How to Assess Supplier Flexibility?

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Abstract

The oil and gas industry is very volatile; it is characterized by unpredictable cycles of sharp rises and plunges in oil prices. This cyclical nature presents a huge challenge for companies that are operating in the industry. Companies have to be able to ramp up their production quickly so that they have enough capacity to meet increasing demand when oil prices go up and be able to survive when oil prices go down. In this context, companies have to make sure that their suppliers are flexible to changing demand. Assessing supplier flexibility is one of the major challenges facing our thesis sponsor company, which is one of the largest oil field services companies in the world. Our project has two primary goals. First we would like to develop a sound understanding of common factors that characterizes flexibility of suppliers in oil and gas industry. Second, we would like to develop the first version of a self-administered auditable instrument to assess the flexibility of suppliers. We developed a comprehensive list of factors influencing flexibility of suppliers through systematic literature review and interview research methodology. We then designed a survey to validate the flexibility factors using statistical measures. Finally, we developed the first version of a self-assessment instrument using Microsoft Excel. The instrument would help our thesis sponsor company to assess the flexibility of their supply base. The findings of our research would be useful to companies operating in seasonal and cyclical industries. The research might help companies develop insights regarding flexibility of their suppliers to adapt to changing market demands, and develop strategies to balance supply and demand at minimum cost.
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-Remya Pushpangatha Kurup
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Chapter 1 Introduction

Section 1.1 - Setting the stage

The oil and gas industry is one of the most important industries for the world economy. It includes the global processes of exploration, extraction, refining, transporting and marketing petroleum products such as crude oil and gas. Oil and gas accounts for more than half of humanity’s primary energy supply. It is the lifeblood of world economy powering the other industries such as manufacturing, agriculture, and mining.

Oil and gas markets are characterized by their volatility. The whole industry is shaped by these unpredictable cycles of sharp rises and plunges in oil prices. Unlike most products, oil prices are not just determined entirely by the supply, demand and markets of the physical product itself, but also by those of oil futures contracts, which are traded heavily by speculators. In addition to financial markets, other factors that influence the price of oil include production decisions of OPEC (the Organization of Petroleum Exporting Countries), governmental policies of other oil producing nations, and geo-political tensions. This makes predicting oil price trends extremely hard. Even professional analysts are consistently wrong in their forecasts about this industry (see Appendix 1).

The oil and gas industry is divided into three major components: upstream, midstream and downstream. The upstream is composed of oil producers and oil field services companies that are involved in the production and exploration of oil, whereas midstream and downstream focuses on refining, marketing and distribution of products for end consumption. In the upstream segment, oil producers adapt their activity levels to fluctuating oil prices by either increasing or decreasing the production levels.

Due to physical and financial constraints, there are significant delays in the oil production system: it takes several years to launch a new oil extraction project or to discontinue the operation of an existing oil well in a financially sound manner.
The combination of volatile production volumes and significant delays in effecting changes to these volumes creates ripple effects in the entire supply chain. These affect everyone from oil producers, to services companies and to their sub-suppliers.

Oil field services companies that provide field development services to production companies adapt their capacity to match the demand placed by oil producers. There is a clear positive correlation between price of oil and revenue of oil field services companies such as FieldServ\textsuperscript{1} (see Appendix 2). At the same time that oil field service companies adapt their capacity to change in oil production, their tier-1 and tier-2 suppliers are also forced to adjust capacities and capabilities to match the demand.

Managing the gap between supply and demand in accordance with the unpredictable nature of business cycles is a huge challenge facing companies that play the role of suppliers in this industry. Suppliers are subjected to high cost overruns to increase production capacity when oil prices and production volumes go up (known as ramp-up periods) and are forced to adopt aggressive cost reduction tactics and reduce capacity when oil prices and production volumes go down (known as ramp-down periods).

Some suppliers to oil field service companies have proven able to cope reasonably well with this uncertainty. They adapt their internal operations to match the supply and demand in an economically sustainable way. Other suppliers, on the other hand, are not so adept at coping with this uncertainty.

Suppliers with a diversified portfolio of customers across many industries do not rely heavily on their customers from the oil and gas industry. Such suppliers are less impacted by the unpredictable cycles of oil prices. On the other hand, suppliers that rely on oil and gas industry customers as their primary revenue source are hit the hardest when the market goes

\textsuperscript{1} This is a fictitious name. The real name of the company and other sensitive data, have been disguised for confidentiality purposes.
south: as oil prices and production volumes fall, the demand of their goods and services drops. Such suppliers may end up in financial distress.

At the time of this writing, oil prices have fallen to around $32 per barrel, after spending several years at levels many times higher. Because of this, the oil and gas industry is currently going through one of its worst crises ever. Oil producers react to sustained lower oil prices by sharply cutting investment in exploration and production. Oil and gas services companies are increasingly adopting aggressive measures such as drastic capacity reduction and resorting to massive layoffs to reduce the overall costs. Scores of companies have gone bankrupt and an estimated 250,000 oil workers have lost their jobs in this on-going bust-cycle. Since many suppliers in the oil and gas industry are not thoroughly prepared to face the impact of these business cycles, they are bound to be affected by the consistent decline in oil prices that we see today.

Section 1.2 - The problem at hand

The ever-changing dynamics of oil prices described above has created the challenge that our thesis project will address. The sponsor company for this thesis, FieldServ Limited, is one of the world's largest oilfield services company, with ~$49 Billion revenue in 2014. Employing more than 120,000 people representing over 140 nationalities and working in more than 85 countries, FieldServ provides the industry's widest range of products and services from exploration through production. Appendix 3 provides more details on major business divisions of FieldServ. FieldServ’s supply base consists of 100,000 tier-1 suppliers, including small, medium, and large enterprises. Of these, 3 percent (3,000) are considered critical to operations. Each of these tier-1 suppliers has in turn their own suppliers (we will refer to these as sub-suppliers).

Following the recent 2015 oil crisis, FieldServ has come under intense pressure from its customers to cut its prices. FieldServ reduced 42,000 jobs in this ongoing oil crisis and set
its suppliers aggressive cost reduction targets. Many of FieldServ’s suppliers have suffered severe financial stress accentuated by order cancellations and cost pressure, and some have even initiated bankruptcy proceedings. This increases FieldServ’s total cost of operations through higher prices from alternate suppliers, less secure supply and increased vendor qualification and development costs.

The consistent lower oil prices also present other challenges for FieldServ. A study conducted by PricewaterhouseCoopers (PWC, 2015) suggests that lower activity levels associated with sustained low prices could make some suppliers lose interest in the industry and move to other industries with a more stable demand. This could result in shortage of suppliers for FieldServ when oil prices go up in future, creating a potential bottleneck in its supply chain.

In the particular case of our sponsor company, not all of its suppliers are able to cope effectively with the uncertainties that characterize the oil and gas industry. According to the company, in its supplier base there are some “high-performing” suppliers, who are able to successfully cope with the ups and downs in demand by carefully managing their internal operations. The expression “high-performing” is used by the executives in the company to refer to the ability of these suppliers to provide a consistent level of service during upturns and downturns in oil and gas industry. FieldServ considers these suppliers the “high-performing” suppliers among those in its supply base.

FieldServ would like to develop a supply base that can cope with the volatility of the oil and gas industry by having more of these “high-performing” suppliers in their portfolio. While FieldServ can identify “high-performing” suppliers, they do not know what characteristics allow these particular suppliers to adapt readily to change. According to FieldServ, some characteristics that might suggest a “high-performing” supplier are the
ability of the supplier to adjust capacities and capabilities, and whether the supplier has flexible contracts with sub-suppliers.

