An Exploratory study of agility in the UK oil and gas cluster and related supply chains
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Abstract
Extant theory on agility in supply chains does not explain the nature of competitiveness in the operations of cluster based organisations adequately. Also, generally, research on supply chain management has been concentrated on discrete manufacture with lack of in-depth study of the process industry. These limitations are particularly evident in the oil and gas industry despite in the UK being the focus of much government initiatives to reduce cost and uncertainties. This paper models the enablers of supply chain agility in the oil and gas cluster. It reports case studies to develop an understanding of the factors that enable and inhibit the diffusion of agile supply chain attributes in the upstream oil and gas industry. The results suggest that, in this diverse multi-tiered environment, this is a complex phenomenon driven by a number of factors including timeliness, flexibility, proactivity, being commercially aware, visibility, and knowledge of the industry.

1. Introduction
This chapter reviews oil and gas industry operations with the view of enumerating the activities first, and then the problems associated with undertaking the activities. The former is a necessary prelude to auditing the extent of agile supply chain practise in operations of the industry.

According to Crabtree et al. (2000) the oil and gas industry is a complex mix of activities involving many different organizations from a wide range of industrial sectors. Although the industry is often seen as a single industry, this is far from the reality. Furthermore, most of the activities which take place in this environment are project driven and involve diverse complex product systems which are highly customized, large scale and engineering intensive products which tend to be produced as one-offs or in small tailored batches (Crabtree et al., 2000). Further complicating factor is the high number of suppliers – several thousand firms subcontract and supply the offshore industry – each of which may be highly specialised and involved in complex networks.

The main players in the oil and gas industry are broadly classified into Oil operators, contractors and major oil service companies’. These players undertake tasks in diverse areas, typical fields and activities in which the players in the oil and gas industry are involved include:

- Drilling
- Engineering construction.
- Wells Completions
- Geology & Geophysics
- Reservoir Monitoring & Testing
- Well Logging & Formation Evaluation
- Facilities Engineering
- Production Operations
- Fluid Mechanisms & Oil-Recovery Process
- Reservoir Engineering
- Gas Technology
- Project Management
- Health, Safety & Environment
- Supply of facilities, equipments and chemicals
Figure 1 and 2 show typical oil and gas value chains. Figure 1 in particular shows the chains as well as the activities at the various phases of the supply chain while figure 2 is the corresponding corporations’ active in the North Sea oil and gas region – which is the site for this study.
Figure 1: Oil and gas value stream.
Figure 2: Players in the North Sea oil and gas value stream.
2 Classification of companies operating in oil and gas industry

Davies (1999) classified the companies operating in the petroleum industry into majors, other integrated and independents. Prominent companies within each category are as follows:

- **Majors** refer to major international oil companies with large integrated players comprising for example Exxon, Royal Dutch/Shell, British Petroleum (BP), Mobil, Chevron and Texaco. Included in this category are a group of slightly integrated companies such as Amoco and Arco and the privatised state owned oil companies – such as Total and Elf Aquitaine of France and Ente Nazionale Idrocarburi (ENI) of Italy.

- **Other Integrated operators** are similar to majors but smaller in size and with less geographical spread. It consists of companies such as Amerada Hess, Conoco, Diamond Shamrock, Marathon, Occidental, Philips, Unocal and Ultramar.

- **Independents** are yet smaller companies, most of whom specialise in a single segment. They include for example, Anadarko, Enterprise, Kerr-McGee (KMG), Baker Hughes, Schlumberger, Halliburton, Brown & Root, Coflexip Stena Offshore etc.

Within the former classification by Davies’s (1999) state owned petroleum companies were excluded. Some of the state owned petroleum companies are Aramco of Saudi Arabia, Nigerian National Petroleum Corporation (NNPC) of Nigeria, Petroleum Development Operation (PDO) of Oman, Petroleos de Venezuela, Pertamina of Indonesia, Kuwaiti Petroleum from OPEC and non-OPEC state producers such as Statoil of Norway, Petrobas of Brazil, Pemex of Mexico and Petronas of Malaysia. Most of the state corporations, especially those from OPEC countries, own the oil and gas reserves but do not possess the technical capability for exploiting the oil and gas resources. Thus, they undertake the exploration and production activities in partnership with the international oil majors.

Al-obaidan and Scully (1993) categorised the petroleum companies into:

- **Upstream companies**. These companies engage in the exploration, production and sale of crude oil.

- **Trading companies**, these are mainly privately owned and specialised in the purchase, storing, transporting and sale of crude oil and other petroleum products that are produced by other firms, and

- **Petroleum refining companies**, who are involved in the business of processing crude oil. They differ in the scope of their operations, ranging from purely domestic operations – such as Pemex of Mexico to worldwide operations for example, British Petroleum (BP). Associated with the refining activity is a complex and multi-faceted process of crude procurement and subsequent scheduling of the refinery processes for the production of different product grades. Indeed, crude procurement has a direct impact on refinery profits (Julka et al., 2002).

Hallwood (1991) classified offshore oil supply firms into two types: those that are organized on a global scale (multinationals) and those which provide inputs that are
determined by the location of their use. A multinational corporation is the organization that owns, controls and manages income generating assets in more than one country (Al-Obaidan and Scully, 1993). While a non-multinational oil corporation operates income generating assets in a single country.

In the UK a different classification scheme has been used where players are sometimes referred to as operators, contractors or suppliers Crabtree et al (1997). Operator comprises the oil majors such as BP, Shell and Exxon these are the companies that license the rights for oil and gas extraction from governments (Bower and Young, 1995). Contractors include multinationals such as Kerr-McGee, Schlumberger, Halliburton, Baker Hughes, AMEC, Brown & Root and Kvaerner while suppliers comprise SME’s and suppliers of inputs. Hallwood (1991) report that by 1984 over 1,000 offshore oil supply firms had established themselves in Aberdeen area of the north sea Scotland. This was also corroborated in future studies (Bower and Young, 1995; Barlow, 2000).

