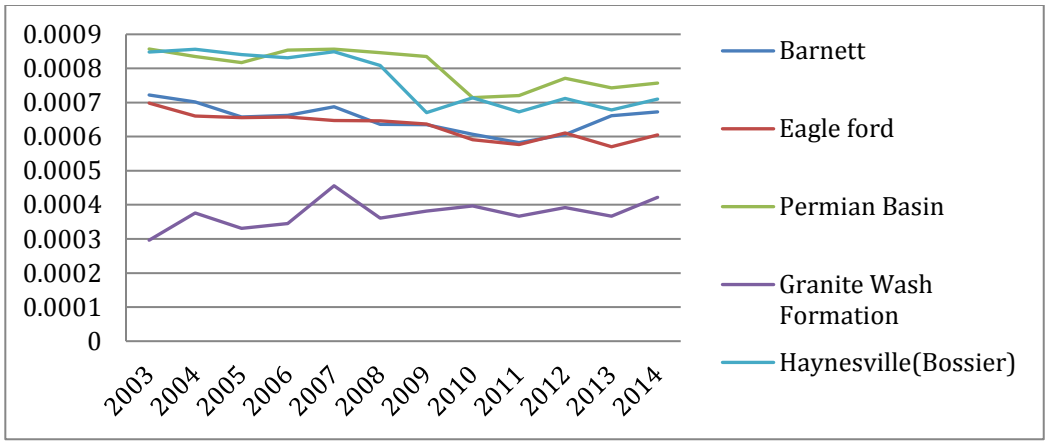
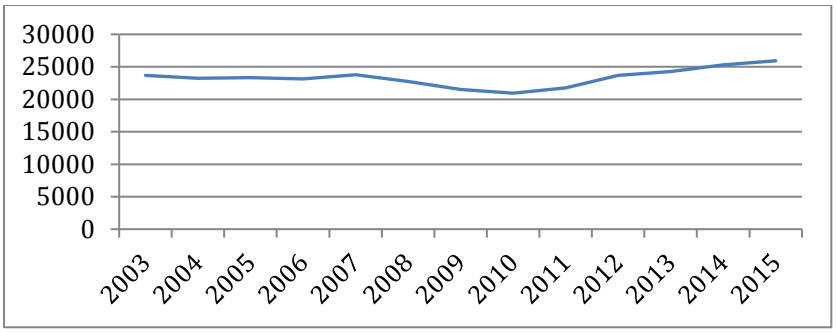


Fig. 3 Total crash rates in Shales

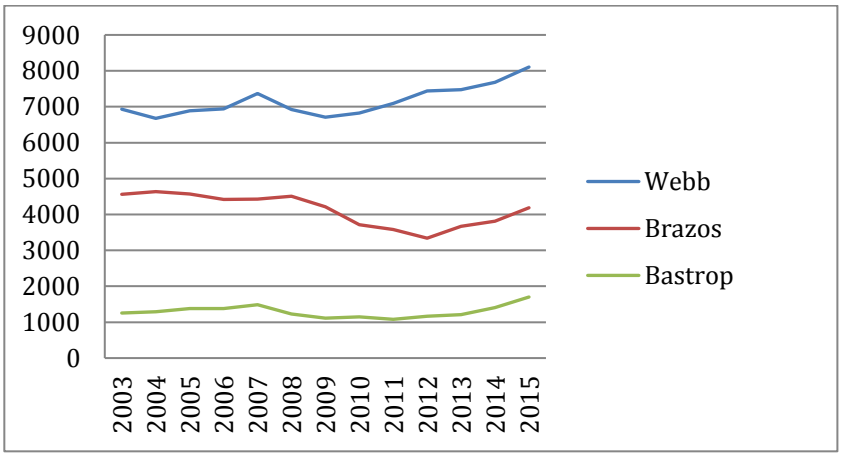
3.2 Eagle Ford Shale

The Eagle Ford Shale is a hydrocarbon producing formation. However, it is capable of producing more gas and oil than other traditional shale plays. The high percentage of carbonate makes it more brittle and "fracable". The shale play ranges across Texas from the Mexican border up into East Texas, roughly 50 miles wide and 400 miles long with an average thickness of 250 feet. It covers 30 counties, but most extraction activities focus on the southwest border of Texas.

