Analysis of Risk Management Practices of the Oil and Gas Industry in Southeast Texas During Hurricane Harvey

Gevorg Sargsyan
Lamar University

Enrique Venta
Lamar University

James Slaydon
Lamar University

Ricardo Colon
Lamar University

Paul Latiolais
Lamar University

The rapid recovery of the oil and gas sector from natural disasters such as Hurricane Harvey is important for the local economic development of Southeast Texas. The recovery of this industry depends on efficient risk management from natural disasters. In this study Participatory Analysis of Risk Management (PARM) methodology is developed to determine the risk management practices used in recovery and resiliency from natural disasters. The other aim of this tool is to diagnose challenges and use past experiences of local stakeholders to avoid big losses in the future. This comprehensive analysis tool will help to analyze how oil and gas companies do risk identification, assessment, response, and monitoring after natural disasters, to reach reliable conclusions and recommendations. This study describes in detail the PARM methodology and applies it to the oil and gas sector in Southeast Texas.

Keywords: risk management, resiliency, recovery, natural disasters, oil and gas industry

INTRODUCTION AND BACKGROUND

In regions where natural disasters are frequent, there is a need to analyze risk management practices that support local economic growth by improving risk management strategies and/or by reusing best practices of the past. "We need to know, very simply, what works and why. Then we need to apply it." (Porter, 1990) This kind of analysis is especially important when a sector of the economy is dominant in the region. Value chain analysis in this project confirmed that the oil and gas sector is an economic driver of Southeast Texas. According to the Texas Workforce Commission this sector of the economy, directly

and indirectly, employed more than 50,000 people in Beaumont - Port Arthur MSA. It is more than 30% of the employed population of this region and the sector showed GDP annual compound growth of between 9.3% (2018/2017) and 21% (2017/2016) (U.S. Department of Commerce Bureau of Economic Analysis, 2019). Examples of major employers in this sector are: refineries - Exxon Mobil, Motiva, Valero, Total, and petrochemical plants - Dupont, BASF, Chevron, Goodyear. These companies have billions of dollars of assets and revenues invested in the Southeast Texas region. The oil and gas sector is important for the stability and growth of the local economy.

Historical data of the National Hurricane Center shows that the Southeast Texas region is vulnerable to frequent tropical storms and hurricanes. Since 2000 Texas saw more than three dozen tropical depressions, tropical storms, and hurricanes. The major storms in this time period include Allison (2001), Rita (2005), Ike (2008), Harvey (2017), and Imelda (2019). These storms affected Southeast Texas dramatically. The following table of the value of economic and insured loss shows the negative impact of these storms

TABLE 1
MAJOR STORMS IN TEXAS AND FINANCIAL LOSSES

#	Storm	Year	Economic loss	Insured loss
1	Allison	2001	$ 12.0 billion	$ 5 billion
2	Rita	2005	$ 23.9 billion	$ 11 billion
3	Ike	2008	$ 43.0 billion	$ 21 billion
4	Harvey	2017	$ 125.0 billion	$ 30 billion

Source: Texas Comptroller of Public Accounts web page

As the table shows about 25% of the losses from Hurricane Harvey were covered by insurance. While insurance is an important financial risk management tool, this research will not consider insurance in detail. Instead, the paper focuses on the discovery of innovative and alternative management practices used in the oil and gas sector to mitigate risk.

The most serious storm for the oil and gas sector was Harvey. Harvey's effect on oil and gas production in Southeast Texas can be summarized as follows:

- 60% of U.S. upstream chemical manufacturing capacity impacted,
- shut down of:
  25% of U.S. refining capacity (24 refineries - 3,871,449 barrels per day),
  24.5% of oil production in the Gulf of Mexico (428,568 barrels per day),
  25.9% of natural gas production (835 mln cubic feet per day), (Aon Benfield, 2018)
  more than 50% of the US production of ethylene,
  50% of the US of polyethylene production,
  60% of the US production of polypropylene (American Fuel & Petrochemical Manufacturers).
- 105 of the 737 production platforms in the Gulf of Mexico were closed,
- disruption of more than one-third of US chemical production,
- crude and oil petroleum pipelines were affected,
- transportation backlog,
- on September 15, 2017, a month after the Harvey made landfall most refineries and chemical plants had restarted. (Cassiday, 2018)

Harvey resulted in an increase in gas and decrease crude oil prices. "Gas prices rose from $2.35 a gallon, before Harvey hit, to $2.49 a gallon on August 31, 2017, six days after the storm first made landfall." (a two-year high) (Amadeo, 2019). Crude oil prices declined by 4%. Because of shutdowns, refiners demanded less crude oil which caused crude oil prices to fall (Oyedele, 2017). Companies were unable to transport shipments of products to their customers. Refineries and chemical plants were unable to receive

shipments of raw materials due to disruption of transportation by truck, railway, and barge (Cassiday, 2018). These factors highlight the importance of risk management in the oil and gas sector.