2.1 The Nature and Organisation of activities in the UK upstream Oil and gas Industry

The upstream operation is mainly concerned with the oil extraction, and within this sector there exists a diverse and complex network of organizations, representing a wide range of industrial cultures and expertise (Crabtree et al., 1997; 2000). For example some of the activities include seismic analysis, exploration drilling, well design, infrastructure design, manufacture and installation. These activities are often referred to as capital expenditure (CAPEX). Other activities include production management or operating expenditure (OPEX), and aspects of supply chain management (Finch, 2002) as shown in figure 3. Also, there are associated specialized services that are linked to CAPEX, and OPEX services. CAPEX services are normally undertaken by service providers such as seismic surveyors, geological consultancies, drilling contractors, pipe layers and sub-sea engineers, while other service providers may be in fabrication or construction of offshore structures. Typical OPEX services are many of the support services that are necessary such as supply vessels, helicopter services and software maintenance. Figure 5 shows activities undertaken in upstream oil exploration scenario. It is apparent that companies from differing organizational backgrounds must work closely on projects. This poses considerable management challenge. Additionally, the activities of oil producers are characterised by unpredictable oil reserves, reservoir exhaustions, and increasing restriction of land access to remote sites all of which combine to increase the uncertainty associated with the discovery and subsequent production of crude oil.

It has been stated previously that, the offshore oil and gas industry activities are primarily geared towards extraction of crude oil. But the infrastructure required for oil extraction is a unique high complexity capital product which, like any other product, has to be produced. Hobday (1998) termed this type of product “complex product and systems (CoPS)” while the production method is referred to as “one - of - a - kind production (OKP)” (Tu, 1997; 271). CoPs are high cost, highly customised, engineering - intensive goods (products, systems, networks and constructs) which often require several producers from diverse backgrounds to work simultaneously in the course of its production. Another characteristic of CoPs is they are often engineer-to-order products (Hicks et al., 2000; Little et al., 2000). CoPs are often produced
within projects which incorporate prime contractors, system integrators, users, buyers, other suppliers, small and medium-sized enterprises (SMEs) and sometimes government agencies and regulators. (Hobday, 2000), Barlow (Barlow, 2000; 974) notes that “due to the importance of tacit knowledge and the need for personal contact in problem solving...” there is high degree of geographical clustering in the supply networks of CoPs projects. In an empirical study on exchange and organization of the offshore oil gathering industry, Hallwood (1990; 577) report that “In fact, it would be unusual for an oil company to deal with a supplier that had not located...in close proximity to its own operating - base.” Thus this practice has attracted about a thousand suppliers to Britain’s main offshore service-base located at Aberdeen in northeast Scotland. Furthermore, Hallwood (1991) studied the offshore industry from business economics perspectives and found that the driver for the “co-location” of suppliers locating close to oil companies is transaction cost economisation. However, from operations management perspectives it can be argued that the reason for contractors and suppliers to co-locate near the operators in the offshore industry, in addition to reducing the transaction cost, is more importantly to enhance the operation flexibility of the offshore industry operations. Uncertainty in the business environment can make planning operations difficult and in the extreme lead to distortion of demand information along the supply chain, this phenomena has been termed “bullwhip” or “Forrester” effect (Lee et al., 1997). To mitigate the effect of the uncertainty and be competitive in a business environment that is characterised by turbulence and high risk requires an agile supply chain. These had been espoused by Goldman et al (1995: 43) who state that agile organisations embrace “…change and uncertainty… [as]…sources of opportunities…” for sustained competitiveness and success.

Some researchers have provided theoretical basis for selecting the right supply chains. For example Webster (2002) suggested that key product features and demand profile for the product determine the appropriate design for the supply chain. Initially, Fisher (1997) distinguish between functional and innovative products. For a functional product the focus of the supply chain is on quality, minimisation of costs and lead time while the focus of management is on optimization of operations to maximize efficiency. While for an innovative product the focus of the supply chain is on responsiveness and the supply network should be geared towards being responsive. Thus the focus of management of operations should be on effectiveness of service rather than efficiency. Fisher’s typology is represented in figure 3.

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<th>Lean supply chain</th>
<th>Functional products</th>
<th>Innovative products</th>
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Figure 3: Relationships between supply chains and product types (Fisher, 1997; 109).

Lamming et al.(2000; 688) extended the work of Fisher from focussing on the supply chain to the whole supply network and concluded that “Management of supply networks of functional products, however complex must focus on cost and quality issues whereas for unique-innovative products, the emphasis is on speed and flexibility.” In essence agile supply chain is the most appropriate for innovative product while lean supply should be used for functional products. In line with using the demand characteristics of a product to distinguish the typology of supply chains (Fisher, 1997) and supply networks (Lamming et al 2000), Christopher (2000; 38) suggests that “three critical dimensions of variety, variability (or predictability) and
volume determines which approach - agile or lean” to choose. However for an
innovative product coupled with high degree of product customisation then the
process needs to be responsive and hence agile (Naim and Barlow, 2003).

Agility is the ability of an organization to respond to changes in volatile and
unpredictable demand. Hobday (1998) presented indicators of product complexity in
CoPS to include the quantity of tailored components and sub-systems, the hierarchical
manner in which they are integrated together and the degree of novelty of the CoPS in
question. These directly contribute to the difficulties of managing by adding
uncertainty and risk. Thus the preceding theories espouse the need for an agile supply
chain in organising to produce CoPs, such as offshore equipment, in the offshore oil
gas industry. Specifically the various companies and organisations involved in the
upstream oil and gas industry requires agility - speed and flexibility in operations.