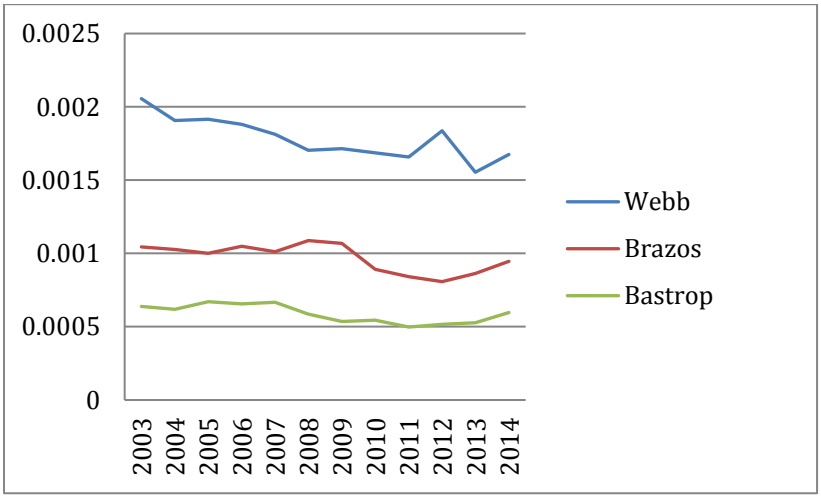
In the Fig. 4 below, the trend of crash numbers of all Eagle Ford Shale counties has been raising since the year 2010. According to the overall crash numbers from 2009 to 2015, we got the top three counties of Eagle ford Shale: Webb, Brazos, and Bastrop. Total crash numbers of Eagle Ford Top3 counties kept increasing from the year 2010. The trends of crash rates of Eagle Ford Top3 counties are kind of different: Webb kept decreasing during the year 2003 to 2011, and the changes are sharp during the year 2012 to 2014; Brazos and Bastrop are kind of same that the trends are raising from 2012 and 2011 separately.



(a) **Total crash numbers of Eagle Ford Shale**



(b) **Total crash numbers of Eagle Ford top3 counties**



(c) **Crash rates of Eagle Ford top3 counties**

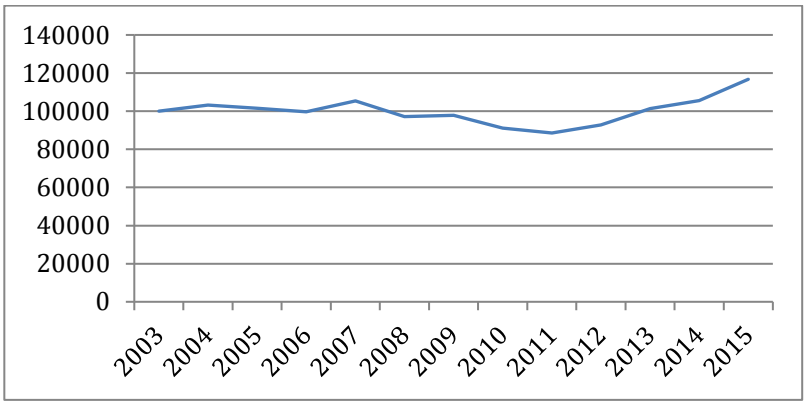
Fig. 4 Total crash numbers and crash rates in Eagle Ford shale

3.3 Barnett Shale

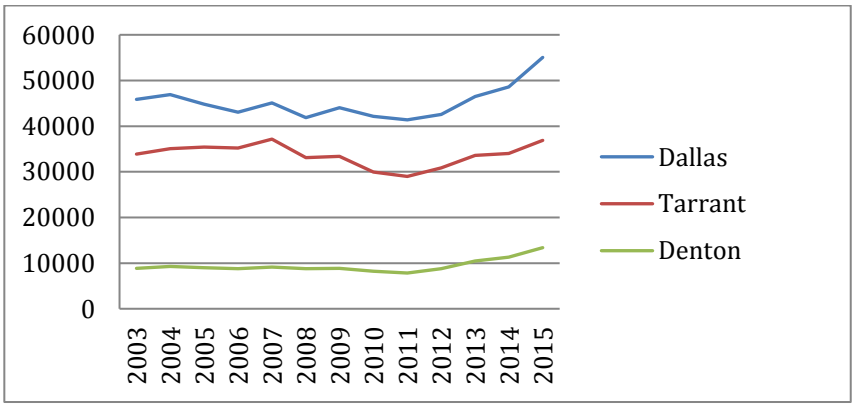
Barnett Shale is located at the border of Texas and Oklahoma, and it is one of the earliest exploratory shale areas in Texas. According to the Railroad Commission of Texas, the Barnett

Shale is also a hydrocarbon-producing geological formation of great economic significance to Texas. Barnett Shale is the largest active onshore natural gas field in Texas as well as one of the largest in the United States, with known reserves of more than 2 trillion cubic feet (TCF) of natural gas and an estimated 30 trillion cubic feet of natural gas resources. The counties where the shale resides include 15 counties. The core counties include Denton, Johnson, Tarrant, and Wise.