The purpose of this study was to observe and analyze the practices of risk management that oil and gas sector companies used in Southeast Texas to be resilient and recover from Hurricane Harvey. In order to achieve the research goal, we adapted a well known local economic development analysis model Participatory Appraisal of Competitive Advantage (PACA) designed by Brazilian and German researchers (Meyer-Stamer, 2006).

RESEARCH METHOD

As mentioned above in areas where natural disasters are frequent, there is a need to design and implement participatory local economic recovery plans. "Successful local economic development is based on collective action and involves a partnership between the public and private sector." (Meyer-Stamer, 2006) We believe that successful risk management, recovery, and resiliency of the oil and gas industry in Southeast Texas also requires collective action. "Successful initiatives have a common characteristic: shared understanding." (Porter, 2000) Moreover, the recovery of the oil and gas industry from natural disasters like Hurricane Harvey should always begin with planning to efficiently manage risks in the future. This argument is similar to the classic approach of local economic development by Blakely and Bradshaw (Blakely and Bradshaw, 2002). According to World Bank "local economic development should always begin with the formulation of a strategy." There is also evidence that a top-down (governmental) approach is efficient only in large development projects and investments (i.e. development of infrastructure: roads, railroads, airports, etc.). "Active government participation in a privately led effort, rather than an initiative controlled by the government, will have a better chance of success." (Porter, 2000) Risk management is challenging because of its efficient implementation in the local economy depends on the involvement/engagement of different stakeholders, and it requires continuous communication and coordination of risk management actions and recovery efforts.

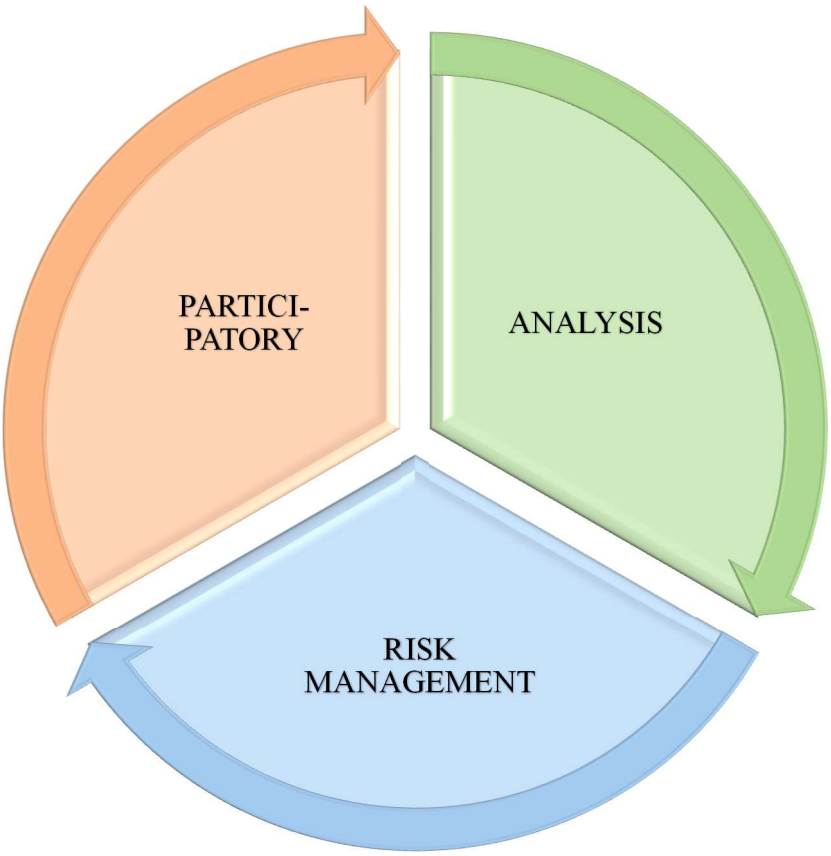
The Participatory Analysis of Risk Management (PARM) methodology used in this study is based on the Participatory Appraisal of Competitive Advantage (PACA). PACA method emerged from the cooperation between the Chamber of Industry and Commerce, Brazil, and the Chamber of Arts and Crafts, Germany. (Meyer-Stamer, 2006) The PACA model uses the theory of location competition and economic development by well-known researcher and Harvard Business School professor Michael Porter. (Porter, 1990) The methodology uses Porter's diamond and Porter's five forces and value chain analysis to capture the structure of each sector of the local economy and helps to facilitate the entire research. (Meyer-Stamer, 2004) PACA methodology has been successfully used in more than twenty countries by researchers, universities, international organizations, local governments, and others.