The upstream oil and gas industry in the UK is one of the largest industries and it
accounts for a substantial part of the overall economy such that around the late
nineties it constituted approximately 20 percent of total UK industrial investment
(Collins, 1999). Overall, it provided direct and indirect employment for more than
300,000 people out of which 27,300 work offshore. It has also contributed £12 billion
to the UK’s GDP in 1994 (Crabtree et al., 2000). However development from two
sources is creating a major challenge to operations in the UK oil and gas industry. The
main source of challenge to the UK upstream oil and gas industry are as follows:

1. Global outlook of the industry is marked with attendant uncertainty and
volatility. This is evidenced by sharp fall in oil price on the world market to an
unprecedented level, indeed the last decade has seen oil price being “at or
below only one-fifth of the mid-1980s values in real, sterling terms” (Collins,
1999; 28), this was followed by recovery which peaked presently.

2. The UK continental shelf is now characterised by maturity of the oil and
reserves and higher costs of prospecting (exploration) for oil and its
subsequent production (Finch, 2002). In fact due to the maturity of reserves in
the UK North Sea, it is now one of the places with the highest exploration and
production costs (Finch, 2002). Collins (1999) contend that “while costs of
finding and developing new oil reserves remain substantial, typical new fields
are only 20 percent of the size of those developed in the early 1980s”.

For some of the oil majors such as BP Amoco, Shell, Exxon/Mobil for example, their
activities span the entire supply chain from upstream to downstream. Exploration and
production constitute the upstream operation while refining, transportation,
distribution and retailing are at the downstream end of the industry (Mabert and
Venkataramanan, 1998). Furthermore, within the exploration and production phase of
the activities there exist diverse and complex supply requirements, representing a
wide range of organizational cultures and expertise as illustrated in figure 5. The
figure represents many of the supply requirements of the oil companies within the
upstream operations (Crabtree et al., 1997). This goes to show the challenge in
managing companies from this varied background. These companies must often work
very closely on projects, in inter-firm teams, typical of the construction industry
generally (Barlow, 2000). This is said to be common place in the highly subcontracted
North Sea environment (Crabtree et al., 1997).
2.1.1 Pressures on the North Sea oil Industry

In the UK upstream oil extraction business initiatives such as CRINE and NORSOK have been introduced in the UK and Norway respectively as cost cutting measures. Thus operators have sought to reduce exploration and production costs by adopting different organisational forms and encouraging different working practices (Barlow, 2000). A prominent trend has been towards organising both exploration and production activities into project groups, alliances or joint ventures involving at least one operating company and groups of services companies (Finch, 2002). Indeed consolidation, alliances, outsourcing, enhanced supplier relationships and advantaged networks of producers and suppliers have been identified to be the trend of activities of the oil majors in their North Sea operations. The alliances are to reduce costs and cycle times, and improve performance after exhausting the scope for cutting internal costs and reengineering business processes (Ernst and Steinhubl, 1997). Thus most services companies have worked over long periods of time with different operating companies through various types of relationships, thus enhancing the capabilities of the services companies and enabling them have high impact on operating performance (Finch, 2002). This in essence makes the operators reliant on contractors for their expertise. In this regard, Ernst and Steinhubl (1997) said that oil majors and services company acts as a “systems integrator,” arranging and coordinating alliances and contractual relationships involving suppliers, service providers and even other operating companies aimed at reducing overall costs, cycle times and ensure access to critical inputs and technology.

Bower and Young (1995) report that a cluster of technology suppliers has grown up in response to the opportunities offered by the North Sea offshore oil industry in Aberdeen. The geographical clustering of the new entrants to the oil-related industry is around the main operational subsidiaries of the operator companies similar to the aerospace/electronics industry in Southern California. Crabtree et al. (2000) studied the manufacturing strategy adopted by the offshore industry oil suppliers. They observe that the industrial network of UK oil and gas industry has become increasingly complex and difficult to access. This is due to the recent changes in contracting arrangements brought about by a government sponsored initiative known as cost reduction in the new era (CRINE), manufacturers operating in the North Sea face problems with respect to material management in their supply chain. These problems are as a result of:

1. the geographical location of Aberdeen increases delivery times and cost; and
2. most manufacturers not buying material in sufficiently large quantities to hold significant influence over the suppliers.

The material management problem mostly affects smaller companies, as they constitute relatively small business of their suppliers they experience long lead times for their primary materials. In turn this negatively affects production further along the supply chain (Wright, 2001). The above problems necessitate the manufacturing companies choose appropriate strategies to cope with the unique pressures. Specifically – for the survival of small manufacturers in the sector – the strategies must address the following key issues:

- Whether to invest in manufacturing capacity and training to meet the range of supply requirement locally or to relocate and subcontract
- Trust and commitment based relationship with purchasers
- Diversification and/or global operations
• Funding modalities for expansion and growth (Crabtree et al., 2000).

By the end of the 1990s the economic climate in the upstream oil and gas industry experienced substantial pressures due many factors including falling oil prices, depleting oil reserves, maturing regions, increasing competition in the market and high costs for developing projects that posed a threat to margins in the nineties necessitated the launching of a taskforce by the UK government to ensure a more viable future for the industry in the UK (Nolan, 1998). “The oil price has given impetus to this work but there is also [the] recognition that the industry hasn’t picked on the supply chain” said a government source. The taskforce is to identify a vision in terms of the components of success and how companies down the chain can implement them. Membership of the taskforce is drawn from operators, contractors and suppliers and chaired by a cabinet minister (Energy Secretary). The taskforce has the mandate of taking an industry wide approach to progress. It is of note that supply chain management formed the key issue in the initiative along with technological innovation and new approaches to design and development. Essentially, the aim of the task force initiative is to entrench due diligence and supply chain control in the UKCS oil extraction business in a bid to make it more competitive and responsive to market pressures (maturing of the industry and fluctuating oil price). This point was buttressed by Tony Collins, supply chain manager for Shell Exploration and Production, who said that:

Figure 4: Upstream oil supply activities. (Source: Crabtree et al., 1997; 182)
“we need to do something about costs and value…we are going through assessment in the industry on what is good and bad…at Shell, for example, we have found a lot of issues around relationships. Outsourcing activity has increased and we have to get value out of the management of those relationships” (Nolan, 1998).

