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Analysis of Disruptions in the Gulf of Mexico Oil and Gas Industry Supply Chain and Related Economic Impacts

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ANALYSIS OF DISRUPTIONS IN THE GULF OF MEXICO OIL AND GAS INDUSTRY SUPPLY CHAIN AND RELATED ECONOMIC IMPACTS

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To my devoted parents for their endless love and support

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NOMENCLATURE

I-O	Input-Output
LOOP	Louisiana Offshore Port
GoM	Gulf of Mexico
GDP	Gross Domestic Product
BOP	Blowout Preventer
DWH	Deep Water Horizon
FPSO	Floating Production, Storage and Offloading
LP	Linear Programming
VAR	Vector Autoregressive
IRF	Impulse Response Function
LOOP	Louisiana Offshore Port
GDP	Gross Domestic Product
CI	Confidence Interval
MA	Moving Average
SC	Supply Chain

ABSTRACT

Catastrophic events are human and economic tragedies in collaboration. Oil spills have enormous impacts on the local economy of the area and for the local labor markets. The Deepwater Horizon oil spill was caused by an explosion on semisubmersible drilling rig (Macondo) on April 20, 2010. Another regional disaster, Hurricane Katrina as it ripped over the core of the Gulf of Mexico producing zone, one of the most important oil and gas production region. With Geological complexities, continued of drilling and production in GoM increases the risk of having leak/spill. Therefore, the Econometrics methods, and Modeling to forecast impacts of potential disasters are utilized and conduct optimization modeling to capture key components for building reasonable supply chain models of actual situations for petroleum industry in order to make the best possible choices consequences of disaster in this dissertation,. The dynamic response of a different of industrial sectors in Louisiana to oil and gas disasters is considered. The likely magnitude of the net economic impact of a major oil spill (Macondo) will be determined in terms of jobs and wages with Vector Autoregressive method. Forecast the potential impacts of future changes in employment after disaster on economy will be studied.

In the second part, the offsetting economic injection due to BP expenditures in the economy, will estimate by economic impact analysis method, which is Input-output models. Then the gross economic damage, which is created by BP oil spill will be calculated. The final results provide beneficial knowledge on determining the potential economic impact of future large-scale catastrophes and helpful for companies to react better to the economic impact of events. At the end, a mathematical framework will be presented for optimal network design of oil and gas supply chain with application for Louisiana Offshore Oil Port (LOOP); due to determine the optimal oil flow through the mid-stream/ downstream networks and its profit even if it is experiencing natural/ man-made damages. The outcome of this work is a new distributed decision support framework which is intended to help optimize the profit for critical energy zone and to boost economy under unpredictable situations.

CHAPTER 1: INTRODUCTION

1.1 General Introduction

The Gulf of Mexico establishes as one of the United States' largest sources of oil and gas production. The Gulf of Mexico district is one of the most critical zones for energy sources for the country. The damages which created by hurricanes and oil spills can cause huge losses for oil and gas industry and economic of area. The probability of a large oil spill occurring may be low but the environmental and economic consequences of such accidents are tremendous. Understanding, managing, and reducing disaster risks can provide a foundation for building resilience towards disaster (National academy press, 2001).

The importance of decreasing the severity and seriousness of oil spill event consequences, providing the best decisions to recover the situation, estimating the suitable amount of help needed for the event, measuring society potential and responsibility in front of the disaster are dependent on the amount of economic damage to the area. Also, economic impacts of disasters depend on the structure of economy, its geospatial location, and in what manner the economy is damaged. To choose a suitable strategy for reducing economic losses from natural catastrophes or man-made disasters, we should know the measurement of resilience in regional economies. The Gulf of Mexico region is one of the most critical areas for energy sources and other related organization. It also serves as an economic leader for the country. The Gulf of Mexico is bounded by five U.S. states to the north and east; Texas, Louisiana, Mississippi, Alabama and Florida. The Gulf of Mexico has a complex geology. It is a combination of water depths of up 10000 ft. and ultra- Deepwater. Therefore, drilling in this area can be very difficult issue and potentially hazardous. There are over 7000 active platforms drilling in the Gulf of Mexico. Many occur in shallow waters (<500 ft. water depth) due to their ease of accessibility (NETL 2012). For each active platform in the Gulf an associated oil line should be put in place to transport the production of the platform to the shore. Also, from there the oil is linked to additional oil lines in order to distribute to larger area. The Figure 1.1 represents the geographic of the Gulf of Mexico and oil and gas activities in the area.

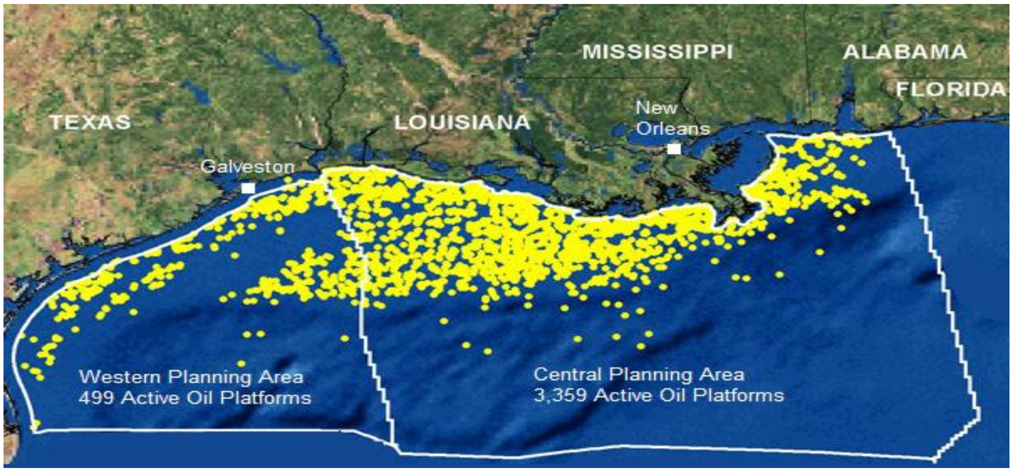

Figure 1.1 Geographic of the Gulf of Mexico. (http://gulfofmexicooilspillblog.com)

The offshore oil industry is responsible for one-third of the United States' oil production, of which 90% takes place in the Gulf of Mexico. (Roach et al. 2010). Energy production from this area supplies %30 of US oil and %20 of gas. The Deepwater rigs located in the GoM are responsible for the employment of over 700 workers per rig (GNO, Inc. 2011). Therefore, when any accident happens there, recovery time is effective to reduce the harmful consequences on production and transportation sectors. The economic impacts of oil and gas industry disruptions in GOM are not bounded only to oil and gas industry and gulf coasts, but also to other industries and the entire country.

The probability of a disaster occurring may be low but the environmental and economic consequences of such accidents are tremendous. Hurricane Katrina has become a classic example of a natural disaster. This famous hurricane had a more significant impact on oil and gas industry and longer lasting than any other historical hurricane event. Or The Deepwater Horizon oil spill accident is the most historical oil spill in U.S. The main causes of the blowouts in the Gulf of Mexico (GoM) reported in a recent study (Zulqarnain and Tyagi, 2014) are unexpected high-pressure formation and delayed response to the indications a potential blowout situation. Therefore, understanding, managing, and reducing disaster risks can provide a foundation for building resilience towards disaster. (National Academy press, 2001). Oil spills and other anthropogenic environmental disasters have economic consequences that transcend business losses and property damages, and include those experienced by recreational users. Measurement of the non-market economic consequences of manmade disasters is often complicated by the ex-

post nature of such analysis, as behavioral data collection before, during, and after events (Grigalunas et al., 1986).

Property destruction tells only part of the story. The potential total economic impact of a hurricane is always countless caused by the loss of infrastructure, productions earning and personal losses such as diminished health status. Increasing frequency and magnitude of hurricanes that increasing the probability of oil spill are significant reasons to study the severity of economic impacts of these events on different industries and related businesses.

1.2 Goals and Objectives of this Study

The primary goal of this study is to provide a broad picture of the potential impact of any disaster (manmade or natural) on oil and gas industry, labor market and economy. It is hoped that the results of such analysis will helpful to minimize the cost of the impacts of the event and quick recovery in order to reduce the harmful consequences on the related industry and region economy. In other word, what measures must be taken to recover from the disaster scenario of an oil spill impacting the same region in the aftermath of hurricane.

The importance of decreasing the severity and seriousness of oil spill event consequences, providing the best decisions to recover the situation, estimating the suitable amount of help needed for the event, measuring society potential and responsibility in front of the disaster are dependent on the amount of economic damage to the area. The main means to achieve that goal in this study is to investigate and minimize the cost of the impacts of the event and quick recovery in order to reduce the harmful consequences on the related industry and region economy.

In this study, the supply chain interruptions in oil and gas industry aftermath of disaster and its economic impact on this industry will be considered by generating a mathematical model on delivering oil from offshore to the port, temporary storing, the real processing, and selling and distribution of oil based products in this study; how a major breakdown in a refining node or a distribution link that is part of a supply chain aftermath of disasters (natural or man-made) can cause huge damage to several businesses and facilities at the same time.

The technical objectives to achieve the research goal include:

1. To study the effect of different shocks on employment and oil and gas industry and other relevant regional economies.
2. To investigate the likely magnitude of the net economic impact of a major oil spill using the Macondo oil spill as an example.
3. To forecast the potential impacts of future changes in employment after disaster on economy
4. To estimate the gross economic loss that created by BP oil spill.
5. To optimize the oil and gas supply chain framework design with application for Louisiana Offshore Oil Port (LOOP).
6. To develop a framework to optimally design of oil and gas supply chain while any breakdown happens.

Moreover, we also concluded that the direction, causation, duration, responsiveness and correlation between industry and states' employment and economic activity and oil price over time. In addition, using the optimal framework we investigated the problem of any breakdown in the supply chain operations in mid-stream and downstream (a refining node or interconnections) happens aftermath of natural or man-made disasters. Based on our findings its impact on the flow on the cost and the sales will be estimated while still have maximum net present value.

This study examined the effects of different shocks on employment and oil and gas industry and other relevant regional economies like Louisiana and Texas by developing a Vector Autoregressive model (VAR). The dynamic response of a change in Louisiana employment and also its oil and gas industry to each of these disasters was considered. In this research, the Deep-water Horizon accident compensation generated base on final demand output multipliers, demand earnings multipliers and demand employment multipliers from U.S. Annual I-O data and Regional data for 2010 and BP spending for state of Louisiana will be calculated. I-O analysis was used to measure the impact of BP spending on Louisiana economy, from 2010 to 2013, the latest available I-O table year for the Louisiana economy. In addition, a optimization supply chain modeling for mid-stream and downstream will be conducted to capture key components for building a reasonable replica of real situations to make the best possible choices. Because the economic impacts of oil and gas industry investment in GOM are not limited only to oil and gas industry and gulf coasts, but also to other industries and the entire country.

CHAPTER 2: LITERATURE SURVEY

2.1 Introduction

The Gulf of Mexico borders five of fifty U.S. states; Texas, Louisiana, Mississippi, Alabama and Florida. Many onshore refineries and offshore drilling platforms operate in the Gulf region, and produce oil and natural gas in the United States. Losses in access to Louisiana's oil and natural gas production can affect offshore industry owners and operators in GoM zone and country. In this chapter we first introduce the oil and gas characteristic of Louisiana, then discuss and compare onshore and offshore damages by hurricanes and oil Spills, and related literature review.

2.2 Role of Louisiana in Oil and Gas Industry

Louisiana is the nation's number two producer of crude oil and the number two producer of natural gas and refinery capacity among the 50 states. Approximately 112,000 miles of pipelines are transporting oil and natural gas within the state and also offshore area of the Gulf of Mexico. The Table 2.1 presents the crude oil production in U.S. in 2013 and some critical states.

Table 2.1 Crude Oil Production in U.S. in 2013

Area	Production (1000 Barrels per Day)	Percent U.S.
United States	7441	100.0%
Texas	2561	34.4%
Louisiana	1449	19.5%
North Dakota	858	11.5%
California	548	7.4%

Source: Scott, 2014.

According to Energy Information Administration (EIA) report in 2014, Louisiana has 79,289 miles of pipelines in onshore and also 37,554 miles active offshore pipelines. The oil and gas industry expands all over the state. North Louisiana has over 14,000 producing crude oil wells and over 10,500 producing natural gas wells. South Louisiana and the Louisiana offshore have about 5,000 producing crude oil wells and about 2,300 producing natural gas wells (Louisiana Energy Facts Annual, 2002). Crude oil, natural gas, petrochemical products, gasoline, jet fuel, and refined products are carried across the country by these pipelines. Therefore, any

accident that happens damage the pipelines can cause huge economic impact for the country. The industry supports 2,885 jobs (laworks, 2013). Therefore, any accident that happens damage the pipelines can cause gigantic economic impacts for the country. Port Fourchon which is located close to Bayou Lafourche in Lafourche Parish is playing important role to the U.S. energy supply, to the Houma MSA and state's economy. This port services approximately to 90 percent of all deepwater platforms and rigs in GoM. It plays another vital role in U.S. economy as a host for the Louisiana Offshore Port (LOOP).

This industry impact is not as large as refinery and extraction section. Based on the I/O table, which went to the 2011 Louisiana gross state product (GSP) statistics provided by the BEA, the pipeline industry was responsible for almost $1 billion in sales at Louisiana businesses, almost a quarter of a billion dollars in earnings for Louisiana households, and 5,606 jobs for Louisianans. According to the Louisiana Workers report in 2013, Petroleum refining industry supports 11,496. Table 2.2 presents the petroleum refining operating capacity and the number of refineries in United States and some other states in 2014.

Table 2.2 Petroleum Refining Operating Capacity in 2014

Area	Refinery Capacity	Number	Percent of U.S.
United States	17.924	139	100.0%
Texas	5.174	27	28.8%
Louisiana	3.274	19	18.4%
California	1.958	16	11.0%
Illinois	0.958	4	5.3%

Source: Energy Information Administration

Two tropical storms, two hurricanes and four major hurricanes (Category 3 – 5) smashed into the Louisiana and Mississippi in recent years. This report is focused on Hurricane Katrina, which hit the central Gulf of Mexico Coast in August 2005, and also Hurricane Rita that ripped over Texas–Louisiana border in September 2005. Katrina, one of the worst natural disasters to ever strike the United States, made the 2005 season the costliest in the nation's history (DNV report, 2007).

An economic impact analysis can address the business and financial activity resulting from local residents' expenditures. Richardson and Scott (2008) find that a shutdown of the Port

Fourchon port for just three weeks because of any disaster would associate to a national economic impact of $9.9 billion in sales loss, $2.9 billion in household earnings loss, and over 77,000 jobs loss nationally. An investigation on how to develop economic resilience in order to reduce the impacts of disasters on the regional as well as national economy and various communities is timely.

2.3 Onshore and Offshore Damages by Oil Spills and Hurricanes

The Gulf of Mexico area, onshore and offshore, is one of the most important zones for energy resources and infrastructure. Therefore, the development of GoM resources provides significant impacts to economy in terms of employment, Gross Domestic Product (GDP) and tax revenues. According to a Loren and Scott report in 2014, the extraction, pipeline, and refining industries accounted for nearly $5.9 billion in wages for Louisiana households in 2013. This amount is 7.2 percent of total wages in the state that year. Therefore any disruption in each three industries can cause huge economic impacts. Over 45% of total U.S. petroleum-refining capacity is located along the gulf coast. Louisiana is the nation's number two producer of crude oil and the number two producer of natural gas and refinery capacity among the 50 states. The Nelson study estimate that a seven-day closure of the lower Mississippi to shipping after oil spill would cost $50 million, and a fourteen day closure would result in $200 million in direct losses for the US, Louisiana, and a group of states that be dependent on greatly on shipping that transports through the Mississippi(Richardson and Scott, 2004). Port closures may disrupt crude oil and petroleum product imports into the Gulf. A shutdown of the Port Fourchon port for just three weeks because of any disaster would be associated with an economic impact of $9.9 billion in sales loss, $2.9 billion in household earnings loss, and over 77,000 jobs loss nationally. (Richardson and Scott, 2008).

If catastrophic disaster occurs and the emergency response supply chain is not adequately prepared, then the economic consequences of this disaster can be huge. Enhanced resilience allows for better anticipation of disasters and improved planning to reduce or mitigate disaster losses – as compared to waiting for an event to occur and paying for it afterwards. The effective response time plays a critical role in determining the extent of the environmental damage, the economic impacts to various businesses, and the subsequent demographics comprising of people who are directly or indirectly affected by such disasters. Katrina and Rita were caused more

lasting damage to energy infrastructure to compare with hurricanes Gustav and Ike. Recovery after hurricanes Gustav and Ike in 2008 was rushed by the actions of the energy industry and Federal, State, and local government organizations. All these organizations were better equipped and organized after the experience gained from 2005.

2.4 Oil Spill Accident

An oil spill can happen for many reasons. In general, the geological complexities, equipment reliability, weather and environmental conditions and human factors are important factors in causing oil spills. It is possible when an offshore engineering project goes wrong such as Macondo well incident. Weather condition can result in an oil spill. Weather conditions can cause mudslide, adrift of offshore structures, platform and pipelines damages. If the level of damage is high, it can lead to spill. Whenever the pressure control systems fail, crude oil or gas will be released from the well; the oil spill happens in the aftermath of blowout. The well is equipped with barriers and pressure control system to prevent any blowout. In the drilling section, the primary barrier is the hydrostatic pressure cause by mud and then BOP, casing, cement and wellhead seals. When all of this barriers fail at the same time then a blowout will occur.

Weather conditions are one of the important factors in deep-water drilling and production operations. In the recent years, the hurricanes caused several offshore spills from pipeline to platform damage. Hurricanes can cause seafloor failures by their high waves and create mudslides. Slope angle, water depth, wave power and shear strength of sediments are factors that determining the probability of mudslide (Hitchcock, 2006). The occurrence of the mudline can cause pipelines and platforms to be damaged. The soil up to a certain depth (300-400ft) in the GoM, is not consolidated and it can move under certain conditions. When it moves it is called mudslide. According to the Mineral Management Service report, the hurricane Ivan caused 24 incidents of pipelines damage by mudslide. Mooring failures during hurricanes Ivan, Katrina, and Rita caused 16 deep-water MODU’s to go adrift (Figure 2.1). Drifting MODU’s can potentially damage other critical elements of the offshore oil and gas infrastructure, e.g., colliding with floating or fixed production systems and transportation hubs, or damaging pipelines by dragging anchors.(Ward, Zhang, Gilbert, 2008).

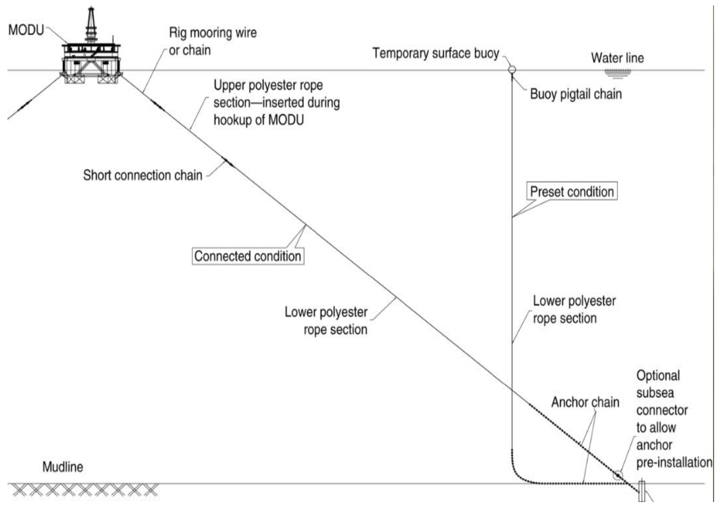

Figure 2.1 Mooring Systems for Ultra-deep Water.
Source: Sea Engineering Inc., Houston

2.5 Economic Impacts of Oil Spill

The Deep-water Horizon oil spill accident is regarded as the largest accidental marine oil spills in the history of the petroleum industry. By the end of 2010, BP estimated that the impact of the Deep-water Horizon oil spill cost (Table 2.3) the U.S. coastal economy $40 billion over a period of three years (Skoloff and Wardell 2010).

Table 2.3 Top Five Oil Spill Accidents by Cost

Event	Cost	Amount of Oil Spilled (bbl)
Deepwater Horizon	$40 billion	4,900,000*
Exxon Valdez	$6.3 billion	284,900
Amoco Cadiz	$3.0 billion	1,679,800
Ixtoc	$1.3 billion	3,552,000
Gulf War (Kuwait Oil Fields)	$540 million	11,100,000

Source: Smith, L 2012.

Afterward the Deep-water Horizon incident, BSEE inspectors have implemented more severe rules on the drilling division, such as critical tests of blowout preventers. Also, the oil and gas industry has focused more on research regarding improving technologies for oil spill prevention, containment and response. The potential for a huge oil spill not only depends on the

volume of the spill, but also depends on the structure of economy of the area. Therefore boosting the structure of economy can helpful to reduce the recovery time and consequences for facing future disasters.

In this study, we will only focus on the negative consequences of disaster on oil and gas industry. Economic losses and economic achievements are two different aspects of offshore oil spill scenarios. Economic losses can cause business disruption in different areas. Interruption of business activities can be considered one of the most negative consequences of the event. On the other hand, some companies (cleaning companies, import organizations, etc.) can benefit from the disaster by improving oil and gas industry equipment or boosting economic structure.

Recently, the probability of an oil spill occurring has been reduced because of improved safety measures. Performing more subsea BOP testing, well containment systems, and claiming second down hole mechanical barriers are some examples of safety technique that have been developed that can impact the severity of tremendous oil spills. The technological changes in this industry are caused developing successful drilling and increasing the total recovery from a field. The potential of a huge oil spill not only depends on the volume of the spill. In addition to potential direct impacts on humans or environmental impacts the key economic sectors affected were tourism, fisheries and oil and gas industry. In some scenarios transportation, refining and other sectors could be impacted. These impacts depend on the following factors: location of spill, volume of spill, ecosystem, human activity and the season.

2.5.1 Economic Impacts of the Gulf Oil Spill on Fishery

According to data published from the National Oceanic and Atmospheric Administration (NOAA), commercial seafood in the Gulf in 2011 reached their highest levels before and after oil spill. But, the level of increase is different in different states. Like the rest of the US, the Gulf Coast has experienced slow economic growth over the past decade. The Figure 2.2 shows the fishery closure in Gulf of Mexico after the Deepwater Horizon Oil Spill in 2010.

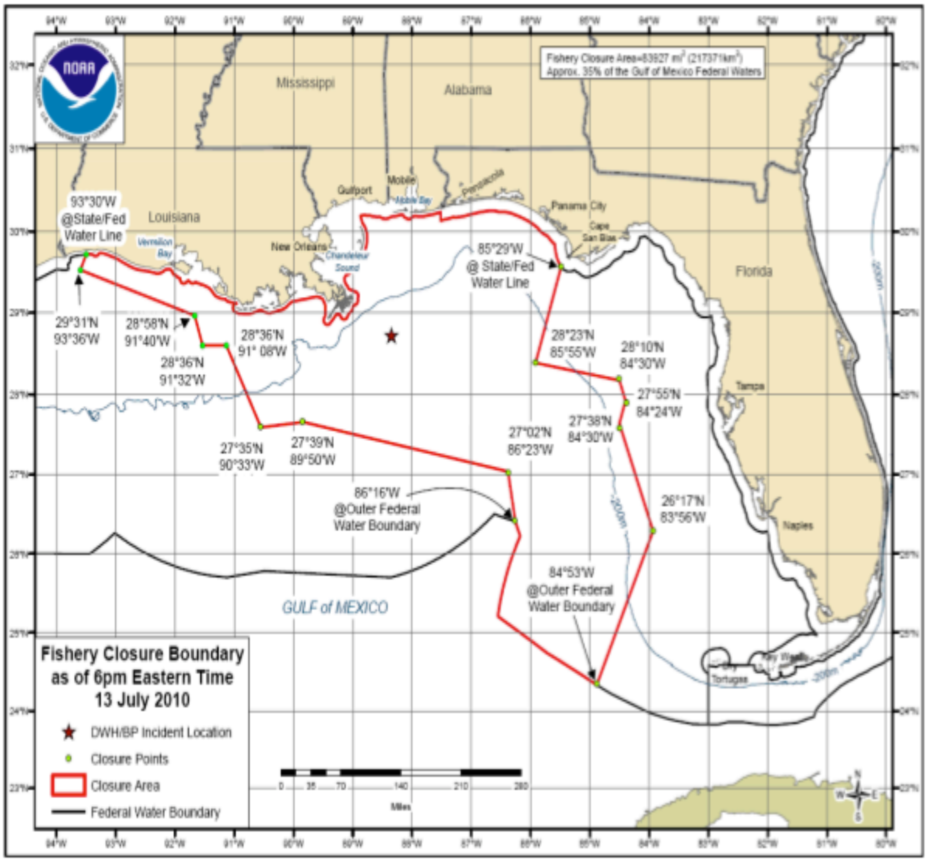

Figure 2.2 Federal Fishery Closure in GoM after the Deepwater Horizon Oil Spill
Source: NOAA, 2013.

After oil spilled into coastal waters, both federal and state governments have established protocols to test and monitor seafood safety. When spill response managers determine that seafood may be affected, the next step is to assess whether seafood is tainted or contaminated to levels that could pose a risk to human health through consumption. Both Federal government and the state closed some waters to fisheries.

2.5.2 Economic Impacts of the Gulf Oil Spill on Tourism

According to the Oxford Economics report, the Deep-water Horizon oil spill in the Gulf of Mexico is the biggest offshore spill in Unites States history. Millions of gallons have spilled since the explosion of the rig on April 20, 2010 in the Gulf of Mexico. In Figure 2.3 oil spill impact on tourism revenue is presented.

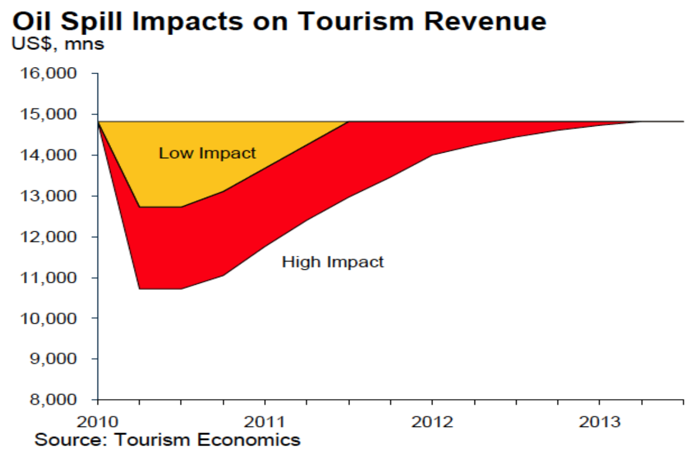

Figure 2.3 Oil spill Impact on tourism Revenue
Source: The U.S Travel Association, Oxford Economic

Tourism is one of the top economic drivers of the Gulf region economy. Visitors to the Gulf Coast Congressional Districts spent more than $34 billion in 2008. The largest share of this spending is received by Florida with more than $20 billion in visitor spending, followed by Texas with $7.2 billion and Louisiana with $3.6 billion. The Louisiana Office of Tourism commissioned two successive surveys, which were fielded by MDRG. The first was a national survey conducted from May 19 – 21 in 2010. The second was a regional survey of key visitor source markets conducted 2010 June 18 -21.