FieldServ would like to acquire insights into what makes “high-performing” suppliers good at managing the uncertainties. This means that FieldServ is interested in learning more about the source of the flexibility that characterizes its best suppliers by understanding their key practices and what these suppliers do differently with respect to others in the industry.

FieldServ would like to develop a self-assessment tool for its suppliers. The suppliers should be able to self-administer this tool without the involvement of a third party to assess its flexibility and FieldServ can audit the results afterwards. The purpose of this tool, as envisioned by FieldServ, is two-fold. The first purpose is to assess the flexibility of suppliers and to better understand the ability of these suppliers to manage the costs associated with sudden ramp-ups and ramp-downs in demand. The second purpose is to help the suppliers learn—through this self-assessment process—about what it takes to become a more flexible supplier for FieldServ.

Hence our thesis pursues two objectives. The first is to understand the common factors that characterize “high-performing” suppliers of FieldServ, helping them to navigate the uncertainties typical to oil and gas industry. The second is to develop a first version of a self-administered auditable tool or instrument to assess the flexibility of the supplier base, one that could also help suppliers better understand the key factors that could make them more flexible.

The time horizon of the Supply Chain Management program at MIT may not allow us to refine and validate the instrument and produce a finalized version of the tool that can be deployed at FieldServ. The validation and implementation of tool can be completed by the future researchers or by FieldServ’s procurement function themselves. However, in this
thesis, it is important that we develop a good understanding of the factors contributing to supplier's flexibility because the quality and validity of the instrument we would develop afterwards would depend on the quality and validity of the factors we arrived through the various measures we use in this research.

This research thesis would benefit other companies in similar business environment. This includes other suppliers in oil and gas industry such as peers and competitors of FieldServ. The results of the study would also be applicable to companies in cyclical and seasonal industries such as construction, fashion, and electronics manufacturing, where the objective is to maximize delivery performance and minimize the supply chain costs as demand changes rapidly. Today, flexibility receives attention from both academicians and managers, as a way to create sustainable competitive advantage for companies. For example, 64% of respondents to PricewaterhouseCooper's 2013 Global Supply Chain Survey said that they consider flexibility a top supply chain priority (PWC, 2013). Our research would help the suppliers in these industries to be more flexible and cost-effective to improve the overall performance of their supply chains.

Let us conclude this chapter with an outline of the rest of the thesis. In chapter 2, we take a look at the existing literature to understand what companies in volatile industries do to increase their flexibility to cope with the rapid changes in demand. In chapter 3, we intend to outline the research methodology we adopt to address the un-answered part of the question on identifying the factors and developing a tool for the sponsor company. Chapter 4 describes findings from our research and summarizes the master list of flexibility factors. In chapter 5, we design a survey to validate flexibility factors and show the survey results. Chapter 6 discusses the instrument we develop using our findings. We conclude our thesis in chapter 7 with a discussion of the managerial and research implications, limitations of our study, and suggestions for future research.
Chapter 2 Literature review

This literature review has two parts. The first part (Section 2.1) looks at previous research related to supplier flexibility, with the idea of developing a better understanding of what factors—according to the literature—result in more flexible suppliers. The second part (Section 2.2) looks at self-assessment tools, preferably those that may be used to assess suppliers and/or that are auditable, with the idea of understanding what kinds of self-assessment tools are currently available and used in supplier assessments.

Though our thesis focus is on the oil and gas industry, our literature search included other industries that are similarly characterized by business cycles and seasonality. Some companies in these industries are able to successfully navigate the challenges brought by abrupt changes in external demand, by better managing their internal operations and sub-supplier network. This literature review looks at various sources of supply chain flexibility that enable companies to manage rapid changes in demand. We also look at existing literature on supplier flexibility assessment. This would help us arrive at our own customized self-assessment tool specific for oil and gas industry.

Section 2.1 - Literature review on supplier flexibility

As global economic and competitive forces create uncertainty in turbulent and volatile markets, the key to survival for an organizations is agility, characterized by their flexibility or maneuverability to adapt to the changes (Christopher, 2000). Suppliers without ability to react to variances effectively and with efficient utilization of resources will limit the flexibility potential of even capable firms (Liao, Hong, & Rao, 2010). Supply chain management seeks to enhance competitive performance by closely integrating the internal functions within a company (e.g., marketing, product design and development, manufacturing) with the external operations of suppliers and channel members (Vickery, Calantine, & Dröge, 1999). In this
context, ensuring flexibility of its supply base to cope with ups and downs of oil and gas industry is an on-going challenge for most oil field companies such as FieldServ.

Supply chain flexibility is understood as the supply chain’s capability to quickly respond to changing customer requirements without compromising performance (Kumar, Fantazy, Kumar, & Boyle, 2006). Flexibility is often seen as a reaction to environmental uncertainty, and it in turn influences the variables of manufacturing strategy, such as manufacturing flexibility (Swamidass & Newell, 1987). There have been quite a few research efforts to understand how supply chains can be more flexible to avoid supply disruption.

A ‘process capability approach’ was introduced by Seebacher & Winkler (2015) to evaluate supply chain flexibility, both qualitatively and quantitatively. Seebacher & Winkler state that it is difficult to measure supply chain flexibility due the complexity of global supply chains. They recommend using a composite of auxiliary metrics relevant to the supply chain under consideration.

Brill & Mandelbaum (1989) suggest that supply chain flexibility should be viewed from the perspective of the entire value-adding system, i.e. total system flexibility. This viewpoint suggests that supply chain flexibility should be examined from an integrative, customer-oriented perspective, considering the end-to-end value chain connecting sub-suppliers and intermediaries all the way to end customers.

**Section 2.1.1 - Industry focused studies on supply chain flexibility**

There has been significant literature in the past that studied several dimensions of supply chain flexibility across various industries and businesses.

**Oil and gas industry**

Sivapornpunlerd & Setamanit (2014) working on a case study of a Thai offshore oil and gas exploration company, develop a supplier performance evaluation system using four main criteria, namely (i) quality, (ii) delivery, (iii) service, and (iv) flexibility, as well as
eighteen sub-criteria. These criteria and sub-criteria are derived from a literature review and from in-depth interviews with key company staffs. They find that inventory availability, capacity to respond to unexpected demand, order customization and negotiability\(^2\) are major sub-criteria of flexibility.

**Furniture industry**

Based on research on the furniture industry (another cyclical industry), Vickery et al. (1999) conclude that (i) volume flexibility, (ii) launch flexibility and (iii) distribution flexibility are key dimensions for supply chain flexibility. *Volume flexibility* refers to the ability to rapidly adjust capacity so as to accelerate or decelerate the production in response to change in customer demand. *Launch flexibility* refers to the ability to handle non-standard (custom) orders and *distribution flexibility* refers to ability to provide widespread distribution coverage. *Volume flexibility* is found to be positively correlated to financial performance factors (ROI, ROS) and market share growth of the company.

**Manufacturing industry**

Empirical research by Tachizawa & Giménez (2009) in the manufacturing industry examine many possible sources of supply chain flexibility and measure their statistical significance as predictors of flexibility by means of regression. They identify more than 10 different sources of supply chain flexibility and group them into three major dimensions of flexibility: (i) *supplier responsiveness*, which they define as the ability to manage sudden changes; (ii) *delivery policy flexibility*, which they define as the ability to vary delivery lot-sizes and frequencies; and (iii) *adaptability*, which they define as the ability to change from one state to another in a timely, cost effective way. Tachizawa & Giménez, (2009) conclude that the significance of supply chain flexibility sources varied based on what dimension of

\(^2\) The author uses the term 'negotiability' to indicate the willingness of the supplier to offer price discounts to customers.
supply flexibility was considered. For example, supplier responsiveness is correlated with percentage of domestic sourcing and strength of supplier collaborations such as joint planning, information sharing etc. Supplier's delivery flexibility is correlated with capacity utilization whereas supplier’s adaptability is correlated with logistics flexibility and IT investments in infrastructure such as EDI, supply-planning software etc.