A survey carried out in 1999 by CRINE Network pointed that; up to £1 billion could be saved by North Sea oil and gas companies in three years by focussing on their supply chains. Therefore, as part of the initiative, supply chain element code of practice is being implemented, this aims to improve efficiency and reduce waste by targeting working practices, behaviours and purchaser/supplier relationships. Furthermore, partnership was sought between the two countries sharing the North Sea oil and gas reserves, i.e. UK and Norway. It was recognised that there is increasing change in the global energy marketplace, additionally; partnership is becoming increasingly important particularly in the challenging environments of the North Sea. Therefore, to strengthen the UK/Norway cooperation, a government industry workgroup was mandated to study options for development of the North Sea oil and gas resources. It was observed that closer supply chain relationships are capable of enhancing their current products and services in the North Sea and other oil and gas markets.

The following is the background information to the petroleum supply chain. This is intended to highlight the activities involved in the oil and gas industry and provide a basis for understanding the supply chain management within the industry.

3 Petroleum supply chain

The petroleum supply chain consists of subsystems such as oilfield infrastructure, crude oil supply, refinery operations and product supply. All levels of decisions such as strategic, tactical and operational arise in the petroleum industry, as such it can be characterised as a typical supply chain (Neiro and Pinto, 2004). The distinct units/entities are; upstream operations, refining and supply, and transportation. These are broadly categorised as upstream and downstream operations. Upstream operation consists of the oil exploration and extraction, while downstream is refining, distribution and retailing. Figure 5 shows some activities of the petroleum supply chain. Obviously the supply chain for petroleum products extends beyond product distribution as shown in figure 6. This shows that the petroleum supply chain could be extended further to retailing or other industrial usage – especially petrochemicals.
The process of petroleum product starts with exploration which is at the highest level of the supply chain (Neiro and Pinto, 2004). Oil is discovered through exploration and prospecting. Exploration activity involves carrying out geophysical survey to locate the underground reservoir. Further investigation using seismic information is then carried out to ascertain the quantity of the oil. If it is in commercial quantities it is then pumped out as crude oil. Crude oil is transformed into products at refineries. Products generated at the refineries are then sent to distribution centres. Crude oil and products up to this level are often transported by pipelines. From this level on, products can be transported either through pipelines or trucks, depending on consumer demands. However, there are cases in which products are transported using vessels or train. Product transportation focuses on scheduling and inventory management of the distribution network and facilities. The major activities that happen within the supply chain are Exploration, Production, Refining, Storage, Distribution, Transportation Services and Retailing. These main activities consist of sub-activities and are described as follows.

Hull (2002) used data flow diagram (DFD) to model information flow among supply chain links. The model was applied to the Alaskan North Slope Oil (ANS) supply chain. Supply chains can be push/pull hybrids. The Alaskan Oil information system was shown to be a classic push from the oil fields to refineries. Gasoline deliveries though are often pulled from the refineries by retail demand. Thus this conforms to the “leagile” characterisation (Christopher and Towill, 2000; Towill and Christopher, 2002; Aitken et al., 2002). A major limitation of this work is that it did not show how the model impact organising for the most important aspect of the oil and gas supply chain - exploration and production.

The following section will detail the various activities involved in the oil and gas supply chain.

1. Exploration operation and facilities: Exploration is the beginning of the petroleum supply chain. It is the act of searching for and finding oil in commercial quantities. It starts with oil companies acquiring exploration rights, for onshore exploration this involves obtaining lease agreements, titles and right-of-way accesses for the land. While for off-shore sites, legal jurisdiction must be determined from government of the country where oil extraction will be carried out. Exploration involves seismic survey, which is a study of fields using satellite images, to examine surface rocks and
terrain. Information from the seismic survey are used to drill appraisal wells using drilling rig, this enable the oil to be pumped out and used to determine the amount of oil present underground. On successful completion of the exploration drilling and oil is determined to be available in commercial quantities, the oil well undergoes what is termed development and completion services prior to full production (Freudenrich, 2004). Exploration and production are closely related and together they constitute the oil extraction activity. In the UK, companies such as the majors, contractors and suppliers are present and operate in all sectors of the oil industry. Bower and Young (1995) estimate that there are approximately 1000 service sector oil related companies which supply, service, subcontract or manufacture for the large oil companies notably majors and contractors. The oil and gas industry faces the challenge of more expensive exploration and operation costs, thus total cost of operation is the major focus of both the operator and service companies.

2. Production activities: Succeeding the exploration activity is oil production field development and completion exercise. Field development and completion involves installation of equipment and facilities for pumping the crude oil from the reservoir or oil well to the surface in a safe and efficient manner. This involves construction of oilfield infrastructures. It is a complex processes that involves diverse activities. It involves construction of production platforms, well platforms and pipeline connections. Essentially, once the oil is flowing as a result of the exploration drilling, the oil rig is removed from the site and production equipment is set up to extract the oil from the well. After the rig is removed, a pump is placed on the drilling equipment (also known as well head) used for exploration drilling to pump out the oil from the underground reservoir (Freudenrich, 2004). The various activities involved in the development and completion stages are:

- Construction: involves construction of wells such as down holes, tubing, casing, wellheads and risers.
- Production facilities: involves “Christmas tree” installation, topsides and production platforms.
- Subsea systems: This involves subsea tiebacks and infield flow lines. The scope associated with this system covers installation of pipelines, flexible production risers, umbilical, jumpers and flying leads.
- Process Engineering is about the choice of appropriate processing technology for the oil and gas pumped out. This depends on the quality of the oil and gas. The quality of oil and gas is depends on the amount of water mixed with it. Thus, the amount of water associated with the oil and gas determines the amount of processing or purification/separation to be undertaken.

3. Oil Refining: Oil refining separates crude oil into useful substances. Some of the products extracted from oil are: Petroleum gas, Gasoline or motor fuel, Kerosene, Gas oil or Diesel distillate, Lubricating oil, Heavy gas or Fuel oil, and Residuals (Zhang et al., 2001; Freudenrich, 2004). The products are stored on-site until they can be delivered to various markets such as gas stations, airports and chemical plants.