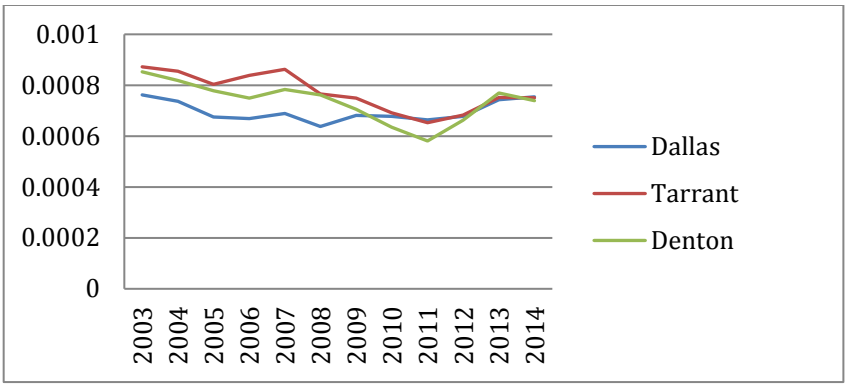
A historical crash number and crash rate report are shown in Fig. 5 below, and the trend of crash rate of Barnett shale is also raising from the year 2011. Based on the overall crash numbers from 2009 to 2015, the top three counties of Barnett Shale were selected: Dallas, Tarrant and Denton. From the year 2011, both the crash numbers and crash rates of Barnett Shale Top3 counties increased. The crash number of Dallas is the largest and has increased sharpest. The crash rate of Denton increased sharpest.



(a) **Total crash numbers of Barnett Shale**



(b) **Total crash number trend of Barnett top3 counties**



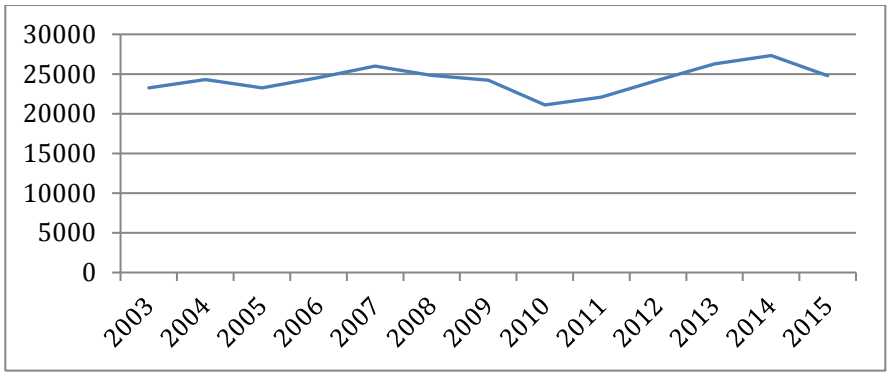
(c) **Crash rates of Barnett top3 counties**

Fig. 5 Total crash numbers and crash rates in Barnett Shale

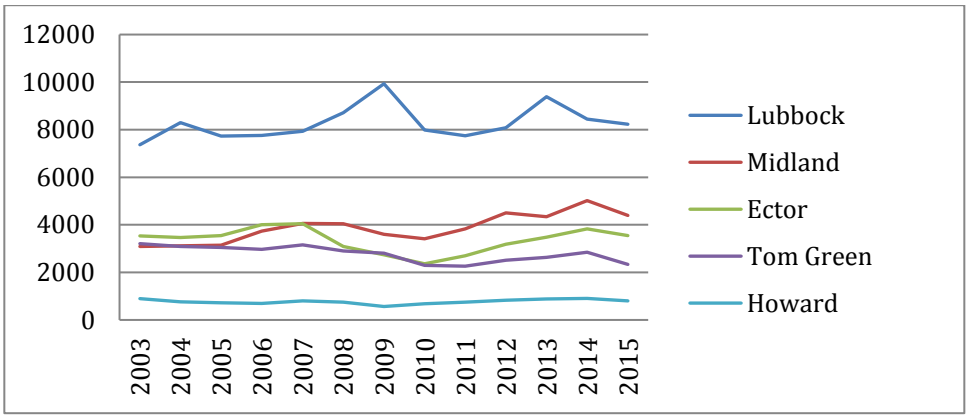
3.4 Permian Basin

The scope of Permian Basin is the 38 counties in the western part of the U.S. state of Texas. Permian Basin has a large oil and natural gas producing area, part of the Mid-Continent Oil Producing Area. Counties such as Upton, Midland, Ector, Tom Green, Howard, and Hale are all part of Permian Basin. Permian Basin remains a significant oil-producing area, producing more than 270 million barrels of oil in 2010 and more than 280 million barrels in 2011. A recent increase in the use of enhanced-recovery practices in the Permian Basin has made a substantial impact on U.S. oil production.

