The risk in Petroleum Supply Chain: A review and typology

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***Abstract*—** The petroleum supply chain is extremely inflexible and complicated. It appears as a significant risk with a high impact on the national economy. The complexity leads to the existence of different types of risk that needs to be considered for when designing, planning and operating such a system.

The main objective of this paper is to represent a literature review on the risk in the oil industry and to develop a typology of risk management. First, this article identifies main risks related to each stage of the petroleum supply chain. Then, it concentrates an overview of the modelling techniques of the risk management.

The results show that the type of risk depends on certain operation of petroleum supply chain and depends on the country (importer or exporter) and that the methodologies of the risk management classified into three types: qualitative, quantitative and mixed models. The future research efforts should aim to develop the techniques applicant in this area.

***Keywords*—** petroleum supply chain, risk, risk management, literature Review.

I. INTRODUCTION

In the petroleum supply chain, the literature review works is few. Some of them are in form a discussion and critique rather than a systematic literature review. Shah et al. (2010) conducted a very similar literature review of the refinery operations. Their novelty is that they overview some works of the crude oil supply chain design and planning, as well. Leiras et al. (2011) survey the existing literature in the field of refinery planning models. They emphasize the solution techniques used to optimize the model under uncertainty, and classify them. Grossmann (2012) reviews the area of supply chain optimization in the process industries. The traditional focus of supply chains looking at operational risks shifted towards more tactical and strategic risks due to an increase in global outsourcing activities (Ghadge et al. (2012)). The September 11 disrupted major supply chains in the early part of the decade and triggered interest in the supply chain risk management (Chopra and Sodhi (2004) and Sheffi (2005)). For many countries, the inflow of energy is essential to keep economies running. Oil is typically considered the most critical fuel as an input for the petro-chemical and transportation sector and due to limited and less spread reserves (Moerkerk and Grijins-Graus (2016)). Oil Companies have embarked on a process of continuous improvement in order to reduce costs and ensure an excellent level of service and greater stability.

Major oil companies are characterized by integrated and vertical structures. This is justified by significant economies of scale, especially in the refining and transportation activities, and because it is a business that involves many uncertainties, and consequently many risks (Chen et al. (2014)). Given the uncertainties of demand and supply, the lack of reliable and timely data about consumption, production and inventory levels and the unreliability of short-term forecasts, it is difficult for the Organization of the Petroleum Exporting Countries (OPEC) to anticipate the direction of the market (Fattouh (2007)). Uncertainties in the choice of logistics and ship arrivals also affect the crude planning process (Julka et al. (2002)).

In 1998, this was most graphically demonstrated when an explosion at an onshore processing plant in the Australian state of Victoria caused the disruption of gas supplies to all customers throughout the entire state for a period of nearly two weeks (Yeeles and Akporiaye (2016)).

The petroleum supply chain is a complicated assortment of infrastructures and process whose mainstream begins with the explication of crude oil and finalizes with the delivery of petroleum products to consumers. This industry moves huge quantities of products and value and is backbone to almost all economic activity. This strategic sector is highly automated and optimized, so disruptions can rapidly escalate to an industry-wide or nation-wide crisis. Oil companies, aware of these risks, have put significant effort in risk management; however, most of the work is qualitative and is still at the initial stage.

According to Lima et al. (2016), the oil supply chain is inserted in an unstable context, influenced by geopolitical unrest, global competition and price volatility, where the business focuses on margins and the savings are carried out through improved forecasts and schedules with shorter planning horizon. As a result, the seek for designing and implementing new tools aims to establish an integrated and adaptive supply chain in order to improve the decision making process, reduce costs, decrease inventories and enhance margins (Capgemini (2008)).

The purpose of this paper is to investigate the research development in risk management in petroleum supply chain, which has shown an increasing global attention in recent years. Literature survey has undertaken a thorough search of articles in the area of supply chain in petroleum industries. The review has piloted us to identify and classify the potential risk associated with different stage.

The above background provides the motivation to investigate the current trend and issues in petroleum supply chain. Our main objective through literature review is to identify the main risk issues and mitigation models and techniques of risk management.

Remaining parts of this paper are organized as follows. In section 2, we review the definition of the petroleum supply chain and the different classification. The research methodology is illustrated in section 3. Section 4 provides a short discussion of results of our search. The conclusion and the contributions are provided in section 5.

II. Definition of petroleum supply chain

The structure of the oil supply chain must be described clearly. Nnadili (2006) defines the petroleum supply chain as all logistical activities from feedstock of exploration and movement into refineries, to refining operations. The bibliographic study shows that there are two classifications (see Table 1).

In a study by Cigolini and Rossi (2010), oil supply chain is divided into three main stages: drilling, primary transport and refining. A typical crude oil supply chain consists of production oilfields (both on and offshore), processing terminals, storage facilities and refineries, which are connected through pipelines. Different base crude oil are received, processed and blended in processing terminals, and the produced commercial varieties sent to refineries and/or exported to the market through tankers (Fazli et al. (2015)). According to Carneiro et al. (2010), the oil supply chain can be divided into upstream and downstream segments. The former involves well prospecting, exploration, drilling and completion, and production, whereas the latter segment includes the transportation, refining, and distribution of oil and refined products.

Table 1

Classification definitions oil supply chain.

Classification	**Authors**
Two segment (upstream- downstream)	Hussain et al. (2006) Carneiro et al. (2010)
Three segment (upstream- midstream-downstream)	Cigolini and Rossi (2010) Sahebi (2013) Sahebi et al. (2014) Fernandes et al. (2014) Nasab and Amin-Naseri (2016) Lima et al. (2016) M. Nasab and A. Naseri (2016) Kazemi and Szmerekovsky (2015)

The petroleum supply chain in paper of Fernandes et al. (2009) divides into two major areas: upstream and downstream. The upstream comprises of crude oil exploration, production and transportation. The downstream industry involves product refining, transport, storage, distribution and retail. While a vast network of tankers, barges, pipelines, railways and trucks transport crude oil from the oil fields to the refineries, pipelines, trucks, vessels and trains transport refined products to distribution centres and finally to retailers which include oil and gas stations, factories, different business services (such as hotels or hospitals) that may directly consume the product or retail it to the end consumer. Storage facilities including above-ground and underground tanks, underground caverns and offshore storage, are located along transportation routes allowing upsizing or downsizing of batches to match the capacities of the next transportation mode.

The downstream petroleum supply chain can be defined as a network of petroleum companies, which acts over a system comprised by refineries, distribution depots, transportation modes and routes that cumulatively satisfy the retail customer demands for multiple petroleum products in various regions under study. The downstream petroleum supply chain network comprises the refining, logistics and commercialization of the petroleum products, whereas the upstream petroleum supply chain includes the activities that allow crude oil to be explored and transformed. In each segment, there are petroleum companies, which rely on physical infrastructures across the network to develop these functions d (Fernandes et al. (2013)).

Sahebi (2013) present three different classification of the oil supply chain. The first considers the oil supply chain divided between upstream and downstream segments, incorporating the refinery and petrochemical plants within downstream segment. However, the second divides the network into upstream, midstream and downstream segments, where the midstream part comprises the refinery and petrochemical operations. Lastly, the third also considers the oil supply chain divided into three segments, but the midstream part refers to crude oil transportation to terminal and storage facilities. Lima et al. (2016) use this classification because it is more adequate for the objectives of their literature review paper.

The oil supply chain encompasses a set of functions such as exploration, oil production (i.e. primary recovery, enhanced recovery, and abandonment), crude oil transportation, oil transformation, and distribution of crude oil and refined products. In addition, Sahebi et al. (2014) present the major facilities that compose the infrastructure into each segment as follows: in upstream, wellhead, well platform, production platform and crude oil terminal; in midstream, refinery and petrochemical industries, and then, in downstream, primary and secondary transport, storage depot and wholesale and retail market.

Tong et al. (2011) addressed a multi-site planning model. In their paper, the crude oil supply chain consisted of crude oil suppliers, a jetty tank area to unload crude oil, a crude oil tank before production, a refinery with its input and output interfaces, final product tanks, distribution centers, and customers.

In a study by Li et al. (2013), each component of the oil system interacts and interrelates to form a collective entity (exploration, refining, transportation, and end user). If the oil supply chain operates normally, the final energy service can be fulfilled.