The May survey found that 26 percent of those who had plans to visit the state of Louisiana had postponed or canceled their trip. The June survey, which focused on relatively nearby visitor markets in Texas, Mississippi and Florida, found that 17 percent had postponed or canceled their planned vacation to Louisiana. Significant misperceptions were also identified by these surveys.

2.6 Economic Impacts of Hurricane

The oil and gas industry continues to improve its hurricane preparation and response plans because of experienced from 2008's major hurricanes like Gustav and Ike, as well as other great storms like Katrina and Rita 2005 and Ivan 2004. Undeniably the most dramatic economic events in Louisiana's economic history occurred in late August and September of 2005. Two highly destructive hurricanes hit Louisiana and caused huge damage in the area. Any disaster has different consequences or impact on the local economy. Economic losses can cause business disruption in different areas. Interruption of business activities can be considered one of the most

negative results of the event. According to the Saffir-Simpson Hurricane Wind Scale hurricanes are classified into five different categories based on a continuity speed of wind. Hurricanes Category 3 and higher are considered major hurricanes because of their potential property damage. Hurricane Katrina was classified as major category because of level of catastrophic damage occurred. Katrina had a significant impact on the offshore oil and gas industry approximately 95% and the oil and gas production 85% of was shut in for couple of days. Figure 2.4 shows the impacts of hurricane on Gulf of Mexico.

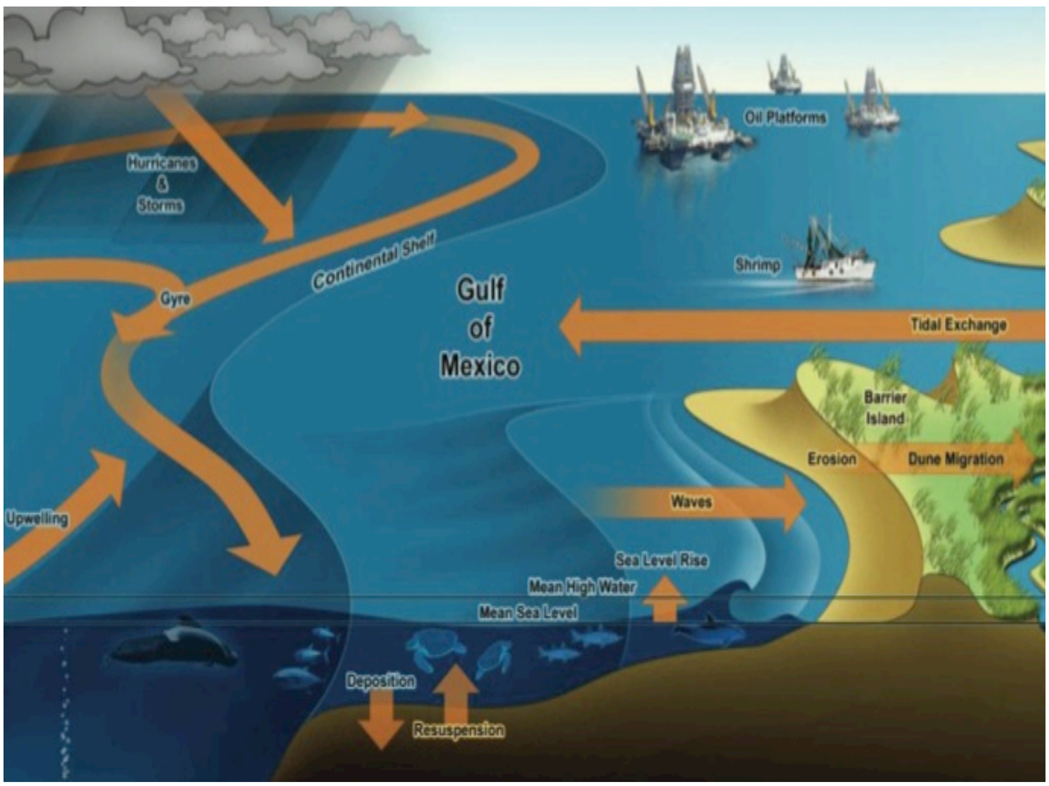

Figure 2.4 Impacts of Hurricane on GOM.
Source: Interim Report

Some of the platforms, which were exposed to hurricane experienced serious damaged, may take from three to six months to repair. The underwater structural damage or major pipelines damage are considered as major or serious damage. The Table 2.4 presents the number of damaged and destroyed platforms as a result of some specific hurricanes that published by Mineral Management Service (MMS) Gulf of Mexico regional office.

Table 2.4 Platform exposed, Damaged or Destroyed during Past Hurricanes

Hurricane	Year	Platforms Exposed to Hurricane	Platform Destroyed	Platform Serious Damaged
Andrew	1992	700	22	65
Lili	2002	800	2	17
Ivan	2004	150	7	31
Katrina	2005	1000	47	20
Rita	2005	2050	69	32
Gustav-Ike	2008	2127	60	31

Source: Mineral Management Service (MMS) Reports –
Bureau of Safety and Environmental Enforcement

Prior to hurricane landfall, more than 700 platforms and rigs were evacuated taking more than 90% of the oil and more than 83% of gas production in the GoM offline (Feltus, 2005). According to MMS reports released in January and updated in May 2006, a damage assessment following the storm revealed that Hurricane Katrina, which was a Category 5 hurricane when it entered the US GoM Outer Continental Shelf (OCS), completely destroyed 44 platforms and severely damaged 21 others (MMS, 2006).

2.6.1 Economic Impacts of Hurricane on Platforms

Prior to hurricane landfall, more than 700 platforms and rigs were evacuated taking more than %90 of the oil and more than %83 of gas production in GoM (Feltus, 2005). Table 2.5 presents the number of platforms destroyed by Hurricanes Katrina By water depth.

Table 2.5 Number of Platforms Destroyed by Hurricanes Katrina by Water Depth

Water Depth d (m)	Number of platforms destroyed
d<30	16
30<d<60	14
60<d<120	14

Source: MMS.2006

A permanent installation such as a tension leg platform (TLP), a floating production is named platform. Rig refers to a temporary installation like mobile offshore drilling unit. Drilling rigs were also affected.

The hurricane destroyed four drilling rigs and severely damaged nine others. In addition, six drilling rigs, including semi-submersible and jack-up units, were set adrift (Ghonheim & Colby, 2005; Tubb, 2005). The Table 2.6 is presented the number of damaged platforms by hurricane Katrina base on water depth that published by MMS in 2006.

Table 2.6 Number of Platforms Damaged by Hurricanes Katrina by Water Depth

Water Depth d (m)	Number Of Platforms Damaged
d<60	6
60<d<120	6
120<d<240	5
300<d<1000	4

Source: MMS.2006

Hurricanes Katrina and Rita caused significant damage to the oil and gas production structure in the GOM, with estimates by Minerals Management Service (MMS) stating that roughly 3050 of the 4000 platforms and about 22,000 of the 33,000 miles of offshore pipelines were in the path of these two hurricanes.

Additionally, the onshore damage had a significant impact on the ability of the oil and gas industry to respond due to the lack of resources, personnel, and infrastructure, as well as significant damage to onshore processing facilities and power supplies. There were significant competing resource needs with the impacts caused by the devastation of New Orleans and western Louisiana/eastern Texas shore communities that normally provide the services and supplies for the industry. These impacts included the temporary relocation of the MMS GOMR staff and functions to Houston, Texas.

Figure 2.5 presents the hurricanes Katrina and Rita's paths in the area. Hurricane Katrina (easterly in Figure 2.5) was a category 5 hurricane, which destroying 46 platforms and damaging 20 others. Hurricane Rita was a category 4 hurricane destroyed 69 platforms completely and damaged 32 platforms (the westerly in Figure 2.5). Hurricane Katrina was classified as major category because of level of catastrophic damage occurred.

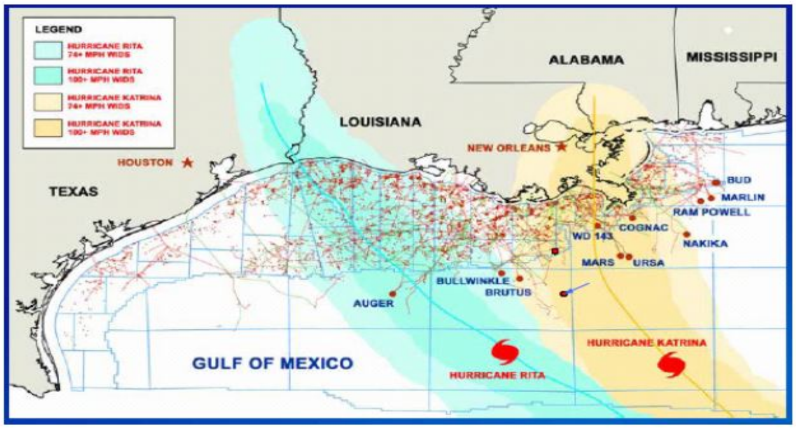

Figure 2.5 Hurricanes Katrina and Rita's paths

According to the Det Norske Veritas (DNV) report in 2007, there were about 211 minor pollution events reported to the MMS after Hurricane Katrina. Minor pollution incidents are categorized as incidents involving less than 500 barrels of oil that do not reach the coast line. The Figure 2.6 in below shows the path of Hurricane Katrina and the location of offshore platforms and rigs in the Gulf of Mexico. Grey circles represent fixed manned platforms; orange circles show mobile rig locations.

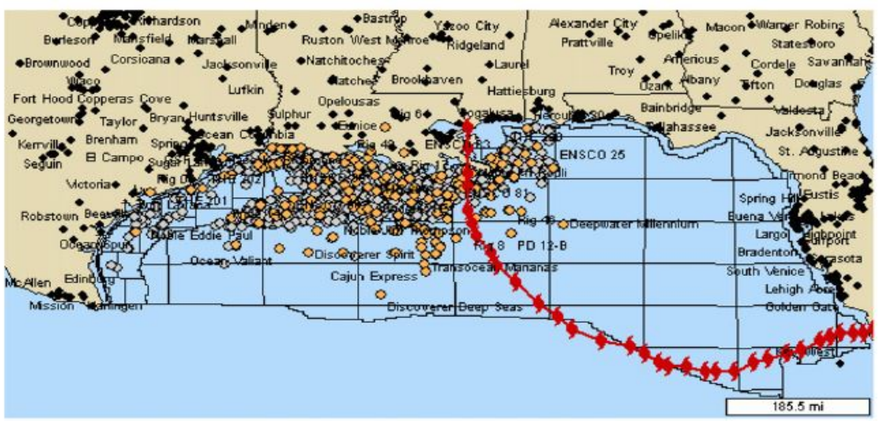

Figure 2.6 Path of Hurricane Katrina and the location of offshore platforms and rigs
Source: Rigzone (2006).

Oil and gas platform workers shut down offshore production in the Gulf of Mexico as a safety before both hurricanes Gustav and Ike. The loss caused by the storms retained a significant share of that production offline more than a few months after the storms. Some smaller platforms were completely destroyed and a small amount of Gulf of Mexico oil and gas production is likely to be permanently lost. Hurricanes Gustav and Ike also shuttered onshore

natural gas processing plants and several gas pipelines, restricting the flow of gas throughout the United States for weeks.

2.6.2 Economic Impacts of Hurricane on Refineries

According to Office of Electricity Delivery and Energy Reliability report at 2009, numerous refineries in the Gulf were shut down due to hurricane-induced flooding, wind damage, and loss of electricity in 2005 and 2008. By August 30, 2005, 11 refineries in Louisiana and Mississippi with a combined capacity of 2.5 MMBD were shut down as a precaution in advance of Hurricane Katrina. Hurricane Rita made landfall further west along the Gulf Coast, resulting in the precautionary shut down of 16 additional refineries in Houston, Galveston, Port Arthur and Lake Charles with a combined refining capacity of 4 MMBD. Due to severe damage and flooding, more than 2 MMBD of this capacity remained offline two weeks after Rita's landfall, and about 1 MMBD remained offline four weeks after landfall. In addition, a number of refineries operated at reduced rates for several weeks following the storms. Figure 2.7 presents the duration of refinery shut downs during 2005 and 2008 Hurricanes

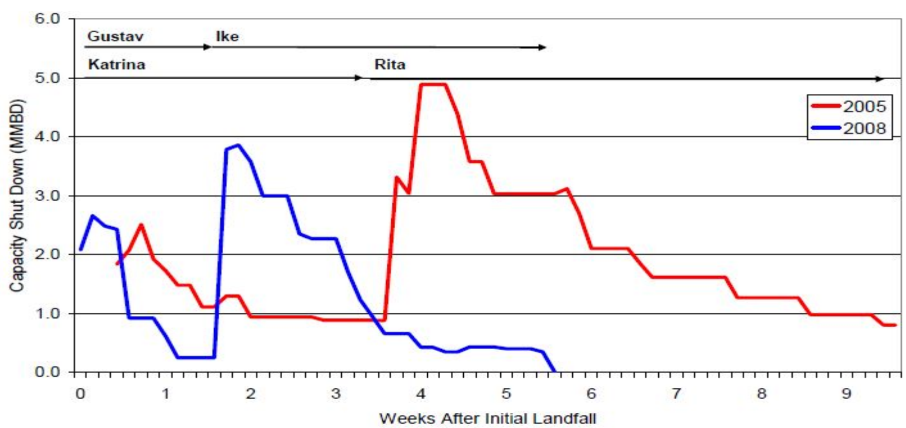

Figure 2.7 Duration of Refinery Shut downs during 2005 and 2008 Hurricanes
Source: OE/ISER situation Reports

U.S. petroleum supply was also impacted by the hurricanes, which shut key petroleum infrastructure, including refineries, ports, waterways, and pipelines. More than a dozen refineries were shut as a precaution before each hurricane, but only a few remained offline for several weeks after Hurricane Ike due to a lack of power supply. According to EIA statistics in 2013, this region accounted for around 44.6 percent of U.S. refining capacity. Any accident or disaster that happens can cause delay in refinery process. Therefore, having strong resiliency allows us better anticipation of disasters and better planning to reduce disaster losses—rather than waiting

for an event to occur and paying for economic loss afterward. The goal after any hurricane or tropical storm is to return to full operations as fast as possible to reduce economic losses.

The Richardson and Scott study focused only on the largest economic cost---rising gasoline prices. They argue that a three week disruption to Louisiana's pipeline system would raise gasoline prices by 21.6 cents per gallon nationwide. Over a three-week period, this translates into a $1.74 billion cost to consumers. Also, The Nelson study developed a scenario that disruption of oil pipelines transports 625,000 barrels per day from U.S. oil materials. In the case of the 3-week disruption consumers would pay $1.74 billion more for oil products. (Richardson and Scott, 2004).

The American Petroleum Institute (API) announced that oil and gas companies have reported around 58 platforms and drilling rigs destroyed or severely damaged. Nelson study estimate that a seven-day closure of the lower Mississippi to shipping after oil spill would cost $50 million, and a fourteen day closure would result in $200 million in direct losses for the US, Louisiana, and a group of states that be dependent on greatly on shipping that transports through the Mississippi. (Richardson and Scott, 2004).

2.6.3 Economic Impacts of Hurricane on Pipelines

Colonial pipeline plays an important role by transporting petroleum products from Houston, Texas to ports in New York and New Jersey. The capacity of this pipelines was reduced significantly in 2008 because of lack of supply from refineries following hurricane Ike. In addition to other economic impacts in south due to hurricane Ike, other parts of country experienced negative economic impacts. Property destruction only tells about part of the story. The total economic impact of a hurricane typically captures includes the loss of infrastructure, occupants and tourists, manufacturing, retail, workers and lost hours that effect businesses. Only Hurricane Gustav shut down a few major pipelines in 2008. The Capline and Locap shut down on September 1, 2008, returning to reduced service four days later. Centennial pipeline was shut on September 2, 2008 and remained down through Ike's landfall, restarting on September 21.

In contrast, a disaster can also generate positive impacts; Cleanup and recovery from an oil spill or hurricane can create different opportunities for some businesses. Such as cleaning companies, import organizations. Improving oil and gas industry equipment or boosting economic structure.

In recent times, the chance of an oil spill happening has been decreased because of development in oil and gas technology and safety. Performing more subsea BOP testing, well containment systems, and claiming second down hole mechanical barriers are some examples of safety technique that have been developed that can impact the severity of terrific oil spills. Gulf of Mexico production is about 1.5 million barrels per day of crude oil and 10 billion cubic feet per day of natural gas. Katrina in 2005 removed approximately 1,300 offshore platforms and Rita roofed nearly 1,600.

Hurricane Gustav caused disruptions in oil and natural gas transportation systems and production platforms about two weeks and crude oil spills also occurred. Hurricane Ike caused a shutdown of major parts of the production, drilling operation, and pipeline structure beside the Gulf Coast in East Texas and Louisiana to shut down. According to the American Petroleum Institute's report more than 20 percent of total U.S. refinery capacity was idled after hurricane Ike.

2.6.4 Economic Impacts of Hurricane on Employment in New Orleans

Hurricane Katrina was the eleventh named storm, fifth hurricane, third major hurricane, and second Category 5 hurricane of the 2005 Atlantic hurricane season, and was the sixth-strongest Atlantic hurricane ever recorded (DNV, Report No. 448 14183). After Hurricane Katrina, Total nonfarm employment in Louisiana declined by 184,600 jobs from September 2004 to September 2005(See Table 2.7). The oil and gas sector showed decreases in employment over the both years 2005 and 2006 same as all other sectors.

Table 2.7 Yearly changes in employment in New Orleans (Sep 2004-May 2006)*

Industry	Change in Employment (in thousands)			
	Sep 2004-Sep 2005		May 2005-May 2006	
	Number	Percent	Number	Percent
Oil and Gas	-16.5	-43.3	-8.6	-22.4
Construction	-17.1	-57.4	-10.5	-35.0
Manufacturing	-11.6	-29.9	-9.8	-25.5
Trade, Transportation, Utilities	-38.1	-31.5	-33.3	-27.0
Total Nonfarm	-204.6	-33.5	-185.0	-30.1

Source: U.S. Bureau of Labor Statistics (*not seasonally adjusted).

2.7 Offshore Vs. Onshore

Offshore drilling is more complex and expensive than onshore. According to the Pipeline and Hazardous Materials Safety Administration report, the first offshore drilling platform dates from 1869. The first offshore platform in the Gulf of Mexico was built in 1947. Today there are hundreds of offshore platforms off the coast of the United States that are producing oil and natural gas.An offshore well are more recoverable oil to compare with onshore wells. Structuring, carrying, handling and removing of the onshore facilities are less challengeable than the offshore facilities. Then, it can be seen small private wells with 100 barrels a day in onshore shallow fields. However some offshore large bores can produce 4000 barrels a day. To better understand of differences, given crude oil can be recovered from shallow wells (e.g. in 30 meters earth depth) to wells of 3000 meters deep in 2000 meters water depth. And also development of an onshore well requires 10.000 dollar, while investment in an offshore development needs 10 billion dollar. World crude oil production (Sahebi, 2013).With the advanced technologies, an increase in the growth is expected in the future. Offshore structures vary according to the water depth of oilfields.

2.8 Role of Economic Resilience

Aftermath of any hazard event, we will deal with two different losses; direct and indirect. Sometimes the indirect losses are more important and harmful than the direct side effects of the event. For instance, service companies cannot provide services. Because of the oil spill accident. Therefore, business interruption can happen even if there is not any property damage. Direct effects, such as property damage (oil platform) and indirect consequences, such as business interruption have affects; understanding them helps to making appropriate decision in events. In the consequences of disasters, we may deal with direct loss of public utilities; therefore, we will lose production.

A usual oil industry supply chain includes exploration of new reservoirs, drilling of wells, withdrawal at onshore and offshore platforms, transport to the refineries, the refining of the crude in the refineries in order to produce the petroleum products (such as gasoline and diesel) the transport of those products to distribution terminals where they are dispatched to distribution companies, and finally the delivery of the derivatives to the customers. Rose (2004) defined economic resilience into two different responses, inherent and adaptive, to disasters in

order to protect individuals and communities from losses. It applies during and after the event. Modeling all individual and organizations in operational level in resilience economy, identifying resilient actions a conceptual level and also gathering data on resilience for modeling in empirical level are some challenging difficulties in this area (Rose, 2004).

When a disaster happens, minimizing the cost of the impacts of the event and the recovery time necessary in order to reduce the harmful consequences on the public and private sectors. Whenever a disaster happens, another reaction to this event that should be considered is resiliency. It is ability to reduce or remove potential losses due to disaster events. Also, adaptive behavior under stress should be used in addition to inherent possibilities (Rose, 2006). Economic Resilience refers to two different responses, to disasters inherent and adaptive in order to protect individuals and communities from losses. It is divided into two aspects under different conditions: i) Inherent responses: ability under normal conditions, and ii) Adaptive responses: responses under crisis conditions.

Many ecological economists believe that resilience is a part of sustainability. Sustainability is a function of a society's ability to react effectively to a crisis, and with minimal reliance on outside resources. It refers to long-term survival and the non-decreasing quality of life and also depends on environmental and natural resources. From an economic perspective, sustainability is a function of the degree to which key hazard impacts are anticipated (Klein et al.2003). In addition, some scientists relate resilience to vulnerability.

It must be mentioned that vulnerability is a pre-disaster condition; on the other hand, resilience is the outcome of a post-disaster response. Economic resilience emphasizes and applies during and after the disaster happens. It reduces failure probability, consequences of failure and also decreases time of recovery from disaster impacts. Mitigation and recovery management are important loss reduction strategies. Mitigation is the decreasing of the probability of failure with applying new technologies. Recovery management is making recovery time as rapid as possible; it also helps to lead businesses and households into normally after disaster situation. In order to choose a suitable strategy for reducing losses in the economy from natural catastrophes, we should understand the measurement of resilience.

2.9 Role of Supply Chain in Oil and Gas Industry

Supply chain management assumes a major role in the logistic activities associated with responding to disasters caused by hazards such as major hurricanes, earthquakes, and acts of war and terrorism.[1]. If catastrophic disaster occurs and the emergency response supply chain is not adequately prepared, then the economic consequences of this disaster can be huge. Catastrophic events such as oil spills have enormous impact for the local economy of the area and even for the local labor markets. A supply chain disruption is defined as a major breakdown in a production node or a distribution link that is part of a supply chain. Natural disasters such as hurricane are one reason of disruptions to supply chains. These disasters typically cause huge damage to several businesses and facilities at the same time. This has a severe impact on an industry and significant time is often required for recovery from natural disasters.

Supply-chain problems result from natural disasters, labor disputes, supplier bankruptcy, and other causes. These kind of disasters can seriously mess up or delay material, systems breakdown, inventories problems and capacity and cash flows then all can increase the cost or decrease the sales. Due to the essential role of oil and gas industry in the today's world business, this industry involves huge financial flows. This industry has significant impact on the global economy. Oil and gas supply chain management has to solve a lot of challenges caused by the nature of the supply chain in the oil industry; such as difficulty, strict characteristics, long lead time, limited and sensitive transportation forms and distribution capacity at the different levels in the supply chain. Economic shock or political changes, which have an impact on the price of the oil, are other challenges caused unexpected experiences. Any disruptions on supply chain in oil and gas industry can cause huge impact on this industry and economy. Therefore, optimization of supply chain models within the oil and gas context is critical.

The oil and gas industry is divided to the upstream and the downstream segments. The upstream section refers to the exploration, extraction, separation, and transportation of crude oil to refineries (included crude oil reservoirs, wells, separator, storage tanks, oil tankers, and pipeline system). Downstream section refers to tasks that follow transformation, storage, distribution, and marketing. Upstream covers exploration and production activities, Midstream deals only with transportation of crude oil and gas to terminal and storage, And downstream refers to the reminder of activities to delivery final products to customers (An, Wilhelm, &

Searcy, 2011; Leiras, Ribas, Hamacher, & Elkamel, 2011; Manzano, 2005). The distance from the oil exploitation point to the final consumers could often be thousands and thousands of miles which is the important reason for the oil supply chain having longer lead time than in other industries. In addition, crude oil has to go through a complex, capital intensive refinery process as well (Gainsborough, 2006; Ribas, Leiras & Hamacher, 2011). The long lead time also indicates the involvement of various means of transport such as ships, pipelines, rail and road as well as high transportation cost (Hussain et al., 2006; Ribas, Leiras & Hamacher, 2011).

Any supply chain commonly is distributed into segments or stages. Each of them includes entities, facilities, with the same functionality. Though, as distinguishing between segments is often fuzzy and units can be a member of various segments (Chandra & Grabis, 2007). The crude oil industry is divided to three major segments; upstream, midstream, and downstream. There are some links between facilities in the crude oil supply chain. These links symbolize the flow of materials, services, cash, and information which cause the performance of exploration, production, refining, storage, and distribution possible. Beamon and Chen (2001) classified the supply chain structure into four main classes: Convergent (CV) or Assembly which each entity (node or facility) in the chain has at most one successor, but may have several predecessors. Divergent (DV) that entity has at most one predecessor, but several successors. Conjoined (CJ) is a combination of each divergent and one convergent structure.

The oil industry supply chain consists of the three levels of decisions: strategic, tactical, and operational. The crude oil supply chain mathematical models optimize the design and planning of a number of subsystems of this network, e.g. crude oil transportation oilfield development, refinery planning, and distribution (Shah et. al, 2010). The crude oil industry supply chain consists of the same levels of decisions (strategic, tactical, and operational). In this context, oil supply chain models optimize a number of subsystems of this network, e.g. oilfield development, refinery planning, crude oil transportation, and distribution (Shah, Li, & Ierapetritou, 2010). One of the main problems that create a center of attention in this context is the oil field development. The problem embodies substantial required investment, long planning horizon, and a vast number of potential locations for crude oil wells, well platforms, production platforms, and their pipeline interconnections (Shah et al., 2010).

There exists few literature review works in the crude oil supply chain. Some of them are like a discussion and critique rather than a systematic literature review. Only three studies were found which presents a systematic study of the mathematical models for the oil and gas supply chain problems. Bengtsson and Nonås (2010) explain an overview of the midstream section of refinery planning and scheduling activities. They present planning and scheduling of crude oil unloading and blending, production planning and process scheduling, and product blending and recipe optimization. Shah et al. (2010) carry out a very similar study on the refinery operations literature. Their uniqueness is that they overview some works of the crude oil supply chain design and planning. They also are also addressed the importance of the capturing nonlinearity and developing of the solution approaches. Leiras et al. (2011) emphasizes on the solution techniques used to optimize the model under uncertainty, and classified them. This study focuses on the refinery operations instead of the united oil and gas supply chain. The designs of oil and gas supply chain usually are based on economic purposes. During the last two decades, environmental objectives are becoming of high importance (e.g. (Al-Sharrah, Elkamel, & Almanssoor, 2010; Guillén-Gosálbez & Grossmann, 2010; Pinto-Varela, Barbosa-Póvoa, & Novais, 2011)). In the oil and gas supply chain, economic and environmental performances must be taken into account at once. Recently the objectives of mathematical programming models for supply chain have extended to contain supply chain security, risk, and sustainability dimensions (Speier, Whipple, Closs, & Voss, 2011). Figure 2.8 presents a schematic view about the typical oil and gas supply chain.