Van der Rhee, Verma, & Plaschka (2009) studied the role of flexibility, delivery, and value-added services in the supplier selection process using empirical data collected from metal alloy manufacturing organizations in Europe. They used a computer-based supplier selection discrete choice survey. Three important levers of flexibility were identified: (i) production flexibility, understood as the capacity and capability to produce custom parts; (ii) demand flexibility, understood as the ability to handle changes in orders; and (iii) variety of product offerings. Metal industry suppliers constitute a significant portion of FieldServ’s supply base and they share most of the characteristics of manufacturers in the above case study.

According to Jeeva & Guo (2010), logistics flexibility is an important dimension of supply chain flexibility for manufacturing companies, because it impacts directly how flexible suppliers can modify logistics arrangements, in line with cost and lead-time trade-offs among transportation modes to serve customer demands.

Automobile industry

A multi-tier study by Thomé, Scavarda, Pires, Ceryno, & Klingebiel (2014) on supply chain flexibility in the Brazilian automotive industry identified that suppliers’ capacity, suppliers’ diversity, suppliers’ cooperation, trust and commitment, and inventory are the main factors influencing the observed volume and mix flexibilities.

Fishing industry

In order to understand more about the linkages between environmental uncertainties and company specific flexibility factors, Dreyer & Grønhaug (2004) study fish processing
plants in Norway. The study gives empirical evidences that by developing types of flexibilities that match different factors of uncertainties in the industry, firms can achieve sustainable competitive advantage.

Dreyer & Gronhaug use a design based on bankruptcy prediction models using logistics regression. They identify that (i) volume flexibility, (ii) production flexibility, (iii) labor flexibility, and (iv) financial flexibility are highly correlated with the financial performance of the firms. The researchers use return on assets (ROA) as a measure of financial performance. Volume flexibility is measured in terms of fluctuations in annual quantities of fish processed by each firm. Production flexibility is measured based on the degree to which a firm changes its product-mix during the period. Financial flexibility is measured by the firms' cash position (net liquidity balance). Labor flexibility is modeled using fluctuations in annual labor costs as a variable. This research also provides evidence that firms can remain flexible without suffering productivity losses, in direct contrast with theoretical models, which assume a negative correlation between flexibility and productivity. This is an important observation, since companies in uncertain environments generally would like to maintain a flexible workforce. The popular notion is that the flexible workforce could potentially reduce productivity, since it takes time for new workers to get up to speed due to learning curve effects. Since most of our sponsor company's suppliers rely on a flexible workforce, as an effective mechanism to stay lean, the findings by Dreyer & Gronhaug (2004) are relevant for our sponsor company and its supply base.

Semiconductor industry

During the global financial crisis in 2008, many suppliers in the electronic industry scaled back capacity or closed altogether. As a result, companies faced shortages of critical components when the market picked up. To improve visibility in its supply chains and enable faster capacity ramp up, a major electronics equipment company jointly implemented an
information system with its supply chain partners to better align supply and demand (Geissbauer & Householder, 2011). In another case, Samsung ensures optimum performance at minimum inventory risks by working closely with its highly responsive suppliers integrated by information technology to minimize the gap between supply and demand (M. S. Sodhi & Lee, 2007).

Maturity of the organizational structure is also one factor influencing flexibility. Increased firm formalization helps emerging firms develop stable routines and processes to increase their chances of survival during downturns in environmental uncertainties. Patel (2011), based on a sample of 167 high-technology manufacturing firms in UK, applies a moderated polynomial regression approach to conclude that formalized structures, in conjunction with manufacturing flexibility, lead to enhanced performance of the organizations.

Section 2.1.2 - Other studies on supply chain flexibility

Role of manufacturing flexibility

Literature on supply chain flexibility has emerged largely from literature on manufacturing flexibility, and hence remains to this day largely confined to manufacturing context, neglecting the role of services (Stevenson & Spring, 2007). Manufacturing flexibility is the ability of a firm to change or react with little penalty on time, effort, cost or performance (Upton, 1994) and it can be further divided into product, mix, volume and delivery flexibility. Manufacturing flexibility can also be divided into two types, namely (i) external flexibility (ii) internal flexibility. External flexibility refers to the flexibility types that matter to the supplier's customers, e.g. “What the customer sees” (Upton, 1994), while internal flexibility comprises all types of flexibility that are internal to the system and are used to deliver external flexibility (Upton, 1994). According to Upton (1995), machine, labor, material handling, and routing flexibilities are examples of internal flexibilities and volume flexibility (i.e. the ability to
increase or decrease volume of output), whereas mix flexibility (i.e. the ability to handle a wide range of products) is an example of external flexibility.

Role of supply network and supplier relationships

In addition to the more tangible sources of flexibility, qualitative factors, such as supplier relationships, trust, experience of the management team and maturity of the organizational structure, also have considerable influence in the flexibility of the supply chains. The importance of supply networks and supplier relationships frameworks as a key determinant of supply chain flexibility has been thoroughly studied by Wang & Wei (2007). They emphasize the importance of cooperation with channel members to achieve flexibility in the supply chain. In another research, Liao et al. (2010) divide supply flexibility into two aspects: (i) supplier flexibility (ii) supply network flexibility. Supplier flexibility refers to the extent of responsive abilities through the use of supplier-specific capabilities. Supply network flexibility is defined as the extent of responsive ability through the use of collaborative capabilities to reconfigure the supply base effectively and efficiently. Firms can derive competitive advantage, which others find difficult to imitate, from networked collaborative capability, providing the firm a sustainable competitive advantage.

Role of trust and shared vision in flexibility

To explore the relationship between social mechanisms (i.e. trust and shared vision) and supplier flexibility, Chu, Chang, & Huang (2011) develop and test hypotheses with data from 162 members of the Supply Management Institute, Taiwan (SMIT). The results show that trust has a direct impact on supplier's volume flexibility and delivery flexibility. Furthermore, the findings indicate that a shared vision has direct impact on supplier's mix, new product, and delivery flexibility. However, Chu et al. (2011) in this research considers only the buyer's perspective in examining social mechanisms that enhance supplier flexibility.

Role of flexible contracts
Contracts constitute the legal framework of a relationship between a supplier and a buyer. Supply contracts formalize the negotiations around all the variables specific to the sourcing environment including the cost of components, quantity purchased, time of delivery, and quality of goods (Li & Kouvelis, 1999). As they can benefit both suppliers and buyers, contracts are a relatively easy means to reach greater supply chain flexibility. Contracts can be of two types, namely: (i) time-flexible contracts and (ii) quantity-flexible contracts. *Time-flexible contracts* allow a firm to specify how many units it will purchase without specifying the exact purchase time, whereas *quantity-flexible contracts* allow a firm to purchase quantities within a pre-specified window (Li & Kouvelis, 1999). Companies in uncertain and volatile industries resort to these flexible contracts as an effective mechanism to reduce risks and improve flexibility.

**Section 2.1.3 - Supplier flexibility assessment**

As organizations increasingly look at flexibility as a key competitive advantage, they use flexibility as a criterion in their sub-supplier selection and evaluation process. Companies use price and other dimensions such as quality, flexibility, delivery, and service in the supplier selection process (Hirakubo & Kublin, 1998). Assessing flexibility of the suppliers to respond to sudden market changes is an important metric for organizations in volatile industries.