Petroleum supply chain is illustrated in Neiro and Pinto (2004). Petroleum exploration is at the highest level of the chain. Decisions regarding petroleum exploration include design and planning of oil field infrastructure. Petroleum may be also supplied by international sources. Oil tankers transport petroleum to oil terminals, which are connected to refineries through a pipeline network. Decisions at this level incorporate transportation modes and supply planning and scheduling. Crude oil is converted to products at refineries, which can be connected to each other in order to take advantage of each refinery design within the complex. Products generated at the refineries are then sent to distribution centers. Crude oil and products up to this level are often transported through pipelines. From this level on, products can be transported through either pipelines or trucks, depending on consumer demands. In some cases, products are also transported through vessels or by train (Neiro and Pinto (2004)).

III. Review Methodology

Our research follows the systematic literature review methodology that differs from traditional

Narrative reviews by adopting a 'replicable, scientific and transparent process' (Tranfield et al. (2003)). Then, the systematic literature reviews according to Saunders et al. (2009) are completed through an iterative process of defining appropriate search keywords, searching the literature and completing the analysis. In particular, systematic literature reviews try to summarise the studies objectively (Petticrew and Roberts (2006)).

In this work, a literature review is performed which aims to investigate the relevant works around the different risk in oil supply chain and the various tools applied to manage this risk. The search was performed through the Web of Science.

In this study, we use search keywords such as petroleum (oil, crude oil) supply chain, petroleum (oil) industry, distribution, transport and scheduling (supply) in the titles with risk, uncertainty, security and disruption. In addition to the selected papers obtained from the above combination of keywords, their cited references were analysed and the relevant references collected. Some rules were used in order to filtrate some undesirable articles. Firstly, only articles written in English have been considered. Secondly, the articles are selected from Energy journal, Management Science and Operations Research (MS/OR) type of journals and Process, Chemical and Engineering journals and Operations Management (OM) journals.

In addition, the paper is selected when it is related to any operation or stage of the petroleum supply chain. The list of journal is given in Table 2. In order to improve the quality of research we finally selected 60 quality articles through manual selection. These articles were critically analysed by manual and statistical techniques with SPSS.

IV. Results of Search

A. *An overview of literature survey*

The entire document should be in Times New Roman or Times font. Type 3 fonts must not be used. Other font types may be used if needed for special purposes.

Recommended font sizes are shown in Table 1.

B. *Title and Author Details*

This section presents an overview of literature survey. The number of publication on each year is indicated in Fig. 1. Main issues discussed during the year 2000 until 2015.

Table 2

List of journals reviewed.

I. Energy
Applied Energy
Energy Economics
Energy Policy
Energy Procedia
Energy Source B
Journal of Natural Gas Science and Technology
Petroleum Science and Technology
II. MS/ OR types journals
European Journal of Operational Research
International journal of Production Economics
Production Planning and Control: the management of operation
Quantitative financial Risk Management
III. Process, Chemical and Engineering journals
American Institute of Chemical Engineers Journal

Chemical Engineering and Processing
Computers and Chemical Engineering
Industrial and Engineering Chemistry Research
Journal Loss Prevention in the Process Industries
Ocean Engineering chemistry Research
IV. Operation Management Journal
Int. J. Global Logistic Supply Chain Management
International journal of Business Performance and supply chain Modelling
Risk Management
Supply Chain Management an international journal

Journal	Year														Total
	2002	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
Energy Policy	-	-	1	-	1	-	1	-	1	2	1	-	1	2	10
Industrial and Engineering Chemistry Research	-	1	-	-	-	1	-	2	-	1	1	-	1	-	7
J. Loss Prevention in the Process Industries	-	-	-	-	1	-	-	1	-	-	1	-	-	-	5
European Journal of Operational Research	-	-	-	-	-	1	-	-	-	-	-	-	1	1	3
Computers and Chemical Engineering	-	1	-	-	-	-	1	-	-	-	1	-	-	-	3

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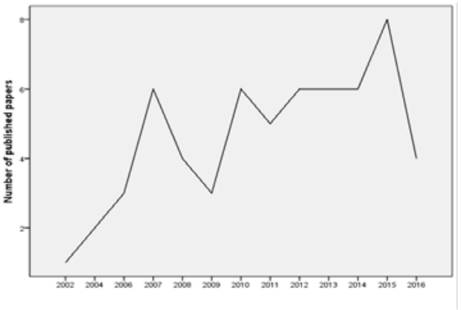


Fig. 1. Publishing in trend in the area of risk in oil industry.

We see from Fig.1 that the paper published in the science journals were up during the period 2000 to 2015. Between years 2000 and 2003, the number of articles in the field of risk in oil industry slowly increases. During the screening of the database, it was found that there was a radical increase in number of articles published in this field from year 2004. Several tiger events marked the moment and companies were pushed to focus on supply chain risk management issues. Events like the September 11 attacks and the typhoon in South East Asia in 2001, demonstrated inherent weaknesses in supply chains and their management (Lavastre et al. (2012)). Although in 2007, 2010 and 2015, the number of publications presented three peaks, 2007 (5), 2010 (6) and

2015 (8), the year 2015 represented a promising year in petroleum supply chain risk research contributing the most in the volume of papers published.

The same fact was not observed in the other years, and the scientific production remained on lower levels between one and two released papers per year.

In compare with the Fig.1 of (Fahimnia et al. (2015), that shows the publishing trend in this field (supply chain risk) we see different points and commonalities. The first difference is the period when publication of the risks in the supply chain according Fahimnia et al. (2015) began in 1978 with very low manner. A geometrical growth of the number of publication may be observed especially after 1997.

The second difference is the amount of publication where the number of papers published in the area of risk in oil is very limited. As against the original research (Fahimnia et al. (2015)) results 2304 papers. Preliminary studies showed that, the traditional focus of supply chains looking at operational risks shifted towards more tactical and strategic risks due to an increase in global outsourcing activities (Ghadge et al. (2012)). The comparative figures have the same allure. The same downward trend in the 2009-2010 interval is made up immediately by the significant increase in the number of publication for the 2010-2015 interval.

Our study also shows that the most articles are found in the Energy journals. Table 3 presents an overview of the number of articles published by journals. The Energy Policy, Industrial and Engineering Chemistry Research, Loss Prevention in the Process Industries, Computers and Chemical Engineering and European journal of Operational Research journals referred to 26 or 43.33% of all published articles.

TABLE 3

TOP FIVE JOURNALS CONTRIBUTING TO THE AREA OF OIL SUPPLY CHAIN RISK MODELLING.

Even so, between 2002 and 2010, Weisser (2007), Potocnik et al. (2007) and Pelletier and Wortmann (2009) in Energy Policy published the only three works found, whereas the main body of literature collected was found for the period between 2011 and 2016.

The author field was extracted from the data file and frequency of appearance of all authors associated with those articles was recorded.

Table 4 presents the key contributing authors based on the number of articles published. We also carried out an analysis to identify the main perpetrators matched those working on several papers (those collaborating on multiple papers).

TABLE 4

KEY CONTRIBUTING AUTHORS.

Author	No. of published articles
Relvas. S	3
Barbosa-Póvoa. A	3
Fernandes. L.J	3
Doukas. H	2
Flamos. A	2

Passas. J	2
Oliveira. F	2
Hamacher, S	2

There are cooperatives papers among some authors: Fernandes. L.J with Barbosa-Póvoa. A with Relvas. S, 2 articles published and a conference paper. We can also add the authors Oliveira, F and Hamacher, S (Oliveira et al. (2013)) and (Oliveira et al. (2016)). Fahimnia et al. (2015) indicates that many of the authors have also co-authored the highly influential papers in the field, indicating a positive relationship between the quantity and the quality of papers published by the key contributing authors.

There are authors who researched the risks in the supply chain in general then he chose the oil sector. Include the author Grossmann, IE who studied all the first demand uncertainty in the supply chain (You and Grossmann (2008)) and in 2009, he studied allocation problem in the oil business (Grossmann et al. (2009)). Include also the author Tiwari, Mr. K and Chan, F. T. S ((Chan et al. (2008) and Sinha et al. (2011)).