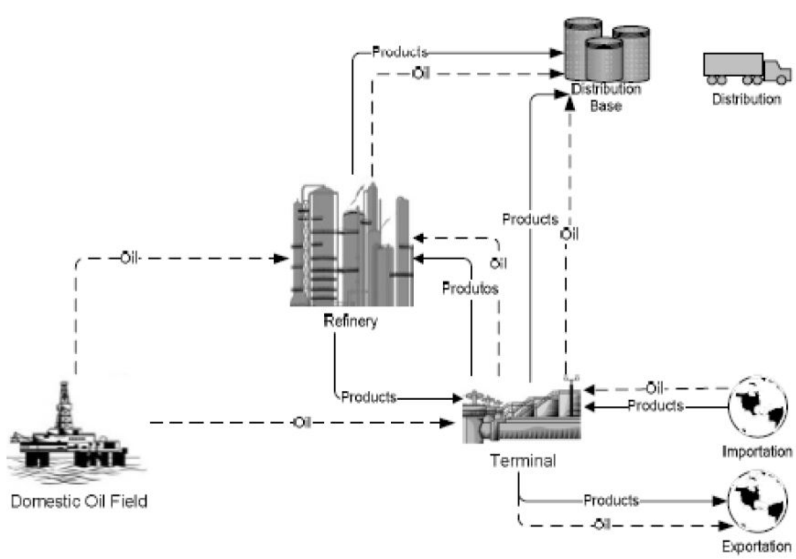

Figure 2.8 Typical Oil and Gas Supply Chain (Ribas et al., 2011)

CHAPTER 3: VECTOR AUTOREGRESSION SIMULATION STUDY OF MULTIPLE SHOCKS ON LOUISIANA'S ECONOMIC PERFORMANCE

3.1 Introduction

Catastrophic events such as hurricanes and oil spills have enormous impacts on the local and regional economies and labor markets. The U.S. Gulf Coast has recently experienced the largest marine oil spill, the highest mobilization of spill response sources, and also the first drilling moratorium in the history of deepwater operations during 2010. Another regional disaster, Hurricane Katrina impacted Louisiana, Mississippi, and Alabama, as it ripped over the core of the Gulf of Mexico producing region, one of the most important oil and gas production areas of the world during 2005. The disruption of oil and gas production and fisheries due to an oil spill or a drilling moratorium can be modeled as the negative shock impacts on the local labor markets. Therefore, the analysis of the damage initiated by the storms at offshore oil and gas drilling and production facilities brings a valuable opportunity to learn how to be well prepare for hurricanes with the aim of avoid future damages. The objective of this chapter is to find the impact of such shocks on the employment numbers and wages in the Gulf Coast region. This research uses econometric tools to provide quantitative estimates of the response and correlation between past and current activities of Louisiana employment and other relevant regional economies. In this study, we have determined the likely magnitude of the net economic impact of a major oil spill like the Deepwater Horizon oil spill on certain sectors with Vector Autoregressive (VAR) method. Also, the potential impacts of future changes in employment after a disaster on economy are discussed.

3.2 Economic Power of Gulf of Mexico

The Gulf of Mexico is a major body of water bordered. The gulf's eastern, north, and northwestern shores lie within the states of Florida, Alabama, Mississippi, Louisiana, and Texas. We know that Gulf of Mexico area takes vital responsibility for energy resources. According to the Energy Information Administration report, the Gulf of Mexico is one of the largest contributors of oil and gas production to the U.S. national production. Thus, it establishes the Gulf of Mexico district as one of the most critical zones for energy sources for the country. Therefore, the development of GoM resources provides significant impacts to economy in terms of employment, Gross Domestic Product (GDP) and tax revenues. With the recent

exploration/discovery of deep-water reservoirs and continued developments of drilling and production and probability of man-made mistake or natural disaster, it remains very important to have a comprehensive and quantitative risk assessment of the drilling/production processes including effective response to deal with such disasters.

The economic impacts of oil and gas industry investment in GOM are not limited only to oil and gas industry and gulf coasts, but also to other industries and the entire country. Now a question may be raised as how has oil and gas industry disruption affected the economic lives of Louisiana employment. And also, has the industry's impact on state and local businesses been significant or not.

3.3 Goal And Objectives Of The Chapter

It is hoped that the resultd of such analysis will provide a broad picture of the potential impact of any disaster (manmade or natural) on economy and labor market. It will helpful to minimize the cost of the impacts of the event and quick recovery in order to reduce the harmful consequences on the related industry and region economy. In other word, what measures must be taken to recover from the disaster scenario of an oil spill impacting the same region in the aftermath of hurricane.

This study develops economic and econometric models that examine the effects of different shocks on employment and oil and gas industry and other relevant regional economies like Louisiana and Texas. The research uses recent econometric tools to provide quantitative estimates of the responsiveness and correlation between past and current activities of the oil industries and employment. Specifically, the following objectives are addressed:

- Determine the likely magnitude of the net economic impact of a major oil spill using the Macondo oil spill as an example
- Focus on areas of impact
- Forecast the potential impacts of future changes in employment after disaster on economy.

In order to meet the above challenges. Recent developments in time series econometric modeling tools are employed. This tool enable us to create the direction, causation, duration, responsiveness and correlation between industry and states' employment and economic activity and oil price over time. This study covers selected representative states in the GoM region. Here

we selected the following states based on their unique structural and economic characteristics indicated in each one and their role in oil and gas industry: Louisiana and Texas.

3.4 Data Analysis

Location of the oil spill, duration and volume of the oil spill, and weather condition (hurricane season) data are some variable play an important role in oil spill impact study. Also, the total number of jobs directly attributable to offshore oil and gas. These jobs involve exploring, producing, transporting, and delivering oil to downstream elements or provide critical supplies or onsite services to the offshore oil and natural gas industry. In addition, the total number of jobs indirectly involved in offshore oil and natural gas. Indirect employment is defined as the employment in other industries that supply material and labor to the offshore industry. These are some other data that are using to estimate the economic damages.

The Occupational Employment Statistics (OES) program produces employment and wage estimates annually for over 800 occupations. Also, the data on employment is gathered from The Bureau of Labor Statistics *(BLS*) which is collecting the United States Labor. The U.S. Energy Information Administration (EIA) is a major organization of the U.S. Federal Statistical System responsible for gathering, analyzing, and publishing energy information that provides the data related to spills. Data on global crude oil production are available in the Monthly Energy Review of the Energy Information Administration (EIA). Due to estimate the dynamic response of different of industrial sectors in Louisiana to oil and gas disasters models, STATA/SE (statistical software package) was the best option for this part of the study.

3.5 Description of Data

According to the data we gather and the model, we decide to use monthly data of the some industries variables from January 1983 to October 2014 to build model. Every variable has 382 observations. We have data on Louisiana employment, Texas employment, price of oil, refineries, and production rate and industry production.

The oil price data unit is Dollars per Barrel and it's a monthly and not seasonality adjusted. The Louisiana employment and Texas employment units are thousands and industry production is index 2007=100. The base year, here is 2007, refers to the year in that an index number series starts to be calculated. This will regularly have a starting value of 100. The

Industrial Production Index (INDPRO) is an economic indicator that measures real output for all facilities located in the United States manufacturing, mining, and electric, and gas utilities. Since 1997, the Industrial Production Index has been determined from 312 individual series(classified in market groups and industry groups) based on the 2007 North American Industrial Classification System (NAICS) codes (Board of Governors of the Federal Reserve System (US),2015). Table 3.1 presents the summary statistics of variables.

Table 3.1 Summary of Statistics of the Key Variables in our Model

Variable	Mean	Std. Dev.	Min	Max
Louisiana Employment	1777	160.7	1459.4	1996.8
Texas Employment	8689.7	1599.8	6107.7	11768.3
Oil Price	41.2	29.8	11.2	133.9
Industry Production	75.3	18.3	41.5	102.4

Figure 3.1 shows the Louisiana employment stayed more or less constant, except a sharp decreasing from September 2005. It refers to the hurricane Katrina that happens at the end of August 2005. We can see another sharp decrease, not as big as previous one, in April 2010 aftermath of Macondo accident in Louisiana employment.

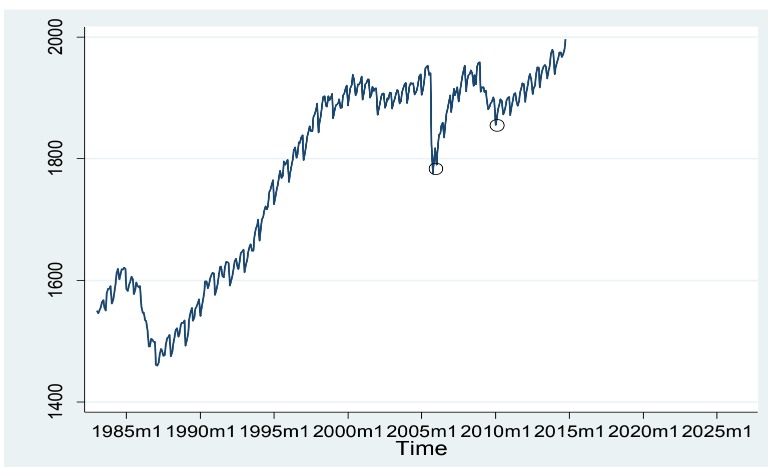

Figure 3.1 Trend in Monthly Louisiana Employment January, 1983 –October 2014

Figure 3.2 presents the Texas monthly employment since 1983. The Texas employment has exponentially grown in the overall. For the same time periods, in 2005 and 2010, there is a sharp decline in Louisiana employment and contrastingly the decline is not as severe for Texas.

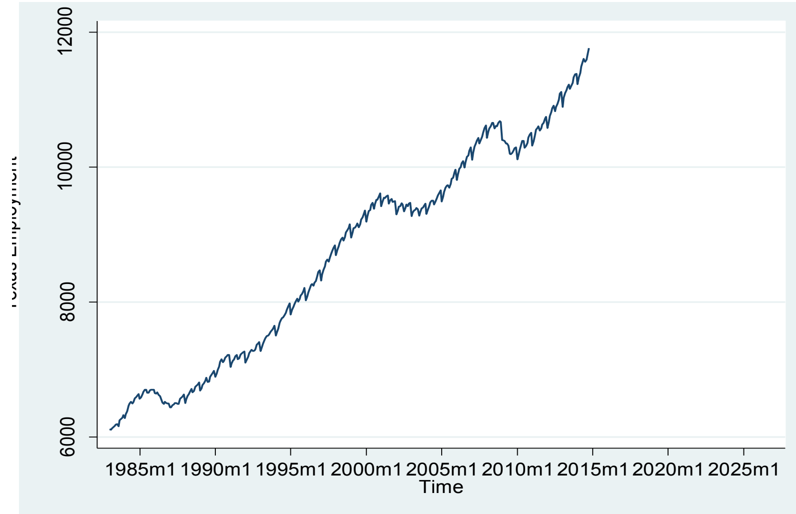

Figure 3.2 Trend in Monthly Texas Employment January, 1983 –October 2014

In figure 3.3, monthly oil price, we can see two significant sharps in the trend of data. Booming Asian economies and global economic growth caused to high demand and low supply as crude oil prices, increased to their highest level in history in mid-2008. Financial organizations collapsing caused the global financial crisis in 2008, and the brought trillions of U.S. dollars losses. Oil prices dropped to $39 per barrel in December 2008 because of low demand; it is famous as the wildest crash in history. It took world economies four years to climb back from the global recession in 2012. The price increased gradually to reach approximately to $110 per barrel in 2012.

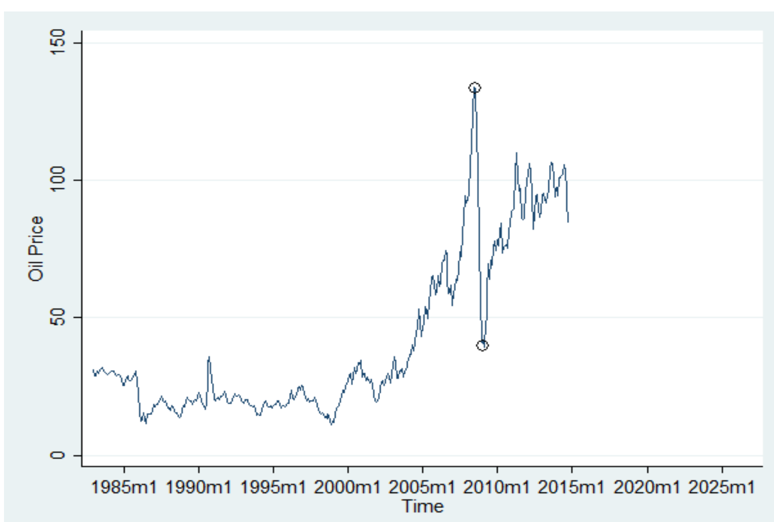

Figure 3.3 Trend in Monthly Oil Price January, 1983 –October 2014

Figure 3.4 presents the Industry Production monthly data since 1983. The U.S. Industry Production has exponentially grown. The significant drop in U.S. Industry Production is related to the U.S. recession that began in December 2007 and ended in June 2009, and which was extended over 19 months (U.S. National Bureau of Economic Research). The Great Recession was linked to the U.S. financial crisis of 2007–08 and also subprime mortgage crisis of 2007 through 2009. The Great Recession was the general economic failure observed in world markets. As you can see in graph this decline in late 2009 beginning of 2010 starts to recover.

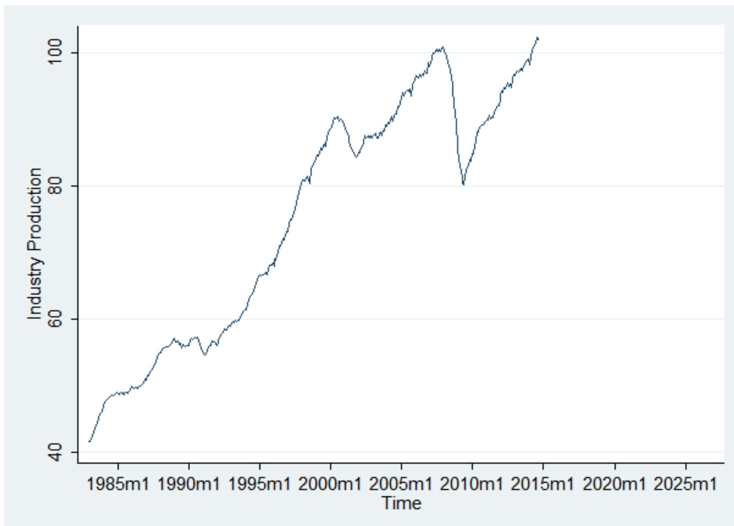

Figure 3.4 Trends in Monthly U.S. Industry Production January 1983 –October 2014

3.6 Methodology

Impact analysis looks at the effects of a positive or negative change in economic activity. Impact analysis is based on economic multipliers, which account for the total effect across the entire economy of the event under study. (Hughes, 2003). In order to estimate the economic loss when accidents occur, there are a number of potential econometrics modeling approaches:

- Input-output model (I-O)
- Computable general equilibrium (CGE)
- Dynamic Stochastic General Equilibrium (DSG)
- Vector Autoregressive Models(VAR)

Even though a variety of methods can be applied to create economic multipliers, the focus here is on Vector Autoregressive models. Since 1980 macroeconomic time series are interested in

Vector Autoregressive models which described the dynamic behavior of the variable in the given system. The Input-output model is an analytical approach used in evaluating the regional economic impact. It is a linear function of both sales and purchases in all sectors of economy. Wassily Leontief won the Nobel Prize at 1973 for the development of the Input-Output method and for its application to important economic problems.

The input-output model has large tables of data that presents the interconnectedness of the industries, government and households in the region. Therefore it is helpful to track the flow of money from one unit to the next. They can be used for predicting and forecasting the impacts of potential future performance of a regional economy. The input-output major components are transactions table, direct requirements tables and total requirements tables.

Computable General Equilibrium is widely used to estimate the accuracy of economic loss estimation, especially on the regional level. According to Rose (2004), it is a multi- market simulation model based on the simultaneous optimizing behavior of individual consumers and companies in react to price changes, subject to economic account balance and resource constraints. We are able to make a model of the behavioral response to input shortages and changing market conditions under natural hazard events. CGE modeling is one of approachs to analyzing impact and policy in response to disasters.

Dynamic Stochastic General Equilibrium (DSG) models can explain aggregate economic phenomena in the business cycle, economic growth, and the effect of monetary shocks. These models are based on macroeconomic models and extension of CGE models. These dynamic models help us to study how the economy evolves over time in response to any shocks.

Three decades ago, Christopher Sims (1980) proposed a new macroeconometric framework that held great promise: vector autoregressions (Stock and Watson, 2001). VAR modeling is typically applying to forecasting structures of interconnected time series and studying the dynamic effect of random shocks on a system of variables. In this approach, every endogenous variable is defined as being dependent on its own lag and the lags of other endogenous variables. The Vector Autoregressive model has proven to be especially useful for describing the dynamic behavior of economic and financial time series and for forecasting. It often provides superior forecasts to those from univariate time series models and elaborate theory-based simultaneous equations models. Forecasts from VAR models are quite flexible because

they can be made conditional on the potential future paths of specified variables in the model (Zivot et al., 2006). VAR models simplify the univariate Autoregression (AR) models by allowing for more than one evolving variable.

All variables in a VAR are treated structurally symmetrical; each variable has an equation explaining its evolution based on its own lags and the lags of the other model variables. Each variable is related not only to its own past, but also to the past of all the other variables in the system. (Diebold, 2001). Once the vector Autoregressive model has been estimated, it can be used as the multi equation forecasting model (Enders, 2010). The standard VAR model is:

$$y_t = a_i + \sum_{i=1}^{p} A_p y_{it-p} + \sum_{i=1}^{p} B_p z_{it-p} + \varepsilon_{it}$$

y_{it} is $p{\times}1$vector of endogenous variables (dependent variables), α_i is $p{\times}1$ vector of constant terms or contemporaneous relationships. A_p and B_p are matrices of estimated coefficients and ε_t is a white noise disturbances.

The VAR method has advantages and disadvantages. Sims (1980) introduced a new reduced form multivariate methodology known as Vector Autoregressive Models (VAR). One of the uses of VAR that most closely resembles the dynamic multiplier is the impulse response function. Sims major observation is that it is possible to write a general model where all variables are endogenous Forecasts do not require theory to provide information about causal relationships. We are interested in the interaction of several endogenous time series therefore Vector Autoregressive Models (VAR) can be good method for our research.

The vector autoregressive model has two major disadvantages compared to other methods. Since most aggregate economic time series are highly correlated with their own previous values and with present and past values of other time series, multicollinearity can turn out to be a serious problem while more series and lagged values of series are added to the model. As the system expands, it can become very difficult to separate the effects of the explanatory variables, and the parameter estimates can become highly sensitive to the combination of variables used in the model (Schlegel, G,. 1985).

Defining which explanatory variables are significant, while the standard errors of the coefficient estimates will have a tendency to be large, will be difficult because of existence a high

level of multicollinearity, therefore, seems to present a problem for VAR forecasting. Another disadvantage of the VAR is as the number of variables of a VAR model rises, the number of parameters to be estimated increases rapidly. If a variable is added to the model, each equation has n more coefficients to be estimated, where n is the number of lags for each variable. If a lag period is added, each equation has r more parameters, where r is the number of variables in the system.

As the number of coefficients increases relative to the amount of available data, random events of the past, as well as systematic relationships, are increasingly reflected in the coefficients. If these coefficients are used in out-of-sample prediction, a set of future random events that differs from the shocks of the past would be expected to result in less accurate forecasts (Todd 1984). The main steps of the VAR modelling approach are depicted in figure 3.5.

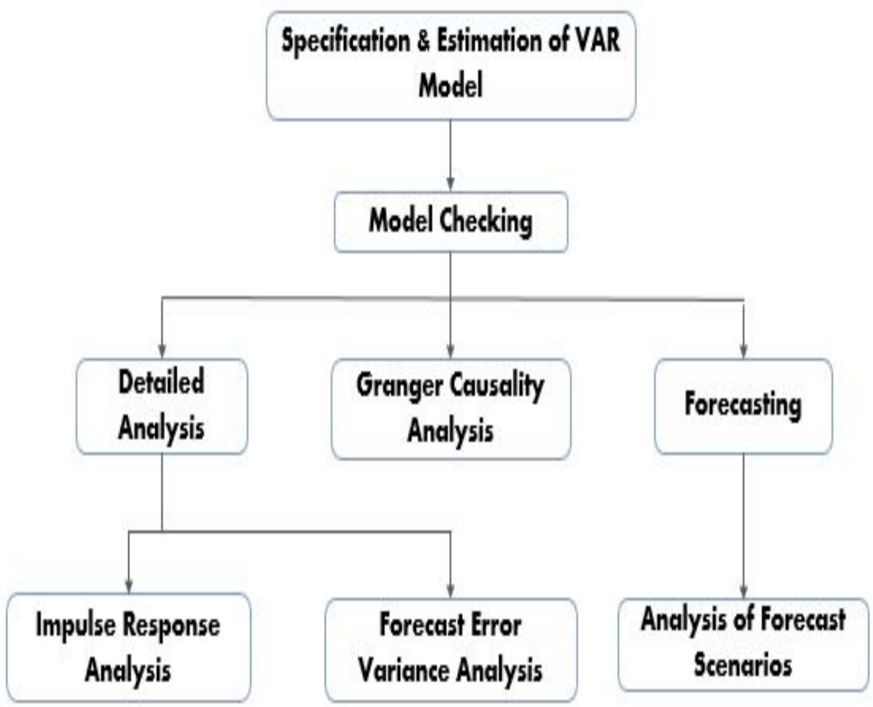

Figure 3.5 Vector Autoregressive (VAR) analysis

3.7 The Model

In this study a VAR modeling approach is adopted. Vector Autoregression (VAR) was introduced by Sims (1980) as a technique that could be applied by macroeconomists to describe the shared dynamic behavior of a collection of variables without needing strong restrictions. The VAR modeling is generally used for forecasting systems of interrelated time series and analyzing the dynamic impact of random disturbance on the system of variable. It has become a prevalent method of time-series modeling. The VAR model has established to be especially valuable for describing the dynamic behavior of economic and financial time series and also for forecasting. Forecasts from VAR models are pretty flexible because they can be set conditional on the potential future paths of specified variables in the system.

The Vector Autoregression model is also applicable for policy analysis. In structural analysis, certain assumptions about the causal structure of the data under investigation are imposed, and the resulting causal impacts of unexpected shocks or innovations to specify variables on the variables in the model are summarized (Zivot, 2006). These causal impacts are usually summarized with impulse response functions and forecast error variance decompositions.

3.7.1 Checking the Model

Model specification in the present context involves selecting the VAR order and Granger Causality test and possibly imposing restrictions on the VAR parameters. The VAR model can be used for investigating relations between the variables. A specific type of relation is known as Granger Causality (Granger 1969).

3.7.2 Choosing Lag Length

Choosing the appropriate lag-length is a main concern in the specification of VAR models therefore we must consider what variables should be in the VAR model in advance. The correct model specification plays an important role in all intervention in the VAR model. Lutkephl (1993) indicates that selecting a higher order lag length than the true lag one causes an increase in the mean square forecast error in the VAR and that under fitting the lag length often generates auto correlated errors. Braun and Mittnik (1993) show that impulse response functions and variance decompositions are inconsistently derived from the estimated VAR when the lag length differs from the true lag length. Information criteria are designed to consistently check the model that fits

better the data from a group of models. The common approach is to fit VAR (p) models with orders $p = 0, \dots, p_{max}$ and choose the value of p which minimizes some model selection criteria. The Akaike (AIC), Schwarz-Bayesian (BIC) and Hannan-Quinn (HQ) are the three most common information criteria to help use to choose p:

$$AIC(p) = Ln\left|\sum(p)\right| + \frac{2}{T}pn^2$$

$$BIC(p) = Ln\left|\sum(p)\right| + \frac{\ln T}{T}pn^2$$

$$HQ(p) = Ln\left|\sum(p)\right| + \frac{2\ln\ln T}{T}pn^2$$

T is the number of observation and n is the number of parameters.$\sum$ is estimated covariance matrix. The AIC criterion asymptotically overestimates the order with positive probability, while the BIC and HQ criteria estimate the order consistently under fairly general conditions if the true order p is less than or equal to p_{max}.

3.7.3 Granger Causality Test

The Granger causality is a statistical hypothesis test for examining that a time series is applicable in forecasting another time series or not. A time series X is Granger cause of Y if current values of X have statistically significant information regarding the Y in future. Assume Y and X are stationary time series. X is said to Granger cause Y if Y can be better predicted if estimated by both X and Y than only using Y.

$$\mathrm{Y(t)} = \sum_{i=1}^{L} \alpha_i \, \mathrm{Y(t-i)} + \varepsilon_1(t)$$

$$\mathrm{Y(t)} = \sum_{i=1}^{L} \alpha_i \, \mathrm{Y(t-i)} + \sum_{i=1}^{H} \beta_i \, \mathrm{X(t-i)} + \varepsilon_2(t)$$

Multivariate Granger causality analysis is usually performed by fitting a vector autoregressive model (VAR) to the time series. Granger (1969) called a variable y_{2t} causal for a variable y_{1t} if the facts in the past and present of $y_{2t}$is useful for improving the forecasts of y_{1t}.

3.7.4 Dummy Variable

Dummy variables can be very useful in time series applications. A dummy variable represents, in each time period when the unit of our observation is time, a specific event has happened. For example, for looking at the impact of BP oil spill or hurricane Katrina in all Gulf of Mexico states, we can define a dummy variable for each year equal to one if these states had impacts during that year, and zero otherwise. In this example the dummy variable value will be one for 2005 and for the rest it will be zero. Often dummy variables are used to isolate certain periods that may be systematically different from other periods covered by a data set (Wooldridge, 2013).

3.8 Structural Analysis

The interaction between economic variables is considered by studying the consequences of changes in one variable on the other variables of concern. Therefore, the effects of nonzero residuals or shocks are traced through the system by studying the relations between variables. This type of analysis is well-known as impulse response analysis. Forecast error variance decompositions are another tool for examining the impacts of any shock in VAR models.

3.8.1 Impulse Response Function

The Impulse response function measures the dynamic effects of any external disturbance in a given economic system and also characterizes the stability and duration of such effects. In other words, an impulse response represents the defined response of a time series model to an innovations development that has the worth of one standard deviation in one element at the initial time, and zeros in all others. If there is a reaction of one variable to an impulse in another variable we will study that by tracing out the effect of an exogenous shock or innovation in one of the variables on some or all of the other variables. A VAR can be written in vector MA (∞) form as:

$$y_t = \mu + \varepsilon_t + \varphi_1 \varepsilon_{t-1} + \varphi_2 \varepsilon_{t-2} + \cdots.$$

Thus, the matrix φ_s

$$\frac{\partial y_{t+s}}{\partial \varepsilon_t'} = \varphi_s$$

has the interpretation that φ_s is the response to a one unit increase in the *j*th variable's innovation at time t (ε_{jt}) for the value of the i-th variable at time $t + s(y_{t+s})$. $\frac{\partial y_{i\,t+s}}{\partial \varepsilon'_{jt}}$ as a function of s is known as the impulse response function (IRF). It describes the response of y_{it+s} to a one-time impulse in y_{jt} with all other variables dated t or earlier held constant. In the other word, the impulse response represents the effects of unit shocks in the variables of the system after i periods. A shock to the i-th variable immediately touches the i-th variable, and as well transmitted to all of the endogenous variable through the VAR since the lagged of that is appears in all equations.