For this study, we adapted the PACA logic to design the Participatory Analysis of Risk Management (PARM) methodology. The PARM method helps to identify the risk management practices of recovery and resiliency from natural disasters. The other aim of this tool is to diagnose challenges and risks that local stakeholders experienced during previous disasters to help mitigate losses during the next events. The model also helps with reaching reliable conclusions and recommendations. Another purpose of PARM methodology is to stimulate learning among local stakeholders and establish a shared vision of local economic growth and common strategy to overcome risks and challenges from natural disasters.

The three components in Figure 1 are the core elements of the methodology.

- **1st component.** The **participatory** approach involves local stakeholders who have knowledge and experiences from the recovery of the previous natural disasters.
- **2nd component.** Risk management **analysis** is a careful study of managerial practices of risks, recovery efforts, and resiliency.
- **3rd component.** The study focuses on the analysis of **risk management:** eliminate or reduce risk through risk identification, risk assessment, risk response, and risk monitoring.

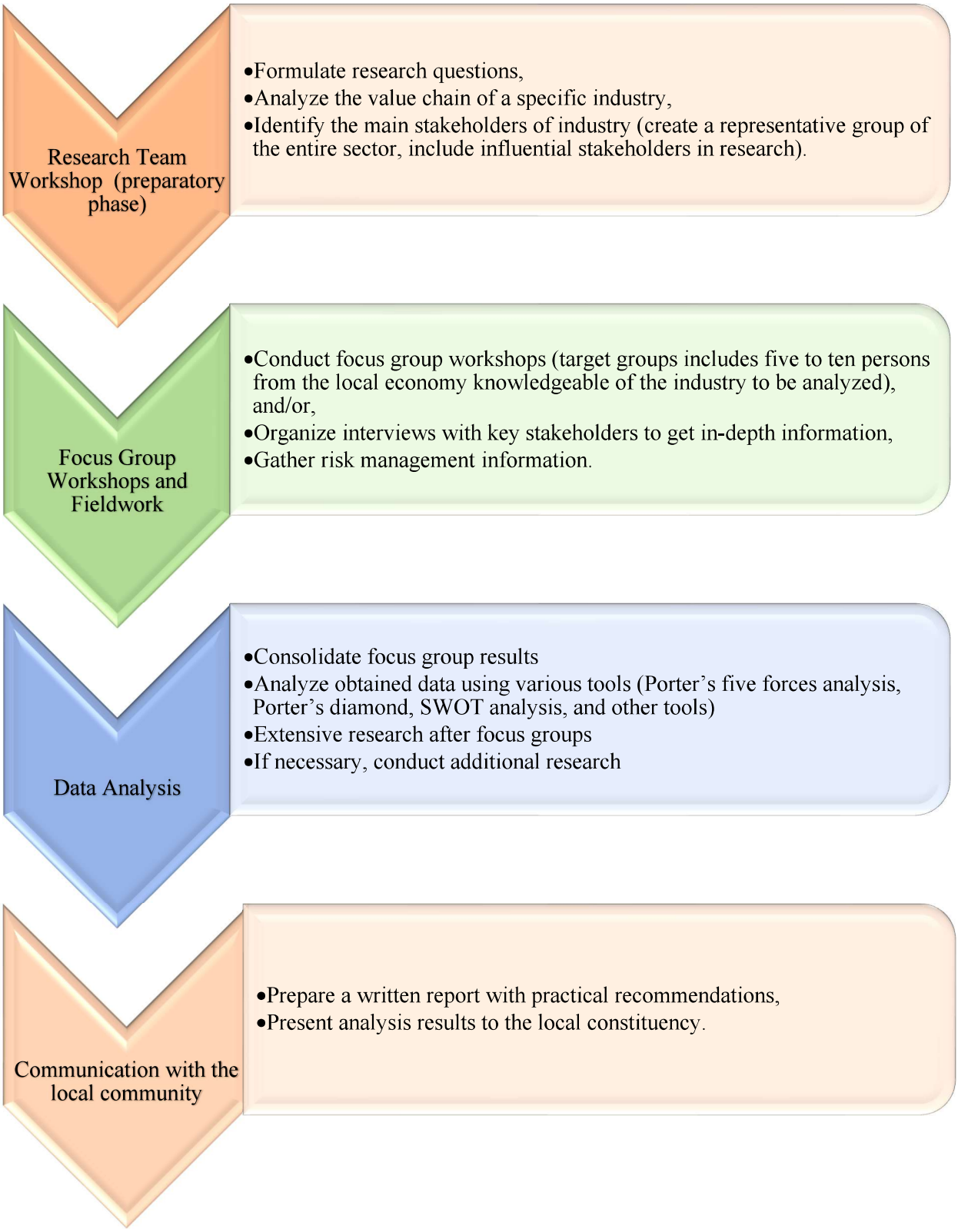
FIGURE 1
THREE CORE ELEMENTS OF PARM METHODOLOGY



PARM is appropriate for areas where a natural disaster has happened recently and there is a need to analyze the situation and plan local economic growth. Its participatory approach can help to find solutions. The most important advantage is that this tool helps to formulate appropriate projects to recover from natural disasters more quickly.