Petroleum refining is a flow process production system which is capital intensive. It requires the use of specialized assets and raw materials with the attendant requirement of a constant throughput. A crude stock out would necessitate unit shutdowns and must be prevented under all circumstances (Julka et al., 2002). Thus, critical for successful refining operation is a ready and reliable source of crude oil supply. These
make crude procurement one of the most important business processes in a refinery. Crude procurement also interacts with many functional departments within the refinery. For example, a crude mix can yield many different grades product quantities and qualities depending on process parameters such as cut points, blending and others. Factors such as variable crude prices, crude availabilities, product prices and product demands must be considered and optimised to achieve profitable combination of crude purchased and crude mix refined for products. Additionally, scheduling of processing equipment, storage tanks and transportation related facilities, such as jetties, is also hinged on crude procurement process (Julka et al., 2002).

Uncertainties in choice of logistics and ship arrivals also impact the crude planning process. Therefore, uncertainty in the supply of crude oil leads to the refiner resorting to what can be called panic buying (tendency to allocate more resources) in an effort to secure an adequate flow of the raw material in order to hedge refinery downtime (Al-Obaidan and Scully, 1993). Despite the need for crude availability in the refinery operation, the nature of technology in the oil industry does not require the refiner to be vertically integrated. Thus, it is quite possible for the upstream and the downstream companies to be separate but closely coordinated (Al-Obaidan and Scully, 1993). Indeed, Hallwood (1991; 39) cite a report that showed “American oil refining companies to be vertically integrated into ownership of crude oil reserves, pipelines, marketing and research and development to a high degree.”

Like any supply chain setup being composed of supplier, internal processes and customer. The refinery supply chain is also similarly characterised. Within the refinery supply chain, there are internal and external activities to the refinery as shown in figure 7. Activities within the departments of the refinery include; procurement, sales, storage, operations and logistics. While activities performed by external elements are; oil exchange, oil suppliers and logistics providers.

Figure 6: Refinery supply chain elements (Source: Julka et al., 2002; 1773)
Julka et al. (2002) gave an account of the activities performed by parties external to the refinery operation to be as follows. Oil suppliers submit to the exchange postings regarding the available crude grades and prices. Logistic service providers transport crude from the oil supplier’s terminals to the refinery. Within the refinery, the functions performed by various departments are briefly enumerated as:

a. Procurement department coordinates the crude procurement process. It retrieves crude availability postings from the online oil exchange and decides the crude grade and quantity to be purchased. Pertinent information is crude properties, refinery targets, product data and logistics.

b. Sales: this department provides product price and demand both present and forecasted.

c. Operations: decides daily crude grade and quantity to process. Also decides refinery operating parameters.

d. Storage: manages the storage tanks and schedules the loading and offloading jetties. It also ensures regular supply of crude grade for refinery process.

e. Logistics: arrange transport of crude from supplier terminal to the refinery. It normally does that through bidding or contract to select shippers or third party logistics suppliers (3PLs).

4. Storage: Storage involves using facilities to hold the crude oil at refineries. After the refining process products are also stored for distribution to retailers or export. Storage facilities are:

- Underground storage facilities
- LNG terminals
- Tanks

5. Transportation: Indeed the world-wide crude-oil transportation aspect of the petroleum supply chain is the central logistics that links the upstream and downstream functions. It is very crucial in the global oil industry supply chain management (Neiro and Pinto, 2004). Key oil and gas modes of transportation are:

- Pipeline: pipeline is a piece of equipment that transports crude oil and products. No modification in either physical or chemical properties takes place during transportation.
- Trucks
- Rail
- Marine/Ship (LNG, Crude and Refined product)

To move the product from the refinery to a storage terminal through the pipeline or marine is not a high cost. However, the final leg of the distribution chain, when the product is moved from a terminal to a service station is the most costly, another costly task is transporting crude to the refinery.

6. Distribution Network: Distribution assets include Trucks, Pipelines and Terminals. Distribution aspect of petroleum supply chain involves pipeline connection from petroleum terminals to refineries and from refineries to intermediate terminals or directly to distribution products (Neiro and Pinto, 2004). Pipeline is characterised as a custom built facility also known as “asset specificity” (Hallwood, 1991). Specific assets are designed to support one end-user and are much less productive when deployed (Koenig, 1997), in some cases, once a facility is built it cannot be moved to another site or removed entirely, it is normally installed to a client’s specification, and
therefore its can only be used by a specific customer. Therefore, the owner of such an asset is vulnerable because the value of the asset drops when employment in its specialized role is not available and secondary users must be found. Where it can be used by a group of customers, its capacity would then be normally traded among the firms, rent then is charged for its used (Al-Obaidan and Scully, 1993). Ernst and Steinhubl (1997; 153) report of “advantaged networks of producers and suppliers” in which a coordinated network offers the opportunity for oil majors to link oil wells in a common pipeline infrastructure. Terminals are storage facilities such as farm tanks or retail gas stations. Trucks are used to transport products from intermediate storage terminals to local distribution terminals for retailing.

7. **Services:** These are complementary activities – e.g. supply of inputs, operations and maintenance – carried out in the course of performing the previous functions such as exploration, production or refining. It also includes transactions with government agencies. The following is a list of some supplementary services in the execution of the major activities in the oil and gas projects: Well services; Pumps; Software systems; Speciality chemicals; Construction; Contracting; Decommissioning; Environmental services; Fabrication; Facilities Management; Field development; Installation and Positioning; Duty on transports between countries; and Taxes, Tariffs and Royalties regulations (Heever et al., 2000). These activities constitute a significant sector of operations that are performed without which the operations of the offshore activities will be impossible to be carried out.