In the other word, the φ_s's point out any random disturbance in our system. Thus the φ_i matrices represent the model's response to a unit shock/innovation at time t in each of the variables i periods ahead. It named dynamic multipliers in economic literature. The response of y_i to a unit shock in y_j is known as Impulse Response function. If we suppose the first element in ε_t changes by δ_1 at the same time that the second element changes by δ_2 and till the *m*th element by δ_m, then cumulative impact of all these changes on y_{t+s} would be specified by:

$$\Delta y_{t+s} = \frac{\partial y_{t+s}}{\partial \epsilon_{1t}} \delta_1 + \cdots + \frac{\partial y_{t+s}}{\partial \epsilon_{mt}} \delta_m = \varphi_s \delta$$

Where $\delta' = (\delta_1, \ldots, \delta_m)$.

Impulse response function shows the dynamic paths of the effects of an independent shock of one variable on another variable and it is also useful for characterizing the stability and duration of such effects. The persistence of such a shock reveals how fast the system will return to its original equilibrium. The faster it takes a shock to dampen, the shorter the adjustment period (Brown and Yucel, 1995).

3.8.2 Variance Decomposition

Forecast error variance decompositions are another tool for studying the impacts of shocks in VAR models. The variance decomposition presents facts regarding to relative importance of any accidental innovation that touching the variables in the VAR. What portion of the variance of the forecast error in predicting $y_{i,t+n}$is due to the structural shock? Given our structural model:

$$y_{t+n} = \bar{y} + \sum_{i=0}^{\infty} \emptyset_{11}(i)\epsilon_{y_{t+n-i}} + \sum_{i=0}^{\infty} \emptyset_{12}(i)\epsilon_{z_{t+n-i}}$$

$$y_{t+n} - E_t y_{t+n} = \emptyset_{11}(0)\epsilon_{y_{t+n}+}\emptyset_{11}(1)\epsilon_{y_{t+n-1}} + \cdots + \emptyset_{11}(n-1)\epsilon_{y_{t+n}} + \emptyset_{12}(0)\epsilon_{z_t} + \emptyset_{12}(1)\epsilon_{z_{t+n-1}} + \cdots + \emptyset_{12}(n-1)\epsilon_{z_{t+1}}$$

The forecast error variance:

$$E(y_{t+n} - E_t y_{t+n})^2 = \sigma_y^2(n) = \sigma_y^2[\varphi_{11}(0)^2 + \varphi_{11}(1)^2 + \cdots + \varphi_{11}(n-1)^2] + \sigma_z^2[\varphi_{12}(0)^2 + \varphi_{12}(1)^2 + \cdots + \varphi_{12}(n-1)^2]$$

Base of this formula, we can compute the proportion of the total variance of the forecast error for each variable attributable to the variance of each structural shock. The proportion of the n-period ahead forecast error variance due to y is:

$$\frac{\sigma_y^2[\varphi_{11}(0)^2 + \varphi_{11}(1)^2 + \cdots + \varphi_{11}(n-1)^2}{\sigma_y^2(n)}$$

3.9 Case Study

In this study, to determine the likely magnitude of the net economic impact of a major oil spill using the Macondo oil spill as an example. Our analysis is based on a dynamic simultaneous equation model in the form of a structural VAR. Let y_t be a vector of endogenous variables including the percent change in Louisiana employment, the real price of crude oil and the change in Texas employment and industry production rate. All data are monthly. The sample period is 1983:1–2014:10. We remove seasonal variation by including seasonal dummies in the VAR model.

3.9.1 Net Economic Impact of Macondo Oil Spill

To advance quantify the reaction of the economic performance indicators to general shocks (Katrina, BP oil spill) in Gulf States, the impulse response function technique for characterizing the dynamic effects of an unexpected shock in a given economic system is applied to Louisiana and Texas separately. Impulse response function shows the dynamic paths of the

effects of an independent shock of one variable on another variable and it is also useful for characterizing the stability and duration of such effects.

3.9.2 Choosing Lag Length

The next step in building our model is the finding appropriate number of lags of y_t to include in the VAR model. Choosing the appropriate lag-length is a main concern in the specification of VAR models therefore we must consider what variables should be in the VAR model in advance. In order to identify the suitable lag length of our VAR, we estimate multiple VARs of varying lag lengths and compute a variety of test statistics. The Stata's *varsoc* command estimates the entire set silently and reports a table of test statistics.

For each lag length, the table reports the log of the likelihood function (LL): a likelihood ratio test statistic (LR) followed by its degrees of freedom (df) and P-value. And then information criteria: The Akaike (AIC), Schwarz-Bayesian (BIC) and Hannan-Quinn (HQ). For each statistic, the preferred value is marked with a *. These information criteria are based on information theory and are supposed to indicate the relative information lost when the data are fit using different specifications. The lag length that produces the minimum value of the information statistic is the preferred specification (Becketti, 2013). In this study, the FPE and AIC prefer 7 lags, also the HQIC prefers 7 lags, and the SBIC chooses 2 lags. According to Lutkephl (2005), the SBIC and HQIC provide consistent estimates of the true lag order than the FPE and AIC. Therefore, we are going to use 2 lags to match the specification. (Figure 3.6)

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	3205.46				2.4e-14	-20.0091	-19.9903	-19.962
1	3829.28	1247.6	16	0.000	5.4e-16	-23.808	-23.714	-23.5725
2	3888.94	119.32	16	0.000	4.1e-16	-24.0809	-23.9116	-23.657*
3	3903.93	29.975	16	0.018	4.1e-16	-24.0746	-23.83	-23.4622
4	3925.58	43.298	16	0.000	4.0e-16	-24.1099	-23.7901	-23.3091
5	3939.89	28.627	16	0.027	4.0e-16	-24.0993	-23.7043	-23.1101
6	4021.1	162.41	16	0.000	2.7e-16	-24.5069	-24.0366*	-23.3293
7	4041	39.798*	16	0.001	2.6e-16*	-24.5312*	-23.9858	-23.1652

Figure 3.6 Summary of Statistics of choosing the appropriate lag-length

3.10 Results of Different Scenarios

The study will find the impact of such shocks on the employment numbers and wages in the Gulf Coast region. This research uses econometric tools to provide quantitative estimates of the response and correlation between past and current activities of Louisiana employment and other relevant regional economies. Here we defined different scenarios to compare the correlation of different variables (industries/states) and how they respond to the shock in the system.

3.10.1 Scenario 1: Interactions among The Oil And Gas Industry And Related Businesses

We are interested in the response of Louisiana industries employment to any shock in oil and gas industry. In other word, how is oil and gas industry and construction employment effect oil and gas industry in future. The VAR model, which describes the interactions among the oil and gas industry, service providing, construction is represented by the following system of equations:

$$y_{1t} = a_{10} + \sum_{k=1}^{n} \beta_{1i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{1i} y_{2t-i} + \sum_{k=1}^{n} \omega_{1i} y_{3t-i} + \varepsilon_{1t}$$

$$y_{2t} = a_{20} + \sum_{k=1}^{n} \beta_{2i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{2i} y_{2t-i} + \sum_{k=1}^{n} \omega_{2i} y_{3t-i} + \varepsilon_{2t}$$

$$y_{3t} = a_{30} + \sum_{k=1}^{n} \beta_{3i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{3i} y_{2t-i} + \sum_{k=1}^{n} \omega_{3i} y_{3t-i} + \varepsilon_{3t}$$

y_{it} (i=1,2,3) is $k\times1$vector of endogenous variables for oil and gas industry, service providing, construction (i), α_{i0} is $k\times1$ vector of constant terms. β_{ti} matrix of estimated coefficients on the lagged value of oil and gas employment y_{1t} and γ_{ti} matrix of estimated coefficients on the lagged value of service providing y_{2t} , and ω_{ti} matrix of estimated coefficients on the lagged value of constructiony_{3t},, and , ε_{It} is a white noise term for each i. the lag length (n) is equal to 2. The impulse response of oil and gas Louisiana employment to a one time positive shock to oil shock is presented in figure 14 and 15. The Katrina in 2005 caused disruption in the oil and gas industry that we considered as dummy variable, which has impact for a year on industries. Figure 3.7 shows the structural IRF of an innovation in oil and gas employment shock on own industry employment in Louisiana, indicating that a positive shock to

oil and gas industry causes an increase in oil and gas industry, which dies out after 4 or 5 periods.

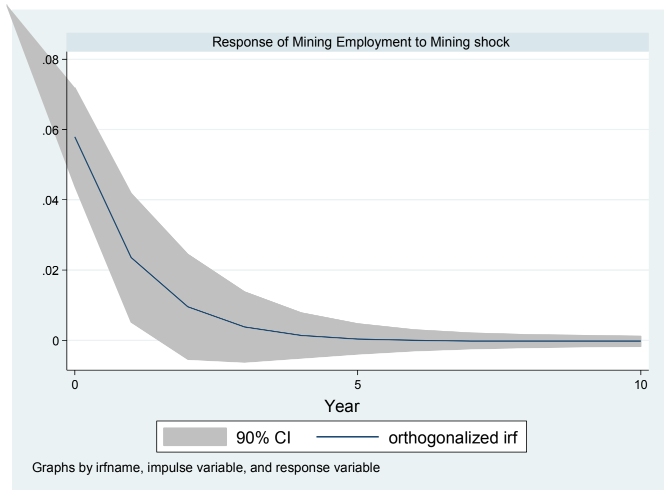

Figure 3.7 Respnse of oil and gas industry to own shock

Figure 3.8 presents if we have shock in oil and gas industry it will push the Louisiana construction employment up and slowly decay back to get to the zero or equilibrium. IRF represents the positive relationship between these industries.

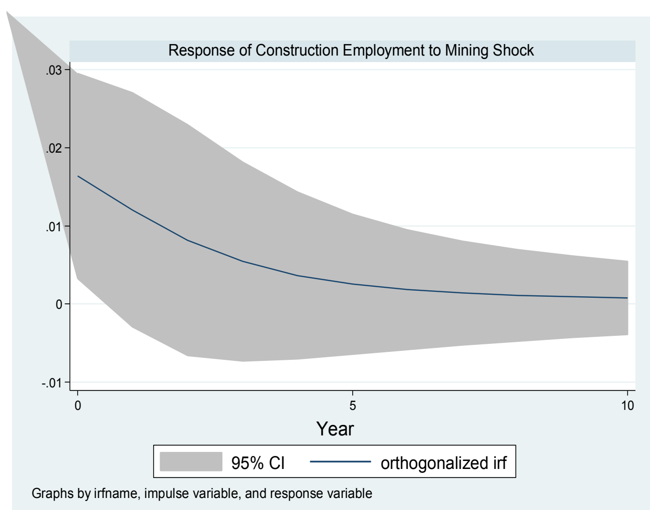

Figure 3.8 Respnse of construction to oil and gas industry shock

In this study we estimate that if any decline happens in oil and gas industry how will be the impact of it on other industry. As figure 3.8 shows if we have 5 percent decline in oil and gas industry in Louisiana it will be persistent for a while and after 3 years it starts to decay.

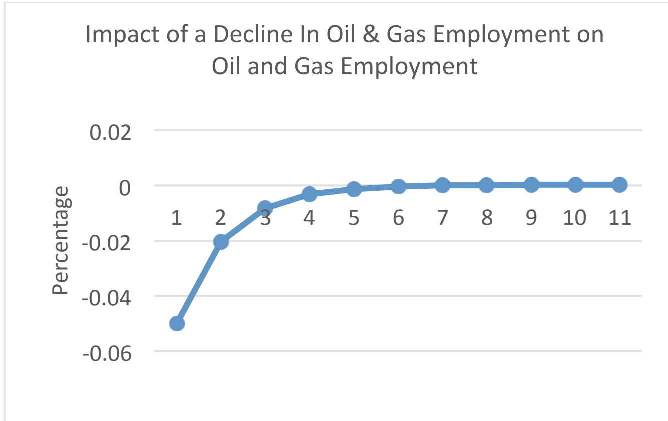

Figure 3.9 Five percent decline in oil and gas industry in Louisiana

The responses of different impulses in this model are shown to demonstrate the interdependence of various time series data. It represents the impact of oil and gas industry is significant after first year and it starts to decay after 3-4 years.

3.10.2 Scenario 2: Predicting Louisiana Employment

The VAR model, which describes the interactions among Louisiana employment, Texas employment, oil price and U.S. industry production rate, is represented by the following system of equations:

$$y_{1t} = a_{10} + \sum_{k=1}^{n} \beta_{1i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{1i} y_{2t-i} + \sum_{k=1}^{n} \omega_{1i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{1i}\, y_{4t-i} + \varepsilon_{1t}$$

$$y_{2t} = a_{20} + \sum_{k=1}^{n} \beta_{2i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{2i} y_{2t-i} + \sum_{k=1}^{n} \omega_{2i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{2i}\, y_{4t-i} + \varepsilon_{2t}$$

$$y_{3t} = a_{30} + \sum_{k=1}^{n} \beta_{3i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{3i} y_{2t-i} + \sum_{k=1}^{n} \omega_{3i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{3i}\, y_{4t-i} + \varepsilon_{3t}$$

$$y_{4t} = a_{40} + \sum_{k=1}^{n} \beta_{4i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{4i} y_{2t-i} + \sum_{k=1}^{n} \omega_{4i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{4i}\, y_{4t-i} + \varepsilon_{4t}$$

y_{it} (i=1,2,3,4) is $k\times1$vector of endogenous variables for oil and gas industry, service providing, Louisiana and Texas employment (i), α_{i0} is $k\times1$ vector of constant terms. β_{ti} matrix of estimated coefficients on the lagged value of Louisiana employmenty_{1t} and γ_{ti} matrix of estimated coefficients on the lagged value of Texas employment y_{2t} , and ω_{ti} matrix of estimated

coefficients on the lagged value of oil price y_{3t},, and φ_{ti}matrix of estimated coefficients on the lagged value of U.S. industry production ratey_{4t} , ε_{It} is a white noise term for each i.

Our analysis is based on a dynamic simultaneous equation model in the form of a VAR. Let $y_t$be a vector of endogenous variables including the percent change in Louisiana employment, Texas employment, the real price of oil and the change in production industries and change in oil production rate. All data are monthly. The sample period is 1983:1–2014:10. We remove seasonal variation by including seasonal dummies in the VAR model. The graph 3.10 represents the response of Louisiana employment to a one time positive shock on own employment.it indicates 0.4 increase in Louisiana employment, which dies out after4 or 5 periods.

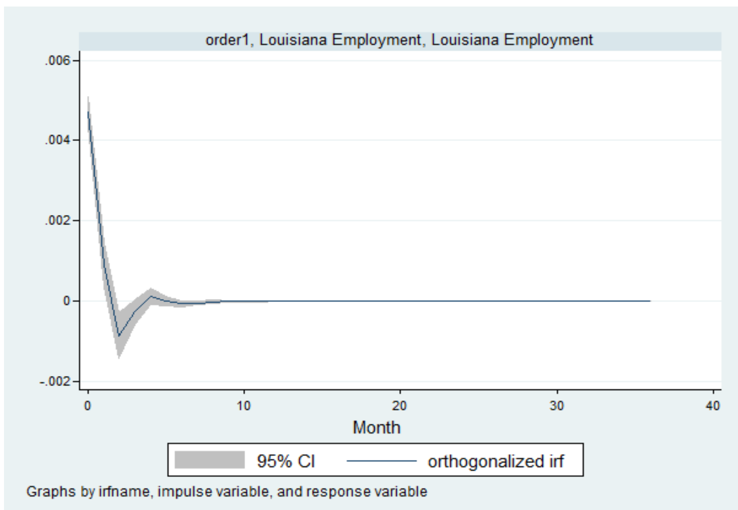

Figure 3.10 Response of Louisiana employment to own shocks

The figure 3.11 presents if we have shocks in production industry it will push the Louisiana employment up for 0.1 percent up and after about 35 periods will back to the equilibrium. It shows the impulse response of Louisiana employment to an oil production shocks. That has sharp negative impact on Louisiana employment and it gets back to normal situation about 10 months later

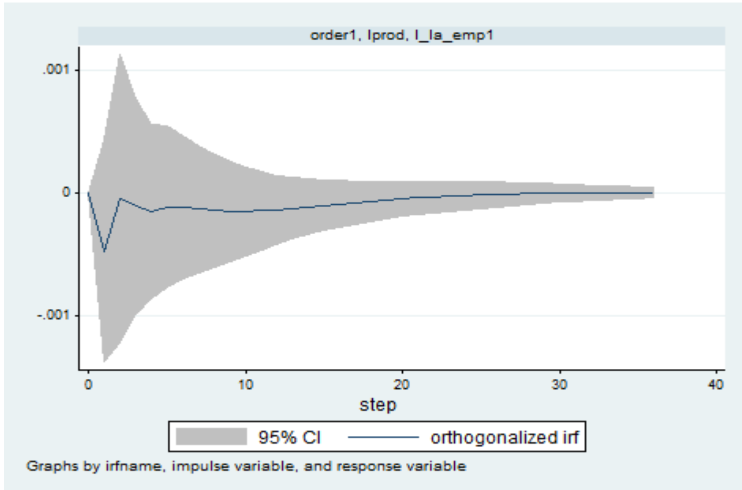

Figure 3.11 Response of Louisiana employment to production shocks

Figure 3.12 shows the response of Louisiana employment to U.S. industry production shock. According to impulse response graph, Louisiana employment gets negative impact at the beginning then it starts to be decrease this negative impact. After 4 or 5 months the Louisiana employment impact get back to normal situation.

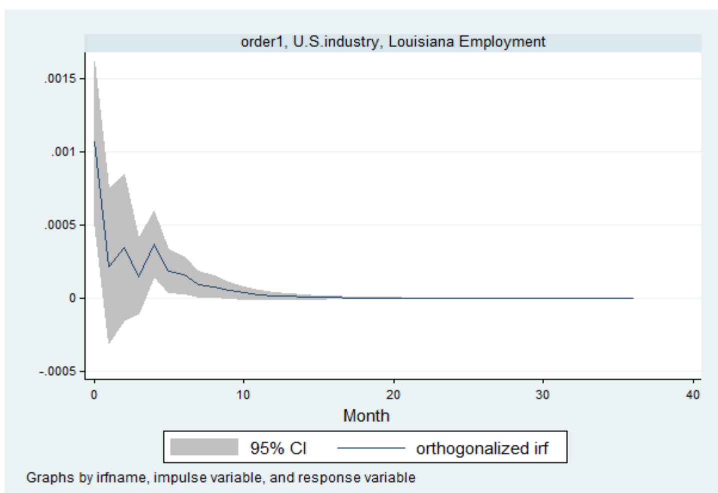

Figure 3.12 Response of Louisiana employment to U.S. industry production shocks

Figure 3.13 shows the response of Louisiana employment to oil price shock. According to impulse response graph, Louisiana employment gets negative impact at the beginning then it starts to be decrease this negative impact. After 6 or 7 months the Louisiana employment impact get back to zero.

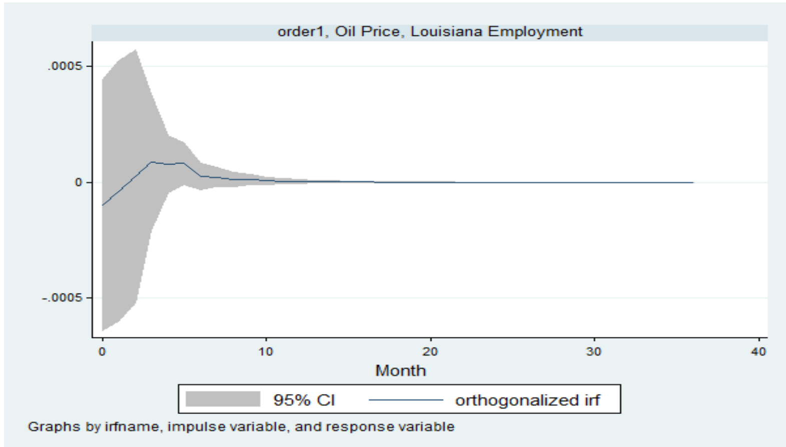

Figure 3.13 Response of Louisiana employment to oil price shocks

The graph 3.14 represents the response of Louisiana employment to a one time positive shock on Texas employment and after 5 periods (months) will get back to pre-shock situation.

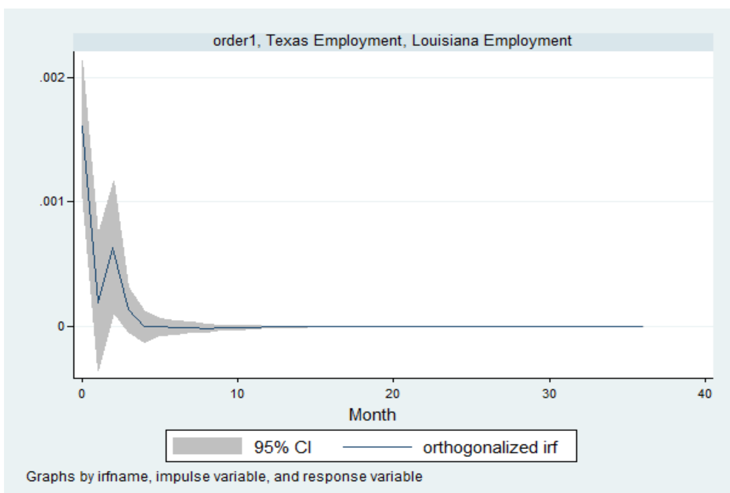

Figure 3.14 Response of Louisiana employment to Texas employment

3.10.3 Scenario 3: Adding Industrial Production for Mining To The Model

In this scenario, we add new data category to scenario 2 model. We add Industrial Production for Mining: Drilling oil and gas wells to our model to compare the result with previous scenario. We want to consider the effect of presence of the industrial Production for Mining in our system. The sample period is 1983:1–2014:10. We remove seasonal variation by including seasonal dummies in the VAR model. Our analysis is based on a dynamic simultaneous equation model in the form of a VAR. Let y_t be a vector of endogenous variables containing the percent change in Louisiana employment, Texas employment, the real price of oil and the change

in U.S. Industry production and. All data are monthly. The VAR model, which describes the interactions among Louisiana employment, Texas employment, oil price and U.S. industry production rate and oil and gas industry production rate, is represented by the following system of equations:

$$y_{1t} = a_{10} + \sum_{k=1}^{n} \beta_{1i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{1i} y_{2t-i} + \sum_{k=1}^{n} \omega_{1i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{1i}\, y_{4t-i} + \sum_{k=1}^{n} \lambda_{1i}\, y_{5t-i} + \varepsilon_{1t}$$

$$y_{2t} = a_{20} + \sum_{k=1}^{n} \beta_{2i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{2i} y_{2t-i} + \sum_{k=1}^{n} \omega_{2i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{2i}\, y_{4t-i} + \sum_{k=1}^{n} \lambda_{2i}\, y_{5t-i} + \varepsilon_{2t}$$

$$y_{3t} = a_{30} + \sum_{k=1}^{n} \beta_{3i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{3i} y_{2t-i} + \sum_{k=1}^{n} \omega_{3i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{3i}\, y_{4t-i} + \sum_{k=1}^{n} \lambda_{3i}\, y_{5t-i} + \varepsilon_{3t}$$

$$y_{4t} = a_{40} + \sum_{k=1}^{n} \beta_{4i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{4i} y_{2t-i} + \sum_{k=1}^{n} \omega_{4i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{4i}\, y_{4t-i} + \sum_{k=1}^{n} \lambda_{4i}\, y_{5t-i} + \varepsilon_{4t}$$

$$y_{5t} = a_{40} + \sum_{k=1}^{n} \beta_{5i} y_{1t-i} + \sum_{k=1}^{n} \gamma_{5i} y_{2t-i} + \sum_{k=1}^{n} \omega_{5i} y_{3t-i} + \sum_{k=1}^{n} \varphi_{5i}\, y_{4t-i} + \sum_{k=1}^{n} \lambda_{5i}\, y_{5t-i} + \varepsilon_{5t}$$

y_{it} (i=1, 2, 3, 4, 5) is $k\times 1$vector of endogenous variables for oil and gas industry, service providing, Louisiana and Texas employment (i), α_{i0} is $k\times 1$ vector of constant terms. β_{ti} matrix of estimated coefficients on the lagged value of Louisiana employmenty_{1t} and γ_{ti} matrix of estimated coefficients on the lagged value of Texas employment y_{2t} , and ω_{ti} matrix of estimated coefficients on the lagged value of oil price y_{3t},, and φ_{ti}matrix of estimated coefficients on the lagged value of U.S. industry production ratey_{4t} ,, and λ_{ti}matrix of estimated coefficients on the lagged value of oil and gas industry production ratey_{5t}, ε_{It} is a white noise term for each i.

The dynamic response of Louisiana employment to Texas employment and its own shocks are depicted in figures 3.15 and 3.16 positive shock to Louisiana employment initially leads to a positive response from Louisiana employment. Figure 3.15 presents the response of Louisiana employment to its own shocks.

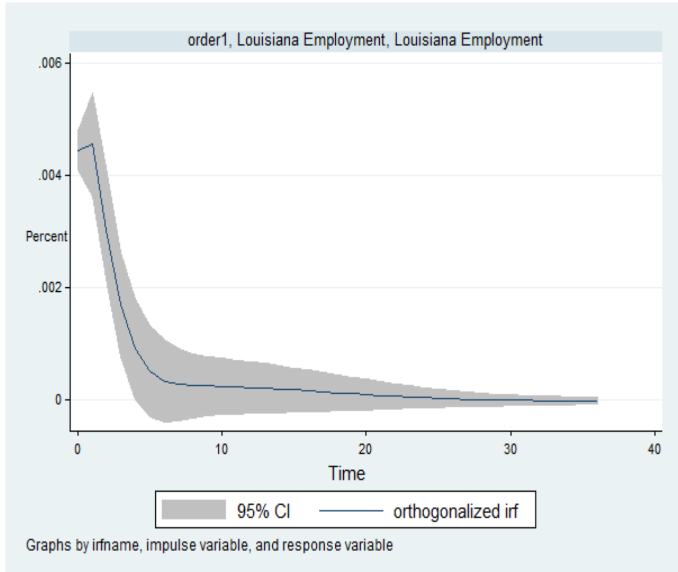

Figure 3.15 Response of Louisiana employment to its own shocks

The impulse response of Louisiana employment increase in response to the Texas employment (Figure 3.16). It is also noted that both impulse responses return to their original equilibrium levels.