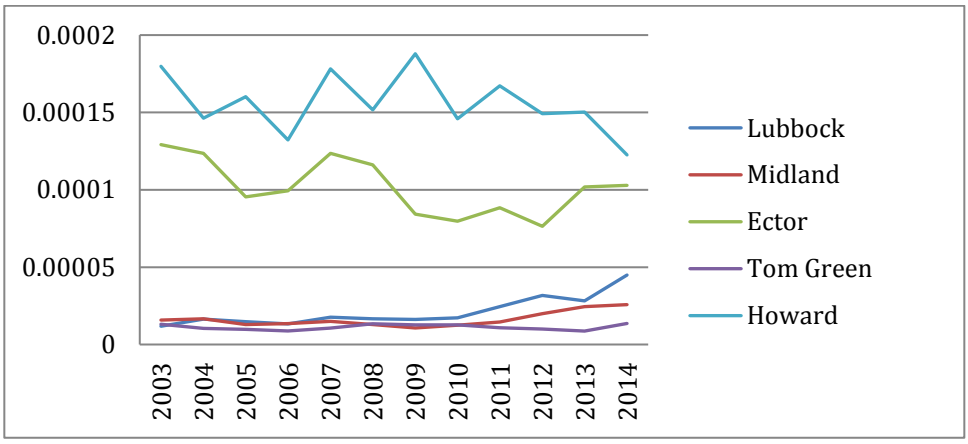
Based on Fig. 6 below, we can see that the total crash numbers in Permian Basin increased steadily since the year 2010 and dropped a little in the year 2015. Based on the overall crash numbers from 2009 to 2015, the top five counties of Permian Basin were chosen: Lubbock, Midland, Ector, Tom and Howard. The crash rates of Permian Basin Top5 counties have no regular changes except Midland, which has a lower rate but increased since the year 2010. Concerning the total crash numbers of the top 5 counties, the trends are not clear.



(a) **Total crash numbers of Permian Basin**



(b) **Total crash numbers of Permian Basin top5 counties**



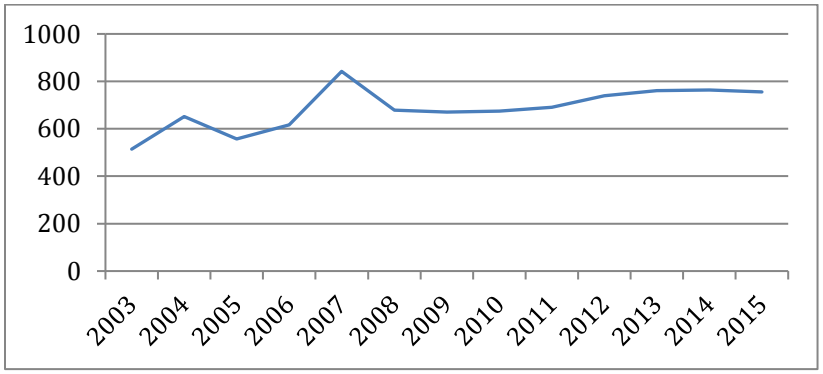
(c) **Crash rates of Permian Basin top5 counties**

Fig. 6 Total crash numbers and crash rates in Permian Basin Shale

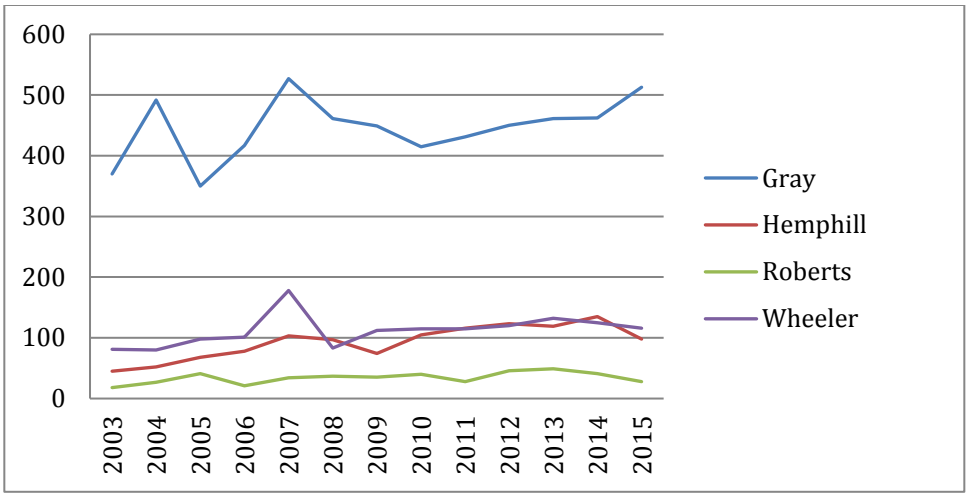
3.5 Granite Wash Formation

The Granite Wash (GW) runs northwest to southeast across the Texas Panhandle into Oklahoma. The scope of Granite Wash (GW) Formation in this project is only 4 counties in Texas. This unusual tight-gas sandstone formation is geographically large. It is a significant field for both oil and gas production and, has been a beneficiary of horizontal drilling methods developed for shale plays. Parts of its deposits are conventional, producing significant amounts of gas and liquids with little technological intervention. Well completions in the Granite Wash have steadily increased since the early 1970s. The current activity is focused on the Stiles Ranch field where several horizontal wells have recently been gauged at more than 20 million cubic feet per day.