The analysis includes risk acceptance, risk mitigation, risk transfer, risk financing, and risk avoidance. The five steps that are the principal phases of PARM are shown in figure 2.

FIGURE 2
PARM METHODOLOGY'S WORKFLOW CHART



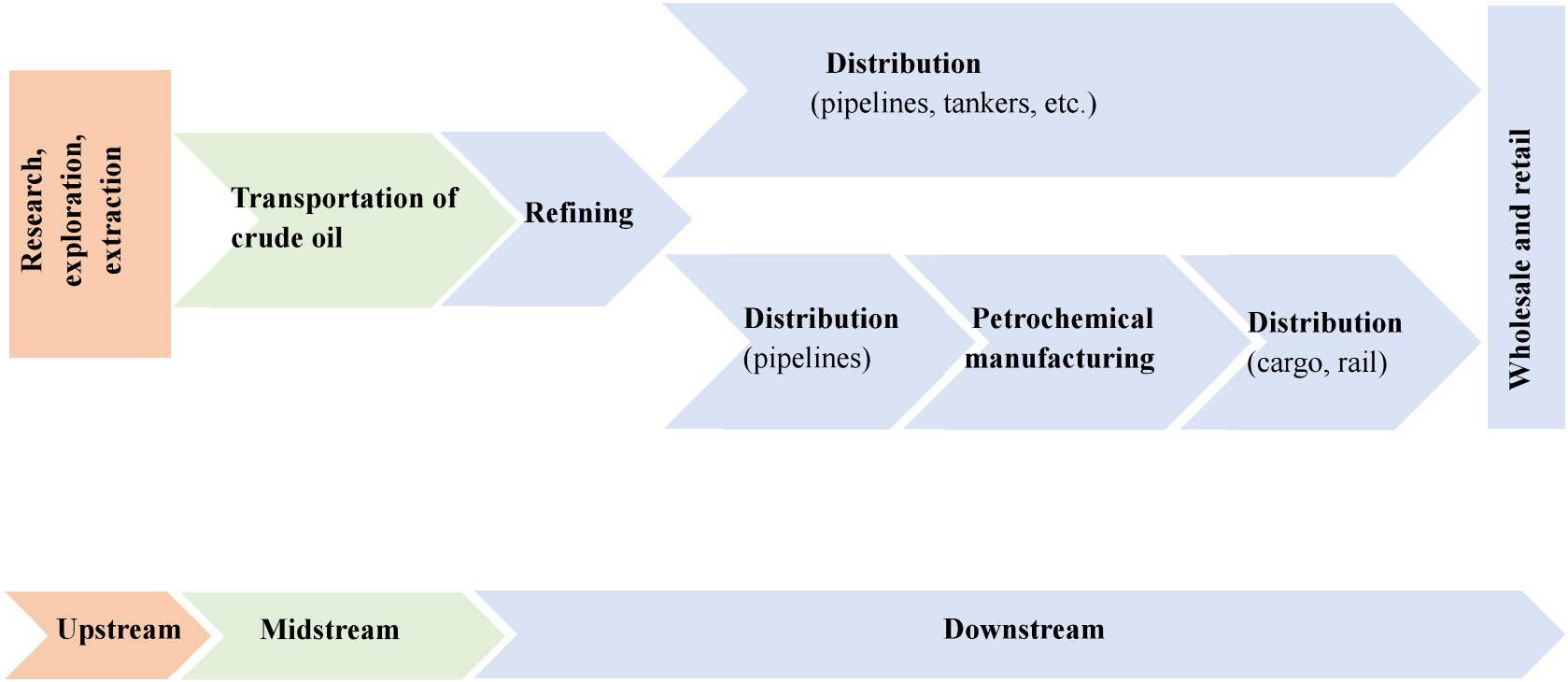
APPLICATION OF PARM TO THE OIL AND GAS SECTOR IN SOUTHEAST TEXAS

This research followed the PARM workflow. As a first step, we set our research goal. The main research question of this study was to detect and analyze the practices of risk management that oil and gas sector companies implemented in Southeast Texas to be resilient and recover from Hurricane Harvey. Based on that we formulated the following questions for focus group workshops:

- What risks/problems did you experience during Hurricane Harvey?
- What were the most successful risk management strategies that you/your group used during Hurricane Harvey? Why?
- Were there risk management strategies that were not as successful that were used during Hurricane Harvey? Why?
- How did you manage the recovery process? What risks or challenges did you encounter during recovery?
- What role did technology (including communications) play in the Hurricane Harvey response? Which were the most critical technologies? What do you see as the role of technology in the future?
- What would you like to see happen if there is ever another hurricane in Southeast Texas and what steps will help us to move in that direction?