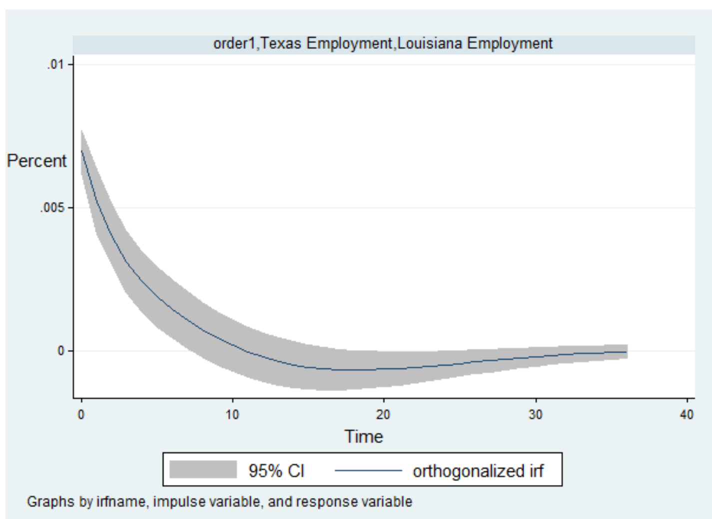

Figure 3.16 Response of Louisiana employment to Texas employment shocks

On the other hand, the Louisiana employment (Figure 3.17) rises within ten periods to a maximum of 0.002 above the initial equilibrium and then gradually moves forwards equilibrium after reaching its maximum.

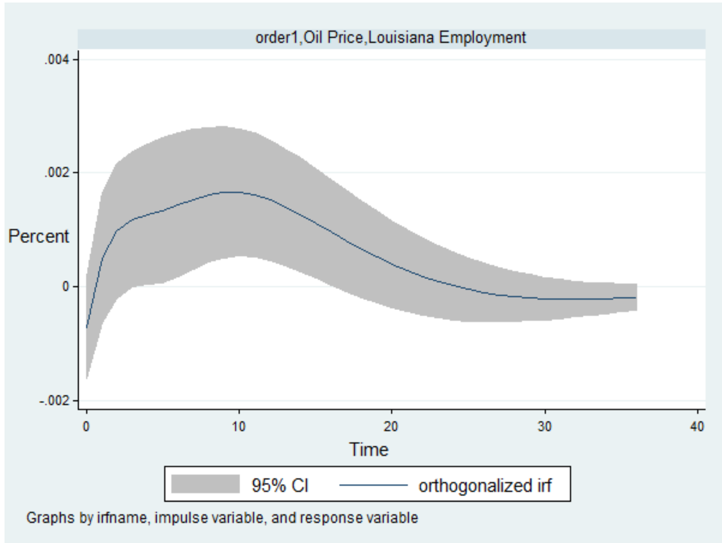

Figure 3.17 Response of Louisiana employment to oil price shocks

The impulse response of Louisiana employment to a one time positive shock to U.S industry production and oil and gas industry production are presented in figures 3.18 through 3.19. Figure 3.18 presents the response of Louisiana employment to a one time positive1-standard deviation shock to U.S industry production. The immediate effect is an increase in employment rate.

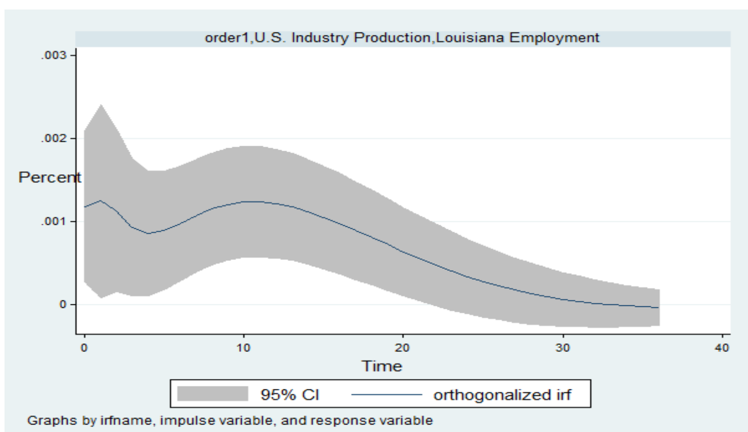

Figure 3.18 Response of Louisiana employment to industry Production shocks

Figure 3.19 shows the response of Louisiana employment to a one time positive shock to oil and gas industry production. The highest level of Louisiana employment reached is about 0.0013 after about 8 months above its initial equilibrium level while the minimum reached is 0.0003 below equilibrium.

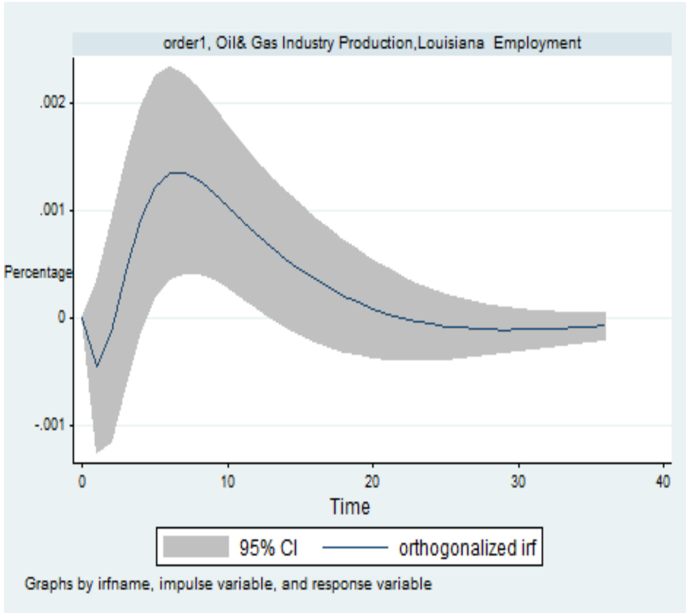

Figure 3.19 Response of Louisiana employment to oil & gas industry shocks

3.10.4 Scenario 4: Model with Intervention

Suppose that at time t = T (where T will be known), there has been an intervention to a time series. By intervention, we mean a change to a procedure, or law, or policy, etc. that is intended to change the values of the series y_t. We want to estimate how much the intervention has changed the series (if at all). Here in our study, the hurricanes Katrina is an intervention to the time series.

$$y_t = a_0 + A(L)y_{t-1} + B(L)y_{t-2} + c_0 z_t + C(L)\varepsilon_t$$

y_t is $k\times1$vector of endogenous variables for oil and gas industry employment, a_0 is $k\times1$ vector of constant terms. $A(L)$ and $B(L)$ are $k\times k$ matrix of estimated coefficients on the lagged value of y_t and ε_t is a white noise term. The dummy variable $z_t$will be determined in the systems as an intervention. It captures the period when the hurricane Katrina 2005 is happened. The short term impact of Katina on oil and gas industry is 6. Percent decline. The long time impact is 44 percent. The reason for estimating this model is justifying the previous results in scenario1. This estimation is focused on the impact of Katerina and Rita hurricanes specifically on oil and gas industry employment. This model does not give us reasonable results. We are working on it to get better results for it. The results are not reliable.

3.11 Forecasting Louisiana Employment

Calculating forecasts from a VAR is straightforward. An important decision in any time series model is to select either one-step-ahead forecasts or dynamic forecasts. Whenever predicting beyond one period, the dynamic forecasts occur and intermediate predicted values of at least some of the lagged variables are needed to complete the VAR model system information. In the forecast study, the duration during 3 years (2010:4 to 2013:4) is reserved for out of the sample forecasts. Louisiana employment forecasts rarely drift too far away from actual observations (Fig. 3.19).

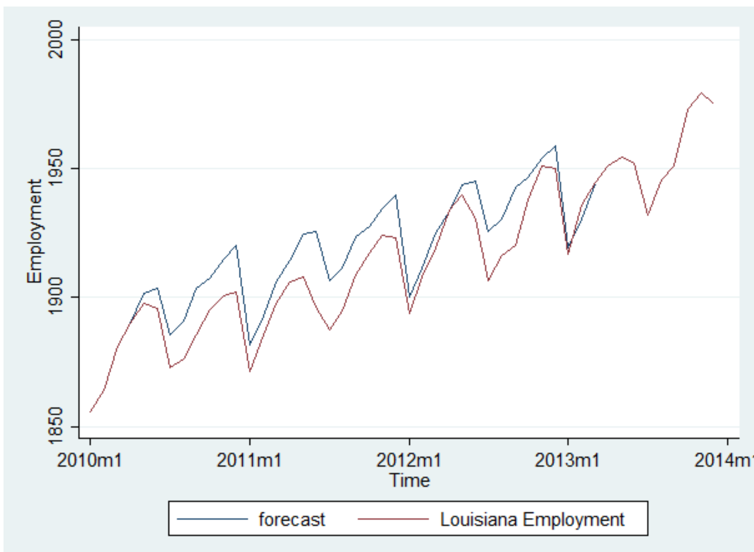

Figure 3.20 Forecast of Louisiana Employment 2010:4-2012:4

The blue line (forecast estimate) is Louisiana employment in absence of the Deepwater Horizon oil spill event while the red line is the actual observation (data) of Louisiana employment indicating the influence of the oil spill event. The differences between these forecast estimates and data are termed as the loss. Note that the Louisiana employment data and its forecast estimates match after about three years duration since the Deepwater Horizon oil spill in 2010 indicating recovery in this VAR model (Fig. 3.20). Similarily, the amount of wage loss that would exist between the forecast estimates and actual value (data) are presented in Fig. 3.21 and it can be concluded that the VAR model suggests recovery to the same levels prior to the spill event in three years.

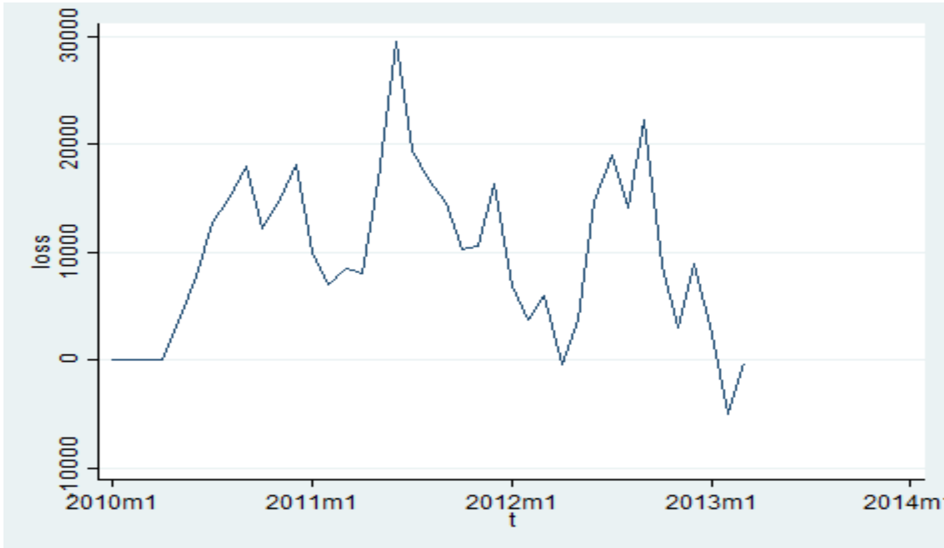

Figure 3.21 Louisiana Employment Loss 2010:4-2013:1

Dynamic forecasts after oil spill event starts after April 2010 for 36 periods. Table 3.2 presents the job loss, wage loss based on the forecast estimates data during the first year (2010:5-2011:4)after the spill event by considering dummy variable hurricane Katrina in 2005. It was estimated that in April 2011 (one year after oil spill) the state of Lousiana had lost 2568 jobs. This number is slightly lower than the numbers immediately following the Deepwater Horizon oil spill. Based on the results in Table 3.3 the average wage loss after the Deepwater Horizon oil spill in 2010 is equal to $27,493 and in a year later is equal to $ 41,013. The average number of job lost in 2010 is equivalent to 9,236 and in 2011 is 8,260 jobs.

Table 3.2 Number of Employment in thousands and wages losses after 2010 oil spill

Time	Lost Employment*	Percent	Wage loss($)	percent
2010m5	2727.6	0.15%	$8,829	0.1%
2010m6	6184.6	0.34%	$20,024	0.3%
2010m7	9980.2	0.55%	$33,222	0.5%
2010m8	11417.1	0.63%	$37,928	0.6%
2010m9	13739.1	0.76%	$45,385	0.7%
2010m10	7464.2	0.41%	$27,235	0.4%
2010m11	9556.3	0.53%	$34,758	0.5%
2010m12	12819.5	0.71%	$46,546	0.7%
2011m1	4696.4	0.26%	$15,828	0.3%
2011m2	1638.7	0.09%	$5,486	0.1%
2011m3	2934.1	0.16%	$9,757	0.2%
2011m4	2568.0	0.14%	$8,577	0.1%

We estimate that in April 2011, one year after oil spill, state of Lousiana lost 2568 of jobs. This number has been decreased to compare when the Macondo disaster happened. Figure 3.21 shows the trend of Louisiana Employment Loss in 2010:4-2013:1 that is gradually decay and get back close zero a year after oil spill. The average wage loss in 2010 is $ 27,493 and in 2011 is $ 41,013 after the Deep water Horizon oil spill happens in 2010. The estimation for 2010 leads to a smaller average wage loss because the jobs are only lost for 2/3 of the year.

Figure 3.22 Louisiana Employment Loss 2010:4-2013:1

We approximated one year after oil spill in April 2011, state of Lousiana employments lost 2478.8 thousands of dollars of their wages. This number has been decreased to compare when the Deepwater Horizon oil spill happened. The figure 3.22 shows the trend of Louisiana Employment Loss in 2010:4-2013:1 that is gradually falling-off and getting back to zero a year after oil spill.

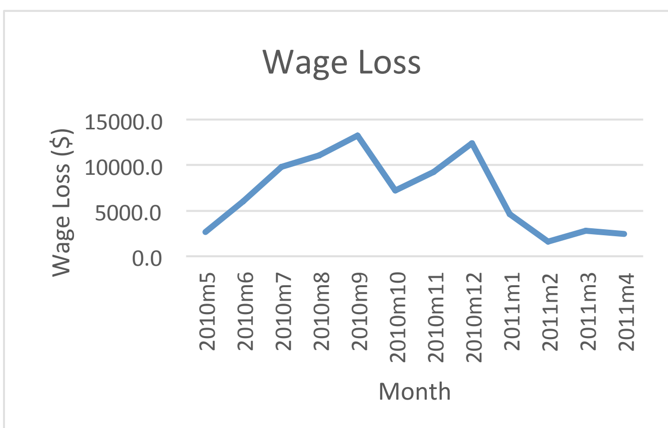

Figure 3.23 Louisiana Employment WageLoss 2010:4-2013:1

3.12 Conclusion

In this research study, the likely magnitude of the net economic impacts of a major oil spill like the Deepwater Horizon oil spill in 2010 are determined with Vector Autoregressive (VAR) method. Also, forecast estimates of changes in employment and wages after the disaster are investigated for the state of Louisiana data. This research used recent econometric tools to provide quantitative estimates of the sensitivity and correlation between past and current activities of Louisiana employment and other relevant regional economies. The Impulse response function measures the dynamic effects of any change/shock in oil and gas industry and in a given economic system and also characterizes the stability and duration of such effects. This method is not useful specifically for oil spill or hurricane, however it is applicable for measuring impact of any change (shock) in oil price, transporting oil, refinery, technology of equipment, etc. therefore we understand what measures must be taken to recover from the change (shock) or to reduce the recovery time and consequences for facing future changes.

Impacts of different shocks on various aspects of Louisiana's economic performance are estimated using a Vector Autoregressive (VAR) model. Louisiana and Texas employment time series were selected based on their unique structural and economic characteristics indicated in each one and their role in oil and gas industry and how they dependent on each other. What is more exceptional is the effect of oil and gas industry on the incomes of Louisianans employees in different industries. The dynamic responses of Louisiana employment, Texas employment, oil price and U.S. industry production to various disasters are considered. The estimates on Louisiana employment and wage losses from the oil and gas industry disruption due to the oil spill and hurricanes indicate recovery to the pre-spill event values within three years. However, the approximate wage loss in Lousiana is estimated about $2.5M even after one year from the spill event. Though, we should manage to pay for the opportunity to make the best of a bad situation. With thousands of working oil and gas platforms still operating in the Gulf, there is difficulty to find more accurate answers and better prepare for the unpredictable next spill. Help prevent another disaster by taking action to make the exploration safer. Safety is an essential value of the oil and gas industry. In the next chapter, we will estimate the gross economic damage of BP accidents to Louisiana. These information can be guidance how respond to the economic impact of events by having information on calculating the economic impact of future large-scale catastrophes.

CHAPTER 4: REGIONAL INPUT-OUTPUT ANALYSIS IN LOUISIANA AFTERSHOCK OF THE DEEPWATER HORIZON ACCIDENT

4.1 Introduction

In this chapter, Input-Output model will be used to estimate the offset created by BP spending. Chapter 3 contained VAR estimates of the net impact of the BP oil spill on the Louisiana economy measured by lost employment, output, earnings, and tax revenues. By definition the net loss equals the gross loss (economic damages created by the spill) minus the offsetting economic injection due to BP expenditures in the economy. The scale of BP expenditures on stopping the leaks, cleaning up the oil spill, and payments of damages to Louisiana citizens is measured in the billions. The final missing element, gross damages of BP to Louisiana before offsets are the sum of the net loss and offsets. The question addressed in the next section is whether the gross damage estimates implied by Chapters 3 and 4 appear realistic. This question may also have implications with regard to the methodology employed in this study and by economic experts of the BP court proceedings. More importantly, the final results should provide a useful information on measuring the economic impact of future large scale disasters and for how companies should react to the economic impact of events.

After the Deepwater Horizon oil spill, BP took responsibility for the clean-up, respond quickly due to pay compensation people affected by the impact of the disaster. The company tried to recover the health, safety and to support the economic recovery of the Gulf Coast's tourism and seafood industries impacted by the spill. We have conducted study in this chapter to focus on the positive impact of BP spending that offset negative impacts of the spill to fisheries, oil and gas (the moratorium), and tourism. To identify and define the injury to natural resources in the Gulf of Mexico we used the Input-output model that is valuable tools to approximate the effects any changes in spending will have within the Louisiana.

No wonder at this point, the state and local government's related businesses cope with a significant change in their resources as result of any shocks (oil spill/hurricane) in the oil and gas industry in Louisiana. What is more outstanding is the influence of oil and gas industry on the incomes of Louisianans workers in oil and gas industry. These multipliers all carry an estimate of the total impact through all industries. Disasters are human and economic tragedies in cooperation. Though, we should manage to pay for the opportunity to make the best of a bad

situation. With thousands of working oil and gas platforms still operating in the Gulf which supports employments across a widespread of industries, there is difficulty to find more accurate answers and better prepare for the unpredictable next spill.

4.2 How Important Is Louisiana In Oil And Gas Industry?

Louisiana has the facilities to support the oil and gas industry in terms of trades, launching spots for servicing the deepwater drilling and production activities; it has a strategic and critical port that acts as a terminal for foreign oil; Louisiana is the nation's number two producer of crude oil and the number two producers of natural gas and refinery capacity among the 50 states. Louisiana has storage amenities for the nation's strategic oil reserves and has the pipeline arrangement to support the production of oil and gas and also the importation of oil. Approximately 112,000 miles of pipelines are transporting oil and natural gas within the state and also offshore area of the Gulf of Mexico.

According to Energy Information Administration (EIA) report in 2014, Louisiana has 79,289 miles of pipelines in onshore and also 37,554 miles active offshore pipelines. The oil and gas industry expands all over the state. North Louisiana has over 14,000 producing crude oil wells and over 10,500 producing natural gas wells. South Louisiana and the Louisiana offshore have about 5,000 producing crude oil wells and about 2,300 producing natural gas wells (Louisiana Energy Facts Annual, 2002). The Marathon Refinery in Garyville is the second largest refinery in the country and the eleventh largest in the world and the ExxonMobil refinery in Baton Rouge is the third largest in the country and the twelfth largest in the world. The Citgo refinery in Lake Charles is the fifth largest in the nation. The Louisiana Offshore Oil Port (LOOP) plays a significant role in preparing the daily energy needs. LOOP has offloaded over eleven billion barrels of foreign and domestically produced crude oil since its inception.

4.3 Methodology in Measuring Economic Impact: Input-Output Model

The input-output analysis is the standard method for measuring the spread effects of changes in the final demand for the product of an industry or sector (Surugio, 2009). The fundamental of the input-output analysis is the input-output table. An input-output model includes of a system of linear equations, each one of which describes of an industry's product throughout the economy.

The fundamental information used in input-output analysis concerns the flows of products from each industrial sector, considered as a producer, to each of the sectors, itself and others, considered as consumers. This basic information from which an input-output model is developed is contained in an inter-industry transactions table.

Figure 4.1 shows a general view of an input-output table. A very general and simplified overview of an I-O table presented in Input-Output table comprises four quadrants. Quadrant I (intermediate consumption) is the basis for the input-output model itself and includes the matrix of intermediate flows. It represents the transactions for intermediate sales and purchases of goods and services among firms. Quadrant II shows the final use of goods and services by households (HH), state and local governments units (Gov), investments (Inv) and exports (Exp). Quadrant III contains the requirements of each sector for primary inputs (labour, capital, land). It includes the inputs absorbed by the national branches from the rest of the economic system and outside of the country (imports). Here we include the labour expenses (i.e. compensation of employees), other taxes less subsidies on production, consumption of fixed capital and net operating surplus. These payments are also called value added; since they are so hard to identify individually, these incomes are frequently recorded as one value-added row. In quadrant IV no transactions are denoted, as very few market transactions are reported in this sphere (Surugiu, 2009).

BRANCHES / PRODUCTS	1 2 3 ... n	HH	Gov	Inv.	Exp.	Out-put
1 2 ... n	X_{11}..........X_{1j}.........X_{1n} Quadrant I .... X_{n1}..........X_{nj}.........X_{nn}	Quadrant II Final demand				
Gross Value Added a. Compensation of employees b. Gross operating surplus c. Taxes on production (- subsidies) Imports	Quadrant III	Quadrant IV				
Input						

Figure 4.1 General View of an Input-Output Table (Source: Surugiu, 2009).

The rows of such a table describe the distribution of a producer's output throughout the economy. The columns describe the composition of inputs required by a particular industry to produce its output (Miller & Blair, 2009). The transaction among various sectors and used in the table can be described by the following equation:

$$X_i = \sum x_{ij} + Y_i \quad (1)$$

Where x_{ij} is the amount of inputs sector j purchases from selling sector i, X_i is the output for the sector j and Y_i is the final demand of sector i (Surugio, 2009). One of the advantages of the Input-output model is that it has the ability to modify engineering data and has great structure for data collection. It also can give a clear view of the framework of an economy. On the other hand, it does not have behavioral content and also it has price and output independency. The Input-output model needs replacement for input and import possibilities. The I/O table is aggregated in twelve branches: agriculture, forestry, fishing and hunting, mining, utilities, construction, manufacturing, wholesale trade, retail trade, transportation and ware housing, information, finance, insurance, real state, rental and leasing, educational services, health care and social assistance, art, entertainment, recreation and food services and finally the other services except government.

The literature on the calculation of I-O multipliers traces backs to Leontief (1941), who developed a set of national-level multipliers that could be used to estimate the economy-wide effect that an initial change in final demand has on an economy. Isard (1951) then applied input-output analysis to a regional economy. According to Richardson (1985), the first attempt to create regional multipliers by adjusting national data with regional data was Moore and Peterson (1955) for the state of Utah.

BP committed to help the people of the Gulf Coast recover from the Deepwater Horizon accident. Based on statistics from BP, government agencies and many reliable third-party sources, that BP has spent more than $29 billion on response, cleanup, early restoration and claims. BP is supporting economic-recovery efforts in Louisiana by paying legitimate claims and backing two of the state's most important industries – tourism and seafood. BP has spent more than $4.9 billion on claims, advances and settlements to individuals, businesses and government agencies, not including the Vessels of Opportunity program. (BP, 2015). BP was trying to bring back, generate and keep swamp, fish, oyster environments and other natural resources to speed up

environmental recovery in Louisiana after the oil spill in 2010, and pay for loss of use of natural resources. This study estimates the Deep water Horizon accident compensation generated base on final demand output multipliers, demand earnings multipliers and demand employment multipliers from U.S. Annual I-O data and Regional data for 2010 and BP spending for state of Louisiana. These multipliers all carry an estimate of the total impact through all industries. This study emphasizes in detail on multipliers created by the Regional Input-Output Modeling System (RIMS II) developed by the Bureau of Economic Analysis (BEA). Since the 1970s, BEA has produced regional I-O multipliers that show the inter-industry purchases resulting from changes in final demand. Adjusting national I-O relationships with regional data4 creates the RIMS II model. Earnings-by-industry and personal consumption expenditure data are used to expand the model to include households as both suppliers of labor and purchasers of final goods and services. (Bess & Ambargis, 2011). By using RIMS II, we can estimate four measures of changes in total economic activity: gross output; value added, earnings, and employment (Table 4.1).

Gross output is a duplicative total in that goods and services will be counted multiple times if they are used in the production of other goods and services. Earnings consist of wages and salaries and proprietors' income. Employer contributions for health insurance are also included. Personal contributions to social insurance and employee pension plans are excluded because the model must account for only the portion of personal income that is currently available for households to spend. Employment consists of a count of jobs that include both full-time and part-time workers (Bess& Ambargis, 2011).

Table 4.1 RIMS II Final-Demand Multipliers

Multiplier	Definition	Application
Outputs	Total industry output per $1 change in final demand	Total gross output impact
Earnings	Total household earnings per $1 change in final demand	Total earnings impact
Employment	Total number of jobs per $1 million change in final demand	Total jobs impact

RIMS II considers Type I and II multipliers. Type I multipliers explain the direct and indirect impacts base on how goods and services are streamed in an area. Type II multipliers do not specifically explain for all these direct and indirect impacts, but they additionally explain induced impacts according to the purchases done by employees.

4.4 BP's Expenditures on the Oil Spill

Any oil spill in the Gulf of Mexico will impact the coastlines of Louisiana, Alabama, Mississippi, and Florida. Impacts can involve different industries such as oil and gas service companies, marine and air transport services, food industries, financial, insurance companies and also threaten hundreds of species. Oil and natural gas industry activity supports employment across a wide-ranging of industries in manufacturing and services, including oil and natural gas machinery, air and marine transport, legal and insurance services. Losses in access to Louisiana’s oil and natural gas production can affect offshore industry owners and operators in GoM zone and country. Oil and gas industry exposes a powerful economic engine with wide range of jobs and income creating powers.

Federal, state, and international parties that put pressure on BP to response and to compensate enforce oil spill regulations due to the oil spill in 2010. In response, BP spent a compensation fund on stopping the leaks, cleaning up the oil spill, and payments of damages to Louisiana citizens, which these injections applied to estimating the offsetting positive impact of BP spending (in the billions of dollars) in this study. About $20.8 billion settlement to recover natural resource damages and economic claims considered against BP due to the BP oil spill in 2010. The civil claims settlement includes the following components: $1 billion for natural resource damages (NRD) allocated under an early restoration outline (NOAA, 2011). BP committed to help the people of the Gulf Coast recover from the Deepwater Horizon accident. Based on statistics from BP, government agencies and reliable third-party sources, BP has already spent more than $29 billion on spill response, cleanup, early restoration and claims. BP had supported economic-recovery efforts in Louisiana by paying legitimate claims and backing two of the state’s most important industries – tourism and seafood. BP has spent more than $4.9 billion on claims, advances and settlements to individuals, businesses and government agencies, not including the Vessels of Opportunity program. (BP, 2015).