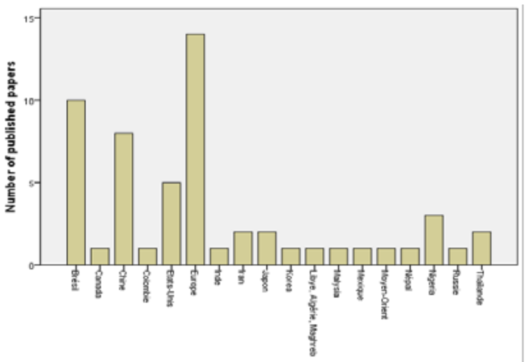


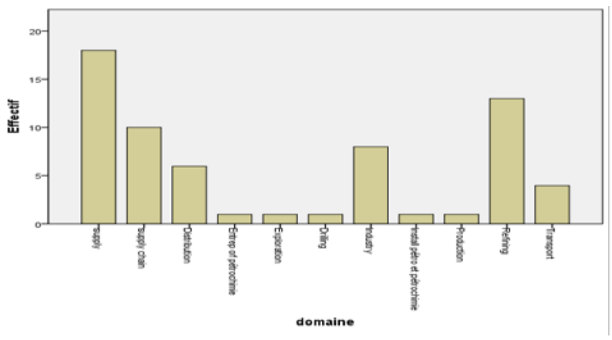
Fig. 2. Number of articles per country.

Descriptive analysis of countries contributing to risk management in petroleum supply chain showed that the European countries and the Brazil country contributed the most articles (Fig. 2). This is believed to be driven by the fact that these countries with other countries like China, Iran, Union States and the African country Nigeria outsource the most and are more vulnerable to risks or disruptions. This is assumed to drive the interest of researchers from these countries. Other leading countries researching risk in oil supply chain and showing keen interest in supply chain disruptions are Canada, Colombia, Mexico and some Asian countries (Japon, Inde, Korea, and Middle East).

Although the specific research area was favoured by researchers from these countries in the initial years of the decade, the oil supply chain risk research area grew rapidly within researchers in the European countries and in China because this countries are increasingly dependent on oil imports to meet their energy needs.

According to the results found, there are two kinds of interested countries to study the risks in oil supply chain. The first type is the consumer countries like Europe, China and the United States. The consumption of these countries increases and depends on the oil import of oil. Overall, oil suppliers' country risk has impacts on security of external oil supplies of importers (Yang et al. (2014)). The second type is the producer countries, citing Brazil, Iran and Nigeria, where oil export plays an important role in the economy. These countries are so heavily dependent on the production, for Nigeria the production was reduced due to vandalism on oil pipelines, kidnapping and actions of militants against oil installations.

The petroleum supply chain divides into two major areas: upstream and downstream. The upstream comprises of crude oil exploration, production and transportation. The downstream industry involves product refining, transport, storage, distribution and retail (Fernandes et al. (2010). Therefore, each step requires special importance. Fig. 3 shows the areas related to this chain contributing in the literature.



Country	Authors	Year	Problem area
Europe	Pelletier et al. (2009) Stern (2002) Winzer (2012) Torhaug (2006) Weisser (2005) Doukas et al. (2011)	2009 2002 2012 2006 2005 2011	Infrastructure supply supply industry Supply supply
Brazil	Oliveira et al. (2016) Leiras et al. (2013) Esteves et al. (2007) Carneiro et al. (2010) Neiro et Pinto (2004) Rocha et al. (2009) Oliveira et al. (2013) Oliveira et Hamacher (2012) Leiras et al. (2011) Ribas et al. (2012)	2016 2013 2007 2010 2004 2009 2013 2012 2011 2012	Refinery Refinery Production Refinery Petroleum supply chain Petroleum supply chain Petroleum supply chain Distribution Refinery Refinery
Chine	Yanting et Liyun (2011) Zhao et Chen (2014) Zhang et al. (2013) Chen et al. (2015) Lu et al. (2015) Zhou et al. (2014) Yang et al. (2014)	2011 2014 2013 2015 2015 2014 2014	Production Production Petroleum supply chain Refinery Distribution Distribution Supply
Iran	Saidi et al. (2014) Fazli et al. (2015)	2014 2015	Refinery Petroleum supply chain

Fig. 3. Number of papers per stage.

Research areas in the most dominant oil sector according to the selected sample in this study are oil scheduling (supply), supply chain and refining; the number of papers on risk studies in the petroleum industry and distribution petroleum products is also interesting (see Table 5). It is noted that all oil-related steps are studied but still the number of published research is not important compared to those related to the supply chain in general. Supply risk was one of the risks most discussed and researched in the literature.

Several researchers have addressed the oil supply risk. The scheduling domain is increasingly studied in the countries of Europe, China, the Middle East and the USA. Compared to the domestic oil supply, external oil supply is still a more important aspect of energy security for China. Lochner and Diechhoner (2012) study the impact of gas supply disruptions to Europe that led the uprising and the military confrontation in Libya began in February 2011.

Papers made using Chinese data is usually in the distribution area (Lu et al. (2015)), industry (Yanting and Liyun (2011) and Zhao and Chen (2014)) and the supply chain (Zhang et al. (2013)). The risks discussed in the refinery located in producing countries such as Brazil, Iran and Thailand are considerable. The most forward-risks in African countries Nigeria are mainly related to distribution area (accidents tankers, theft, and pipeline sabotage). Producer countries and consumer countries, both submit risks in oil industries, as they appear risk to the entire oil supply chain.

Many works are focused on the refinery industry (see Table 5) like (Saidi et al. (2014), Carneiro et al. (2010), Tong et al. (2012), Leiras et al. (2011), Park et al. (2010) , Chen et al. (2015), Lakkhanawat et Bagajewicz (2008), Snivastava et Gupta (2010), Ribas et al. (2012), Leiras et al. (2013)).

TABLE 5

PAPERS PUBLISHED IN THE AREAS OF THE RISK.

C. *Risks*

In this section, we summarize the main issues of risk according to our study of literature. The supply chain risk are categorized in various ways, for example, Jianlin (2011) categorized supply chain risks as operational and disruption risks. Operational risks are referred to as the inherent uncertainties such as uncertain customer demand, uncertain supply and uncertain cost. Disruption risks are referred to as the major disruptions caused by natural and man-made disasters as earthquakes, floods, hurricanes, terrorist attacks, etc., or economic crises as currency evaluation or strikes. Tang (2006) apply also this classification (operational risks and risks of disruption). The literature on supply chain risk management of Heckmann et al. (2015) present two categories: sources of risk and target risk area.

Juttner et al. (2003) provide a classification of sources of risk as organizational risk, network risk and other risks comprising of environmental (men made and natural disasters), political/social and exchange rate risks.

The study of Tang and Musa (2011) shows other risk classification, it identified risks in supply chain in three streams (physical, information, financial). Zhao and Chen (2014) identify the risk based on energy flow, flow of finance and environmental flows.

In the crude oil supply chain, like in other supply chains, there exist some links between entities. These links represent the flow of materials (i.e. crude oil, refinery' (semi-) finished products), services, cash, and information that make possible the functions of exploration, production, refining, storage, and distribution (Sahebi et al. (2014)).

The risks of the logistics chain are many and varied and numerous studies have attempted to list them, including those of Chopra and Sodhi (2004), Christopher and Lee (2004), Hallikas et al. (2004), Jüttner et al. (2003) and Jüttner (2005). Studies concerning the sources of risk in the supply chain are also multiple. For example, Harland et al. (2003) focused on different classifications of the types of risk in their literature review covering 1996 to 2000. These risks concern the different branches of the management, including (without limitation) the strategy, operations, supply, customer relations, asset impairment, competition, reputation, financial markets, fiscal and regulatory and legal requirements.

For a list of operational risks, we may refer to Chopra and Sodhi (2004), which identifies nine categories of risk: the disruption, delays, systems, forecasting, intellectual property claims, the market, stock and capacity. Meanwhile Christopher and Peck (2004) identify five sources of risk: Process, control, demand, supply, and the environment. In 2003, Jüttner et al. (2003) focused on the environment, network and organizational risk sources for supply chains.