3.1 **Oil and gas production in some OPEC countries**

A lot of countries of the Middle East are producers of oil and gas. They together with some other countries spread all over the world constitute the organisation of oil producing and exporting countries (OPEC). A key characteristic of the OPEC countries is that political rather than free market economy prevails in the allocation of rights (Al-Obaidan and Scully, 1993; Davies, 1999). The Middle East oil and gas producing states are: Saudi Arabia, Iran, Kuwait, Libya, Oman, Qatar, Abu Dhabi (UAE), Iraq, and Bahrain.

**Qatar Oil and gas value stream**

In most of the Middle East oil and gas resources are exploited in partnership with the international oil majors. Normally a country enters into partnership that vests all the right to exploit the resources to a single oil operator. The decision for allocation of these right is often based on political exigency but not subject to competitive bid (Davies, 1999). Allocation of concession to a particular operator in essence locks out the other operators, and due to the asset specificity of oil based infrastructure (Hallwood, 1991) it is not economical for the other operators to maintain presence in a country that they lost out.

In Qatar for example, ExxonMobil is the leading foreign investor (Anonymous, 2004). Recently, Qatar and ExxonMobil Qatar GTL Limited (a subsidiary of Exxon Mobil Corp.) have entered into a “Heads of Agreement (HOA)” for an approximately $7 billion, Gas-To-Liquid project. The facility to start production in 2011 with a projected capacity of 154,000 barrels per day (bpd), will have the projected capital cost wholly financed by ExxonMobil. Thus, ExxonMobil will design, construct and perform all petroleum operations in connection with the GTL project. This includes
the rights to develop and produce gas, associated liquids and other hydrocarbons for the 154,000 bpd capacity of the GTL plant (Anonymous, 2004).

It is apparent here, that in Qatar it is the oil majors that perform upstream activities of the value stream, though in partnership with or on behalf of the host government. There is less participation in terms of investment or technology by the host government in the upstream operation. There is presence of local participation in the downstream activities, particularly refining by the Qatar Government.

**Saudi Arabian Oil and gas industry operation**

In Saudi Arabia, Saudi Aramco is a state monopoly that operates the oil and gas industry on behalf of the state. It operates joint venture with the international oil majors in the upstream sector for the exploration and production of oil and gas. While in the downstream sector, it is the sole operator of the refining and regional distribution activity. Local distribution and retailing is deregulated to local industry.

**Nigerian oil and gas supply chain**

In the upstream sector, Nigeria operates a joint venture agreement with the oil majors – Shell, BP, Chevron, Mobil, Elf, Agip, and Texaco – for oil and gas exploration and production. Shell Petroleum Development Company is Nigeria’s biggest crude oil and gas producer. It accounts for more than 40 per cent of the country’s crude oil output, with a daily production capacity of over one million barrels and reserve levels in excess of 18 billion barrels. The company operates a joint venture with the Nigerian National Petroleum Corporation (NNPC). NNPC holds 55 percent of the venture on behalf of the Nigerian Government with Shell retains the remaining 45 percent.

NNPC – Nigerian government’s oil and gas holding company – participates in all aspects of the downstream petroleum value stream. Specifically it is the sole player in the refinery and petrochemical sector. While the storage, distribution, transportation and retailing business is deregulated opening this sector for foreign and domestic firms to compete with the Nigerian government – through its holding company NNPC.

**Oman Oil and gas value stream**

The value stream of oil and gas sector in Oman is as shown in figure 8. In Oman a joint venture known as Petroleum Development of Oman (PDO) was formed between the government of Oman and Shell Petroleum. As the figure shows PDO undertakes upstream exploration and production while the other parts of the value stream is deregulated to local industry. However, high technology contracting and service input activities are all performed by foreign contractors.
Oman Oil and Gas Value Stream

Petroleum Development Oman (PDO):
Partnership between Shell and Oman Government

PDO
-Drilling
-Exploration
-Production
-Storage

Transport

Refining

Retailing

Contracting and Services providers

Full Value Stream

Figure 7: Oil and gas value stream of some state owned corporations.
3.2.2 Oil and gas production in Non-OPEC producing Countries

Prominent among the non-OPEC oil producing countries are Norway, Malaysia, Brazil, Mexico, China and Russia and adjoining Commonwealth of Independent states made up of Kazakhstan, Uzbekistan, and Azerbaijan. Out of these oil producing countries, Norway’s oil and gas value stream will be briefly presented, it is as follows.

Norway oil and gas industry

Norway and UK share most part of the North Sea. According to Mr. Olav Fjell Statoil’s President and CEO, Norway’s policy was the desire to create a strong domestic oil industry since the discovery of oil in the Norwegian continental shelf. Statoil operates the oil and gas resources on behalf of the Norwegian government. Therefore, Norwegian companies win most of the contracts for the oil and gas development but mostly after a stiff competitive bid. Furthermore, Statoil operates Girassol the world’s largest deepwater field in Angola, making it a multinational oil corporation. But the main influence of oil and gas resources on the Norwegian economy is the development “…of a strong petroleum cluster with many competent companies, large and small” (Statoil Magazine, 2003; 2). This indicates the tendency for strong bunching together of the companies involved with the prospecting and production of oil and gas.

3.3 Natural Gas Value Stream

Natural gas is associated with crude oil; previously it was burnt off as a waste or bye product of crude oil production. Gas as a hydrocarbon has many attractive qualities. It is clean to burn and has very high conversion efficiencies which lower the cost of energy at the burner tip. It also has great potential as a feedstock for petrochemicals (Stevens, 2000). However, gas requires expensive infrastructure. Furthermore, gas, unlike oil which can be managed in batches, requires a constant flow which necessitates complex pipeline networks even for minimal usage (Stevens, 2000). There are only two means of transporting natural gas: pipeline and liquefied natural gas (LNG). Each mode of transportation poses a challenge. Pipeline is used to connect the source of the gas and the user directly, therefore in pipeline transmission the gas is transported in original gaseous state. While in LNG the gas is liquefied and then loaded onto a tanker to transport it to the destination market. LNG is generally more competitive than pipeline at transportation distances greater than 3,000 km for a nominal quantity of 6 bcm (billion cubic metres) /year while pipelines can be competitive at longer distances, 6,000 km or more, for very large gas quantities in the order of 30 bcm/year (Avidan, 2000).