BP was trying to bring back, generate and keep swamp, fish, oyster environments and other natural resources to speed up environmental recovery in Louisiana after the oil spill in 2010, and pay for loss of use of natural resources. BP has supported the seafood industry by providing $74 million for state-led marketing and testing programs and $179 million for tourism and also allocated another $57 million for Gulf Coast nonprofit groups and government entities to

Alabama, Florida, Louisiana and Mississippi. I applied all these BP expenditure as the economic injection due to the oil spill that occurred in 2010 in my calculation.

In 2013, there were 62,417 covered workers (unemployment insurance) employed in the oil and gas extraction, support activities for mining, refining, and pipeline industries (Table 4.2). If the extraction, refining, and pipeline industries are taken under one title" the energy industry "has it been a powerful controlling economic engine for Louisiana. Table 4. 2 is devoted to the direct income and employment effects of the energy industry. How many people are employed in it and what is the nature of the wages paid its employees? The annual wage numbers for these sectors are so big because these four sectors are among the highest wage industries in the state.

Table 4.2 Employment and Annual Wages Paid in Petroleum-Related Industries: Louisiana2010-11 (Source: www.laworks.net)

Sector	Employment	Annual Wages Paid ($Million)
Oil & Gas Extraction	8,483	$ 878
Support Activities for Mining	39,756	$ 2,873
Refining	11,567	$ 1,054
Pipelines	2,611	$ 203
Total	62,417	$ 5,000

Based on Scott report (2014), oil and gas extraction's weekly wage of $2,140 which is 77.3 percent higher than the average wage in manufacturing sector ($1,207). Oil and gas extraction wages are two and a half times greater than the average wage earned by a Louisiana employee ($824 per week). In refining sector, it was 68 percent higher at $2,026 and the extraction division waged $2,140 weekly---77.3% higher than the average in manufacturing. Because oil and gas extraction and refining sectors require very skilled workers for their tasks. By overviewing the direct wage and employment effects of these industries reveal significant character of the energy sector. The exploration sector will order offshore platforms from any oil and gas company in Louisiana for its oil extraction in Gulf of Mexico. Therefore it generates sales, income and jobs in the company, which in turn the company orders suppliers for its order. Then it creates sales, income, and jobs in other related companies, and so on. The exploration sector hires more employees which they then spend their wages at real state, grocery stores, restaurants,…, that creates new sales, income, and jobs there and so on.

4.5 Assessment of Economic Impact

The energy sector has been a powerful factor for creating thousands of high-wage jobs and income in Louisiana. Therefore any disruption in this sector can cause huge cost for the state. BP made a commitment to help the people of the Gulf Coast recover from the Deepwater Horizon accident. Oil spill regulations are enforced by federal, state, and international parties that put pressure on BP to response and to compensate. In response, BP created a compensation fund. The massive amount of money that BP would pump into the area's economy for the cleanup effort and pay out on claims for losses due to the spill. An input-output (I/O) table is a useful tool for measuring these multiplier effects for the industries. The U.S. Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce has built an Input-Output table for the Louisiana economy.

Money remains to flow into the Louisiana economy from BP to compensate damages due to the 2010 oil spill in the Gulf of Mexico. The total impact across all industries can be considered with the final-demand multipliers whenever the variation in final demand is stated as variation in gross output. The six months moratorium (a dramatic drop in deep-water exploration) was a big part of this number of job losses after the Macondo disaster. The industry's impact on state and local treasuries has been significant. The results indicate most affected group by the deep-water drilling moratorium losses would have shown up in the employment.

A moratorium issued on offshore after the Deep-water Horizon stopped work on 33 exploratory drilling rig in GoM (U.S. Department of the interior, 2010). The moratorium for six months issued at that point also caused lots of job loss offshore support services and other related businesses. Each deep-water rig creates 700 jobs for Louisianans alone; a shallow-water rig generates 350 jobs, according to Greater New Orleans Inc. But it's not just Louisiana and Gulf Coast states tolerating the weight of moratorium, even some of organization across the U.S. suffered from it. Decreasing production on existing wells and governmental deferrals on new wells in the Gulf of Mexico are costing too much for Gulf States and local governments.

The loss of well control and the failure of the blowout preventer (BOP) mechanism are two primary failures in the drilling process that may have led to the Macondo disaster. The BOP atop the Deepwater Horizon well failed to activate as designed. In fact, there are benefits gained by some sectors from oil spills. Benefits accumulated to those tasked to do the clean-up, support

services, and associated activities; Research opportunity, sale of dispersants that break the oil into smaller molecules, Consultancies for oil spill experts, increase sale to the benefit of manufacturers. The BP spending may be broken down into the impacts on other industrial sectors in the region (Louisiana) using the RIMS II breakdown tables. Table 4.3 represents an input/output table for Louisiana job creation due to the Deepwater Horizon oil spill yearly in each sector.

Table 4.3 Louisiana Employment Created due to the Economic Injection after the Deepwater Horizon accident (Breakdown by sector)

Branches	2010	2011	2012	2013
Agriculture, forestry, fishing, and hunting	355	2,739	614	278
Mining	34,380	3,664	288	369
Utilities*	673	80	9	8
Construction	5,537	603	52	61
Manufacturing	3,530	439	48	45
Wholesale trade	1,935	261	32	27
Retail trade	6,389	838	102	88
Transportation and warehousing*	1,893	240	30	25
Information	786	102	15	11
Finance and insurance	2,071	265	32	28
Real estate and rental and leasing	4,666	610	73	64
Professional, scientific, and technical services	4,174	493	54	52
Management of companies and enterprises	2,581	287	29	30
Administrative & waste management services	2,992	380	53	41
Educational services	1,302	179	23	19
Health care and social assistance	6,540	874	109	91
Arts, entertainment, and recreation	819	108	14	12
Accommodation	710	244	193	58
Food services and drinking places	3,234	433	59	46
Other services*	2,519	340	46	36
Households	388	52	6	5
Total	87,475	13,232	1,881	1,396

It presents a breakdown of the final-demand output multiplier for BP spending after Deepwater Horizon on industries that were calculated for Louisiana. It explains that in which sectors employees are benefiting the most from these possible spillover outcomes. Six months after the oil spill and in the middle of the moratorium on drilling, the Louisiana Economic Outlook announced that the area experienced significant job losses. Eleven deepwater drill ships

left the Gulf, and activity at Port Fourchon dropped 35-40% below pre-spill levels. Normally, that would translate into a major decline in employment in the Metropolitan Statistical Areas (MSA). Table 4.4 represents an input/output table estimates for the Louisiana earning gained due to the Deepwater Horizon oil spill annually in each sector. It shows that economic injection by BP spending caused 3.9 billion dollars benefit in 2010. It provides a breakdown of an industry's impact on 20 aggregated sectors. The output figures show how the oil spill impacts are huge. The drilling moratorium does not particular impact but also the cleanup operation and oil and gas support activities are creating the big number.

Table 4.4 Annually Louisiana Earnings Gain due to the Economic Injection after the Deep-water Horizon Accident (Million$)

Branch	2010	2011	2012	2013
Agriculture, forestry, fishing, & hunting	$8.8	$71.1	$16.2	$7.5
Mining	$1,855.9	$205.0	$16.3	$21.4
Utilities*	$55.1	$6.8	$0.8	$0.7
Construction	$250.1	$28.2	$2.5	$3.0
Manufacturing	$222.7	$28.7	$3.2	$3.1
Wholesale trade	$112.6	$15.8	$2.0	$1.7
Retail trade	$162.8	$22.1	$2.7	$2.4
Transportation and warehousing*	$110.2	$14.1	$1.7	$1.5
Information	$36.4	$4.9	$0.7	$0.6
Finance and insurance	$82.7	$11.0	$1.4	$1.2
Real estate and rental and leasing	$115.1	$14.0	$1.5	$1.5
Professional, scientific, technical services	$235.4	$28.8	$3.2	$3.1
Management of companies, enterprises	$165.2	$19.0	$1.9	$2.1
Administrative & waste management	$74.1	$9.7	$1.4	$1.1
Educational services	$36.3	$5.2	$0.7	$0.6
Health care and social assistance	$264.2	$36.6	$4.6	$4.0
Arts, entertainment, and recreation	$20.1	$2.7	$0.4	$0.3
Accommodation	$21.5	$7.6	$6.1	$1.9
Food services and drinking places	$56.4	$7.8	$1.1	$0.9
Other services*	$92.8	$13.0	$1.8	$1.4
Households	$3.8	$0.5	$0.1	$0.1
Total	$3,982	$553	$70	$60

Based on results from our study related to the employment and earnings impacts of shocks in oil and gas industry makes known how oil and gas industry is a powerful economic machine with wide-ranging opportunities for state. Therefore, no wonder state and local governments copes with a significant knock to their revenues due to the shocks (oil spill/hurricane) in oil and gas industries in Louisiana. Table 4.5 presents an input/output table for gain Louisiana sales due to the Deepwater Horizon oil spill yearly in each sector. It provides a breakdown of an industry's impact on 20 aggregated sectors.

Table 4.5 Annually Louisiana Sales Gain Due to the Economic Injection after the Deep-water Horizon accident

Branch	2010	2011	2012	2013
Agriculture, forestry, fishing, hunting	$33.8	$190.6	$43.2	$20.0
Mining	$13,528.7	$1,494.0	$118.9	$155.6
Utilities*	$298.1	$36.6	$4.2	$4.0
Construction	$631.4	$71.3	$6.2	$7.5
Manufacturing	$1,206.1	$156.8	$17.6	$16.7
Wholesale trade	$366.7	$51.3	$6.3	$5.5
Retail trade	$472.0	$64.2	$7.9	$6.9
Transportation &warehousing*	$316.8	$40.7	$4.8	$4.4
Information	$187.0	$25.0	$3.5	$2.8
Finance and insurance	$378.2	$50.2	$6.2	$5.4
Real estate and rental and leasing	$962.6	$128.0	$15.2	$13.8
Professional, scientific, technical services	$490.8	$60.1	$6.7	$6.5
Management of companies & enterprises	$358.0	$41.2	$4.2	$4.4
Administrative and waste management	$177.0	$23.3	$3.3	$2.6
Educational services	$75.1	$10.7	$1.4	$1.2
Health care and social assistance	$568.5	$78.7	$9.9	$8.5
Arts, entertainment, and recreation	$53.9	$7.4	$1.0	$0.8
Accommodation	$81.4	$29.1	$23.3	$7.2
Food services and drinking places	$181.8	$25.2	$3.5	$2.8
Other services*	$221.9	$31.1	$4.2	$3.4
Total	$20,590	$2,615	$292	$281

BP spending of 25.6 billion dollars after oil spill there is huge injection in economy. So there were 87,475 additional jobs created, 3.9 billion dollars new output, 20.5 billion dollars new output into the economy. These are significant gains that occur due to BP spending after the oil spill.

This industry effects on tax payments to government; the taxes paid directly by the oil and gas industry to state and local governments (sales taxes, royalties, property taxes, fees, etc.). The presence of oil and gas industry generates earnings for household through the direct salaries paid and indirect earning produced through the multiplier effects. This is another main source of revenues that state and local governments gather them as indirect taxes. Therefore, any collapse in oil and gas industry comes up with important impacts on local economy and U.S. economy in terms of job creation, energy supply, and GDP and tax revenues.

Each active deep-water rig contributes significantly to state and local tax revenues. Oil spill events can cause slowing down the exploration and development of offshore oil plans. By occurring different levels of oil spill, the risk of offshore drilling has become more obvious, therefore approval of new drilling/exploration projects must be more difficult around the world, and oil companies invest more in safety and technology improvement in such projects. A moratorium issued on offshore after the Deepwater Horizon that stopped work on 33 exploratory drilling rigs in GoM (U.S. Department of the interior, 2010). The moratorium targeted drilling rigs in water depths more than 500 feet and lasted for a period of six months, to ensure that disasters like the Deepwater Horizon blowout would not happen again. The moratorium also caused financial problems for offshore support services and other related businesses. The moratorium will do more harmful than beneficial. By stopping offshore drilling, even for as little as six months, the moratorium will further depress onshore state and local economies dependent on oil production (Mason, 2010).

The I/O table provided estimates of the impact of BP spending on three key variables in the state of Louisiana (1) sales at firms (output), (2) Households incomes; and (3) Jobs (employments). According to the I/O table, BP spending in 2010 created nearly $20.6 million in output at Louisiana. The output is measured the total industry output per $1 change. Employment is total number of the jobs and earnings is total household earnings. The greatest beneficiary is the mining.

The impact is much larger in terms of output than it is in terms of employment or earnings. Base on broken down by industry for GDP share of mining is about of the 2.2% of U.S. GDP. How will look like for Louisiana? The share of mining in Louisiana, much larger compared

to U.S share, is about 10.4 percent of Louisiana GDP. Figure 4.2 presents the Gross Domestic (GDP) of United States and Louisiana breakdown by sector.

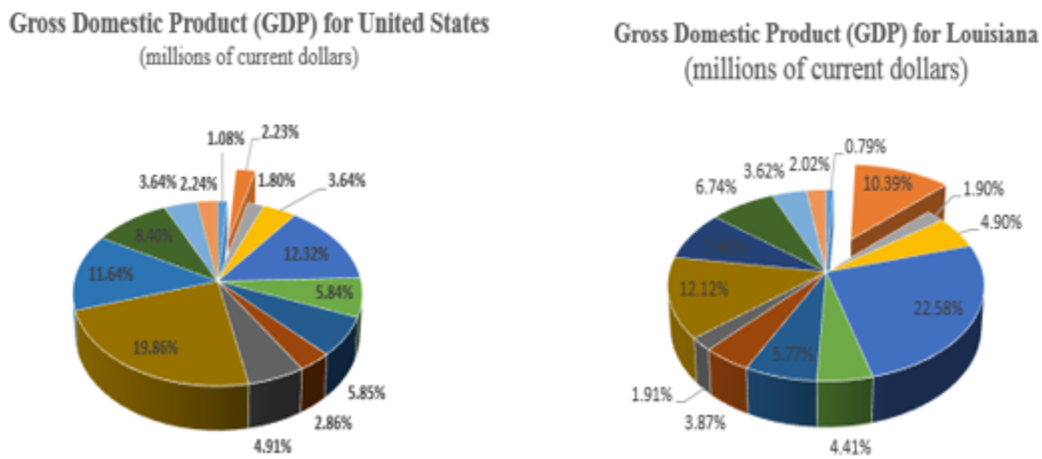

Figure 4.2 Breakdown by sector of Gross Domestic of United States and Louisiana (Bureau of Economic Analysis, 2015)

Oil and gas industry is really important in terms of GDP not in terms of employment because of dollar value. Therefore our calculation shows a big impact in outputs but not in employment sector. Table 4.6 presents the total Earning gains, Jobs creation and new output from 2010 to 2013 separately.

Table 4.6 Total Jobs, Earning and Output from 2010 To 2013

	Employment		Earning (Million Dollar)		Output (Million Dollar)	
	Total	Percentage	TOTAL	Percentage	Total	Percentage
2010	87,475	4.7%	$3,982	2.4%	$ 20,590	8.8%
2011	13,232	0.7%	$553	0.3%	$ 2,615	1.1%
2012	1,881	0.1%	$ 70	0.04%	$ 292	0.1%
2013	1,396	0.1%	$ 60	0.03%	$ 280	0.1%

According to the I/O table, the BP pumped almost $4 billion in Louisiana household earning to compensate the oil spill damage. Number of the employment in mining sector is large and this section earned the largest fraction of the earning. But the earning and number of employment are not as big as the output. The Louisiana additional jobs rise to 87475 in 2010 and the region experienced the biggest gain approximately about 103,984 jobs. Gains in Louisiana's job decline are estimated at 1,396 after 3 years.

The positive impact of injection on the employment at first year is about 4.7 percent but this number decreased significantly to 0.7 percent in 2011 because some of the workers in fishery start to work in cleaning sector while the oil spill happened. Also the moratorium caused some negative impact on the other side. The total new earnings in 2010 is about 2.4% and for output is about 8.8 percent. Therefore, the economic injection impact is much larger in terms of output than it is in terms of employment or earnings. In table 4.7, the average Louisiana wages and employment are compared with wages and employment gain of Louisiana after Deepwater Horizon Oil Spill.

Table 4.7 Comparison of Average Wages and Employment with Wages and Employment Gain of Louisiana after Deep-Water Horizon Oil Spill

Year	Avg. Wage*	Avg. Wage Gain**	Employment*	Employment Gain**	% Emp. Gain
2010	$41,461	$45,521	1,832,357	87,475	4.7%
2011	$42,375	$40,301	1,848,399	13,232	0.7%
2012	$43,300	$35,402	1,871,037	1,881	0.1%
2013	$44,008	$40,739	1,893,823	1,396	0.07%

(Source: *Bureau of Labor Statistics **Current study)

The average of the new wage owing to BP expenditures in 2010 and 2011 are $45,521 and $40,301 respectively after the Deep water Horizon oil spill that happens in 2010. The number of additional jobs that is created by injection is about 4.8 percent of total employment. This is a big benefit to compare to the actual number of Louisiana employment that is about 1.8 million employees in 2010. Based on the results in table 4.8 the level of benefit on employment will be negligible after 3 years. There is about 0.07 percent additional number of jobs. Table 8 presents the total earning and output (for 2011 to 2013) calculated based on income and earnings in 2010.

Table 4.8 Total Earning and Output Base on 2010 Dollar Value

	Earnings in 2010$ (Million Dollar)	Output in 2010$ (Million Dollar)
2010	$3,982	$20,590
2011	$533	$2,524
2012	$67	$278
2013	$57	$ 262

This disruption generates proportionately larger sales and earnings losses as well. For the entire State of Louisiana, business sales would achieve benefits from BP spending of over $20 billion, and household earnings would increase by over $3 billion. A quick review of the last three rows of Table 8 reveal that the sales and earnings losses hit Louisiana the hardest in 2010, followed by 2011 and 2012.

The net impact of the BP oil spill on the Louisiana economy which measured by lost employment and earnings was approximated with VAR models (Dahi & Tyagi, 2016). The study contained VAR estimates of the net impact of the BP oil spill on the Louisiana economy measured by lost employment, output, earnings, and tax revenues. By definition the net loss equals the gross loss (economic damages created by the spill) minus the offsetting economic injection due to BP expenditures in the economy. The scale of BP expenditures on stopping the leaks, cleaning up the oil spill, and payments of damages to Louisiana citizens is measured in the billions. With Input-Output approach we estimate the offsetting economic injection due to BP expenditures in the economy in this paper. The scale of BP expenditures on ending the spill, cleaning up the oil spill, and payments of damages to Louisiana citizens is measured in the billions. The final missing element, gross damages of BP to Louisiana before offsets equals the sum of the net loss and offsets. The gross damage estimates implied by VAR model (Dahi and Tyagi, 2015) and Input-Output appear realistic. In this research study, we applied the likely magnitude of the net economic impacts of a major oil spill like the Deepwater Horizon oil spill in 2010 which determined with Vector Autoregressive (VAR) method due to calculate the gross economic damage of the Oil spill. (Dahi and Tyagi, 2015). Table 4.9 presents the net loss, Gross Injection due to BP spill and Gross Damage for wage and employment.

Table 4.9 Net Wage Loss, Gross Injection Due To BP Spill and Gross Economic Damage

Year	Net Wage Loss(VAR (Thousands Dollar)	Gross Injection due to BP (I/O) (Million Dollar)	Gross Economic Damage (Million Dollar)
2010	$253,926	$ 3,982	$ 4,236
2011	$ 338,758	$ 553	$ 892
	Net Employment Los	Gross Injection due to BP	Gross Damage
2010	9,236	87,475	96,711
2011	8,260	13,232	21,492

The gross of loss employment of Louisiana in 2010 is estimated about 96,711 that are approximately 5.3% losses in number of employment to compare 1833 thousands (Bureau of Labor Statistics) in year of disaster. This loss decreased to 1.2% after a year that is equal to 21,492 jobs to compare 1848 thousands (Bureau of Labor Statistics) in 2011. The oil spill put the billions of dollars generated from commercial fishing and beach tourism along the Gulf Coast at risk. The actual six-month moratorium impact on offshore oil and natural gas production was reported about nearly $2.1 billion in output loss, 8,169 jobs loss, above $487 million in wages loss (Mason and Joseph, 2010). The State of Louisiana also closed a number of state waters to fishing. the Gulf of Mexico commercial fishing industry was estimated to have lost $247 million due to the post spill fishing closures (Paul, et al. 2013).Louisiana reported that lost visitor spending through the end of 2010 totaled $32 million, and losses through 2013 were expected to total $153 million in this state alone (NRDC, 2015).Based on the estimation in this study the gross damage estimates are big number. The scale of BP expenditures on ending the spill, cleaning up the oil spill, and payments of damages to Louisiana citizens is measured in the billions. It is a huge compensation that happens by BP expenditures. Using input-output models developed by the US Department of Commerce, we estimated the loss of jobs, household earnings, and business transactions for the regional economy if disruptions in oil and gas industry occur because of natural or man-made disasters. The gross damage estimates implied by VAR model and Input-Output appear realistic and really significant based on losses in different industries.

4.6 Conclusion

Oil spills are a problematic episode in the oil and gas industry that can slow down the exploration and development of offshore oil plans internationally. By occurring different levels of oil spill, the risk of offshore drilling has become more obvious, therefore approval of new drilling/exploration projects must be more difficult around the world, and oil companies must invest more in safety and technology improvement in such projects. Resilience is an important concept for the disaster management of structures. This study of the employment and earnings in Louisiana aftermath of accident in oil and gas industry makes known how oil and gas sector is a powerful economic machine with wide-ranging opportunities for state. Therefore, no wonder at that point state and local governments related businesses cope with a significant change in their resources from any shocks (oil spill/hurricane) in this important industry in Louisiana. What is

more outstanding is the influence of oil and gas industry on the incomes of Louisianans workers in oil and gas industry. Louisiana was most meaningfully impacted by the oil spill in 2010, being a state that relies greatly on both the fishing and oil and gas industries in the Gulf of Mexico. Because, for every job created in this industry additional jobs are generated in other industries in the state. Therefore, the improvement of Gulf of Mexico resources comes up with important impacts on region economy and U.S. economy in terms of job creation, energy supply, and Gross Domestic Product (GDP) and tax revenues. The six month moratorium (a dramatic drop in deep-water exploration) got a big part of this number of job losses after the Macondo disaster. The industry's impact on state and local treasuries has been significant. The results indicate most affected by the deep-water drilling moratorium losses would have shown up in the employment. Input-Output Analysis is an economic tool used to measure the impact of an existing, proposed or anticipated business operation, decision or event on the economy (Richardson & Scot, 2014).

This study estimates the Deep-water Horizon accident compensation generated base on final demand output multipliers, demand earnings multipliers and demand employment multipliers from U.S. Annual I-O data and Regional data for 2010 and BP spending for state of Louisiana. I-O analysis was used to measure the impact of BP spending on Louisiana economy, from 2010 to 2013, the latest available I-O table year for the Louisiana economy. These multipliers all carry an estimate of the total impact through all industries. This disruption generates proportionately large sales and earnings gains. For the State of Louisiana, business sales would increase by over 8.8 percent, and household earnings would fall by over 2.5 percent in 2010. A quick review of the last three years reveals that the sales losses hit Louisiana the hardest in 2010. The impact is much larger in terms of output than it is in terms of employment or earnings; because the share of mining in Louisiana's GDP, is significantly larger to compare to U.S share Oil and gas industry is playing really important role in terms of GDP not in terms of employment.

We should manage to pay for the opportunity to make the best of a bad situation during any economic tragedies. With thousands of working oil and gas platforms still operating in the Gulf, there is difficulty to find more accurate answers and better prepare for the unpredictable next spill. Help prevent another disaster by taking action to make the exploration safer. Safety is an essential value of the oil and gas industry. Therefore, the industry must continuously develops best performs for safe offshore operations, such as preparation, regulations, industry principles,

operational procedures and technology to prevent or reduce the number of offshore incidents. From the response perspective, the industry's primary spill response to prevent the spill from moving onshore should be strong. The regional economy should boost its structure then can be helpful to reduce the recovery time and consequences for facing future disasters. The economic impacts will feel by the oil and gas, fisheries tourism and other business related sectors following an oil spill. The oil and gas industry must focus more on safety aspects of offshore operations and must make substantial improvement in technologies for oil spill prevention, containment and response. Oil spill prevention have to be the critical goal for oil and gas industry, then significance of response readiness will take more serious by the industry. This requires constant improvement in every single phase of operations where oil is produced, transported, stored and sold.

CHAPTER 5: A MODELING FRAMEWORK FOR OPTIMAL NETWORK DESIGN OF OIL AND GAS SUPPLY CHAIN, WITH APPLICATION FOR LOUISIANA OFFSHORE OIL PORT (LOOP)

5.1 Introduction

Supply-chain disruptions result from natural tragedies, labor disputes, provider/seller bankruptcy, and other causes. These kinds of disasters can extremely mess up or delay material flow, systems failure, inventories problems and capacity and cash flows, resulting increase in the cost or reduction of the sales. Therefore, this research will focus on supply chain interruptions in oil and gas industry and its economic impact on this industry, by generating a mathematical model on delivering oil from offshore to the port, temporary storing, the real processing, and selling and distribution of oil based products in this study. How a major breakdown in a refining node or a distribution link that is part of a supply chain aftermath of disasters (natural or man-made) can cause huge damage to several businesses and facilities at the same time will be explored. In downstream sector, oil arrives at processing plants where it is refined and in the end turned into different products that will then be sold and distributed. Optimization techniques have been applied to virtually all aspects of the oil industry. This chapter proposes a mathematical model to maximize the profit of this chain. The research develops an LP (linear programming) model that is concerned with the supply, set of refineries, a set of storages, and a set of distributions of an oil and gas system in the Louisiana Offshore Oil Port (LOOP). The result of the model determined the optimal oil flow through the mid-stream and downstream networks. Also a scenario that if a major breakdown in a refining node happens aftermath of disasters for 6 months (natural or man-made) will be considered due to how it will impact on the flow then the cost and the sales

5.2 Oil and Gas Supply Chain

By motivation of critical role of oil and gas industry in the today's world business, this industry involves huge financial flows having a significant impact on the global economy. A lot of challenges influences the nature of the supply chain in the oil industry--complex characteristics, lengthy lead time, and limited distribution capacity at the different levels in the supply chain is solvable by oil and gas supply chain management. The common concern along the links in the oil and gas industry supply-chain is economics and weighing benefits versus costs along the chain. Economic shock or political changes that have an impact on the price of the oil are other challenges that cause unexpected experiences. Any disruptions on supply chain in oil

and gas industry can cause huge impact on this industry and economy. Therefore, optimization of supply chain models within the oil and gas context is critical for smooth and uninterrupted operation of the oil flow.

Crude oil industry sharply became a strategic industry and today, it is the main resource to streamline fuels and energy supply required for different industries all around the world. As oil and gas industry has a worldwide market and oil reservoirs are extended in all places, an oil supply chain (SC) is one of the most complicated systems. Optimization of this compound supply chain has generated new challenges for oil industry companies and researchers in this area. A supply chain is an integrated network of resources and processes that is responsible for the acquisition of raw materials, the transformation of these materials into intermediate and finished products, and the distribution of the finished products to the final customers (Goetschalckx, 2011).