But a few years later, Jüttner (2005) noted two other risk sources: supply and demand. Taking a slightly different angle, Kleindorfer and Saad (2005) focus on three sources that increase the risk of disruption: operational risks (including equipment failures and system failures), natural hazards (earthquakes, hurricanes and storms), terrorism and political instability. Kiser and Cantrell (2006) highlight the internal risks (in manufacturing, business, planning and control, mitigation and contingency) and external risks (demand environment of supply, physical companies and installations). Finally, Wagner and Bode (2008) divide the sources into five distinct classes: the demand, supply, legal and bureaucratic regulation, infrastructure, and catastrophic.

In our literature study, we find that the risks differ depending on the phase of the oil supply chain.

Supply risk

Several researchers have addressed the oil supply risk. Discussing and arguing security of supply dependence is often complicated by a lack of clarity about the risks involved. It has been shown helpful to look at four separate risks, source dependence, transit dependence, facility dependence (Luciani, 2004), structural risks (Weisser (2007)). For Winzer (2012), the supply risk sources are divided into three categories: technical, human and natural.

On a national basis, European import dependence is already an established fact: nine out of 33 European countries are more than 95% dependent on imports; only five are self-sufficient or net exporters (Stern (2002)). The oil supply risk associated with China supply disruption from the dependence on specific countries can be enhanced by diversifying sources of energy imports (Sun et al. (2011)). Thus, this paper attempts to measure the external oil supply risk from the standpoint of diversification of sources.

Crude procurement has a direct impact on refinery profits. A crude stock out would necessitate unit shutdowns and must be prevented under all circumstances. These make crude procurement one of the most important business processes in a refinery. In addition, this process must interact with several other departments in the refinery (Julka et al. (2002)).

External oil supply risk has been considered to be an important aspect of energy security since the first oil crisis when oil price surged because of the Arab oil embargo in 1973 and in 1974 (Yang et al. (2014)).

The external oil supply risk faced by oil-importing countries mainly consists of price fluctuations and supply disruption. Regarding the uncertainties emanating from price fluctuations, external oil supply risk is usually measured by portfolio techniques (NBS (2011), BP (212), Wianwiwata and Asafu-Adjayeb (2013), Wu (2007), Martchamadol and Kumar (2013), Gupta (2008)).

China's oil supply risk associated with supply disruption coming from the dependence on specific countries can be improved by diversifying sources of energy imports (Leung (2011)). Thus, this paper attempts to measure the external oil supply risk from the perspective of diversification of sources.

In energy security terms, diversification is a choice to enhance the security of oil supply by reducing excessive dependence on a single supplier. Supply risks for Moerkerk and Grijins-Graus (2016) are two sources of risks related directly to the supply operation and the risk of external environments.

Richter and Holz (2015) identify four sources of risk: procurement, regulation, infrastructure and procurement import sources in Europe.

Lachner and Diechhoner (2012) study the disruptions resulting from political instability in countries like Libya sources (military confrontation that began in February 2011).

Although the Chinese government has sought to diversify the sources of imported oil, its imported oil comes largely from unstable regions (Middle East, Africa, and South America) researchers are working on supply risks such as Yan et al. (2014) studying the influences of oil resources and country risks of suppliers of oil to the supply security of importing countries.

The supply of natural gas in the European Union meets the risk of addiction, where Weisser (2007) distinguishes the dependence of the source, dependence on transit dependence of the establishment and structural risk.

For Doukas et al. (2011), the supply of oil and natural gas in the European Union finds risk of conflict, political instability, terrorist attacks, export restrictions, accidents, and weather conditions for exporting countries. Fattouh (2007) determines the supply risks in the Middle East as if war and civil conflict, political instability, regime change, revolutions, terrorist attacks on oil facilities, export restrictions, road closures commercial and penalty charges. According to Fattouh (2007), the disruptions can be caused by technical failure; weather-related events such as hurricanes and storms, strikes, terrorist attacks on oil facilities, wars and civil strife, regime change that may restrict the capability of a country to export and a deliberate restriction of exports.

Villada and Olaya (2013) distinguish risk to the economy (oil prices, demand), related to regulation, to the political state, the external environment and technical risks.

It is reasonable to measure the supply risk in combining external oil dependence on oil imports and diversification index. The external oil supply risk was considered an important aspect of energy security since the first oil crisis, when oil prices surged due to the Arab oil embargo from 1973 to 1974.

The external oil supply risk faced by oil importers mainly consists of price fluctuations and supply disruptions. Regarding the uncertainties arising from price fluctuations, the external oil supply risk is generally measured by portfolio techniques (Wu et al. (2007), Wu et al. (2009), Ge and Fan (2013), Lesbirel (2004), and Wabiri and Amusa (2010) and Sun et al. (2012)).

In this section, we summarize the main issues of risk according to our study of literature. The supply chain risk are categorized in various ways, for example, Jianlin (2011) categorized supply chain risks as operational and disruption risks. Operational risks are referred to as the inherent uncertainties such as uncertain customer demand, uncertain supply and uncertain cost. Disruption risks are referred to as the major disruptions caused by natural and man-made disasters as earthquakes, floods, hurricanes, terrorist attacks, etc., or economic crises as currency evaluation or strikes. Tang (2006) apply also this classification (operational risks and risks of disruption). The literature on supply chain risk management of Heckmann et al. (2015) present two categories: sources of risk and target risk area.

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In the crude oil supply chain, like in other supply chains, there exist some links between entities. These links represent the flow of materials (i.e. crude oil, refinery' (semi-) finished products), services, cash, and information that make possible the functions of exploration, production, refining, storage, and distribution (Sahebi et al. (2014)).

The risks of the logistics chain are many and varied and numerous studies have attempted to list them, including those of Chopra and Sodhi (2004), Christopher and Lee (2004), Hallikas et al. (2004), Jüttner et al. (2003) and Jüttner (2005). Studies concerning the sources of risk in the supply chain are also multiple. For example, Harland et al. (2003) focused on different classifications of the types of risk in their literature review covering 1996 to 2000. These risks concern the different branches of the management, including (without limitation) the strategy, operations, supply, customer relations, asset impairment, competition, reputation, financial markets, fiscal and regulatory and legal requirements.

For a list of operational risks, we may refer to Chopra and Sodhi (2004), which identifies nine categories of risk: the disruption, delays, systems, forecasting, intellectual property claims, the market, stock and capacity. Meanwhile Christopher and Peck (2004) identify five sources of risk: Process, control, demand, supply, and the environment. In 2003, Jüttner et al. (2003) focused on the environment, network and organizational risk sources for supply chains.

But a few years later, Jüttner (2005) noted two other risk sources: supply and demand. Taking a slightly different angle, Kleindorfer and Saad (2005) focus on three sources that increase the risk of disruption: operational risks (including equipment failures and system failures), natural hazards (earthquakes, hurricanes and storms), terrorism and political instability. Kiser and Cantrell (2006) highlight the internal risks (in manufacturing, business, planning and control, mitigation and contingency) and external risks (demand environment of supply, physical companies and installations). Finally, Wagner and Bode (2008) divide the sources into five distinct classes: the demand, supply, legal and bureaucratic regulation, infrastructure, and catastrophic.

In our literature study, we find that the risks differ depending on the phase of the oil supply chain.

Supply risk

Several researchers have addressed the oil supply risk. Discussing and arguing security of supply dependence is often complicated by a lack of clarity about the risks involved. It has been shown helpful to look at four separate risks, source dependence, transit dependence, facility dependence (Luciani, 2004), structural risks (Weisser (2007)). For Winzer (2012), the supply risk sources are divided into three categories: technical, human and natural.

On a national basis, European import dependence is already an established fact: nine out of 33 European countries are more than 95% dependent on imports; only five are self-sufficient or net exporters (Stern (2002)). The oil supply risk associated with China supply disruption from the dependence on specific countries can be enhanced by diversifying sources of energy imports (Sun et al. (2011)). Thus, this paper attempts to measure the external oil supply risk from the standpoint of diversification of sources.

Crude procurement has a direct impact on refinery profits. A crude stock out would necessitate unit shutdowns and must be prevented under all circumstances. These make crude procurement one of the most important business processes in a refinery. In addition, this process must interact with several other departments in the refinery (Julka et al. (2002)).