Jeeva & Guo (2010) develop two systems of assessment that use statistical and artificial neural network techniques, respectively for determining the flexibility of suppliers based on multiple dimensions of flexibility, after surveying senior managers in supply chain and procurement in large manufacturing companies. The Q-Sort technique is used to refine the survey items and the Churchill paradigm is used to develop scale items. The study concludes that a neural network is able to predict the supplier’s flexibility, with respect to its five attributes with a higher accuracy, than multivariate regression analysis. However, multivariate regression is useful for manufacturers with fewer suppliers since it can shed light
on the importance of individual attributes for the flexibility assessment through its analytical expression.

Swafford, Ghosh, & Murthy (2006) were the first to develop and test a scale to measure supply chain agility using empirical data. They used the Q-Sort technique to assess initial levels of construct reliability and content validity and then analyzed the relationships among the constructs using structural equation modeling (SEM). They concluded that the supply chain agility of a firm is directly and positively impacted by the degree of flexibility present in the manufacturing and procurement processes and indirectly impacted by the level of flexibility within its distribution and logistics processes.

To conclude, we found that sources of flexibility might vary across industries based on the supply demand mismatches and uncertainties prevailing in the industry. We could also find that both qualitative factors (such as capacity flexibility, financial flexibility, manufacturing flexibility) and qualitative factors (such as trust, relationships, organizational maturity) influence supply chain flexibility across industries. Identification of industry specific flexibility predictors would help supply chain managers to incorporate them in supplier selection and evaluation mechanisms as a way to assess and mitigate risks.

**Section 2.2 - Auditable self-assessment instruments**

Self-assessment tools are extensively used in supplier evaluations and risk assessments by leading organizations worldwide. According to Institute of Supply Management (ISM), self-assessment tools are designed to help customers understand a supplier’s internal performance while at the same time indicate to the supply base the types of things customer organization considers important to the long term successful operations of their business (Stubbings, 1999). Along similar lines, to ensure that its suppliers behave in a socially responsible manner, a European power utility created a host of new processes and shared new self-assessment tools that helped the suppliers determine when their actions didn’t square with
the utility’s expectations and outline ways to begin rectifying any problems (Billington & Davidson, 2010).

Through literature review and mail survey of manufacturers in Hong Kong, using an analytical hierarchy process (AHP) methodology, Chin, Yeung, & Pun (2006) developed a novel web-based supplier assessment system for supplier quality management.

Though self-assessments are commonly used for supplier evaluations across organizations, literature about their application in supplier flexibility assessments is limited. This thesis research would like to address the gap by taking a first step towards developing a self-assessment tool for evaluating supplier flexibility. At the same time, supply chain managers also have to understand the limitations and pitfalls of the self-evaluation mechanisms, which is the subject of next section.

Limitations of self-assessment tools

Self-assessments have limitations and are no substitute for independent audits of a business continuity program (Trousdale, 2015). Social desirability (tendency to respond in a socially acceptable way) and acquiescence (tendency to agree) are major drawbacks to self-evaluation mechanisms (Bäckström & Björklund, 2013).

According to Taylor (2014), lacking an objective mechanism, self-assessments that people make also tend to be inflated, unreliable, and biased. Taylor studied the self-assessment mechanisms used extensively by management students, such as 360-degree assessment or multisource feedback assessment (MSF) during their management degree program. Taylor states that MSF improves on self-assessment by including others’ assessment of the self.

However, it may be difficult to compare self-assessments on the same topic across an organization because the input may vary based on the competency, skill set and subjectivity of the persons completing the assessment. Using a forced choice format (constraining the responses) in instruments and including an equal number of positively and negatively scored
items in the scale to cancel any tendencies to acquiesce are some of the ways to get around the challenges of social desirability and acquiescence. While we are extending the self-assessment tools across the portfolio of suppliers in an organizational setting, we also need to institute objective evaluation mechanisms, such as on-site audits to overcome the challenges associated with self-assessment tools.
Chapter 3 Methodology

As stated before, our project has two goals: first, to identify the key factors that lead to supplier flexibility; and second, to develop a self-assessment tool that can be used to assess the flexibility of suppliers based on these factors. This Section describes the methods that we apply to achieve these two goals, including methods of data collection and analysis.

Section 3.1 - Developing an understanding of flexibility factors

To achieve the first goal of our project, i.e. gaining an understanding of the factors that make for flexible suppliers, we leveraged three methods. The first was interview research, in particular, qualitative interviewing, which does not rely a very large sample size and will help researchers to achieve a fuller development of information (Weiss, 1994).

• First, we conducted interviews with category purchasing managers from FieldServ, to understand what factors – in their view – contribute to the flexibility of their suppliers. These interviews are discussed in Sections 3.1.1 and 4.1.

• Then, we performed an extensive and systematic literature review of various industries that have seasonal and cyclical business nature to help us understand what general factors and predictors contribute to supplier flexibility from existing research. This literature review is discussed in Chapter 2 and in Sections 3.1.2 and 4.2.

• Last, we conducted interviews with FieldServ’s “high-performing” suppliers, to identify which factors in the view of the suppliers themselves were the sources of their operative flexibility. These interviews are discussed below in Sections 3.1.3 and 4.3.
Section 3.1.1 - Interviews with category purchasing managers

We interviewed five category-purchasing managers at FieldServ’s headquarters at Houston, Texas. The category purchasing managers represented the major spending categories such as machined parts, chemicals, electronics, surface equipment, power driven integration and OEMs (Original Equipment Manufacturer) of FieldServ. The interviews were designed mostly with open questions, with some semi-open questions. Each interview lasted for around one hour. All interviews were conducted face-to-face. With the permission of FieldServ, we took notes of all interviews. Later, we analyzed all the interview records and summarized the key findings regarding flexibility factors. Details regarding these category purchasing manager interviews findings will be further discussed in Section 4.1.

These interviews not only helped us understand more about FieldServ’s purchasing strategy, major spend categories and supply network, but also provided us some sense of FieldServ’s current understanding of their supplier flexibility performance and sources of flexibility.

Section 3.1.2 - Systematic literature review

After the interviews with FieldServ’s category purchasing manager, we conducted systematic literature review to “identify, assemble, critical appraise and synthesize all relevant issues on a specific topic” (Carney & Geddes, 2002) - in this case the topic is supplier flexibility. A systematic approach to literature review has been recognized as the best way to improve reliability and accuracy of conclusions (Booth, Papaioannou, & Sutton, 2012). We reviewed extensively around publications related to topics such as “supplier flexibility sources”, “self-assessment tools”, “auditable assessment tools”, and “cyclical business nature”, etc. The review process provided us with a systematic understanding about what has been studied in the past around these topics. A detailed summary of the results of our systematic literature review will be covered in Section 4.2.
Section 3.1.3 - Interview with FieldServ's suppliers

FieldServ recommended that we interview a series of suppliers that they deem as "high-performing", based on their previous performance. A list of contacts in these suppliers was provided to us for interviewing, so that – through these interviews – we could learn from the best and understand what factors these suppliers consider critical for navigating through changing market conditions. The suppliers in this list were also selected with consideration to geographic diversity, including suppliers from U.S., Europe and Asia. The positions of the contacts we were given in these suppliers (which we will refer to as supplier representatives) ranged from middle level managers to senior level vice presidents.

Based on our initial finding of flexibility factors from category purchasing manager interviews and systematic literature reviews, we designed a list of open-ended and structured questions to guide and facilitate our interviews with suppliers (provided in Appendix 4). The interviews, based on the interview protocol, were mostly semi-structured.

We started each interview with open-ended questions and depending on interviewee’s response, we gradually moved to more structured questions. For example, in response to the open ended questions, the interviewees might come up with some factors they believe contribute to supply chain flexibility. As needed, we asked a series of probing and follow-up questions to get clarifications on some of the points interviewees listed. Instead of fully following the questions on our list during interviews, we often let the interviewees lead the interviews and talk about the topics they believe are most critical.