Unlike oil supply chain classification, the gas supply chain has been classified into upstream, midstream and downstream (Thackeray, 2002; Silk, 2003). Upstream consists of the supply side from onshore or offshore sources. Midstream is concerned with the infrastructure for gas-receiving such as terminal, storage, and pipeline facilities as well as transportation fleets. Finally, downstream is made up of gas market utilisation made of the petrochemical industries, power plants, and retail and gas networks. Figure 9 shows the natural gas value stream.
The major constraints in the natural gas supply chain are the project cost and long lead times in pipeline and LNG projects. Poor macro economic performance is the constraint in developing countries (Stevens, 2000). Thackeray (2002) state that LNG exporting countries by 2001 were: US, Trinidad, Algeria, Libya, Nigeria, Abu Dhabi, Qatar, Oman, Australia, Brunei, Indonesia and Malaysia. Additional exporting countries by 2006 are likely to be: Egypt, Norway, Yemen, Bolivia, Peru and Venezuela. Thackeray reports departure from the traditional contractual links between upstream, midstream and downstream investors in the LNG chains. The new pattern emerging shows players establishing vertically integrated supply chain. It is revealed from the emerging pattern that Royal Dutch/Shell, BP and British Gas (BG) Group invested upstream in gas production, midstream in liquefaction plants and in downstream end-market such as power plants.

Natural gas differs from crude and refined oil products in the relatively large cost of transportation and marine terminal provision (Nissen et al., 1995). Natural gas value stream is made of gas production and transmission. Physical elements of the natural gas supply chain include gas production and transmission, and liquefaction and utilisation. They are discussed as follows:

1. Natural gas production and transmission: As stated previously natural gas is associated with crude oil production, therefore its exploration is often tied to oil exploration. The operational sequence of natural gas production includes drilling, production and gas recovery. The facilities required for the production are wellhead gas processing and treatment. Generally the scope of work for harnessing natural gas from offshore or onshore land sources differ; as offshore is more expensive than onshore due to more facilities that are installed on platforms, thus leading to significantly higher cost.

Transmission of gas and associated condensate from production plant to LNG plant is through pipelines. Advances in pipeline technology (including material) in the past two decades with respect to pipe sizes, distance and maximum water depths has led to lower gas-transportation costs. Avidan,(2000) report that long distance pipeline costs has come down twice as much as LNG costs, thus extending the economic reach of pipelines. Therefore locations far from source of natural gas can now be easily supplied by pipeline.

2. Liquefaction Plant: Choice of transmission by pipeline or liquefaction is a decision to be made based on economics of the mode of transportation as well as the distance
and quantity to be transported. Liquefaction plants reduce the temperature of the gas to minus 161 (below zero) degrees Celsius to liquefy it before loading onto tankers to be transported to long distances (Stevens, 2000). The main units of a liquefaction plant are:

- Liquefaction train
- Storage and loading
- Harbour and mooring facilities for handling
- Construction/small-boat harbour
  - to receive equipment and materials and related ship-handling services such as Tug Boats and navigational aids.
- Temporary Construction camp and related infrastructure for on-site housing of construction labour force and permanent housing and related community support facilities for the permanent plant operating personnel.

3. **LNG shipping:** This is the method of transporting the LNG after the liquefaction process. LNG is normally transported using specially made ships/tankers fitted with the facilities to ensure utmost of safety in transit and at loading and unloading terminals.

4. **Miscellaneous:** These are the associated facilities for storage, loading and unloading at the export and receiving terminals and engineering work in erecting infrastructure for processing, storage and transportation. It consists of:

- Piping (for bulk material)
- Electrical
- Instrumentation
- Major Supply-and-Erect subcontracts for:
  - Storage tanks
  - Loading jetty
  - Buildings
  - Field labour requirement for erection of all plant and equipment.

In conclusion, there is interplay between economic, technical, operational and political considerations underpinning the natural gas supply chain. Generally natural gas has very long lead times associated with complex projects that required agreements covering periods of up to 30 years in highly volatile world. Additionally, because of high costs involved, the netback value of the gas at the well head is extremely small. There are also political problems where pipelines have to traverse potentially hostile territories. All of these constraints affect the diffusion of natural into global energy supplies (Stevens, 2000). Stevens (2000) argue that the dominant position of the state owned utilities is seriously questioned this led to large scale deregulation and liberalization. Thus the spread of deregulation and liberalization in an increasing number of gas markets has led to growing gas to gas competition.

3.4 **Supply chain management in oil and gas operations**

The petroleum industry has one of the most complex industry supply chains (Coia, 1999). Oil and gas supply chain spans activities from the wellhead to the burner-tip. Indeed it is the petroleum supply chain that gets your gas to the pumps. However,
Despite the oil industry’s long supply chain, the portability of oil and gas enables for a shorter supply chain (Middlewood, 2004). Oil and gas supply chain is similar to other supply chains in that it is underpinned by similar model: exploration (supply), refining (production), production development (design) and marketing/distribution (deliver) (Miles and Snow, 1987). However, there are differences in supply chain management for process and discrete manufacturing, unlike other supply chains the petroleum business involves vast quantity of liquid of varying grades that must be contained and transported to highly involved and interdependent operations. The petroleum operations start with the extraction of the crude oil and end with the delivery of finished products. Interspersed between the sourcing and delivery of the oil is an extremely complex manufacturing processes (Hall et al., 2004; Middlewood, 2004).