External oil supply risk has been considered to be an important aspect of energy security since the first oil crisis when oil price surged because of the Arab oil embargo in 1973 and in 1974 (Yang et al. (2014)).

The external oil supply risk faced by oil-importing countries mainly consists of price fluctuations and supply disruption. Regarding the uncertainties emanating from price fluctuations, external oil supply risk is usually measured by portfolio techniques (NBS (2011), BP (212), Wianwiwata and Asafu-Adjayeb (2013), Wu (2007), Martchamadol and Kumar (2013), Gupta (2008)).

China’s oil supply risk associated with supply disruption coming from the dependence on specific countries can be improved by diversifying sources of energy imports (Leung (2011)). Thus, this paper attempts to measure the external oil supply risk from the perspective of diversification of sources.

In energy security terms, diversification is a choice to enhance the security of oil supply by reducing excessive dependence on a single supplier. Supply risks for Moerkerk and Grijins-Graus (2016) are two sources of risks related directly to the supply operation and the risk of external environments.

Richter and Holz (2015) identify four sources of risk: procurement, regulation, infrastructure and procurement import sources in Europe.

Lachner and Diechhoner (2012) study the disruptions resulting from political instability in countries like Libya sources (military confrontation that began in February 2011).

Although the Chinese government has sought to diversify the sources of imported oil, its imported oil comes largely from unstable regions (Middle East, Africa, and South America) researchers are working on supply risks such as Yan et al. (2014) studying the influences of oil resources and country risks of suppliers of oil to the supply security of importing countries.

The supply of natural gas in the European Union meets the risk of addiction, where Weisser (2007) distinguishes the dependence of the source, dependence on transit dependence of the establishment and structural risk.

For Doukas et al. (2011), the supply of oil and natural gas in the European Union finds risk of conflict, political instability, terrorist attacks, export restrictions, accidents, and weather conditions for exporting countries. Fattouh (2007) determines the supply risks in the Middle East as if war and civil conflict, political instability, regime change, revolutions, terrorist attacks on oil facilities, export restrictions, road closures commercial and penalty charges. According to Fattouh (2007), the disruptions can be caused by technical failure; weather-related events such as hurricanes and storms, strikes, terrorist attacks on oil facilities, wars and civil strife, regime change that may restrict the capability of a country to export and a deliberate restriction of exports.

Villada and Olaya (2013) distinguish risk to the economy (oil prices, demand), related to regulation, to the political state, the external environment and technical risks.

It is reasonable to measure the supply risk in combining external oil dependence on oil imports and diversification index. The external oil supply risk was considered an important aspect of energy security since the first oil crisis, when oil prices surged due to the Arab oil embargo from 1973 to 1974.

The external oil supply risk faced by oil importers mainly consists of price fluctuations and supply disruptions. Regarding the uncertainties arising from price fluctuations, the external oil supply risk is generally measured by portfolio techniques (Wu et al. (2007), Wu et al. (2009), Ge and Fan (2013), Lesbirel (2004), and Wabiri and Amusa (2010) and Sun et al. (2012)).

Producing fields risk

The search for maritime safety and protection of the marine environment, Lavasani et al. (2015) analyses the risk of leakage of 34000 wells in the Gulf of Mexico Outer Continental Shelf Region (GOMR).

In 2011 and due to bursting of the Libyan conflict, Toft (2011) analysed the effects of intra-state conflicts in oil producing countries on oil price volatility and security of supply. It concluded four characteristics of conflicts that can explain when oil production is at risk: proximity to oil production fields in areas of major battles, the duration of the conflict, separatism and petroleum location on the separatist territory and the relative size of the oil production.

The uncertainties of nature-related parameters, sample, drill wells, the oil price and the production costs present major risks to an oil tank (Capolei et al. (2015)).

Lababidi et al. (2004) presented an optimization model for the supply chain of a petrochemical company operating under uncertain operating and economic conditions (demand, price, material cost of production and first performance).

Pongsakdi et al. (2006) address the issue of uncertainty and study the financial aspects of risk in an oil company in Thailand.

In Russia, there is a significant volume of the tanks that exceed in total 300 000 m 3, therefore fire safety of these objects becomes a very important task. Shebeko et al. (2007) performs a survey of fire risk for major export terminals.

Khor et al. (2008) suggest approaches to optimal planning of refinery, which has three sources of uncertainty crude oil prices, demand, yield (Chen et al. (2015). Oliveira et al. (2006) adds uncertainty supply, for Ribas et al. (2012), there are two types of uncertainty (exogenous and endogenous). A risk of side uncertainty, Lakkhanawat Bagajewicz (2008) adds financial risk. Srivastava and Gupta (2010) analyses threat scenarios in a refining unit. These threats are computer attack, the explosion in the pipeline, explosion, fire, and leakage of sensitive information, worse impact on and off site. Therefore, any disruption is likely to cause a lot of damage, in physical, financial and psychological terms.

One of the main engineering problems in risk modeling of the complex industries like refineries is uncertainty due to the lack of information (Saidi et al. (2014)), uncertainty may result from lack of information, lexical impression, incompleteness and inaccuracy of measurement (Yaquiong et al. (2010)).

Treatment of risk management of oil operations requires taking into account the risks related to operations in the oil industries such as environmental risks, natural, engineering, management and economics (Yanting and Liyun (2011)).

Zhao and Chen (2014), the risk is not linked only to the environment but also energy and finance. The major risk in the oil industry by Hussain et al. (2006) which is linked to the information system. They recognize the importance of a cooperative system to offer companies significant savings. Leiras et al. (2013) establish iterative integration approach to tactical and operational planning of multi-site networks refining implement the risks associated with uncertainty at every level of decision. In 2006, Torhaug manages the risks of terrorism. Cigolini and Rossi (2010) analyze and assess operational risk in drilling and refining stage.

Transport and Distribution risk

Transporting crude oil to domestic refineries in countries with refining capacity, and petroleum products from refineries whether domestic or overseas to final destinations in all countries, represent a significant fraction of end-user prices, particularly in markets far from major refining centers (Matthews (2014)). An important factor to consider is the uncertainty of the evolution in time of the transport tariff regime imposed by the regulators. In addition, we consider the usual uncertainties in forecasting gas demand and production. Then, to the uncertainty attached to the tariff's policies, Pelletier and Wortmann (2009) also consider the uncertainty attached to the estimation of the demand and the production level during each contracting period. These have also an impact on the risk linked to investment.

Can be distinguished according to the literature results three categories of risks associated with the distribution.

Concern the infrastructure risks such as pipeline, Simonoff et al. (2010) measures the risk of pipeline incidents in the United States. Lu et al. (2015) offer an escape valuation method from transportation and natural gas pipelines (line 1 and 2) in China. They affirm that the consequence assessment system can be categorized into personal casualties, economic losses and environmental disruptions.

For Potocnik et al. (2007) risk distribution are related to errors in forecasting demand in the context of several parameters influenced (seasonal data, weekday, and temperature). Oliveira and Hamacher (2012) study the demand uncertainty to find the optimal distribution solution.

The third category of risk distribution is the human risk. The oil distribution companies found Nigeria meet pipeline sabotage and theft risks under conditions of political turmoil in the country. Zhou et al. (2014) express that fire accidents explosion and toxic broadcast inevitably occur and the individual risk is obtained, they use the pipelines to China as an example to illustrate the risk assessment process and its application in areas urban land use.

States that depend on oil exports for the majority of their revenue experience slow economic growth, have high incidence of poverty, significant levels of corruption and are often authoritarian (Ross (2004)). These conditions lead to conflict. Second, the geography of oil is such that it leads to disputes over the allocation of benefits and the distribution of social and environmental impacts. Third, oil is a valuable commodity, whose access and control can be used to finance militia operations and influence local populations (Yeeles and Akporiaye (2016)).

The impact of disruptions is not uniform. Some disruptions, such as those caused by technical failures, occur often but have limited impact on global oil supplies and productive capacity. Disruptions, such as those due to natural disasters, occur infrequently but their impact on oil supplies can be significant in the short to medium term. Some disruptions are less regular, but their impact might have both short-term effects on oil supplies and long-term effects on productive capacity (Fattouh (2007)).