The authors of this thesis, a team of two MIT students (subsequently referred here as 'researchers') conducted these interviews personally. Each researcher conducted five interviews, covering in total ten suppliers of FieldServ. All interviews were recorded digitally, with the permission of the interviewees.
Section 3.1.4 - Analyzing the interviews

After these interviews with representatives of the suppliers were completed, we proceeded to the analysis. We listened to each interview recording, took notes of important ideas, transcribed either the whole interview or interesting passages, and prepared written summaries capturing the salient points. Each one of the researchers performed the analysis of the five interviews conducted directly by them. In the preparation of the interview summaries, we used concepts from grounded theory methodology, in particular open coding and memo-taking. Grounded theory consists of systematic, yet flexible guidelines for collecting and analyzing qualitative data to construct theories (Charmaz, 2006). Grounded theory is very helpful with “identification of general concepts, the development of theoretical explanations that reach beyond the known, and offers new insights into a variety of experiences and phenomena” (Corbin & Strauss, 2008).

Open coding in particular is a good way to break data apart and delineate concepts to stand for blocks of raw data. It is a very effective way to group interview summaries into a smaller number of categories, themes, or constructs (Miles, Huberman, & Saldana, 2014). In our project, the two researchers conducted open coding separately. Later, we combined our initial codes into a consolidated list of codes, which will be discussed further in Section 4.3.3. The consolidated codes represent the flexibility factors that “high-performing” suppliers likely have.

To identify supplier flexibility factors from our interviews with suppliers, we used case study methods. As defined by Miles & Huberman (1994) a case is a particular phenomenon occurring in a bounded context. The cases we study happen in the oil and gas industry in a particular oil price downturn. Instead of sampling all suppliers of FieldServ, we selected “high-performing” suppliers to interview and learn their perspectives around supplier flexibility. Meanwhile, the suppliers we interviewed have different characteristics. Some of
them are small in scale while others are large multinational companies. It is very critical to understand the background of these companies to learn their best practices. We selected 7 interviews with suppliers and summarize them into mini-cases, which are shown in Section 4.3.1.

To check for bias and verify the quality of individual summaries, we performed a cross-validation exercise of the consistency of our interviews summaries. This was done as follows: one of the researchers picked an interview conducted by the other researcher, and listened to the recording, transcribing it (in whole or in part) and preparing an interview summary independently. By comparing the two interview summaries for the same interview prepared by the two different researchers, we are able to verify the consistency of our summaries, both in the agreement of key ideas and in the absence of conflicting points across summaries. In the two interviews whose summaries were cross-validated like this, no contradictions were found: the summaries were consistent with each other. The output of this cross-validation exercise of one such supplier interview is shown in Appendix 5.

To identify key similarities or differences among the responses from different suppliers, we conducted cross-case analysis. Cross-case analysis is a methodology to study multiple cases jointly in order to investigate a particular topic (Thomas, 2011). In our research case the topic is supplier flexibility. The cross-case analysis enabled us to see which factors are common across different suppliers and which factors are unique and may not be applicable to other cases. Section 4.3.2 will discuss in depth the cross-case analysis results. The results of the cross-case analysis are shown in Appendix 6 and 7.

Section 3.1.5 - Validating the flexibility factors

Combining all the results from the analysis of the interviews with category purchasing managers, the systematic literature review and the analysis of the interviews with external suppliers, we consolidated a master list summarizing the key flexibility factors we identified
(shown in Section 4.4). To test the validity and relative importance of these factors, we designed a survey. The survey was designed to assess which factors are more relevant in contributing to supplier flexibility. The survey instrument will be introduced in details in Chapter 5. The survey was sent to FieldServ’s purchasing managers and its external vendors. Additionally, to leverage our access to the MIT Global SCALE Network, the survey was also sent to a group of supply chain professionals who are familiar with supplier management and cyclical industries. By analyzing the survey responses, we were able to identify which factors respondents consider more important, so as to arrive at a list of factors that might be critical for flexibility of suppliers in cyclical industries. The analysis and results of this survey will be discussed in Chapter 5.

Section 3.2 - Developing the self-assessment tool

As mentioned at the beginning of this chapter, the second goal of our project is to design a self-assessment tool that could be used by FieldServ in assessing its suppliers’ flexibility. We developed this tool by leveraging all the qualitative data collected in previous phases, an existing method of assessing financial stability of firms and suppliers assessment frameworks from industry leaders. The tool includes all factors we identified through the effort described in the previous section, to assess or provide an indication of the flexibility level of suppliers. More details of the tool will be introduced in Chapter 6.

To add quantitative analysis into our tool, we utilize Altman Z-score algorithm to assess financial flexibility of suppliers. The Z-score algorithm is one of best models used to predict companies’ operating performance in financial difficulties. It has been considered effective by most researchers, practitioners and managers to predict the health of companies (Almamy, Aston, & Ngwa, 2016). Details on how to use Altman Z-score are discussed in Appendix 8.
Additionally, we interviewed 6-8 purchasing managers across different companies and industries to learn their current supplier-assessment frameworks. Although we found that none of them measure suppliers' flexibility in any sense, we are able to develop a good understanding of their current supplier assessment framework through the interviews. We used their existing frameworks as a reference for our tool development.
Chapter 4 Results

In this chapter, we discuss the findings of our literature review and of the interview research that we conducted for this project. Our objective, as stated earlier, is to develop an auditable self-assessment tool that can be administered by the procurement function of FieldServ to their suppliers, to both assess and help them improve their flexibility.

Section 4.1 - Findings from interviews with FieldServ

Through five face-to-face semi-structured interviews with purchasing category managers at FieldServ, we developed a comprehensive understanding about FieldServ as a company and about its procurement organization. These interviews helped us understand the challenges FieldServ faces in managing its supply base given the volatility of the oil and gas industry. The interviews also allowed us to get a sense of FieldServ’s internal understanding regarding what factors contribute to supplier flexibility.

Section 4.1.1 - FieldServ’s purchasing organization

Procurement is considered as a shared service across FieldServ’s organization, along with other services functions such as transportation, distribution and maintenance. The procurement organization at FieldServ is largely centralized. Since there are some needs that are specific to a given region, some regional operations are handled by local sourcing centers. FieldServ’s total procurement spending was around $22 billion in 2014. The procurement organization is responsible for purchasing both direct categories (such as machined parts, chemicals, electronics etc.) and indirect categories.

Section 4.1.2 - FieldServ’s Challenges

"Downtime is very expensive in the oil and gas industry!"

- Quote from a FieldServ category manager

When oil prices are high, the challenge facing the procurement organization is to make sure that its suppliers have enough capacity to meet its ever-growing demand. It is not
uncommon for FieldServ to pay a premium for products or services it requires during *boom* cycles, to make sure that it will not experience any downtime. On the other hand, when the oil prices plunge, FieldServ has to make sure that its suppliers can survive the crisis to prevent supply disruption since many suppliers end up in severe financial distress. According to a FieldServ commodity manager, the cost of switching suppliers in the oil and gas industry is very high. It takes a long time to qualify and develop a new supplier for the complex engineered parts used in the industry. In addition, suppliers take many years to understand the nature of the oil and gas industry, develop a good sense of the impact of its cycles, and adapt to meet FieldServ's expectations. Consequently, FieldServ prefers to have a *stable* supply base. This saves considerable time, money and effort that would otherwise be wasted in switching suppliers.

To cope with the ongoing downturn in oil prices at the time of this writing, FieldServ has taken some *actions*, which may introduce *instability* to its supply base:

- In line with lower business volume, FieldServ intends to consolidate its spend with fewer suppliers that are "high-performing" and which offers better pricing terms. One implication of this action would be that some suppliers might lose their business from FieldServ.