In the first phase of PARM, we also analyzed the value chain of the oil and gas industry. Figure 3 presents the oil and gas industry's value chain of Southeast Texas. Using the value chain we identified the main stakeholders of the industry. In this phase value chain analysis helped us to identify the main stakeholders involved and created a representative group of the sector. Table 2 includes the main players in the oil and gas industry of the Southeast Texas region.

FIGURE 3
OIL AND GAS SECTOR'S VALUE CHAIN ANALYSIS IN SOUTHEAST TEXAS



DISCUSSION OF RESULTS

Participatory analysis of risk management in the oil and gas industry helps to fully understand how prepared are the companies in this industry, how quickly they recovered from hurricanes, and also to what extent it impacted their human resource management. This study summarizes the risks and risk management practices and HR management, related to plant shutdown and plant restart. The research team organized focus group workshops and interviews with the key stakeholders in Southeast Texas to discuss resiliency and recovery in the aftermath of Harvey. This helped to discover and elicit the risk management practices used by the oil and gas industry.

In terms of resiliency, industry representatives informed that sensitive equipment has been raised at facilities to avoid flooding. Also, facilities have improved water drainage systems and undertaken flood mitigation projects. Rapid access to power generators has been secured with contractors. Emergency response plans have been updated with policies and procedures that reflect lessons learned from Harvey. Weather stations have been placed in service or will be acquired to obtain real-time and more accurate weather data, particularly with respect to rainfall. Another major finding is that flood gauges across Southeast Texas, which currently require manual readings of gauge height, should be modernized to collect data using sensors that can transmit flood data by radio or satellite. This is particularly important with respect to the flood gauges located upstream in the Neches River. Industry representatives commented that the high cost of satellite telephones and service plans are not an efficient use of financial resources, especially since these telephones remain idle for most of the year. Accessibility to rental satellite phones by providing more affordable service plans is highly recommended.

With respect to recovery, high water vehicles will be acquired to facilitate quick response in flooded areas. Air drones have been acquired to assess the damage and flooding. A significant finding is that current federal regulations by the Federal Aviation Administration (FAA) should facilitate the use of drones in response to an emergency. Another significant finding with respect to regulations is that labor standards regarding industry-based certifications should be revised as current labor standards may cause labor shortages following an emergency. Logistics is an area where improvements are feasible. Industry representatives recommended using the Jack Brooks Regional Airport (BPT) in Southeast Texas as a hub with the ability to receive cargo aircraft. Interstate 10 and other main routes to Houston were flooded after Harvey, and heavy equipment and spare parts were being received at Bush Intercontinental Airport (IAH). There were delays in transporting these spare parts and equipment to industry sites in Southeast Texas. In some instances, helicopters were used to transport spare parts from sites in Houston to Southeast Texas. In addition, a warehouse in a location not prone to flooding may facilitate the centralized storage of spare parts and equipment (especially rental pumps) that may be needed in response to an emergency. Industry representatives also indicated that local and state authorities should prioritize assessing and communicating information regarding the conditions of main highways, bridges, and roads across Southeast Texas.

Preparedness for Hurricanes and

- The safe stop of plant activity takes 24 to 48 hours.
- Usually, it takes a few weeks to close the facility. shutdown takes from 1 to 2 weeks. Even in case of complete shutdown, it is preferable to keep some activities hot, cool or running; for example, hot asphalt moving through pipelines (when it gets cold it can dry and destroy pipeline), and some chemical reservoirs are required to stay cold (temperature increase can cause an explosion).
- There are specific activities for the complete shutdown of the plant. These activities are specified in the plant's hurricane policies. These documents are updated after each event (28^{th} edition of hurricane policy is the most recent manual for one of the plants studied).
- In order to start shut down procedures on time, they use meteorological services to receive timely weather updates.
- The plant has special communication devices always active in case of emergencies (such as satellite phones and shortwave radios).

The following charts present the findings of PARM methodology for **plant shutdown**:

Risks Related to Harvey

- Most of the plants were prepared to receive Harvey.
- The facilities are designed to handle natural disasters of this kind.
- The rainfall during Harvey exceeded the internal drainage capacity of the plants, generally only 14 - 17-inches of floodwater during a 24 hour period.
- Harvey caused a shutdown of the facilities.
- More detailed local weather, flood and river-level forecasts and more accurate prediction models are needed.
- Conflicting information about rainfall from meteorological services created uncertainty as to what measures to put in place to safeguard facilities.
- Loss of the city's water service caused a significant problem for running air conditioners.
- Nitrogen and oxygen supplies were disrupted.