Supply chain

The crude oil supply chain risk management is a challenge of multiple decision criteria. It is necessary that decision makers consider completely different aspects of alternatives as potential advantage, risks and costs to determine the mitigation strategy most appropriate risks.

Fazli et al. (2015) identify the risks associated with the oil supply chain. They classify these risks according to five criteria: risks related to the demand: market risk, transportation risk and risks of competition. The risks of supply chain: the risks of exploration and drilling, production and quality. The risk of regulation: Risks of government decisions, international equity risk and environmental risk. Risks infrastructure: Risk machines, information technology risks. Disasters: Natural disasters, terrorist attacks, socio-political instability. Oliveira et al. (2013) present a scenario decomposition framework under demand uncertainty.

However, accurate estimation has not been performed because of large uncertainties in the actual oil resource and potential for exploration (Zhao and Chen (2014)).

The study of Cigolini and Rossi (2010) emphasizes the importance of risk in the supply chain in the oil industry and indicates that operational risk in this chain is bullwhipped. The operational risks by Fernandes et al. (2010) are seen to stem from various risk agents in the petroleum supply chain, which could generally arise from the business, condition, operations, and hazard and finance agents.

Cordesman and Al-Rodhan (2005) identify the following key geopolitical uncertainties: stability of oil-exporting nations; terrorism in the Gulf and oil facilities security; embargos and sanctions; ethnic conflict and strife. Uncertainties were introduced in market demands and prices (AL-Othman (2008)).

D. Risk management

Risk management is a scientific management method to identify, measure and analyze risk and on this basis to deal effectively with risk, to achieve maximum security at minimum cost (Yanting and Liyun (2011)).

In this section, we present the different approaches of the risk management literature based on the petroleum supply chain. Data synthesis of research methodologies was classified as qualitative, quantitative and mixed methods (see Table 6).

The use of different qualitative and/or quantitative risk assessment methods in the industrial accidents analysis has been undertaken in a number of papers (Antonioni et al. (2007), Bi and Si (2012), Brouwer and Blois (2008), Farzam et al. (2007), Kalantarnia et al. (2010), Khan and Abbasi (1998 a), (1999b), (2001c), Khan and Amyotti (2002), Márquez et al. (2005), Melton and Springer (2008), Nabhani et al. (2012), Pongsakdi et al. (2006), Rathnayaka et al. (2012) and Selvik and Aven (2011)).

Tang (2006) classified various quantitative and qualitative approaches upon the supply chain management unit that is considered to deal with risk (supply, demand, product, or information management). Within each category the author further analyses and differentiates available approaches upon the parameter considered as uncertain (demand, lead times, costs, yields), problem type (supply network design, supplier relationship, supplier selection process, supplier order allocation, supply contract), management strategy (postponement, process sequencing), or industry, respectively.

Qualitative methods

Qualitative research methods were further divided based on research approaches as empirical study, conceptual theory and Literature survey.

TABLE 6

RISK MANAGEMENT METHODS.

Authors	Quantitative	Qualitative	Mixed
Villada et al. (2013)	Simulation		
Weisser (2007), Doukas et al. (2011), Stern (2002), Zhao and Chen (2014)		Security Policy	
Saidi et al. (2014)		Fuzzy logic system (FLS)	
Fazli et al. (2015)			DEMATEL-ANP
Fattouh (2007)			-Approach to risk assessment. - Energy security and investment -Policy of oil experts
Oliveira et al. (2016)	Stochastic optimization model		
Leiras et al. (2013)	Linear stochastic program		
S. Khor et al. (2008)	Stochastic Program		
Gulpinar et Katata (2014)	Extreme-Value Theory (EVT) Copulas Function		
Park et al. (2013)			Assessment approach based on true options and incorporated with decision tree and stochastic discounted cash flows.
Esteves et al. (2007)		1-preliminary risk analysis (PRA), 2-hazard operability study (HAZOP) , 3-vulnerability analysis.	
Carneiro et al. (2010)	Value at risk (CVAR)		
Neiro et Pinto (2004)	mixed integer optimization		
Rocha et al. (2009)	Mixed linear programming integer.		
Lavasani et al. (2015)		The fault tree	
Oliveira et al. (2013)	Stochastic Linear Programming		
Oliveira and Hamacher (2012)			-Stochastic model -scenarios (future demand) -Average approach (SAA) of the optimal solution
Ji et al. (2015)	Stochastic programming: -value at risk (C-VAR) -fraction index model (FI) -Financial derivative instruments -An average reconciliation sample		
Capolei et al. (2015)			1-profit rating 2-certainty equivalent profits 3-expected benefit 4-worst scenario 5-standard deviation and variance 6-margin of safety 7-Mean-Variance

			8-value at risk (VAR) 9-Conditional Value At Risk (C-VAR)
Moerkerk and Crijins-Graus (2016), Cairns et al. (2008)		scenarios	
Simonoff et al. (2010)			-scénarios -analysis fault tree -Space Analysis and Modeling of Hazardous Area Size
Tong et al. (2012)	- Stochastic programming approach -Heuristic algorithm -simulation -statistical analysis		
Lababidi et al. (2004)	Stochastic Optimization		
Al-Othman et al. (2008)	Multi-period stochastic model		
Fernandes et al. (2011)		-Survey on the risk management in the oil supply chain -Hierarchical Risk Management Methodology	
Leiras et al. (2011)	-Stochastic model -Deterministic model (LP, NLP, MILP, MINLP)		
Park et al. (2010)	Integrated model of stochastic programming in two stages		
Pongsakdi et al. (2006)	Stochastic model		
Chen et al. (2015)	Dynamic programming		
Lu et al. (2015)	Combination of bow-tie model and risk matrix		
Fernandes et al. (2010)		The decision tree	
Zhou et al. (2014)			-1- Determination of the probability of an accident 2- calculation of accident consequences 3- calculation of individual risk 4- division of zones at risk 4- land use planning comments
Ribas et al. (2012)	Mathematical models based on stochastic programming and robust programming		
Lochner and Diechhoner (2012)	Linear optimization model		
Ambituuni et al. (2015)		interview (risk management framework)	
Urciooli et al. (2014)		case studies	
Cigolini and Rossi (2016)		1-recognize, 2-identify 3-control	

Vinnem (2004) present four-consequence barrier functions from the BORA (Barrier and Operational Risk Analysis) project: avoid ignition, reduce release, avoid escalation and prevent fatalities.

Reniers et al. (2008) alert that chemical industry cluster accidents are known for severity and domino effect (like the cluster PEMEX, Unigas and Gasomatico plants explosions in Mexico in 1984 and the Buncefield Oil Storage Terminal disaster in the UK in 2005). Cruz et al. (2001) suggest emergency response plans, mitigation measures, and design criteria to minimize hazmat release risk and natural disaster damages.

A cooperative system proposed by Hussain et al. (2007) may offer the oil companies huge savings and introduce new opportunities. To deal with strong dependence on imported oil, the Chinese government has implemented policies including strengthening strategic oil reserves, construction of oil pipelines, energy efficiency improvement, and development of the domestic oil tanker fleet. Zhao and Chen (2014) conclude in their research that the potential risk is intrinsically interconnected.

Weisser (2007) applies a ‘‘Security of Gas Supply’’ policy to supply gas to European Union with a strong multilateral direction. When discussing security of supply dependence it is useful to clearly define the various risks one wishes to protect against. The objective of the research Fattouh (2007) is to refocus the debate on the Middle Eastern logistics considering some concerns that seem to shape the energy security policies and identify some factors that can have a lasting impact on energy security, but who do not receive appropriate attention. An important objective of energy security should be to revise the guidelines under which stocks could be released. Furthermore, the so-called ‘producer–consumer’ dialogue should aim at coordinating efforts in the area of strategic reserves. Fattouh (2007) uses a probability approach to risk assessment, energy security and investment and oil expert’s policy. Doukas et al. (2011) shows the importance of security of supply policy to analyze and minimize risk.

Moerkerk and Crijins- Graus (2016) evaluate the external oil supply risks until 2035 under different scenarios. They build scenarios by several projections of climate oil policy by using the following variables: the supplier of the share of oil imports, a risk factor country, reserves / production ratio, share of oil supplier in the world total oil net oil imports. They note that strong climate policies are needed to reduce future risks and that India, China and the EU have increasing oil supply risks in all scenarios.