- FieldServ reduced its workforce by 20,000 employees. FieldServ's suppliers would take this as a signal for reduced demand and consequently would cut their workforce on a larger scale.

- Whereas during periods of higher prices FieldServ was inclined to use fixed-volume contracts to secure capacity, now that the oil prices have fallen dramatically FieldServ is less inclined to use fixed volume commitments with suppliers. As a consequence, FieldServ's suppliers have less certainty about the volume of business they have with FieldServ.
Section 4.1.3 - FieldServ’s internal views of flexibility factors

Our interviews with purchasing category managers from FieldServ helped us elicit the factors that FieldServ considers as key to the flexibility of its suppliers. These are presented below:

- **Factor #1: Business diversification.** If a supplier is less dependent on the oil and gas industry, it is more likely to survive the oil downturns and provide consistent service to FieldServ.

- **Factor #2: Cash position/equity debt ratio/liquidity.** The financial stability of a company is a good indication of whether the company can survive business downturns.

- **Factor #3: Private vs. public company.** Whether a company answers to stakeholders plays a role in their flexibility as suppliers, but this role is not black or white: there are pros and cons to each regarding their flexibility as suppliers. On the one hand, since private companies are free from shareholder pressure, they could be more flexible in taking actions to adapt changing market conditions. On the other hand, publicly traded companies may have better access to capital, which is crucial for companies to survive downturns.

- **Factor #4: Labor flexibility.** When demand is low, reducing variable costs such as labor becomes a crucial survival mechanism.

- **Factor #5: Degree of vertical integration.** Companies that are more vertically integrated would have more secure access to products and services.

- **Factor #6: Sub-supplier flexibility.** Some companies have experienced supply disruptions from their tier-1 and tier-2 suppliers (what we call here sub-suppliers). The more flexible its sub-suppliers are, the better a supplier can perform during downturns.
Section 4.2 - Section Findings from the literature review

The six factors just summarized provided us with a starting point for preparing a more exhaustive list of factors of flexibility. The master list will be complemented by the factors identified in systematic literature review. The key factors for supplier flexibility that we found in the literature are described below.

- **Factor #1: Inventory availability.** The flexibility of a supplier is affected by its inventory availability. The higher the inventory level that the supplier promises to the customer, the higher the flexibility of the supplier from the customer’s perspective.

- **Factor #2: Volume flexibility / capacity to respond to unexpected demand.** The ability of the supplier to change its capacity to meet unexpected changes in demand in the market increases flexibility of supplier.

- **Factor #3: Launch flexibility / order customization.** The ability of the supplier to customize orders as per customer’s request (such as special coating, marking, color coding etc.) increases flexibility of suppliers.

- **Factor #4: Negotiability.** The willingness of the supplier to negotiate on price and delivery schedule is an indication of the flexibility of the supplier.

- **Factor #5: Manufacturing flexibility.** (Also production flexibility, changeover flexibility, mix flexibility.) The ability of the supplier to change product mix quickly and cost-effectively increases its flexibility. Machine, labor, material handling, and routing flexibilities are factors of manufacturing flexibility.

- **Factor #6: Labor flexibility.** The ability of the supplier to adjust manpower in line with changes in demand indicates flexibility of the supplier.

- **Factor #7: Financial flexibility.** The ability of the supplier to react well to unexpected expenses improves its flexibility. Financial flexibility is measured by cash flow, debt positions and working capital of the company.
• **Factor #8: Distribution flexibility.** The ability of the supplier to provide widespread
distribution coverage to meet the end-customer’s demand is an indication of supplier
flexibility.

• **Factor #9: Logistics flexibility.** The ability of the supplier to use different modes of
transportation (such as truck, air, ocean etc.) to deliver products to customers increases
responsiveness and flexibility.

• **Factor #10: Sub-supplier flexibility/Supply network flexibility.** The ability of the
supplier to reconfigure its supply base effectively and efficiently using collaborative
capabilities increases the flexibility of the supplier.

• **Factor #11: Joint planning.** The willingness of the supplier to get involved in joint
planning with customers and sub-suppliers increases both the supply chain’s visibility and
the supplier’s flexibility.

• **Factor #12: Trust and shared vision / supplier relationships.** Existence of trust and
shared vision across supply chain partners increases the ability of firms to respond jointly
to rapid changes in demand.

• **Factor #13: Procurement flexibility.** The ability of the supplier to source a component
from multiple suppliers (dual sourcing) reduces the supply risk, and increases its
flexibility.

• **Factor #14: Variety of product offering.** The range of products a supplier can offer to its
customers, including types of products, types of packaging and format of packaging, is
typically associated with its flexibility.

• **Factor #15: Delivery flexibility.** The capacity of the supplier to vary its delivery lot-sizes,
delivery frequencies and delivery dates is associated with its flexibility.
• **Factor #16: Maturity and formalization.** Increased firm formalization and stable routines and processes increase a supplier’s chances of survival during downturns in environmental uncertainties.

• **Factor #17: Contract flexibility.** Flexible contracts (such as time flexible contracts and quantity flexible contracts) promote supplier flexibility and reduce the risks faced by companies.

• **Factor #18: Information sharing:** The willingness of the supplier to share information with sub-suppliers through advanced technologies such as EDI (Electronic Data Interchange) increases the flexibility of the supplier.

For more details on the authors that have proposed the factors summarized above, we refer the reader to Figure 1, which presents their references along with the factors of flexibility they discuss.

**Figure 1: Supplier flexibility factors from literature review**

<table>
<thead>
<tr>
<th>Literature</th>
<th>Factors of flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sivapornpunlerd &amp; Setamanit (2014)</td>
<td>Inventory availability, capacity to respond to unexpected demand, order customization and negotiability</td>
</tr>
<tr>
<td>Dreyer &amp; Grønhaug (2004)</td>
<td>Volume flexibility, production flexibility, labor flexibility and financial flexibility</td>
</tr>
<tr>
<td>Thomé, Scavarda, Pires, Ceryno, &amp; Klingebiel, 2014</td>
<td>Suppliers’ capacity, diversity of suppliers, suppliers’ cooperation, trust and commitment, and inventory</td>
</tr>
<tr>
<td>Vickery et al. (1999)</td>
<td>Volume flexibility, launch flexibility and distribution flexibility</td>
</tr>
<tr>
<td>Geissbauer &amp; Householder (2011)</td>
<td>Supplier relationships and information sharing</td>
</tr>
<tr>
<td>Van der Rhee, Verma, &amp; Plaschka (2009)</td>
<td>Production flexibility, demand flexibility, variety of product offering</td>
</tr>
<tr>
<td>Tachizawa &amp; Giménez (2009)</td>
<td>Joint planning and information sharing, delivery flexibility, adaptability, logistics flexibility</td>
</tr>
</tbody>
</table>
---|---
(Wang & Wei, 2007)  | Supply networks and supplier relationships
Stevenson and Spring (2007)  | Robust network and supply chain relationships
Liao et al (2010)  | Supplier flexibility and supply network flexibility
Po-Young Chu, Kuo-Hsiung Chang, & Hsu-Feng Huang (2011)  | Trust and shared vision (Mix, volume and delivery flexibility)
Patel (2011)  | Maturity of organization, formalization of organizational structure
Li & Kouvelis (1999)  | Flexible contracts: Time flexible contracts and quantity flexible contracts
Yu, Cadeaux, & Luo (2015)  | Product customization, manufacturing competence, logistics flexibility, supplier development, information sharing, integration
Swafford, Ghosh, & Murthy (2006)  | Manufacturing flexibility, procurement flexibility (dual sourcing), distribution and logistics flexibility