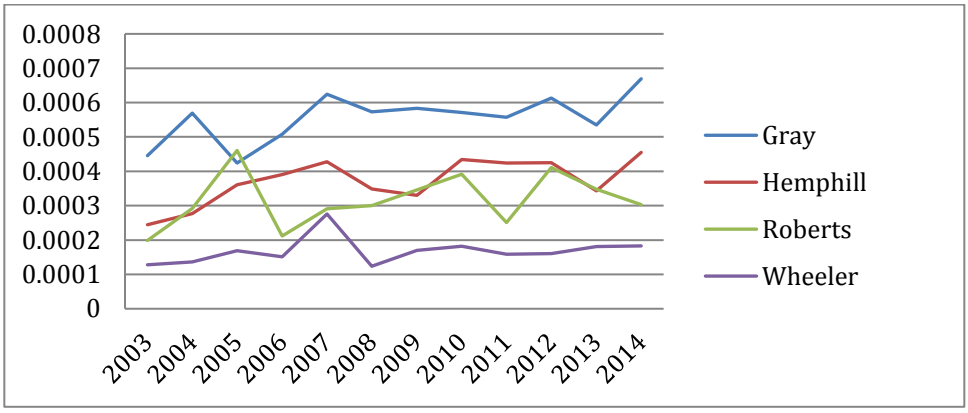
According to Fig. 7 below, we can see that the total crash numbers of Granite Wash Formation increased since 2008 even though the growth size is small. The changes of crash rates are chaotic. However, the total crash numbers of Gray increased steadily since the year 2010. All in all, there are only 4 counties total and the total crash numbers are less than other counties of other Shales in Granite Wash Formation.



(a) **Total crash numbers of Granite Wash Formation**



(b) **Total crash numbers of Granite Wash Formation 4 counties**



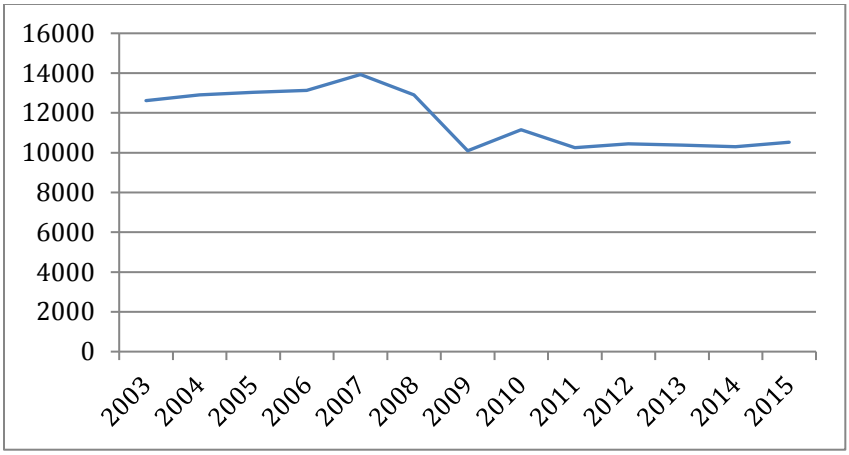
(c) **Crash rates of Granite Wash Formation 4 counties**

Fig. 7 Total crash numbers and crash rates in Granite Wash Formation

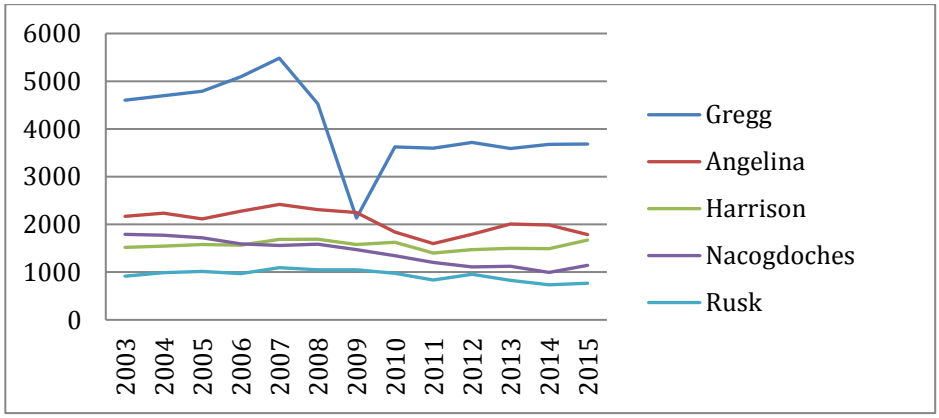
3.6 Haynesville/Bossier Shale

The Haynesville/Bossier Shale is a hydrocarbon producing geological formation that can deliver large amounts of gas. It is located in East Texas and Western Louisiana. The core counties appear to be Panola, Harrison and Shelby. Also in this project the scope of Haynesville/Bossier Shale is the 10 counties in TX. Much like the Barnett Shale, the Haynesville/Bossier Shale is part of a stratigraphic section that operators drilled through to reach the conventionally productive formations.