Risk Management Practices and Lessons from Harvey

- Preparation for hurricane season starts in May. In response to Harvey new policies and procedures have been put in place. In some plants, new chapters related to flooding have been added to the hurricane preparedness guide.
- To manage water flush in a more efficient manner plants improved their drainage system.
- Production facilities and equipment were raised to minimize potential flood damage.
- As a response to Harvey, new weather stations were built, and more stations are planned to allow more accurate predictions of rainfall/wind events. There is a need for real-time rainfall measuring stations for more accurate flood forecasting.
- Establishing a more detailed local weather network could assist industry to prepare and respond to emergencies.
- For better measurement of floodwater and rain, plants placed water gauges in key locations to manage flooding more efficiently.
- A simple solution to overcome the loss of the city's water was to use fire water to run air conditioners.
- Most of the plants didn't lose power. Utilities (power and steam) were kept running at all times during Harvey and Imelda.
- Pumps are needed during hurricanes and storms. Contracts with pump rental companies will help to manage the flood better.
- Shared satellite service for all refineries in the hurricane period can be a better solution than having those phones active all year.

The next charts present the results of PARM methodology during **plant restart**:

Post-Hurricane Recovery

- Restarting plant activity takes 1 to 4 weeks, however complete economic recovery takes much longer.
- Logistics problems to transport spare parts, raw materials and products hampered recovery.
- The Sabine-Neches waterway is a critical and strategic logistical resource. When the waterway shuts down it creates significant problems for shipments of raw materials and finished products.
- There is high reliance on pipelines which are more resilient to hurricanes and storms. Maintaining pipelines operational is an important task during storms (especially those pipelines that transport hot materials such as asphalt).
- Railroads are also an important transportation mode for raw materials and finished products.
- To restart refinery after the hurricane there is always a need for spare parts.

Post-Hurricane Recovery

- Restarting plant activity takes 1 to 4 weeks, however complete economic recovery takes much longer.
- Logistics problems to transport spare parts, raw materials and products hampered recovery.
- The Sabine-Neches waterway is a critical and strategic logistical resource. When the waterway shuts down it creates significant problems for shipments of raw materials and finished products.
- There is high reliance on pipelines which are more resilient to hurricanes and storms. Maintaining pipelines operational is an important task during storms (especially those pipelines that transport hot materials such as asphalt).
- Railroads are also an important transportation mode for raw materials and finished products.
- To restart refinery after the hurricane there is always a need for spare parts.

Risks Related to Harvey

- Harvey's magnitude caused a deficit of spare parts. Plant inventory and local suppliers couldn't meet post-Harvey demand. (hundreds of motors had to be replaced or repaired after Harvey).
- A year after there was still corrosion of equipment throughout the plant.
- Most of the spare parts had been delivered to Houston, but transportation channels from Houston to Beaumont were not open.
- It took about 7 days to get back to normal operations after Imelda vs 4 weeks in the case of Harvey.

Risk Management Practices and Lessons from Harvey

- Suppliers and plants keep higher levels of inventory, despite the additional holding and potential damage cost.
- As a preparedness measure post-hurricane plant restart training for all employees should be implemented.
- In some cases, large supplies and machinery were transported by helicopter from other plants to Lamar University's Montagne Center.
- A centralized transportation hub at the Beaumont airport can be a solution to the deficit of spare parts in post-hurricane recovery.
- Prioritized maintenance (zoned maintanace) of areas of the plant can help to address recovery issues more quickly.
- Flexible production practices help to identify which production processes can be restarted first and at what level (in the case of Harvey, in one plant jet fuel production started earlier than the production of other products because they had enough inventory in tanks).
- Funds are set-aside to purchase necessary supplies during the recovery period.

Finally, the charts that follow explain **human resource management** during plant shutdown and restarting procedures.

Hurricane's Impact on Human Resource Management

- Refinery shut down and especially recovery need extra manpower.
- Hiring new employees is a time-consuming procedure in the oil and gas industry due to safety training and background checks.
- Another human resource challenge is getting the labor force to work because of road

Risk Related to

- Nearly half of the employees of the oil and gas industry were impacted personally.
- The safety of families and damage to the properties of the workers create difficulty in having them return to work.
- Personnel on-site was not able to leave to go home, while personnel off-site was not able to get to the refinery and chemical plants. As a result there is a need for temporary housing for emloyees.
- Strict guidelines and safety protocols add additional time in hiring new temporary personnel thus slowing down recovery.
- High demand for workers to recover from previous hurricanes around the nation in the same year made the job market very tight.
- Availability of vendors to supply food to employees on site was limited.
- Lack of medications for employees on-site became an issue.