Wright (2001) argued that the challenges currently facing the supply management in the oil and gas sector are “lead times for primary materials are increasing which [negatively] impacts production further along the supply chain”. Furthermore, suppliers are under pressure to shorten lead times. Hence to manage the situation better, “purchasers need to work closely with…suppliers to provide information that will enable suppliers to plan sufficient capacity and meet procurement needs more effectively”. However, in a competitive commodity market, assets are no longer a means to differentiate, it is the supply chain capabilities and the associated technology that makes the difference (Lasschuit and Thijsen, 2003). In the context of the offshore supplies industry, supply chain connotes the development of close relationships between customers and suppliers through ‘alliancing’ or ‘partnering’. Specifically, a DTI funded study known as Cost Reduction in the New Era (CRINE) (CRINE Network, 1999) found that in the oil and gas industry, supply chain encompasses: long term supplier relationship development; early supplier involvement in product technology; trust based relationships; supplier associations; benchmarking; and unified supplier performance measures. However, the CRINE report states that second tier suppliers are less positive about the impact of collaborative working on their business, as “operators have asked for excessive detail in bids then touted the best ideas to the lowest bidder.” Equally, there is the feeling that “contractors are doing more work for less reward now...” (CRINE Network, 1999).

Although we often directly compare process industry supply chain – oil, gas and chemicals – to automobile or consumer electronics supply chain, there are is the need to take note of the following. Most discrete manufacturing is a volume industry, whereas the offshore industry operates on a made to order basis. However, the underlying principles of collaboration, trust, transparency and benchmarking are common to both industries. The specialist supply network operating in the offshore oil and gas industry includes many organisations from numerous and varying background (Crabtree et al., 1997). Referring to figure 5, many of the players in the supply network are product suppliers only, yet a large number provide both products and services. Oil and gas industries are capital intensive, they are also characterised by large investments and relatively indivisible production functions – process layout production. It is also characterised by high service expectations or delivery reliability and ever-tighter margins. Thus making lean production (efficient low-cost operation) no longer a competitive advantage; it is just one of the “entry requirement” (Lasschuit and Thijsen, 2003) or “order qualifier” (Hill, 2000). Furthermore, Lasschuit and Thijsen (2003) argue that oil companies have long supply lines, while the market
they serve is volatile, global in scale and demands high level operational transparency. However, supply chain must continuously align with market forces and commercial opportunities. Thus market volatility can only be countered through increased speed and flexibility in directing trading, refining, marketing and associated trade-offs in the supply chain.

Supply chain issues in oil and gas operation is concerned with the activities involved in getting the hydrocarbons out of the ground, to the market and turned into a retail sale in the least amount of time (Cottrill, 1999). It is apparent that time is a competitive criteria. Transport and distribution network integration, therefore is a critical success factor for timely operation of the supply chain.

The smallest unit of supply chain in oil and gas, like other manufacturing supply chain, consists of supplier, manufacturer and customer. Miles and Snow (1987) contend that often firms in the oil and gas industries have limited range of distinctive competence even though they may perform all of the activities associated with a given business. Therefore to overcome this limitation, Finch (2002) observe that the supply chain paradigm emphasises organising activities, and hence existing capabilities or core competencies directed at these activities. Agility and speed are achieved by aligning information, performance, people and tools around critical processes (Lasschuit and Thijsen, 2003). Some supply chain attributes affecting the operations in the oil and gas industry are: Early supplier involvement and new supplier development; Concurrent Engineering (CE); Total quality management (TQM); Safety; Teaming; Virtual enterprises and New technology development. New technology development is more critical in deepwater and ultra deepwater exploration and production, and natural gas processing and transportation.

It has been argued previously that organising to produce an offshore oil platform is an activity that has high level of complexity and risk. There is also high level of product customisation. Accordingly having an agile supply chain will greatly enhance operation flexibility and speedy operations. But it is not well understood to what extent the current level of operations flexibility and delivery support agility of the industry. It is therefore important to know to what extent the oil and gas companies have implemented agile supply chains.

Research question 1:
What is the extent of adoption of established enterprise agility attributes in the oil and gas supply chains?

Yusuf et al (1999) note that competitive objectives of agile supply chain includes speed, flexibility, innovation proactivity, quality and profitability. Furthermore in an empirical study of UK manufacturers, Yusuf et al. (2004) used low cost; quality; dependability; speed; volume flexibility; product customisation; and leadership in new technology products were as competitive bases. They also assessed business performance using sales turnover; net profit; market share; percentage of sales from new products; customer loyalty based on repeat orders to total sales turnover; and overall performance against competitors. All these metrics used in the their study to measure competitive objectives and business performance have been used by prior in prior studies (Flynn et al., 1995; Vonderembse and Tracey, 1999).

Research question 2
What is the impact of agility on the competitive objectives of oil and gas companies?

Although the level of adoption speed and flexibility has theoretically been attributed to enhanced operations (Burgess, 1994) this has never been empirically verified in the oil and gas industry therefore the first research question will provide empirical evidence from this sector. Additionally there is the need to establish relationship between agility and competitiveness in the oil and gas industry. This will be explored through the following research question:

2. What is the impact of agility on the competitive objectives of oil and gas companies? Similarly it will be

3. What are the pathways and obstacles to agility in the oil and gas sector?

Similarly, a study on the operations of the UK offshore oil and gas found that there is high level of geographical clustering of oil supply companies in Aberdeen where the UK oil and gas upstream operation is located (Barlow, 2000) Indeed Hallwood (1990) found that the oil and gas operating companies specifically require firms to locate in close proximity to their operations. Accordingly Scottish Enterprise a regional development agency of Scotland had instituted a development programme to consolidate Aberdeen as an oil and gas cluster (Carrie, 1999; Carrie, 2000; Peters and Hood, 2000). However Hallwood (1990) and Barlow’s (2000) findings raise questions about what oil and gas firms derive from proximity. This contributes to the debate about high technology industrial districts with empirical evidence from an important but neglected sector. Furthermore the impact of agility on operations of firms within the cluster is worth exploring to highlight the:

4. What is the impact of agile supply chain attributes on the business performance of oil and gas clusters?

Numerous studies such as There is the need to benchmark the impact of clusters on the operational efficiency of cluster firms. This can be achieved by measuring competitiveness of companies across clusters. Therefore the following question can be posed:

5. To what extent does the pattern of competitiveness change across cluster typologies?
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