In examining the impact of increased import dependence and liberalization on security of supply, Stern (2002) applies a strategic security for market liberalization.

Responding to accidents of oil in Nigeria Trucking, Ambituuni et al. (2015) are interview with 19 semi-structured and they collected 2,318 accident reports, the results found 79% of accidents caused by human factors (dangerous driving, violation of speed). In a risk management framework used by regulators and operations in Nigeria, Ambituuni et al. (2015) suggest the principles of collaboration flying change, organization and communication, strengthening knowledge about the hazards and risks, and continuous improvement.

In considering the importance of safety culture, Cairns et al. (2008) are interview 354 offshore workers by projecting eight scenarios. They observe that the quality of surveillance is the most dominant factor and the personality of the respondent is a minor factor.

In oil production and gas sedimentary basin of Brazil, Esteves et al. (2007) seek to apply the risk management process. They use a qualitative methodology of risk analysis with a preliminary risk analysis (PRA), then a hazard operability study (HAZOP) and finally a vulnerability analysis. This methodology allows for rapid identification and assessment of key risks of the installations.

Lavasani et al. (2015) analysed the flight of oil and natural gas wells in Mexico drilling industry by applying the fault tree about 34000 wells. This method provided the theoretical and practical contributions to maritime safety and protection of the marine environment.

According to Fernandes et al. (2010), the risk identification process uses the framework to identify and prioritize first related risk agents, the second source of risk, risk objects and finally the risk of events. The hierarchical framework could be used to construct a decision tree to guide the construction of a database of information that could lead to a quantitative model as a mathematical model to optimize the risk management process.

In the United States, there are 959 natural gas transport incidents between the period 2002 and 2009 and 823 incidents of distribution of natural gas between 2004 and 2009. Simonov et al. (2010) applicate two-step approach in the statistical analyses to model the consequences and the costs associated with pipeline incidents. In the first step, the probability that there is a nonzero consequence associated with an incident is estimated as a function of the characteristics of the incident. In the second step the magnitudes of the consequence measures, given that there is a nonzero outcome, are evaluated as a function of the characteristics of the incidents. It is found that the important characteristics of an incident for risk management can be quite different depending on whether the incident involves a transmission or distribution pipeline, and the type of cost consequence being modelled. They develop scenarios to understand the consequences of pipeline failures, then they use the fault tree and then they finish with spatial analysis and modelling of the danger zone size. This methodology allows decision makers to the energy industry to build scenarios to gain a better understanding of how the measures of cost consequences.

In an oil supply chain, Urciooli et al. (2014) apply the five case studies and collection of data from multiple sources used to understand what the external security threats could lead to disruption of oil and gas flows to Europe. They seek to improve understanding of how the logistics of energy chains are working to strengthen the resilience against external security threats and improve the support mechanisms by the European Union. In an Italian company, Cigolini and Rossi (2016) analyse and assess operational risk drilling, transportation and refining primary stage of the oil supply chain. They use an analysis model with three stages: recognize, identify and control. These authors note that each operation is of particular risk management model.

Quantitative methods

Quantitative research methods are broadly classified into mathematical modelling, statistics and probabilistic theory and simulation for detailed thematic analysis (see Fig. 4). Singhal et al. (2010) divide analytical risk modelling approaches into modelling type (mathematical, simulation, and multi-agent) and modelling settings (linear, integer, dynamic, and stochastic problem settings).

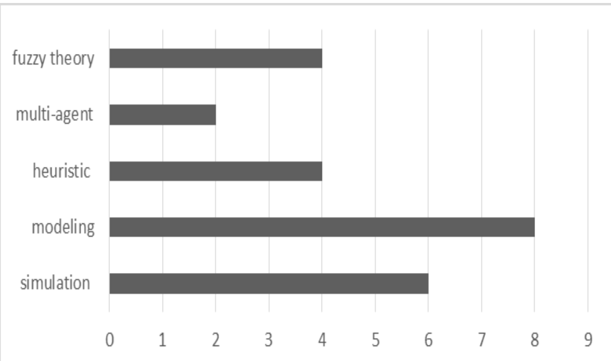

Fig. 4. Preferred research quantitative methodologies in risk management.

In paper of Pelletier and Wortmann (2009), a multi-stage linear program is used to simulate the repartition of the natural gas flow in an interconnected grid system on a succession of contracting periods. This simulation assesses the risk linked to infrastructure investment. Rocha et al. (2009) propose a mixed-integer linear programming formulation of the problem of allocation of 42 platforms that relies on a time/space discretization network. They implement an algorithm based on a heuristic to find a feasible solution and on a local search procedure based on optimization to improve it. This method results in advantages in terms of the quality of the solution when the problem of allocation is a link between strategic and operational decisions. Oliveira et al. (2013) present a scenario decomposition framework based on Lagrangean decomposition for the multi-product, multi-period, supply investment planning problem considering network design and discrete capacity expansion under demand uncertainty.

Leiras et al. (2011) examine a review of literature in the field of refinery planning models focusing on key techniques to deal with the optimization under uncertainty. They apply two types of models: stochastic model and deterministic model (LP, NLP, MILP, MINLP). Leiras et al. (2013) uses a linear stochastic program in two stages (spatial and temporal integration) with data from the Brazilian oil industry. This method has advantages of integration in a stochastic environment for tactical and operational planning of multi-site refining networks. Escudero et al. (1999) proposed an LP model that handles the supply, transformation and distribution of an oil company that accounts for uncertainties in supply costs, demands and product prices.

Kuo and Chang (2008) present a mixed-integer linear program that devises a planning model that coordinates the refinery production planning with the scheduling decisions.

The following authors apply stochastic methods (Oliveira et al. (2016), Khor et al. (2008), Oliveira and Hamacher (2012), Ji et al. (2015), Lababidi et al. (2004), Al-Othman et al. (2008), Pongsakdi et al. (2006), Ribas et al. (2012)).

Khor et al. (2008) propose a hybrid of stochastic programming approaches for an optimal midterm refinery planning that addresses the sources of uncertainties. A stochastic programming technique that utilizes compensating slack variables is employed to explicitly account for constraints' violations to increase model tractability.

A two-stage method is presented in Lababidi et al. (2004). They apply a deterministic model that minimizes the total production costs and raw material procurement. At the second stage, a scenario analysis technique controls risks like demands, market prices, raw material costs and production yields fluctuations.

According to Ghadge et al. (2012), the simulation modelling provides a systematic approach for understanding the relative and interactive impact of factors/parameters for different scenario settings. Tian and Tianfield (2006) demonstrate the advantages of multi-agent modelling and simulation in supply chain management -automation. This nested architecture encapsulates the complex system, and uses agents, which are autonomous software programs, that perform given functions automatically or semi-automatically by communicating with other agents, programs or human agents. Later Tian et al. (2007) develop a multi-agent system to model the interaction among partners in a petroleum supply chain.

The two methods called Security Risk Factor Table (SRFT) and the Stepped Matrix Procedure (SMP) have been developed to assess the security risks to the oil and gas industry as well as to other chemical industries. While the SRFT deals with the effects of individual threats, the SMP deals with the cascading/domino effects which a lone, low probability event can cause. Srivastava and Gupta (2010) applicate this methods in refinery industry.

Hua et al. (2011) developed a multi-agent simulation model to study the impact of different parameters and operational decisions, such as horizontal competition between retailers, order allocation strategies across retail, wholesale prices manufacturers, demand characteristics the market and the number of retailers, bankruptcy spread.

Fuzzy set theory was applied widely in many resources for risk modelling. According to Saidi et al. (2014), this theory has been proven as a useful approach to the risk evaluation of many sciences, because of the imprecision of the data and the frequent lack of quantitative information.