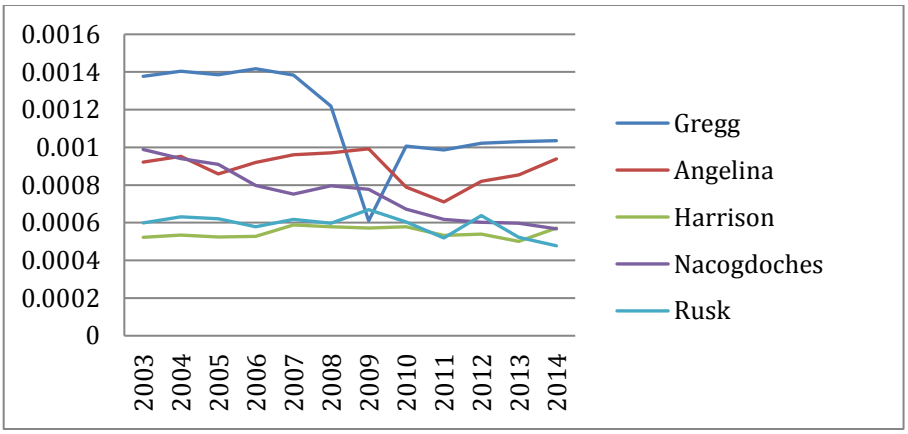
As is shown in Fig. 8 below, total crash numbers of Haynesville/Bossier Shale dropped down in the year 2007 and kept the same level since the year 2011. Based on the overall crash numbers from 2009 to 2015, the top five counties of Haynesville/Bossier Shale were got: Gregg, Angelina, Harrison, Nacogdoches and Rusk. Both the total crash numbers and crash rates of Top5 counties in Haynesville/Bossier Shale have no obvious increasing trends except Angelina, the crash rate of which increased since 2011.



(a) **Total crash numbers of Haynesville (Bossier)**



(b) **Total crash numbers of Bossier top5 counties**



(c) **Crash rates of Bossier top5 counties**

Fig. 8 Total crash numbers and crash rates in Haynesville/Bossier Shale

3.7 Total crash numbers and crash rates in Non-Shales

Non-Shales cover 157 counties in Texas. Based on the data showed in Fig. 9 below, the researcher can conclude that both the total crash numbers and crash rates in TX increased steadily year by year since the year 2011, even though there has been a downward trend from the year 2003 to 2011. The trends of the total crash numbers and crash rates in Non-Shales are almost the same as that in Texas.

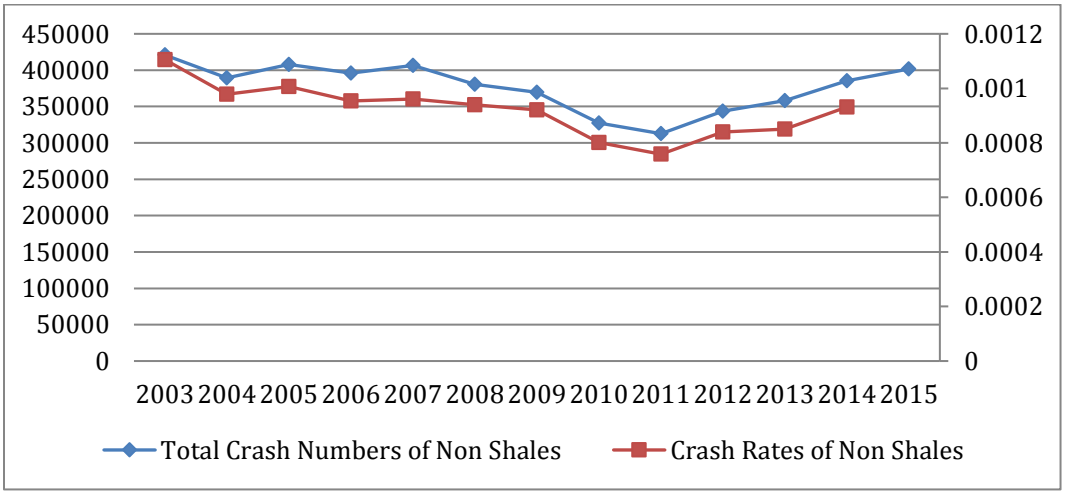


Fig. 9 Total crash numbers and crash rates of Non-Shales

3.8 Crash numbers of large trucks

The spatial distributions of crash numbers and crash rates are different. Fig. 10 below shows the crash numbers by county in Texas from 2011 to 2013 (similar distributions were obtained for other years). It is clear that the highest values are clustered around the Shales, such as Barnett Shale and Eagle Ford Shale. It is obvious to identify which county or area is with the higher crash number. In 2011, Harris and Dallas were with the highest values and hence marked by red color. The crashes were more clustered in eastern and southern Texas in 2013.