Section 4.3 - Findings of interviews with FieldServ’s suppliers

Section 4.3.1 - Findings from mini-case analysis

This section summarizes the interviews we conducted with suppliers of FieldServ. The objective of these interviews was to hear from “high-performing” suppliers of FieldServ and identify those factors, which the suppliers believe are critical for their flexibility. We summarized the interviews into 7 mini-cases. These mini-cases introduce what these suppliers’ organizational structures look like, what they do differently from other players in the industry, and what challenges they face while catering to the needs of customers in the oil and gas industry. Due to confidentiality reasons, we are not revealing the actual supplier names and using alphabets A, B, C etc. to refer them.
Mini-Case #1: Supplier A

Supplier A is a machine part supplier located at Calgary, Canada. It has around 65 employees and a single manufacturing facility. Supplier A is a privately owned company and has been in the oil and gas business for last 25 years. Like other companies in the oil and gas industry, Supplier A has been significantly impacted by the oil price downturn like the one we see at the time of this study. In 2013-2014, it had full capacity utilization. In 2015, its capacity utilization dropped to 80%. At the end of 2015 and early 2016, its capacity utilization further dropped down to 40-50%. The company laid off around 30-40% of its employees in this bust cycle. Regardless of these challenges, Supplier A is still running effectively and continuously providing high quality products and good services to FieldServ.

Supplier A tried to diversify its business into other industries such as aerospace and transportation. However, 80% of its revenue still comes from the oil and gas industry. It also tried to diversify its business into different sectors of oil and gas business to reduce the overall risk. According to VP of Operations of Supplier A, there are various sectors within the oil and gas industry, such as exploration, drilling, completion and service. Some of these sectors may not be impacted as much as the others during bust cycles, providing Supplier A with a natural hedge against risks.

Another area that Supplier A has been continuously focusing on is streamlining its production and operations, to cut down lead-times. It invested in expensive cutting tools to increase productivity and yield. These investments not only cut the production lead-time, but also enabled Supplier A to produce high quality products, giving them a competitive advantage. According to Supplier A, the lead-time of raw material purchase is a huge challenge in oil downturn periods, since partners in the upstream supply chain will reduce their inventory on hand to free up cash. In addition, Supplier A tries its best to share FieldServ’s forecast with its sub-suppliers, as well as their own understanding of the trends in oil prices. Supplier A also
encourages its sub-suppliers to carry some inventory to reduce the lead-time of purchasing raw material. However, Supplier A has less influence on sole-sourced sub-suppliers that were designated by FieldServ, due to their low negotiation power relative to FieldServ. Supplier A would like to rely on FieldServ to manage these designated sub-suppliers.

Although Supplier A had a rough time during the current oil price downturn, by implementing the above mentioned initiatives, it was able to survive and keep up its service level. The company has experienced a few oil price cycles in past 25 years and its management team is optimistic that they can survive another one.

- **Mini-Case #2: Supplier B**

Supplier B is a U.S.-based publicly listed company providing equipment and services to the oil and gas industry. The company has approximately 20,000 employees and operates 30 manufacturing locations in 16 countries. Approximately 90% of its revenue comes from the oil and gas industry. The supplier attributes its ability to adapt to cycles of the oil and gas industry to its long-term partnership and joint business planning with FieldServ. "Supplier B is ready to take short-term losses in oil downturns, in compensation for long-term benefits when oil price goes back to its previous higher levels", says the global account manager. Though Supplier B makes lower profits with FieldServ orders, it makes up for this through higher volumes from FieldServ during the good times.

Supplier B has a dedicated business intelligence team that monitors oil industry trends and other macroeconomic factors, and incorporates them into business planning and forecasting with FieldServ. Using customer inputs, Supplier B adjusts its manufacturing and supply chain capabilities to minimize the gap between supply and demand at minimum costs. Supplier B recently started using S&OP in its business planning and it helped them achieve visibility up to 24 months in their planning of operations. Supplier B ensures flexibility in its
manufacturing as a means to manage demand variability. When demand picks up, Supplier B resorts to outsourcing.

Supplier B maintains strategic relationships with key suppliers and shares forecasts and demand information with its key sub-suppliers. The supplier maintains a flexible labor policy and institutes a comprehensive training mechanism to bring the workforce up to speed when needed. At the same time, Supplier B also makes sure that it does not face talent shortage while demand is going up, by ensuring a steady pipeline of workforce with specialized skills.

The supplier also maintains an inventory of components with long lead-times so that it can maintain promised service levels to customers. The supplier also believes that one of its key competitive advantages lies in its ability to reduce costs by process improvements, which helps them extend discounts to its customers even during oil downturns.

• **Mini-Case #3: Supplier C**

Supplier C is one of the largest electronics manufacturing services companies in the world and a major provider of electronic assemblies to FieldServ. The company is well diversified into segments such as aerospace, automotive, heavy equipment, oil and gas and electronics manufacturing. Being a major player in other segments in which it operates, Supplier C’s dependency on the oil and gas industry is relatively lower.

Supplier C attributes its flexibility to its capability to quickly respond to information and data during upturns and downturns of oil cycles. It has a dedicated business intelligence team that monitors oil prices and other proxies of oil activities on a weekly basis, and initiates discussion with customers if oil prices drops below a certain threshold over a sustained period of time. This process helps Supplier C seek more clarity on forecasting and get more visibility into order pipelines so that it can adjust its manufacturing capability according to market needs. In line with the oil price indicators, the management team at Supplier C also creates an *internal ramp readiness plan* well in advance, to increase manufacturing flexibility. For example, when
oil prices are consistently going down, Supplier C adopts strategies such as freezing head-count, capacity reduction etc.

Supplier C has a flexible manufacturing strategy with multiple interchangeable locations and resources, providing them more leeway to adjust to rapid changes in demand in the oil and gas industry. For example, Supplier C uses generic machines in alternate locations so that it can switch manufacturing from one location to another if needed. The supplier also maintains a flexible manpower strategy with the ability to downsize and upsize the manpower according to changing market needs.

Supplier C also uses different strategies to manage sub-suppliers as market conditions change. In oil downturns, Supplier C buys components from sub-suppliers only upon receipt of actual customer orders and uses flexible contracts to minimize the risk. In upturns, as demand increases, Supplier C prefers to partner with sub-suppliers to invest in people, technology and equipment to facilitate capacity ramp ups. In oil downturns, Supplier C also monitors suppliers in financial distress and seeks potential acquisition opportunities to internalize production of critical items.

• Mini-Case #4: Supplier D

Supplier D is one of the major US corporations offering chemical solutions to oil field services companies. A third of Supplier D’s revenue comes from oil and gas sector. A global account manager at Supplier D attributes its flexibility to close partnerships with customers, manufacturing flexibility with high level of automation and strategic relationships with key suppliers. The supplier also has a dedicated business intelligence team providing feedback to the business planning team to adjust capacity and capability according to changing market needs.

Flexible manufacturing with multiple facilities that are versatile (i.e. capable of manufacturing most of the products in the supplier’s portfolio) provides Supplier D the
capability to shift production among different facilities. Supplier D also implemented heavy automation in its manufacturing facilities, which helps it not only to reduce reliance on labor but also cut drastically the production lead-times, improving the flexibility of its operations. Additionally, Supplier D institutes a flexible capacity policy with ability to use multiple shifts per day and also to outsource or insource capacity with its key partners. Supplier D also maintains labor flexibility with a pool of contract employees.

Supplier D shares forecasts with its key strategic suppliers and uses flexible contracts for raw material purchases. Supplier D maintains warehouses near all major customers to reduce delivery lead-times and ensures that it keeps sufficient inventory to cater to rising demand when oil prices go up, and to minimize inventory exposure when oil prices go down. Supplier D has a global footprint in terms of sourcing and manufacturing. In the U.S. plants, Supplier D usually manufactures products on a make-to-order (MTO) basis, minimizing the inventory exposure.