The process operations risk factors including failure frequency and the consequence components like employees' safety and environment impacts, operation downtime, direct and indirect cost of operations and maintenance, and mean time to repair should be considered in the analysis of these major accidents in any refinery. Saidi et al. (2014) propose a model for the risk of the process operations in the oil and gas refineries. They propose the fuzzy logic system (FLS) for risk modeling. In some researches the uncertainty problem in the FTA and Event Tree Analysis (ETA) in Bowtie modelling have considered by employing fuzzy theory in order to perform a risk analysis for oil and gas industry (Shahriar et al. (2012), Ferdous et al. (2013)). This model also can be accounted as a benchmark for future failures. The study of Shahriar et al. (2012) explored two types of uncertainties involved in a “bow-tie analysis” of oil and gas pipe failure. The first was data uncertainty associated with the basic risk events (at FT) and event (at ET), and the second was uncertainty with respect to interdependencies among risk events. This method helps professionals to decide and take preventive and corrective measures, can help to make an informed decision and to the risk management process.

The paper of Yaquiong et al. (2010) proposes the modelling of the traditional RBM method with fuzzy logic to incorporate uncertain variables.

The study of Lu et al. (2015) propose a comprehensive risk evaluation method by combining a risk matrix with a bow-tie model. First, a bow-tie model is built, considering the risk factors that may lead to an accident using a fault tree; the consequences of unwanted events are then described in an event tree. Second, a fuzzy method is used to calculate the failure probabilities. Third, the severity of an accident is evaluated through an index system that includes personal casualties, economic losses and environmental disruptions. Finally, a risk matrix consisting of a probability ranking criterion and a consequence ranking criterion is proposed to reach an integrated quantitative conclusion of a bow-tie model. A case study of an underwater pipeline carrying natural gas has been investigated to validate the utility of the proposed method.

Carneiro et al. (2010) seek to maximize the net present value expected from the oil supply chain using the value at risk. These authors note that taking into account the uncertainties is a fundamental step in the decision making processes. Research apply heuristic algorithm (Adhitya et al. (2007) and Tong et al. (2012)). Turmoil as crude oil arrived late, the reservoir of unavailability, the change in demand, unavailability of unloading facilities and the unavailability of (CDU) crude distillation unit heuristic algorithm improve computing performance and minimizing changes, it also allows the refinery staff to select one among the many realistic schedules taking into account other factors (Adhitya et al. (2007)). The simulation models Adhitya et al. (2007) for risk management strategies specifically related to managing disruptions in the oil supply chain. Tong et al. (2012) shows effectiveness of the proposed model (stochastic programming approach, heuristic algorithm, simulation, statistical analysis) for optimal planning of the refinery under uncertainty.

To address the complexity of the gas supply security, Villada and Olaya (2013) propose a simulation approach that replicates the structure of the gas supply chain, including transportation constraints and demand fluctuations. They build and calibrate a computer model for the Colombian gas sector, and run the model to assess the impact of expanding transportation capacity and increasing market flexibility on the security of supply. They find that proposed import facilities, specifically LNG import terminals at Buenaventura, increase system's security under the current market structure.

Coelho et al. (2005) propose a methodology connectionist using feedforward neural network as an alternative / complementary approach to traditional Monte Carlo simulation to estimate the total length of drilling a well in deep waters for risk assessment.

The paper of Fazli et al. (2015) implements decision-making trial and evaluation laboratory (DEMATEL) method to determine the interdependency between the main risks related to crude oil supply chain and then applies analytic network process (ANP) method to evaluate the importance of each risk and to determine the best response strategy. The results show that the most important risk area is the regulatory and environmental risks and that the transference and cooperation policy is rated as the best response strategy.

Greene (2010) introduced the Oil Security Metrics Model that allows oil dependence costs to be estimated in many possible uncertain futures.

Although risk management has prime importance in the process industry, research in this area has been limited, especially in the development of quantitative models. This lack of models to control risks in the petroleum supply chain, offers a tremendous opportunity for robust methodologies that could model and control the industry specific as well as overall risks (Fernandes et al. (2009)).

V. Conclusions

This paper suggests reviewing a main risk related to such operation of petroleum industry and to present an overview of the modeling techniques of the risk management.

Literature survey aims at understanding the important issues and mitigation techniques in petroleum supply chain, including the status and the development tendency in the area. Despite the rich body of literature on supply chain risk management in different industries, there exist a little literature review works in the oil supply chain. However, this domain has established as an important research area. The increasing number of publications in this area confirms this trend. Then, the research of risks in the oil industry begins in Europe in 2002 and after two years was a study done in Brazil. By against the country of China began to study this area to 2011.

From the outcome of our investigation, it is possible to conclude that:

The risk depends on such operation of oil industry and depends on country (importer or exporter). The scheduling domain is increasingly studied in the countries of Europe, China, the Middle East and the USA

The second type is the producer countries, citing Brazil, Iran and Nigeria, where oil export plays an important role in the economy. These countries are so heavily dependent on the production, for Nigeria the production was reduced due to vandalism on oil pipelines, kidnapping and actions of militants against oil installations.

Then, the oil supply chain of each country presents specific risks depend as political, economic and social encountered by each country. We also note the dependence between risk countries for example the Libya political risk can cause disruption on the supply chain in China.

We notice that the risks studied during the early period are generally oriented towards the field of industry, but in recent years, there are several areas such as distribution, refining, supply, as supply chain with all the steps.

The risk management has prime importance in the process industry, and research in this area has been limited, especially in the development of quantitative models. On the evolution of risk management models, we note that the most used methods in the first period of study are qualitative methods. Then, most of the authors oriented towards quantitative methods. However, in recent years mixed methods (qualitative and quantitative) are the most effective.

Briefly, the risk aspect has not been further explored in the oil industry and exactly in the area of oil supply chain for this reason in our future research we intend to concentrate on risk management in petroleum supply chain. Therefore, research effort should aim to diversify the risk measures employed in the future modeling approaches and the second challenge should be oriented to quantify the oil supply chain risk. It is extremely important to address risk modeling within the national petroleum supply chain, by developing new methodologies with the main objective of reducing the risk associated with our infrastructures (Fernandes et al. (2009)).

According to Lima et al. (2016), the future research efforts should aim to develop the mathematical programming techniques and the robust optimization decision tools in problems of uncertainty, risk, resilience, sustainability and collaboration in the decision-making. The objectives of mathematical programming models for supply chain, a new, have extended even further to involve supply chain security, risk, and sustainability dimensions (Speier et al. (2011)). Indeed, the decomposition techniques, lagrangian relaxation, rolling horizon, acceleration techniques, besides heuristics and metaheuristics are some examples proposed by Lima et al. (2016) of solution methods, which can be further, explored in the future researches.

The perspective of risk measures is an understudied issue within upstream and downstream oil supply chain. Thereby, in the downstream petroleum supply chain network Kazemi and Szmerekovsky (2015) propose optimal hedging strategies to reduce the impact of the disruptions and the incorporation of the impact of the uncertainties in the petroleum supply chain (such as considering facility disruptions). Lima et al. (2016) insist to apply other methods like the stochastic dynamic programming and the probabilistic programming, as well as the min-max regret robust optimization model or the max-min optimization model to treat the uncertainty in this area.

In refinery operation optimizations, Lavasani et al. (2015) propose to apply the risk management techniques.

According to Al-Othman et al. (2008), the uncertainty in market demand has more impact on the supply chain plan than the actual market prices. Consequently, an accurate forecast of the future market demand of crude oil would be most valuable to the petroleum producing organization.

In other side, Jensen and Nielsen (2007) propose to consider the dependency between basic events, which can be considered by employing method such Bayesian network.

In addition, future work will involve this approach in fuzzy environment. According to Fazli et al. (2015), the fuzzy measurements can be combined with triangular fuzzy numbers to eliminate expert subjective judgment problems involving complex hierarchical relationships among supply chain risk aspects and criteria.

Actually, transportation risk and price risk are also quite important for oil importers from the perspective of the whole oil importing process. As a result, it is essential to evaluate oil supply risk from other aspects and integrate all these risk assessing overall risk of oil imports (Yang et al. (2014)).

Zhang et al. (2013) suggest evaluating the import risks for major importers and giving a comparison of different risk sources for them.

In the future research, Sahebi et al. (2014) intend to concentrate on the qualitative performance measures such as supplier performance, effective risk management, flexibility, and customer satisfaction. In other side, Shahriar et al. (2015) said that the sensitivity analysis should be incorporated to investigate the effect of individual risk items on the over risk of the system. The sensitivity analysis should also be performed to examine the effects of weights and aggregation operators as model predictions may be sensitive to both the types of aggression operators and to weights.

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