Decisions in a supply chain are usually divided into three categories: strategic, tactical and operational decisions. The difference between the decision levels is formed from their planning perspectives. The strategic level includes a reasonably long planning perspective of 5–20 years in the crude oil supply chain and it connotes network design in this process. These decisions comprise of the investment, facility location, facility relocation (e.g., capacity expansion and reduction), facility allocation, technology selection, upgrading, downgrading, and outsourcing. The tactical level may cope with relatively shorter time scope of 6–24 months, and the operational decision level creates weekly or daily or both decisions. At the tactical level, the predetermined strategic decisions are refined since demands, price, political environment, exchange rates and other uncertain factors become more accurate (Schmit and Wilhelm, 2000). The oil industry is increasingly interested in improving the planning of their operations due to the dynamic nature of this business (Ribas *et al.,* 2011).

The crude oil supply chain involves various tasks such as exploration, production, crude oil transportation, transformation, and distribution of oil and refined products to customers. Assuming oil supply flows from the origin to customers, upstream operation covers exploration and production activities, midstream deals only with transportation of crude oil and gas to terminal and storage, and downstream refers to the reminder of activities to delivery final products to customers (Manzano, 2005). Figure 5.1 presents the general framework for oil and gas supply chain as reflected in description herein.

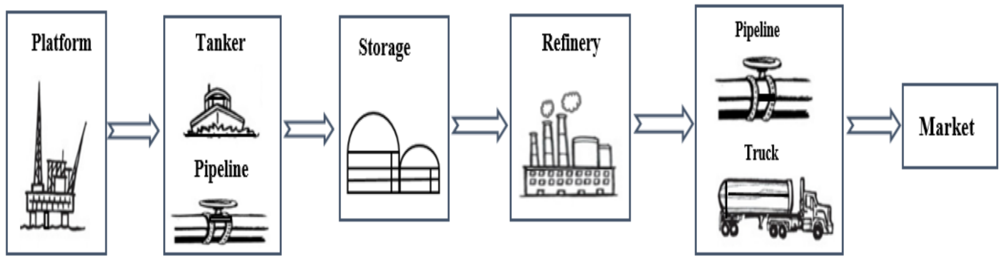

Figure 5.1 General Oil and Gas Supply Chain

Supply chain optimization is the main chance for most companies to significantly shrink their cost and increase their performance. The work by Sear (1993) was probably the first to address the supply chain management in the context of an oil company. He proposed a linear programming system for arrangement the logistics of a downstream oil firm. The model consist of crude oil purchase and transportation, processing of products and transportation, and depot operation. Sahebi and Nickel (2014) developed a mixed-integer model to design the oilfield development and plan crude oil transportation problems in upstream. Also, the model contains the selection of the transportation system and the planning of pipeline network installations.

Optimization strives to achieve the most efficient, optimal way to manage the supply chain in order to satisfy customer needs on the lowest cost. The desired quantity, regular supply of the crude oil, reduced lead-time, lower production and distribution cost are one of the main goals of the oil supply chain (Hussain *et al.*, 2006). Ross (2000) formulated a planning supply network model on the petroleum distribution downstream sector. Supply division such as distribution hubs (new and existing) and vehicles are managed to maximize profit. He determined the delivery cost base on the geographic zone, journey cost, order frequency and travel distance for every customer.

A supply chain disruption is defined as a major failure in a production node or a distribution connection that is part of a supply chain. Natural disasters such as hurricane are one reason of disruptions to supply chains. These disasters typically cause huge damage to several businesses and facilities at the same time. This has a severe impact on an industry and significant time is often required for recovery from natural disasters. Outcome of natural or man-made disasters, supplier economic failure can be supply-chain troubles. These kinds of disasters can extremely mess up or delay material, systems failure, inventories problems and capacity and cash

flows then all can raise the cost or drop the sales. If any disruption happens to Louisiana's pipeline system would raise gasoline prices nationwide. More than one-month break cause price to consumers. Then consumers spend more money on gas, therefore they cut their spending on other things to keep the budget balance, and this shock/change penetrates throughout the US economy, which is a frequent phenomenon during the year.

Hurricane seasons can damage offshore oil platforms, dropping the amount of oil production. Hurricane Katrina of during the 2005 Atlantic hurricane season was regarded as the costliest natural disaster, as well as one of the five deadliest hurricanes, in the history of the United States. It was recorded to have damaged or destroyed at least 30 oil platforms and caused the closure of nine refineries, leading to approximately 24% drop in oil production from the Gulf of Mexico in months following the storm. It also caused oil spills/leaks that were estimated at over 200,000 barrels. Refineries can be shut down because of lack of power, insufficient supply of crude, or fire damage, either by natural causes, attacks, or lack of maintenance. Though power outages may last for only a few hours, destruction of crude oil pipelines can deny service to a refinery for days, while explosion of fire can cause long-term damages, like several months (Achebe, 2011). Thus the cost and probability of each incident will vary without any known certainty. Refinery replacement can cost more than $1billion, and the loss of production (500,000 barrels/day), which can have severe implications on revenues as well as shortages that will lead to price increases at the gasoline station (Lewis, 2006).

When there are disruptions with the pipelines that carrying oil, it cannot deliver to market; this effectually triggering the supply of oil to the refiners, then causing the supply of refined products to collapse. When supplies fall, we will cope with rise in prices. The longer it takes to restore activity at the port or the longer it takes to shift services to other ports along the coast, the greater these losses will be. The majority of the pipeline damages caused by past hurricanes in the GoM mainly occurred at or in the vicinity of the platforms (Atkins *et al.*, 2007). The anchor dragging was also responsible for some of these damages. There have been more than 1,000 reports of damage to Gulf oil pipelines over the past two decades, as stated by the 2005 MMS/DNV report. Disruptions were published from Hurricane Andrew in 1992, Hurricane Lili in 2002, Ivan in 2004 and from Hurricanes Katrina and also Rita in 2005. There were more than 600 pipeline incidents reported to MMS for the Hurricane Katrina and Rita. The mapping of the pipeline damage with respect to the path of Hurricane Ivan in 2004 is reported approximately 168

pipeline damage (Atkins et al., 2007). Also, more than 480 pipelines and flow lines were damaged by the passage of Hurricane Andrew in 1992.

This chapter presents a framework for optimal network design for an oil and gas supply chain with applications to the Louisiana Offshore Oil Port (LOOP) and determines the optimal oil flow through the mid-stream and downstream networks. This mathematical model maximizes total profit which is defined as total revenue-total cost even if it is experiencing natural or man-made damages. It yields the optimal volume of tanker, pipelines, storages, terminal, refineries, trucks and customer pipelines of an oil and gas system in the Louisiana Offshore Oil Port (LOOP). The outcome of this work is a new distributed decision support framework which is intended to help optimize the oil and gas mid and downstream supply chain for critical energy zone and to boost economic in oil and gas industry under unpredictable situations.

5.3 Research Methodology

Linear programming is the name of a branch of applied mathematics that deals with solving optimization problems of a particular form. Linear programming problems consist of a linear cost function (consisting of a certain number of variables), which is to be minimized or maximized subject to a certain number of constraints (Schulze, 1998). The constraints are linear inequalities of the variables applied to the cost function. The cost function is occasionally called the objective function. The linear programming problem in standard form is written as:

$$Maximize \sum_{j=1}^{n} c_j . x_j$$

$$subject\ to \sum_{j=1}^{n} a_{ij} . x_j \leq b_{i,\ \ i=1 \ldots m} \qquad (2)$$

$$x_{i \geq 0,} \qquad j=1..n$$

Any vector x satisfying the constraints of the linear programming problem is called a feasible solution of the problem. Any linear programming problem becomes one of three sets: Infeasible, Unbounded or an optimal solution. A linear programming problem is infeasible if a feasible solution to the problem does not exist; that is, there is no vector x for which all the constraints of the problem are satisfied. Unbounded. A linear programming problem is unbounded if the constraints do not sufficiently restrain the cost function so that for any given feasible solution, another feasible solution can be found that makes a further improvement to the cost

function. Any linear programming problem has an optimal solution. Linear programming problems that are not infeasible or unbounded have an optimal solution; that is, the cost function has a unique minimum (or maximum) cost function value.

5.4 System Description

The Louisiana Offshore Oil Port (LOOP) plays a significant role in preparing the daily energy needs. LOOP has offloaded over eleven billion barrels of foreign and domestically produced crude oil since its inception. This port services about 90 percent of all deep-water rigs and platforms in the Gulf of Mexico and it is also the host for the Louisiana Offshore Oil Port (LOOP). Applications of optimization techniques in maximizing the net present value of the oil transportation, storing, refining and delivering to the customer from Louisiana Offshore Oil Port (LOOP) are reviewed and the highlights on them are summarized here.

5.5 Supply Chain at Louisiana Offshore Oil Port (LOOP)

A linear programming (LP) model to be developed must be concerned with the supply, the set of refineries, the set of storages, and the set of distributions of an oil and gas system in the Louisiana Offshore Oil Port (LOOP). The result of the model determines the optimal flow of oil through the mid-stream and downstream networks. The former studies deal with upstream or downstream, but the current study accounts for midstream and downstream in the model.

Therefore, the problem that we deal with in this study is a model of offshore and onshore oil transportation and storing and refining and marketing. We assume that there exists some production platforms (Mars and Thunder Horse). The oil is pumped from them to the port through the pipelines (P) and oil tanker (TK). Oil will be temporarily stored (S) and then is transferred over short distance to terminals. From there it is transported to different refineries (R). Then, the crude oil will be pumped to the customers via pipelines (PC) or will be carried by oil trucks (K). Intermediate and final product flows through pipelines are used to interconnect oil suppliers, storages, terminal and refineries. The other distribution through pipelines is defined from refineries to customers. Figure 2 depicts different entities of this flow system of oil.

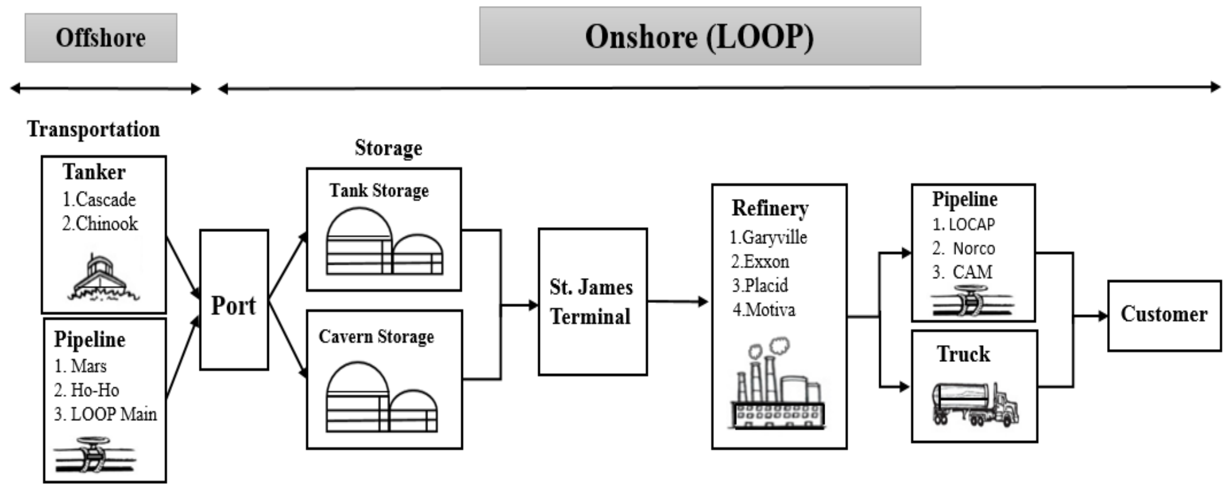

Figure 5.2 Representation of Louisiana Offshore Oil Port Oil and Gas Supply Chain.

The oil supply chain is also known to be a very complex supply chain compared to other industries' (Jenkins and Wright, 1998; Hussain, Assavapokee and Khumawala, 2006). The whole oil supply chain is divided into upstream and downstream sectors based on activities before and after the refining stage. Though, the distance from the oil exploration point to the final consumer could often be thousands of miles, which is the key reason for the oil supply chain having longer lead times than other industries. In addition, crude oil has to go through a complex, capital intensive refinery process as well (Gainsborough, 2006; Ribas, Leiras and Hamacher, 2011). The oil industry supply chain involves strategic, tactical, and operational decision levels, the same as other supply chains. The oil supply chain mathematical models involve the design and planning of some functions of oil transportation, temporary storage, refinery planning, and distribution networks.

5.6 Tactical optimization

The tactical optimization model is derived from oil and gas supply chain system at the LOOP; relevant components of the tactical optimization model are discussed here to give the readers a feel for the model structure and decision tasks. The oil industry is highly involved in developing and improving the planning of their procedures because of the dynamic nature of this business. A linear programming (LP)n model is suggested to optimize the project value of an oil and gas supply system at LOOP, with decision tasks that can involve technological structure design, supply chain design, and strategic capacity planning. Linear programming is a branch of applied mathematics that deals with solving optimization problems of a particular form. Here the

linear programming problem consists of a linear cost function (consisting of a certain number of variables) which is to be minimized or maximized subject to a certain number of linear cost and technological constraints.

5.7 Assumptions

(a) The high economic incentives of the oil and gas business are driving forces for developments in the oil and gas planning process, here we focus on oil section.

(b) The current model assumes constant oil prices for every three months. It is assumed that the number of facilities at each stage is known.

(c) The associated prices and costs assumed to be externally imposed in the planning.

(d) The modeling considers a fixed market.

(e) The model ensures the total fulfillment of the specific customer.

(f) The total amount of oil after refineries will be increased by θ and will delivered to the customers by trucks and pipelines. Here, we assume θ is equal to 0.1.

(g) For the simplicity, we assume the total cost of the all steps (from offloading at port to delivering to the customer) is not changed.

(h) The discount rate of 10% is the standard used in the oil & gas industry and what you always see in companies' filings (breaking into Wall Street).

5.8 System Notations

Before presenting the model formulation, the notation (induces, parameters, and intermediate and decision variables) for the convenience of readers are summarized here.

(a) Indices

t	time Period $t \in T=\{1,2,\ldots,180\}$
tk	Oil tanker, $tk \in TK=\{1,2\}$
p	Offshore Pipeline $p \in P=\{1,2,3\}$
pl	Internal Pipeline $pl \in PL=\{1,2\}$
k	Truck , $k \in K=\{1,2,\ldots,10\}$
s	Storage, $s \in S=\{1,2\}$
r	Refinery, $r \in R=\{1,2,\ldots,4\}$
tm	Terminal

pc Customer Pipeline pc ϵ PC={1,2,3}

l Pipeline lϵ L={1,2,…,4}

mr Refinery Maintenance

mc Customer Pipeline Maintenance

(b) System Parameters

Cap_{it}^{tk} Capacity of tanker for each time t

Cap_{pt}^{p} Capacity of pipeline for each time t

Cap_{s1t}^{s1} Capacity of Storage1 for each time t

Cap_{s2t}^{s2} Capacity of Storage2 for each time t

Cap_{rt}^{r} Capacity of Refineries for each time t

Cap_{plt}^{pl} Capacity of Storage pipelines (pl1, pl2) for each time t

Cap_{lt}^{l} Capacity of Refineries pipeline l for each time t

Cap_{kt}^{k} Capacity of truck to the customer for each time t

Cap_{t}^{pc} Capacity of pipeline to the customer for each time t

Cap_{t}^{TP} Capacity of Terminal pipeline for each time t

Cap_{tmt}^{TM} Capacity of Terminal for each time t

(c) Intermediate Variables

I_t Discounting rate

$Revenue_t$ Total revenue

$price_t$ Oil price

$Total\ Cost_t$ Total costs

(d) Decision Variables

vol_{tmt}^{TM} Volume oil from storage to the terminal by pipeline

vol_{tpt}^{TP} Transported volume oil from storage to the terminal by pipeline

vol_{it}^{tk} Carried volume oil from offshore to the port by tanker

vol_{pt}^{p} Transported volume oil from offshore to the port by pipeline

vol_{s1t}^{s1} Storage cost in the store1

vol_{s2t}^{s2} Storage cost in the store2 for each time t

vol_{plt}^{pl} Transported volume oil from port to the storage by pipeline

vol^{r}_{rt} Carried oil volume from storage to refinery

vol^{l}_{lt} Transported volume oil from terminal to the refinery by pipeline

vol^{k}_{kt} Carried volume oil from refinery to the customer by truck

vol^{pc}_{pct} Transported volume oil from refinery to the customer by pipeline

The notation give above will be used throughout the model. In the next section, we first introduce the objective function and then present the technological and cost constraints.

5.9 Model Formulation

Mid-stream and downstream will be used as a basis for modeling the oil supply chain network in LOOP and the objective function of the mathematical model considered here is to maximize the net present value profit while minimizing the oil transportation, storing, refining and delivering to the customers from LOOP. It contains of the following components:

- Objective function: Maximization of benefit along six months of operation in mid-stream and downstream sectors. Revenue corresponds to the sale of oil to the customers. Expenses are represented by storing costs, refining costs, transportation costs, delivery cost of final products to markets, maintenance costs for any disruption in system, etc.
- Mass balance: Equations representing mass balances.
- Inequality constraints: These constraints are given by capacity limits for each tanker, each offshore pipeline, storages, terminal, each interconnection pipelines, each refinery and each customer.
- Binary variables are assigned for unusual situations such as man-made or natural disasters.

5.9.1 Objective Function

The high economic value and uncertain nature of the oil and gas business are driving forces for developments in the oil and gas planning process. The problem is to develop a method to determine minimum cost for the industry with presence of disruption in the system.

The revenue is the amount of money received for selling oil products, which is determined by multiplying the total amount of oil sold to the customer and the sale price of oil.

$\text{Revenue}_t =$ (Total amount of oil sold to each customer) × (Oil price in each time period)

$$=[\sum_{pc=1}^{3} vol^{pc}_{pct} + \sum_{k=1}^{10} vol^{k}_{kt}] * \sum_{t=1}^{180} price_t \quad (1)$$

The total cost in each time period is the sum of offloading oil cost by tanker and transporting pipeline to the LOOP, storage cost (underground and on ground), interconnected pipelines, refinery process cost, tax, distribution and marketing costs. The cost of crude oil from the platform will be assumed a fixed number that carried through pipeline or tanker. The maintenance costs will be applied into the system whenever any disruption or accidents happens, Otherwise these costs are not considered in the calculation.

$$\text{Total Cost}_t = (\text{Amount of oil in step j}) * (\text{Cost of step j}) \quad (2)$$

$$= \sum_{t=1}^{180}\sum_{i=1}^{2} C_{it}^{tk}.\, vol_{it}^{tk} \quad \text{Tanker Cost}$$

$$+ \sum_{t=1}^{180}\sum_{p=1}^{3} C_{pt}^{p}.\, vol_{pt}^{p} \quad \text{Pipeline Cost}$$

$$+ \left(\sum_{t=1}^{180} CS1_t\right) + \sum_{t=1}^{180} C_t^{s1}\, .vol_t^{s1} + \sum_{t=1}^{180} C_t^{pl1}.\, vol_t^{pl1} \quad \text{Storage 1 Cost}$$

$$+ \left(\sum_{t=1}^{180} CS2_t\right) + \sum_{t=1}^{180} C_t^{s2}\, .vol_t^{s2} + \sum_{t=1}^{180} C_t^{pl2}\, .vol_t^{pl2} \quad \text{Storage 2 Cost}$$

$$+ \sum_{t=1}^{180} C_t^{tm}\, .vol_t^{tm} + \sum_{t=1}^{180} C_t^{tp1}.\, vol_t^{s1} + \sum_{t=1}^{180} C_t^{tp2}.\, vol_t^{s2} \quad \text{Terminal Cost}$$

$$+ \sum_{t=1}^{180}\sum_{r=1}^{4} C_{rt}^{r}.\, vol_{rt}^{r} + \sum_{t=1}^{180}\sum_{l=1}^{4} C_{lt}^{l}.\, vol_{lt}^{l} \quad \text{Refinery Cost}$$

$$+ \sum_{t=1}^{180} C_t^{tax}.\sum_{r=1}^{4} vol_{rt}^{r} \quad \text{Tax Cost}$$

$$+ \sum_{t=1}^{180}\sum_{k=1}^{10} C_{kt}^{k}.\, vol_{kt}^{k} \quad \text{Truck Cost}$$

$$+ \sum_{t=1}^{180}\sum_{pc=1}^{3} C_{pct}^{pc}.\, vol_{pct}^{pc} \quad \text{Pipeline customer Cost}$$

$$+ \sum_{t=1}^{180}\sum_{mp=1}^{3} M_{mpt}^{mP}.\, (1 - y_{mpt}^{mp}) \quad \text{Pipeline Maintenance Cost}$$

$$+ \sum_{t=1}^{180}\sum_{mc=1}^{3} M_{mct}^{mc}.\, (1 - y_{mct}^{mc}) \quad \text{Pipeline C Maintenance Cost}$$

$$+ \sum_{t=1}^{180}\sum_{mr=1}^{4} M_{mrt}^{mr}.\, (1 - y_{mrt}^{mr}) \quad \text{Refinery Maintenance Cost}$$

Which needs to be minimized to maximize the profit. The revenue left over after the coverage of costs represents profits. Thus, the profit is determined by total revenue of oil and gas industry in Gulf of Mexico minus total costs:

$$\text{Profit}_t = [\text{Revenue}_t - \text{Total Cost}_t] \quad (3)$$

In order to maximize the objective function, the net present value should be calculated using the profit and a discounting factor for each time period:

Net Present Value (NPV) = Profit – I_t*$Profit_t$ (4)

Distribution and marketing Costs are associated with the distribution from terminals to stations and retailing of gasoline. Refinery costs and profits are associated with refining and terminal operations, crude oil processing, product shipment and storage, oil spill fees, and purchases of gasoline to cover refinery shortages.

5.10 System Constraints

Delivering oil to the port by tanker or through pipelines, storing at temporary storage (tank or cavern), and refining and distribution of oil in an oil field are usually subject to multiple capacity, transporting, material balance, and economic constraints. The economic performance indictor in this model is the maximization of the net present value of the project even in presence of any disaster (shock) in the system.

5.10.1 Material (Mass) Balance Constraints

The following constraints set up a balance between input and output flow of oil in each pipeline, tanker, port, temporary storage, terminal, refinery and each customers.

$$\sum_{p=1}^{3} vol_{tp}^{p} + \sum_{i=1}^{2} vol_{it}^{tk} = vol_{t}^{port}, t = 1, \dots, 180 \quad (6)$$

$$vol_{t}^{port} = vol_{t}^{pl1} + vol_{t}^{pl2}, t = 1, \dots, 180 \quad (7)$$

$$vol_{t}^{pl1} = vol_{t}^{s1}, \ t = 1, \dots, 180 \quad (8)$$

$$vol_{t}^{pl2} = vol_{t}^{s2}, \ t = 1, \dots, 180 \quad (9)$$

$$vol_{t}^{s1} + vol_{t}^{s2} = vol_{t}^{tm}, \ t = 1, \dots, 180 \quad (10)$$

$$vol_{t}^{tm} = \sum_{l=1}^{4} vol_{lt}^{l}, \ t = 1, \dots, 180 \quad (11)$$

$$(1 + \theta). vol_{1t}^{l} = vol_{1t}^{r}, \ t = 1, \dots, 180 \quad (12)$$

$$(1 + \theta). vol_{2t}^{l} = vol_{2t}^{r}, t = 1, \dots, 180 \quad (13)$$

$$(1 + \theta). vol_{3t}^{l} = vol_{3t}^{r}, t = 1, \dots, 180 \quad (14)$$

$$(1+\theta).\mathrm{vol}_{4t}^{l} = \mathrm{vol}_{4t}^{r}, \ t = 1, \dots, 180 \quad (15)$$

$$\sum_{r=1}^{4} \mathrm{vol}_{rt}^{r} = \sum_{pc=1}^{3} \mathrm{vol}_{pct}^{pc} + \sum_{k=1}^{10} \mathrm{vol}_{kt}^{k}, \ t = 1, \dots, 180 \quad (16)$$

$$\sum_{pc=1}^{3} \mathrm{vol}_{pct}^{pc} + \sum_{k=1}^{10} \mathrm{vol}_{kt}^{k} = \mathrm{vol}_{t}^{c}, \ t = 1, \dots, 180 \quad (17)$$

The total transported crude oil from offshore to the port during time period t can be calculated by summing the total pumped crude oil and the total carried crude oil by tankers transported during time period t. The total amount of pumped crude oil during time period t to the terminal from storage is calculated by summing the carrying over of all types of oil pipelines. The total amount of oil after refineries will be increased by θ and will delivered to the customers by trucks and pipelines.

5.10.2 Capacity Constraints

The following constraints set up the capacity bound for each tanker, each offshore pipeline, storages, terminal, each interconnection pipelines, each refinery and each customer at time t. Extracted oil should be pumped to the pipelines, and the total volume must be less than the capacity of that pipelines if there exists a pipeline (of type p) to transport to port. The total transported crude oil by the tk^{th} type of oil tankers is less than the number of the tk^{th} type tanker (here we have only one tanker) times its capacity.

Tanker capacity: $0 \le \mathrm{vol}_{it}^{tk} \le \mathrm{cap}_{it}^{tk}.\mathrm{y}_{it}^{tk}, \ i = 1,2 \ , \ t = 1, \dots, 180$ (18)

Offshore Pipeline: $0 \le \mathrm{vol}_{pt}^{p} \le \mathrm{cap}_{pt}^{p}.\mathrm{y}_{pt}^{p}, \ p = 1,2,3 \ , \ t = 1, \dots, 180$ (19)

Storage Pipeline: $\le \mathrm{vol}_{plt}^{pl} \le \mathrm{cap}_{plt}^{pl}.\mathrm{y}_{plt}^{pl}, \ pl = 1,2 \ , \ t = 1, \dots, 180$ (20)

Storage1: $0 \le \mathrm{vol}_{t}^{s1} \le \mathrm{cap}_{t}^{s1}.\mathrm{y}_{t}^{s1}, t = 1, \dots, 180$ (21)

Storage2: $0 \le \mathrm{vol}_{t}^{s2} \le \mathrm{cap}_{t}^{s2}.\mathrm{y}_{t}^{s2}, t = 1, \dots, 180$ (22)

Terminal: $0 \le \mathrm{vol}_{t}^{tm} \le \mathrm{cap}_{t}^{terminal}.\mathrm{y}_{t}^{tm}, t = 1, \dots, 180$ (23)

Refinery Pipeline: $0 \le \mathrm{vol}_{lt}^{l} \le \mathrm{cap}_{lt}^{l}.\mathrm{y}_{lt}^{l}, l = 1, \dots, 4 \ , \ t = 1, \dots, 180$ (24)

Refinery: $0 \leq vol_{rt}^{r} \leq cap_{rt}^{r}.y_{rt}^{r}$, $r = 1, \dots, 4$, $t = 1, \dots, 180$ (25)

Truck: $0 \leq vol_{kt}^{k} \leq cap_{kt}^{k}.y_{kt}^{k}, k = 1, \dots, 10$, $t = 1, \dots, 180$ (26)

Customer Pipeline: $0 \leq vol_{pct}^{pc} \leq cap_{pct}^{pc}.y_{pct}^{pc}, k = 1, \dots, 10$, $t = 1, \dots, 180$ (27)

Binary variables are used to control a 'yes' or 'no' decision in the entire model. Specifically, feedstock, technology, and product choices, transportation by offshore pipelines, tankers and, availability of refineries, storages, and maintenance processes, and product distribution by truck or pipeline to the customer were controlled using binary variables:

$$y_{it}^{tk}, y_{pt}^{p}, y_{s1t}^{s1}, y_{s2t}^{s2}, y_{plt}^{pl}, y_{rt}^{r}, y_{lt}^{l}, y_{t}^{tm}, y_{kt}^{k}, y_{pct}^{pc}, y_{pt}^{p}, y_{mct}^{mc}, y_{mrt}^{mr} \in \{0,1\} \quad (28)$$

Having 0-1 binary variables in the system provides the capability to manage the availability and possibility of facilities and connections. For example, if refinery facility is available, we set the $y_{rt}^{r} = 1$, otherwise it is zero. In addition, for example, if the connection of offshore by pipeline to port is impossible, then it is set to $y_{pt}^{p} = 0$.