Risk Management Practices and Lessons from Harvey

- Remote work for those employees who could complete their tasks from distance helped to manage human resources more effectively.
- During recovery, part of the workforce was not needed. Some companies used the remaining workforce efficiently by offering them opportunities to help to fix houses of other employees and of the community.
- Some employees were hosted in temporary housing near plants to avoid transportation issues. There is a need to strategically manage temporary housing, beyond just staying in hotels that have available rooms or office buildings of the plants.
- One multinational company has formed a response team that goes to the site of the disaster and takes over the emergency response actions (this strategy allows return to normal operations more quickly).
- Since Hurricane Rita, plants have implemented better communication with employees. These include text alerts and social media postings by oil and gas companies and by the city. A future step can be creating real-time logistics maps to facilitate employees' and suppliers' access to production sites.
- There is a need to reduce bureaucracy and red tape regarding the use of drone technology in case of emergencies.
- There is a need to set up medical and financial teams to handle employees' immediate needs during a crisis.
- Pre-certification and pre-security screening can shorten the time for new temporary workers to rapidly start working on plants recovery.
- Some oil and gas companies are contemplating acquiring a "High Water Vehicles" with 40'' tall tires to get essential personnel to the site from their residences if necessary.

OIL AND GAS INDUSTRY'S OVERALL RESILIENCY AND RECOVERY FROM NATURAL DISASTERS

After two substantial natural disasters (Harvey and Imelda), there was no permanent loss of production capacity of refineries and petrochemical plants in Southeast Texas. It is an important sign of the resiliency of the oil and gas industry. However, the shutdown caused a temporary decline in production capacity and large financial losses due to replacement and recovery expenses. Months after, oil and gas companies still spent money to fix the damage from Harvey and Imelda. These interruptions also have a negative impact on markets. employees and the natural environment. Any significant interruption in the oil and gas sector of the Gulf Coast region can have a direct effect on global markets as more than 50% of US downstream petrochemical production is based on the Southeast Texas region. (Ramchand & Krishnamoorti, 2017)

Major risks related to hurricanes and storms can be classified as follows:

- Impact on employees. Even though the majority of oil and gas production plants didn't get structural damages to their buildings, significant damage accrued to homes and properties of the employees and the community in general. In addition, all plants had emergency plans from securing physically properties to personal evacuation and complete shutdown. Obviously, this kind of massive emergency plans interrupt the work of thousands of employees.
- Long and expensive recovery. Recovery from natural disasters is a time-consuming and expensive process. Replacing and repairing machines and equipment requires extra manpower and spare parts. A deficit of both resources is a significant risk in this sector.
- Impact on oil and gas prices. On the one hand, gas prices increase as a result of supply decline and "panic buying". On the other hand, crude oil prices decline because of decreased demand due to refinery shutdown and logistics problems even when plants restart their activities.
- Disruption of the petrochemical supply chain. Propylene, ethylene, xylene, and other petrochemical products are raw materials for the production of plastics and chemicals. Hurricanes and storms caused problems in the petrochemical supply chain.
- Exposures and contamination. Another risk is the danger of explosions, fires, and contamination as chemicals are required to be kept at a certain temperature. (Ramchand & Krishnamoorti, 2017)

To avoid risks from hurricanes and storms the oil and gas industry can consider relocating their businesses away from Southeast Texas. Studies have shown that the large investments in infrastructure in this region make relocation economically unrealistic. Established infrastructure, facilities, supply chain, trained and experienced workforce are important conditions that keep oil and gas companies in the Southeast Texas region. (Ramchand & Krishnamoorti, 2017)

It appears that the advantages of staying in Southeast Texas far outweigh the risks from hurricanes and storms. Efficient risk management practices can attract new investments and expansions in oil and gas companies in Southeast Texas. The final step in the PARM methodology is communication with the local community. To that end, the results of this work have resulted in reports, research papers, and conference presentations available to stakeholders on the website for the project (https://www.lamar.edu/resilience-recovery/recovery-and-resiliency-grant/index.html). In addition, the Recovery and Resiliency Summit: Building Tomorrow (August 2020) was sponsored in part by this project.

CONCLUSION

In this study, researchers analyzed risk management practices of the oil and gas sector in Southeast Texas during Hurricane Harvey. This research recognized that resiliency and fast recovery of the oil and gas sector from natural disasters are important for the growth of the local economy of the Southeast Texas region. In areas where natural disasters are frequent, there is a need to analyze the risk management practices in order to plan local economic growth by improving risk management systems or by reusing best practices of the past.

The Participatory Analysis of Risk Management (PARM) methodology was developed to help determine the risk management practices of recovery and resiliency from natural disasters. It also provided an opportunity to diagnose the challenges and past experiences that local stakeholders experienced during Hurricane Harvey. PARM is a comprehensive analysis tool that aided this research on risk identification, assessment, response, and monitoring in the oil and gas industry after natural disasters.