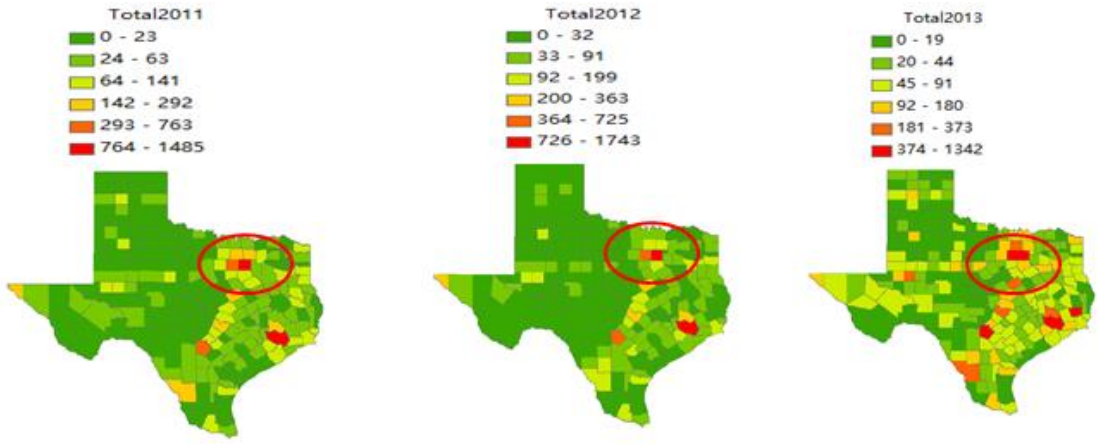
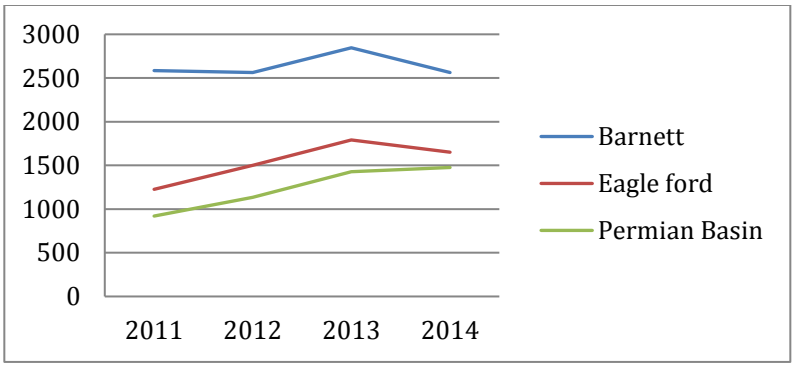


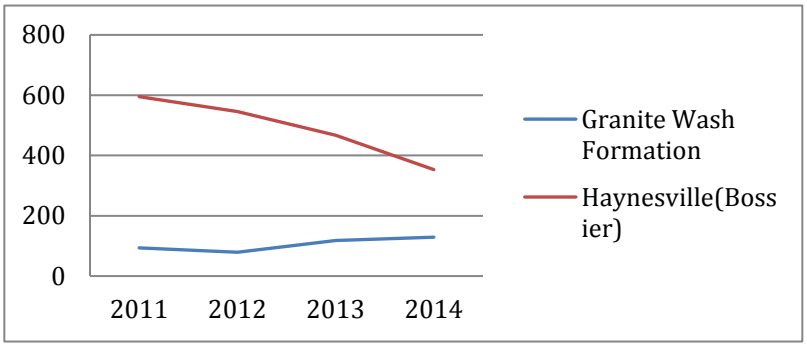
Fig. 10 Spatial distributions of crash numbers of large trucks by county (2011 – 2013)

By utilizing ArcGIS, the crash rate results are visualized on the Texas map the same as the total crash number. Crash rate data were also categorized into six classes. From the map of 2011, it is clear that the crash rate in Northern, Western and Southern Texas was higher than the rates in Eastern Texas. Likewise, in 2012 and 2013, the higher concentrations of crash rates are within the areas, except Eastern Texas.

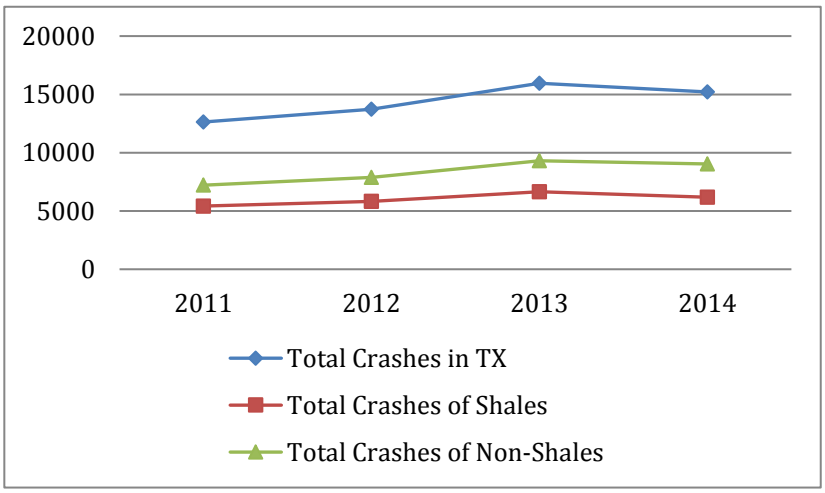
Fig. 11 below summarizes the statistics of total crash numbers in Texas during four years. It is obvious to conclude that in 254 counties, there is an increasing trend of total crash numbers from 2011 to 2014. About the crash rates of large trucks in Shales, almost all Shales increased since the year 2011 except Granite Wash Formation.