5.11 Data Description

The next data presented is assumed to be known a priori. This data will appear in the model in the form of inputs: cost estimates for delivering crude oil to the port, storage, handling, cost of terminal, cost of transportation by interconnection pipelines, cost estimates for final product in refinery, transportation, cost of maintenance (for pipeline and refineries) and the tax rate; the refineries that will be considered in this study are: Motiva, ExxonMobil, Placid and Grayville.

Motiva is the third largest refiner in the Gulf Coast. The oil will be delivered to the refineries by four different pipelines to four different refineries. We assume that the capacity of the pipelines are the same as each refineries in the system. Motiva's Convent refinery, is located in St. James Parish, Louisiana--it is an integrated oil refinery that produces a full slate of conventional petroleum products including regular, premium and low-sulfur gasoline. It has a crude capacity of 230,000 barrels per day (refer Motiva enterprises website). The ExxonMobil Baton Rouge refinery is the third largest refinery in the United States with processing over 502,500 barrels of crude oil per day and more than 2,500 employees and 300 products

(ExxonMobil website). Grayville Refinery is Located in Grayville, La. between New Orleans and Baton Rouge with capacity of 522,000 barrels per day, approximately 850 employees, and 650 contract workers. Placid refinery is a small medium complexity refinery, located in Port Allen, Louisiana with capacity of 80,000 barrels per day (Wikidot, 2015). Table 5.1 presents capacities for system's parameters.

Table 5.1 Parameters for Different Capacities

Description		Notation	Value (bbl/day)
Tanker	Cascade	tk1	332,000
	Chinook	tk2	332,000
Offshore Pipeline	Mars	p1	600,000
	LOOP 48	p2	500,000
	Endymion	p3	1700000
Storage	Tank	s1	9,000,000
	Cavern	s2	58,000,000
Refinery	Motiva	r1	230,000
	Grayville	r2	522,000
	Exxon	r3	502,500
	Placid	r4	80,000
Pipeline	LOCAP	pc1	1,700,000
	Norco	pc2	230,000
	CAM	pc3	230,000

Lines that bring crude oil into the LOOP Clovelly Hub are: LOOP 48" with capacity of 1.7 million barrels per day, Endymion Pipeline with capacity of 500,000 barrels per day and Mars 24" pipeline with capacity of 600,000 barrels of oil per day, which began at the Mars and Olympus platforms in Gulf of Mexico. There are two tankers (Cascade and Chinook) in the Gulf of Mexico that carry oil to the port with capacity of 332,000 barrels per day.

The pipelines, which deliver crude oil to the market place, are: LOCAP 48" pipeline with capacity of 1.7 million barrels per day, Norco 24" Pipeline with capacity of 230,000 barrels per day and CAM 24" Pipeline with capacity of 230,000 barrels per day. Product Distribution also happens by transport truck with capacity of 10,000 barrels (we assumed 10 trucks in our study). LOOP operates eight underground caverns that have a total storage capacity of 58 million barrels. Fifteen storage tanks, each holds up to 600,000 barrels of oil, are currently in service (LOOPLLC, 2016). In the system, we assumed a fixed cost for both kinds of storages, which means that, if there is breakdown in system, delivery of oil to the storage will incur a fixed cost. Since any

system has a probability of failure for different reasons (pipeline rupturing, oil tanker sinking, hurricane, earthquake, etc.) maintenance cost must be assumed for pipelines and refineries in the system. Table 5.2 presents the cost parameters for different system entities.

Table 5.2 Cost Parameters for Different System Entities

Parameter	Cost ($/bbl)
Tanker	1.55
Offshore Pipeline	0.90
Storage Pipeline	0.10
Tank Storage	0.90
Cavern Storage	0.80
Terminal Pipeline	0.12
Terminal	0.15
Refinery Pipeline	0.10
Refinery	12.50
Tax	10.3
Customer Pipeline	0.40
Truck	0.45

These costs will be considered in the calculation whenever a failure is defined in the system. In this model, we define binary variables to manage the availability of each of the sectors in the system. If an accident happens in the system, then the related binary variable will be zero and the related maintenance cost will be added to the total cost. The current model assumes constant oil prices.

For the simplicity, we assume the total cost of the all steps (from offloading at port to delivering to the customer) is not changed. The discount rate of 10% is the standard used in the oil & gas industry and is what is seen in companies' filings. In this study the discount rate is assumed 10% for simplicity. The model presented above was solved with GAMS, a LP linear solver. The model statistics include a total of 24 block equations yielding 7,741 single equations for 14 block variables and obtained total of 5,941 single variables which are automatically calculated by the GAMS software.

5.12 Results and Discussion

In this section, the results for optimal operational level decisions of oil and gas mid and downstream supply chain are discussed based on the proposed decision-making framework. Optimization of the oil supply chain is critical for the reason that any amount of cost savings means a huge amount of money for the oil and gas companies in the long term; thus, optimization is at the focal point of oil supply chain management. The model was run for a typical set of data corresponding to a very realistic scenario of mid-stream and downstream model of oil supply chain network in LOOP. The decision variables considered in the framework are composed of the optimal volumes of each tanker, offshore pipelines for delivering oil to the port, storage, terminal, refineries, trucks, and customer pipelines.

Base on the results of the LP model for the tactical optimization that is implemented in the modeling system GAMS, and solved with a LP linear solver; optimal values of the decision variables are calculated. As indicated, the current model assumes constant oil prices. We assume the sale price of oil in first 90 days $55 per barrel and the $70 per barrel for the rest of the period. We will deal with the time horizon of 6 months. The model optimization gives the optimal net profit of $7,737 million dollars.

Table 5.3 provides a summary of optimal results of the LOOP mid-stream and downstream model that we developed in this study. Based on the results in Table 5.3, total amount of oil sold to customer is 1,334,500 barrel for the first day. The total for whole the system that contains offshore pipeline cost, tanker cost, port fee, storage cost, delivery cost to the refinery, tax rate and transport cost to the customer is equal to $6,414 million.

Table 5.3 Optimal Framework Results

Variable	Final Value
Net Present Value (NPV), (Million $)	7,737
Total Revenue, (Million $)	15,013
Total Cost, (Million $)	6,414
Total amount of oil sold to customer, bbl/day	1,334,500

Oil and gas are often found in areas that are not always peaceful or benign. For example, severe weather conditions can cause critical situations such as failure of offshore installations, offshore pipelines, refineries, or storage structure. Then, suppliers cannot meet their requirements

and delivering an order in full is not possible on time. The longer it takes to restore activity at the port or the longer it takes to shift services to other ports along the coast, the greater these losses will be. Weather and other events can cause disruptions to gasoline infrastructure and supply. Therefore, we have generated a scenario where the system experiences a breakdown in the supply chain that we developed in this study. Natural disasters such as a hurricane is one reason for the disruptions to a supply chains. Therefore, we assumed to have a loss in one of the refineries (refinery No. 3) for 180 days due to damage from a hurricane. Refineries manufacture crude oil into different petroleum products. Hurricanes can result in flooding that damages refining equipment or causes power outages, preventing refineries from operating. When refineries do not operate, the related industries, as well as the state and U.S. government's total gasoline production can decline, affecting supplies of the petroleum products.

Table 5.4 presents optimal framework results for Scenario 1: aftermath of hurricane. In this system, we have a system breakdown; one of refinery shuts down and the loss of refinery capacity causes increased cost due to maintenance and decreased sales. Total amount of oil sold to customers in this scenario decreased by 80,000 barrel per day for six months, from the initial value of 1,334,500 barrels/day. The system produces less profit to compare t before disruption. The optimal results of the framework presents total amount of oil sold to customer at *t1* is 1,334,500 barrel per day before any system failure and total amount of oil sold to customers for 180 days is 240 million barrels.

The results indicate that amount of oil sold to customer at *t1* in absence of refinery No. 3 decreases by 1,254,500 barrels per day, which is equivalently 225 million barrels in 180 days. The results indicate about a 6 percent decrease in net present value (NPV) in the system because of the accident. The cost of the system decreases by about $6 billion in the absence of refinery No. 3 with capacity of 80,000 barrels per day but there is a fixed maintenance cost due to the refinery construction.

Table 5.4 Optimal framework results in absence of Refinery No. 3

Variable	Normal (Million$)	Accident (Million$)
Net Present Value (NPV)	7,737	7,274
Total Revenue	15,013	14,113
Total Cost	6,414	6,029

A strong hurricane season can damage offshore oil platforms, reducing the amount of oil produced. Any kind of oil spill or pipeline leakage can cause disruption in oil supply chain. These uncertainties and risks often interrupt the supply chain operations, causing significant adverse effects in the energy sector. Supply can also be artificially reduced or increased by government taxes or subsidies on oil production. When there are problems with the pipelines that transport oil, it cannot get to market; this effectively reduces the supply of crude oil to the world's refiners, causing the supply of refined products to fall. When supplies fall, prices rise.

The importance of the oil industry's impact on the worldwide economy is noticeable. The sharp decline in oil prices in 2014-2015 generated a heavy impact on the oil and gas industry and related industries. In the second half of 2014 and in 2015, oil prices approximately halved; that is, the depth of the oil price shock looked similar to the crisis in 2008-2009.

The price of oil effects the costs of other production and manufacturing through the United States. This means that investors and banks both have money to lose if the price of oil decreases to where new wells are no longer profitable, compared to their cost and the companies' reliance on drilling, and consequently services fail.

The noticeable relation among oil prices and profitability is indicated by the companies directly involved with the petroleum industry. We assume the reduction in sale price of oil the first 3 months to $30 per barrel per day. Table 5.5 presents the optimal framework results for low oil price scenario.

Table 5.5 Optimal framework results for low oil price scenario

Variable	Low oil Price (Million$)	High Oil Price (Million$)
NPV	2,193	7,274
Total Revenue	8,467	14,113
Total Cost	6,029	6,029

The net present value in lower price is calculated to $2,193,424,463 and the amount of sold oil to the customer will stay the same as with higher price. The total revenue will decrease to $8,467,875,000 for this time period. The system cost will not change despite the oil price change. From our analysis, the conclusion can be drawn that higher prices per barrel of oil helped to justify the cost of the system. We can figure out that the best results for the model were found in the scenarios with high prices.

5.13 Conclusion

We developed a framework to design an optimal network of the oil and gas supply chain, with an application to the Louisiana Offshore Oil Port (LOOP). The tactical planning LP emphasizes on optimizing the net present value (NPV) of a mid-stream and downstream supply chain for LOOP in normal situations and critical situations. The model represents the current economic scenario in the LOOP. It optimally decides supply chain plans for crude oil to satisfy different markets, while it optimally allocates transporting alternatives of crude oil to the port and storing, refining and delivering based on capacities and costs.

Optimization of the oil supply chain is critical for the reason that any cost saving means huge volumes of money for the oil and gas companies in the long term, thus optimization is at the focal point of oil supply chain management. Therefore, the purpose of this research was to discuss the problem of any breakdown in the supply chain operations in mid-stream and downstream (a refining node or interconnections) and what happens in the aftermath of any disaster. We considered how it would affect the flow, the cost, and the sales and still have a maximum net present value. Here, we developed a scenario that one of the refineries went out of order for 6 months in the aftermath of hurricane. By noticeably reducing the amount of refined oil, reduction in profit, having maintenance cost and uncertainty regarding the delay, it effects numerous tiers of supply chain, and the oil and gas industry faces challenging times until the refinery is brought back to normal operations. Therefore, it is critical that sectors and businesses work together collaboratively to improve the supply chain.

Any major breakdown in a production/refining/storing node or a distribution link that is part of a supply chain can cause economic disruption for the company and region. Natural disasters (hurricane, earthquake, etc.) are one reason for disruptions to the supply chains. Therefore, there is a need to make sure that each company in parallel in the supply-chain can respond quickly to the exact material needs of its customers, protect itself from problems with suppliers and buffer its operations from the circumstances it faces. The LP Supply Chain Model (SCM) which is developed and used in this study to analyze the supply chain for tactical/short term planning, is able to establish possible impacts of different scenarios on a generalized oil and gas supply chain network in the Gulf coast. The goal of the supply chain model is to provide maximum revenue and benefit at the lowest possible cost while experiencing a disruption in the

system. A conservative estimate due to a six months loss in one-refinery services from Port Fourchon led to significant loss in the revenue and volume of oil sold to the market. Supply chain management assumes a key role in the logistic activities linked with responding to disasters caused by hazards such as major hurricanes, earthquakes, and oil spills. Such disasters can seriously damage or delay material, result in systems breakdown, create inventory problems and capacity and cash flow issues that in turn can increase the overall costs or decrease sales. Thus, a regional disruption of six months in the oil and gas industry could have significant consequences throughout Louisiana and the United States.

Future work will emphasize on the development of a framework to optimally design the oil and gas supply chain in the upstream systems in offshore Gulf of Mexico. Additional future work may contain more variables within the proposed framework, incorporating uncertainty analysis in the framework by analyzing different scenarios based on changes in the market condition or any accidents that may happen. We can develop a model to analyze the supply chain for strategic/long term planning, to estimate the impacts of different scenarios on the oil and gas supply chain network in the Gulf Coast. Formulating the environmentally conscious model is also necessary to configure the optimal network.

CHAPTER 6: DISCUSSIONS

The research presented in this dissertation focuses mainly on the effects of a few natural/manmade disaster scenarios on oil and gas industries. Analytical expertise in economics, econometrics, optimization and modeling to forecast impacts of potential disasters and conduct optimization modeling are utilized here to capture key components for building reasonable supply chain models of real-life situations for oil and gas industry in LOOP and surrounding region in order to make the best possible choices aftermath of disaster. In this chapter, the economic impacts analysis methods as well as supply chain model results are discussed together to highlight their connections for a comprehensive system scale disaster model. Combination of econometric analysis and supply chain models can be beneficial for analyzing tactical decisions that optimize the response time and recovery in a disaster scenario. It is crucial to minimize the cost of the event's impacts and achieve quick recovery to reduce the harmful consequences of the disaster (shock).

As discussed before, the research is divided into two parts by considering different disruptions in oil and gas industry from two different perspectives. First part illustrates how disruptions related losses would be distributed across various industries in the region. Job losses are especially heavy for inter-connected industries.

In particular, the research analyzed how the total household earnings losses are distributed across industries in Louisiana and estimated the net impact of the BP oil spill on the Louisiana economy using a VAR model. The offsetting economic injection due to BP expenditures in the economy is calculated by Input-Output model. Thus, the gross economic damages from the spill event are estimated by calculating the sum of net loss and the offsetting economic injection in the economy. These results provide valuable information on calculating the economic impact of future large-scale disasters and for how companies must react to minimize the economic impact of disastrous events. Second part focused on the supply chain modeling because a major catastrophic event could potentially delay and disrupt the delivery of products throughout the region and the country.

Optimization modeling estimated that 6 months loss in one of the refinery services from Port Fourchon would lead to noticeable consequences in the regional oil and gas industry. This temporary shutdown can easily be converted into the cost of delay for delivery of oils. Further,

the estimate of the cost associated with the waiting for the goods delivery turn into the reduction in real income that creates the economic ripples throughout the regional economy.

Oil spills remain problematic episodes in oil and gas industry that can cause slowing down in the exploration and development of offshore oil and gas project plans internationally. For example, the impacts of major oil spill like the 2010 Deepwater Horizon accident on the jobs, labor income and oil and gas industry revenue and other relevant industries show a link between the U.S. economic growth and oil and gas industry. Based on the results from VAR model, the average wage loss after the Deep-water Horizon oil spill in 2010 is equal to $27,493 and in a year later is equal to $41,013. The average number of job lost in 2010 is equivalent to 9,236 and in 2011 are 8,260 jobs. The number of job losses is not significant to compare to the actual number of employees (1.8 million) in Louisiana.

Since the major industries in the Gulf area are the oil and gas, seafood and tourism, they all are going to be economically hurt for at least the short-term due to inter-connected nature of businesses in this region. However, if the emergency responses to potential oil spill events are adequately prepared then the economic consequences of such disaster can be reduced while identifying the most effective measures to be undertaken. Economic assessment of the impacts of oil spill accidents is not necessarily confined to the utilization of time series approaches. Other techniques such as input-output analysis and advanced econometric applications also can be used to assess the consequences of these events. The input-output analysis presents the business sales would achieve over 8.8 percent, and household receive new earnings over 2.5 percent in 2010 for the entire Louisiana due to BP spending. This is a huge compensation that happens by BP aftermath of the disaster. A quick review of the last three years reveals that the Louisiana employment gains biggest benefit in 2010 by 4.7 percent enlargement. The impact of economic injection is much larger in terms of output than it is in terms of employment or earnings; because the share of mining in Louisiana's GDP, is significantly larger to compare to U.S share Oil and gas industry is playing really important role in terms of GDP not in terms of employment.

The study of losses in the employment and earnings in Louisiana in the aftermath of accidents in oil and gas industry makes known the importance and significance of the oil and gas sector as a powerful economic machine that provides a wide-ranging opportunities for the state. Therefore, it is no surprise at that state and local governments and related businesses have to deal

with a significant change in their resources from any shocks (oil spill/hurricane) in this important industry in Louisiana. Louisiana was most significantly impacted by the oil spill in 2010, being a state that relies heavily on the fishing, tourism, and especially on the GOM oil and gas industries. In fact, for every job created in the O&G industry sector additional jobs are generated in other industries within the state (Scott, 2 014). The offset created by BP spending was used to determine gross impact of disaster using the Input-Output model. Thus, the gross economic damages from the spill event are estimated by calculating the sum of net loss and the offsetting economic injection in the economy. The average new wage in 2010 and 2011 are equaled to $45,521 and $40,301 respectively due to BP spending into the region after the Deep water Horizon oil spill that happens in 2010. Based on the economic injection because of the BP spending, 4.8% additional jobs created. That is significant number to compare to number of employment (1.8 million jobs) in Louisiana in 2010.

The gross of loss employment of Louisiana in 2010 is estimated about 96,711 that are approximately 5.3% losses in number of employment to compare 1833 thousands (Bureau of Labor Statistics) in year of disaster. This loss decreased by 1.2% after a year which is equal to 21,492 jobs to compare against 1848 thousands (Bureau of Labor Statistics) in 2011. Based on the results, the gross damage estimates are big number which 96,711 million dollars for the 2010 that oil spill happened.

The BP oil spill damaged the shorelines of four Gulf States - Louisiana, Alabama, Mississippi and Florida. Worse yet, it took three months to build the relief well to stop the spill. With increased geological complexities and increased activities in the exploration of deep-water reservoirs and continued activities of drilling and production in Gulf of Mexico, the risks for another spill event also increases. It has been reported in literature (Zulqarnain & Tyagi, 2014) that nearly every third well drilled in the deepwater GoM had a kick, and approximately there were three blowouts for every 1000-drilled wells. The major contributor to the consequences of a blowout remains the delay in responses to situations needing immediate attention. Clearly, to reduce the economic consequences of such disasters that amplify due to interdependent business supply chains it is imperative to decrease the severity of oil spill event duration and to provide the best decisions to recover such stress situation.

The links between exploration, transportation, storing, refining, marketing and finally customer represent the major supply-chain links in the oil and gas industry. The common concern along the links in the oil and gas industry supply-chain is economics; weighing benefits versus costs along the chain. The relations epitomize the boundary between oil and gas companies and materials that flow through the supply-chain. So long as oil companies have required a group of vendors to maintain continuous supply in their systems, there has been a supply-chain.

Any major breakdown in a production/refining/storage node or a distribution link that is part of the O&G supply chain can cause economic disruption for the company and the region. The Refugio oil spill is a recent oil spill example that happened on May 19, 2015 and leaked 3,400 barrels crude oil into the ocean (Cooper, 2015). The ruptured pipeline was not equipped with an automatic shut-off valve but had to be shut down by control operators. The financial impact on the county was estimated by the California Economic Forecast Director at $74 million if Line 901 keeps inactive for three years due to the need of the region's oil and gas industry to transport oil over this line (Kacik, 2015). While the line is out of service then employee's income, property taxes are bargain. This is the result of the region's oil and gas industry being heavily dependent on Lines 901 and 903. Therefore, there is a need to make sure that each company has an alternate supply-chain that can respond quickly to the exact material needs of its customers, protect itself from problems with suppliers and bumper its operations from the circumstances it faces.

Natural disasters (hurricane, earthquake etc.) are another reasons for disruptions in the supply chains. The LP Supply Chain Model (SCM) which was developed and used in this dissertation, to analyze the supply chain (SC) for tactical/short term planning, is able to establish likely impacts of different scenarios on a generalized oil and gas supply chain network in the Gulf coast. The model optimization gives the optimal net profit around 7,738 million dollars. The goal of the supply chain model is to provide maximum revenue and benefit at the lowest possible cost while experiencing a disruption in system. The results indicates that amount of oil sold to customer at *t1* in absence of refinery No. 3 decreases by 1,254,500 barrels per day which is approximately 226 million barrels in 180 days. The results indicate about 6 percent decrease in net present value (NPV) in the system in consequences of the accident. Each oil and gas company's goal in such supply chains must be to innovate (improve, control etc.) practically each manageable process to achieve an efficient production system by optimization modeling.

Oil and gas are often found in the areas that are not always peaceful or benign. For example, the severe weather conditions in certain regions cause failure of offshore installations, offshore pipelines, refineries or storage structure. If a supplier shuts down and can't deliver an order in full and/or on time, the loss in production will be directly related to the duration it takes to restore activity at the port or the duration it takes to shift services to other ports in that region. Therefore an FPSO (Floating Production, Storage and Offloading) can be a more convenient and resilient technological solution for the upstream nodes in the supply chain while being cost effective compared to other options. The offshore oil and gas industry has used FPSOs for processing, storage of oil and gas and offloading it to a tanker, or an alternate for transporting through a pipeline. FPSOs could potentially connect to supply chain node where it receive oil or gas for production, storage and refining. If a major breakdown in a refining node happens in the aftermath of disasters then installing expensive infrastructure is not a cost and time effective measure. In such situations, an FPSO is often an economical answer in deepwater offshore operations. Once the refinery gets back to the system and FPSO is no longer needed in that location, they can simply lift their moorings and move off to another location.

During the latter half of 2014 and 2015, the oil trading prices approximately halved. In that aspect, the current oil price shock looks similar to the crisis situation during 2008-2009. The noticeable relation among oil prices and profitability is indicative of the economic health of the companies directly involved with the petroleum industry. A scenario that models the effects of oil price shocks on the revenue and net present value of the system can help identifying the strategies for high vs. low oil prices per barrel to justify the cost to the system.

CHAPTER 7: CONCLUSIONS AND FUTURE DIRECTIONS

This research study is an attempt to develop economic models that provide a broad picture of the potential impacts of any manmade or natural disaster (shock) on regional labor markets and economy. The aim was to bridge the gap between the theories of econometric models and supply chain optimization modeling and the current practices in realistic industry and economy. It will be helpful to minimize the cost of the disastrous event impacts and in quick recovery in order to reduce the harmful consequences on the related industry and region economy. In particular, what measures must be taken to recover from a disaster scenario of an oil spill impacting the same region in the aftermath of hurricane. Input-Output model was used to estimate the offset created by BP spending in aftermath of the Deepwater Horizon oil spill to determine gross impact of disaster. Lastly, a supply chain model for disruptions in oil and gas industry and its economic impact on this industry is presented.

Two different aspects were studied and their corresponding results were discussed:

First, Vector Autoregression (VAR) model is presented to examine the effects of different shocks on oil and gas industry and employment in the State of Louisiana and other relevant regional economies. Dynamic response of a variety of industrial sectors in Louisiana to each of these disasters is considered and the likely magnitude of economic impacts of a major oil spill like the Deepwater Horizon oil spill is determined. Also, to forecast the potential impacts of future changes in employment after disaster on economy, recent advances in the econometric tools are used to provide quantitative estimates of the responsiveness and correlation between past and current activities of the oil industries and employment.

Specifically, the Macondo oil spill data was used as an example in this study for selected representative states (Louisiana and Texas) in the GoM region based on their unique structural and economic characteristics and their roles in the regional oil and gas industry. Estimates for the economic impacts due to the oil and gas industry disruption (such as oil spill and hurricane) on the Louisiana employment and other related industry's employment. Significance of hurricane impacts on the Gulf States employment and the oil and gas industry employment is quantified and Louisiana employment is forecast based on other related variables. Input-Output model was used to estimate the offset created by BP spending to determine gross impact of disaster. The gross of loss employment of Louisiana in 2010 is expected about 96,711 that are nearly 5.3% losses in

number of employment to compare 1833 thousands (Bureau of Labor Statistics) in year of disaster. This loss decreased to 1.2% after a year which is equal to 21,492 jobs to compare 1848 thousands (Bureau of Labor Statistics) in 2011. Based on the results, the gross damage estimates are large number which is around 96,711 million dollars.

One positive side that will come out of the oil spill is the spotlight on the need for new and developed prevention and response strategies to these kind of major disaster. A few recommends are devote funds into the research and improvement for spill cleanups, new standards for blowout preventers, well design, and cementing practices

Second, key components of mid and downstream supply chain in the Louisiana Offshore Port (LOOP) were analyzed through optimization modeling by creating a reasonable model of actual situations in order to make the best possible choices due to deal with emergency situations.

Specifically, a conservative estimate due to six (6) months loss in one-refinery services from Port Fourchon led to significant loss in the revenue and volume of sold oil to the market. Supply chain management assumes a key role in the logistic activities linked with responding to disasters caused by hazards such as major hurricanes, earthquakes and oil spill. Such disasters can seriously damage or delay material, result in systems breakdown, create inventories problems and capacity and cash flows that in turn can increase the overall costs or decrease in the sales. Thus, a regional disruption of six (6) months in oil and gas industry could have significant consequences throughout Louisiana and the United States.

7.1 Recommendations for Future Work

Future work will emphasize on developing a framework to optimally design upstream oil and gas supply chain system. It should include development of the supply chain model to analyze for strategic/long-term planning and to estimate likely impacts of different scenarios on the oil and gas supply chain network in the Gulf coast. Additionally, future work must include more process variables within the proposed framework and then analyze different scenarios impacts. Since the model presented in this research assumed constant oil prices in the supply chain. Future work will forecast oil price for each day and apply it in the estimation of other model parameters. Also, using the same methodology of this work can be used to estimate the total economic impact in other regions such as unconventional resources (shale) oil and natural gas industry in terms of jobs, labor income.

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