PARM is appropriate for areas where a natural disaster has happened recently and there is a need to analyze the situation and plan local economic growth. Its participatory approach can help to find better solutions. The most important advantage is that this tool helps to formulate appropriate projects to recover from natural disasters more quickly. Participatory analysis of risk management in the oil and gas industry helps to fully understand how prepared are the companies in this industry, how quickly they recovered from hurricanes, and also to what extent it impacted their human resource management.

This study summarizes the risks and risk management practices related to plant shutdown, plant restart, and HR management during those two stages. Positive improvements toward resiliency in the oil and gas industry can be summarized as:

- emergency response plans, policies and procedures have been updated,
- sensitive equipment and facilities have been raised,
- water drainage systems have been improved,
- access to power generators has been secured,
- remote work has helped manage human resources more effectively,
- plants have implemented accurate communication with employees,
- weather stations have been placed in service,
- air drones have been acquired to assess the damage.

Future improvements that can help to overcome disasters:

- revision of labor standards regarding industry-based certifications to ease hiring extra labor during the recovery period,
- establishing a transportation hub with the ability to receive cargo aircraft to move spare parts to where they are needed,
- creation of a warehouse in a location not prone to flooding to facilitate the centralized storage of spare parts and equipment,
- acquisition of high water vehicles to facilitate quick response in flooded areas,
- improving the availability of pumps for rent to meet the exceeding demand of these types of equipment during storms season,
- developing a bank of rental satellite phones to minimize the cost of having these phones active all year.

Recovery and resiliency depend on motivation, engagement, and collaboration of local stakeholders. Risk management knowledge, skills, and resources are crucial for resiliency and recovery. Robust private and public collaboration during risk management is needed before, during, and after natural disasters. Risk management education programs can help to implement efficient risk management. Risk management practices/tools, emergency simulations, and risk management training can help to be better prepared for hurricanes and storms.

ACKNOWLEDGMENTS

The authors are grateful to managers and engineers of petrochemical plants and refineries of Southeast Texas region for collaboration and participation in focus groups workshops, to U.S. Department of Commerce Economic Development Administration for funding "Lamar University Economic Recovery and Resiliency Program", Lamar University's Center for Innovation Commercialization & Entrepreneurship (CICE) of for support of this project, and to Nanda Vardhan Muppidi for research assistance.

REFERENCES

Amadeo, K. (2019). *Hurricane Harvey facts, damage and costs what made Harvey so devastating*. Retrieved from https://www.thebalance.com/

Aon Benfield. (2018). *Hurricane Harvey event recap report*.

Blakely, E.J., & Bradshaw, T.K. (2002). *Planning local economic development: Theory and practice*. Thousand Oaks: SAGE Publications.

Cassiday, L. (2018). *Lessons learned from hurricane Harvey*. Retrieved from http://www.aocs.org/

Greater Beaumont chamber of commerce. (n.d.). Retrieved from http://www.bmtcoc.org/.

Hegar, G. (2018). *A storm to remember: Hurricane Harvey and the Texas economy*. Texas comptroller of public accounts.

Holmes, F. (2017). *We looked into the effects of hurricane Harvey and here's what we found*. Retrieved from https://forbes.com/

Meyer-Stamer, J. (2004). *Regional value chain initiatives: An opportunity for the application of the PACA approach*. Mesopartner Partnergesellschaft.

Meyer-Stamer, J. (2006). *Participatory appraisal of competitive advantage (PACA): Effectively launching local economic development initiatives*. Mesopartner Partnergesellschaft.

Meyer-Stamer, J., Harmes-Liedtke, U., & Schoen, C. (2005). *How to conduct a PACA Exercise.* Duisburg.

Oyedele, A. (2017) *Hurricane Harvey could be the costliest natural disaster in US history - Here's how we'll know the true cost*. Retrieved from https://www.businessinsider.com/

Porter, M.E. (1990). The competitive advantage of nations. *Harvard Business Review*, *68*(2).

Porter, M.E. (2000). Location, competition, and economic development: Local clusters in a global economy. *Economic Development Quarterly*, *14*(1).

Ramchand, L., & Krishnamoorti, R. (2017). *What Harvey taught us: Lessons from the energy industry*. University of Houston energy fellows.

Texas Comptroller of Public Accounts web page. (n.d.). Retrieved from https://comptroller.texas.gov/.

Texas Workforce Commission. (n.d.). Retrieved from https://twc.texas.gov/

Torry, H., & Chaney, S. (2018). *Big storms leave small marks on the U.S. economy.* Retrieved from https://wsj.com/

U.S. Department of Commerce Bureau of Economic Analysis. (n.d.). Retrieved from https://www.bea.gov/

U.S. Federal Emergency Management Agency. (2018). Hurricane Harvey: County update. *FEMA Articles.*

U.S. Federal Emergency Management Agency. (2019). Texas Recovery Hurricane Harvey: Partnership and progress. *FEMA Articles.*

World Bank. (2003). *Local economic development (LED)*. World Bank Urban Development Unit.