(a) **Large truck crash numbers of Barnett shale, Eagle Ford shale and Permian Basin**



(b) **Large truck crash numbers of Granite Wash Formation and Haynesville (Bossier)**



(c) **Total crash numbers of large trucks**

Fig. 11 Total crash numbers of large trucks in Texas (2011 – 2013)

3.9 Discussion on Shale crash number and crash rate trends

The results in previous sections on crash counts in Shales areas of Texas provide interesting information. In terms of the total crash number, not all the Shales displayed strict increasing trends. The exception is the Eagle Ford Shale. The crash number trend of Eagle Ford Top 3 Counties, namely Webb, Brazos, Bastrop kept increasing from the year 2010.

In contrast, the results on crash rates of the Shales displayed trends more reflective to the perception of the general public. While the trends of crash rates in Shales generally have decreased since 2003, the crash rates of all the Shales have increased since 2013. In particular, the crash rate of Barnett Shale rose from the year 2011.

It should be noted that the impacts of Shales on crash rates are even larger in the shale area with more counties. Eagle Ford has average 64.55% more crashes, which is on the top of the list. Barnett, which is on the bottom, has an average of 22.63% more crashes. This trend has probably resulted from more traffic activities around wider coverage of wellheads.

For the total crash numbers in Texas, the crashes increased steadily year by year since the year 2011. Furthermore, crash Numbers and Crash Rate in Texas (both Shales and Non-Shales Areas) increased from the year 2011.

The crash rate analyzes render useful findings associated with the high-risk spots of car crashes in counties within Shales. Shales counties include major metropolitans, like Houston and Dallas, which are considered high-risk areas of on-road accidents. In order to combat the problem, there needs to be close coordination and collaboration, using a holistic and integrated approach, across many sectors and many disciplines. Specific measures may be implemented, such as Drivers' safety education, speed limitations, road Infrastructure constructions, and traffic laws and police surveillance.

Interestingly, not all Shale areas, or Shale counties displayed uniform, increasing trends of car crashes. There perhaps is a force behind the annual trend that counter the crash rates of counties with Shales away from steadily increasing. One possible cause might be the wellhead price for the natural gas. According to Energy Information Administration (EIA), in 2012 there was

a drop-in price in US natural gas market. This factor may tentatively lower the natural gas production and reduce the related traffic.

4 Conclusions

4.1 Concluding remarks

With increasing traffic induced by the development of the “fracking boom”, the number of crashes in commercial vehicles increased dramatically, especially for large trucks. Inevitably, higher traffic tends to result in more risks, causing more fatalities, injuries, property damages, and impacted the logistics conditions. As truck transportation is important for public safety, freight transportation, traffic safety, and the overall economic growth, the recent trends of truck-related accidents in Shale areas in Texas is alarming for the safety of general public. As such, it is necessary to conduct studies on accident trends in Texas Shales. The present research focuses on two aspects of accidents: 1) Annual crash numbers, and 2) Annual crash rates. The data gathered in this project is from the U.S. Department of Transportation and Texas Department of Transportation.

The important contribution of this research project is to identify the high-risk counties in Shales: Denton, Dallas, and Tarrant of Barnett; Webb, Brazos, Bastrop of Eagle Ford; Gray of Granite Wash Formation. Through identifying the high-risk counties in Shales, The results will facilitate the transportation operators and traffic safety regulators in the oil and gas industry to make decisions to reduce crashes in high-risk counties, which means they can have target areas to invest the resources.

4.2 Future research directions

While the results presented in this report are preliminary findings, future research can conduct analytical techniques to statistically test the extent of impacts of Shales activities on traffic safety. Design analytical models to find the relationship between the increased crashes and the development of Shales and confirm the reasons for crashes. Identify the specific areas of the most frequent crashes counties, which mean the researcher can further narrow the scope to

know the specific roads of higher crashes. And Develop recommendations to avoid large truck crashes.

Other possible causes, such as population density, an increase in the number of registered vehicles, VMT in relation to petroleum price, etc., are not analyzed in this study and will be studied through further research. Lastly, future research may consider categorizing risk types and factors associated with large truck crashes (according to the statistics and geospatial findings). A causation study can help develop specific recommendations on risk prevention and mitigation strategy for to enhance traffic safety in Shales areas and the entire Texas road networks.

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