• **Mini-Case #5: Supplier E**

Supplier E is a small-scale supplier that manufactures custom components for FieldServ and has a single manufacturing facility in U.S. employing approximately 100 staff. The company has a huge dependency on the oil and gas industry, and 98% of its revenue comes from FieldServ. The supplier is heavily impacted by declines in demand, such as the one they were experiencing at the time of our interviews.

Supplier E predominantly uses manual labor in its operations with few investments in automation. Supplier E finds it hard to hire and train employees requiring specialized skills. Hence the company has chosen to maintain a pool of qualified employees, which in turn reduces Supplier E’s labor flexibility. This policy, however, is relaxed under extreme circumstances: for example, to survive the oil price crisis in 2009, the company downsized 70% of its workforce, and then hired more people as demand picked up in later years.
In 2015, at the time of our interview with them, as the price of oil was going through one of its lowest points in recent history, the supplier again resorted to aggressive headcount reduction tactics, which enable them to stay lean and survive the turbulent times. However, the operations manager we interviewed foresees challenges due to talent shortage in the future when demand goes up as oil prices increase. For example, due to learning curve effects, Supplier E needs 2 years to train a new hire in assembly line operations up to the required productivity standards. Consequently, the talent shortage could create potential challenges for Supplier E in good times, and it could fail to deliver on promised customer deadlines as volume picks up.

Supplier E operates as a lean organization and pursues opportunities for overhead reduction. For example, the management team spends less time on meetings (one meeting per week) and more time on actual execution, the operations manager said. Supplier E also limits inventory exposure to a minimum by employing a make-to-order (MTO) manufacturing policy and also by scheduling the deliveries of components to match the actual customer orders as in the case of a just-in-time (JIT) system.

Supplier E does not rely on forecasts from FieldServ to manage its operations. “Forecasts in most cases are very inaccurate,” says the operations manager. Likewise, Supplier E will not provide its sub-suppliers with forecast data. Reducing the lead-time of raw material from its sub-suppliers is an on-going challenge for the Supplier E.

* **Mini-Case #6: Supplier F**

Supplier F is headquartered in Austria and provides machined part components to FieldServ. The supplier has 6 manufacturing sites located in the U.S., Austria, Mexico, Singapore, and Vietnam. It has been in the oil and gas business since 1970 and started working with FieldServ since 1981. Supplier F is heavily dependent on the oil and gas industry, with 99% of its revenue comes from this industry. The supplier has been impacted significantly by
the on-going oil crisis that is taking place at the time of this writing. In 2016 revenue from oil and gas plunged to only about 30-40% from what it was in 2014. Supplier F downsized 50% of its workforce since 2014 and has plans to continue prune workforce.

Supplier F believes that workforce flexibility is critical for them to survive the oil price crisis. However, it also believes that it’s important to maintain its core workforce during the downturn and to provide attractive incentives to retain them in good times. Supplier F also has an experienced management team with industry exposure of more than 10 years. Most of these senior managers have seen several oil cycles during their tenure and have developed an in-depth understanding of the oil and gas market. This helps Supplier F to have its own analysis and prediction of oil price changes. Supplier F’s management team will usually make an independent evaluation of worst-case and best-case scenarios to understand the impact of the cycles.

According to Supplier F, the proper management of its sub-suppliers is also crucial to operational flexibility. It has around 200-300 sub-suppliers. Supplier F groups its sub-suppliers into different segments and leverages different strategies to manage each segment. For key raw materials suppliers that are of strategic importance to Supplier F and FieldServ, Supplier F tends to rely on FieldServ to help the suppliers to survive during difficult times. For specialty services suppliers, such as coating services, Supplier F will evaluate potential risks and benefits of suppliers and sometimes resort to vertical integration as a strategy to secure their service. For small- and medium-scale suppliers, Supplier F doesn’t really do much to help them survive; instead it will evaluate the risks of business disruption and develop alternative suppliers if they can’t survive the oil price downturns.

* Mini-Case #7: Supplier G

Supplier G established its business in 1949 and started as a tool die manufacturer. It later transformed into a more diversified business, with most of its revenue coming from the
medical and aerospace industries. Supplier G is a private company with around 750 employees. Employees own roughly 25% of the company stock. The company started to work with FieldServ since 1995. The oil and gas industry only contributes 15% of the company’s total revenue. Currently, 35-40% of Supplier G’s products are made offshore, with total revenue of around $130 million.

Our interview was conducted with a sales account manager with 25 years of experience in the company, who manages FieldServe’s account. According to this account manager, diversification is the biggest factor for the flexibility of their operations. The company does not get impacted as much as the other companies who have much more exposure to the oil and gas industry when oil prices goes south.

Flexibility of the workforce also contributes to the company’s flexibility. The company has a sales team with 11 members. Each sales person covers a particular industry or a few clients. However, when one particular industry is not performing as expected, the sales team covering that industry will support other industry or clients since sales team has developed transferable skills, which can be used for any clients. Furthermore, its sales team is very experienced, with an average of more than 20 years’ experience in sales.

The company also has some built-in flexibility in its manufacturing. Supplier G uses make to stock (MTS) production strategy in good times when demand is stable and easy to forecast. It uses make-to-order (MTO) in bad times when demand is volatile and difficult to forecast. This differentiated strategy helps Supplier G to cope with demand of fluctuating oil industry.

Cross-validation of mini-cases

Each one of the mini-cases presented above summarizes our findings from the interviews with “high-performing” suppliers of FieldServ. Each one of these summaries was prepared by analyzing the audio recording of the interview, by means of qualitative data
analysis techniques from the grounded theory tradition, such as coding and memoing. Each one of the two authors of this thesis coded five interviews, covering in total ten interviews. The purpose of this coding was to arrive, individually, at a list of the factors that contribute to the flexibility of each supplier, in the form of a mini-case summary.

To verify the quality and validity of the individually prepared mini-case summaries and the coding that led to them, we performed a cross-validation exercise. It was done as follows: We sampled two out of the ten supplier interviews, one from each interviewer, and had that interview recoded by the other researcher. This researcher would prepare a new mini-case summary, and would compare its findings to those of the first researcher. The fact that no incongruences were found across the different summaries of the same interviews serves as evidence in favor of the validity of the mini-case summaries prepared by each of the researchers separately. Details of the cross-validation exercise for one supplier interview are shown on Appendix 5.

Section 4.3.2 - Cross-case analysis of supplier interviews

After the cross-validation exercise, a cross-case analysis of the supplier interviews was conducted. Using as starting point the summaries of all ten supplier interviews, each one of the researchers prepared, on their own, a cross-case analysis to identify the flexibility factors behind “high-performing” suppliers. Part of this analysis was to understand the relative importance of each flexibility factor: we counted the frequency of references to each factor in all supplier interviews. The more frequently different suppliers are mentioning a factor, the more relevant we consider it to be.

Two cross-case analyses were done separately, one by each researcher. Their outputs are shown in Appendix 6. The findings of these separate cross-case analyses were compared: no major inconsistencies we found.
Section 4.3.3 - Consolidated list of factors of flexibility from supplier interviews

The flexibility factors identified in the cross-case analysis mentioned above were then consolidated into a single list of flexibility factors derived from the interviews with suppliers. This list is provided below.

- **Factor #1: Business portfolio diversification.** Having steady revenue streams from different sources minimizes business risk.

- **Factor #2: Ability to reduce raw material purchasing lead-time.** Reducing raw material purchasing lead-time will enable suppliers to carry fewer inventories during oil prices downturns and consequently maintain better cash positions.

- **Factor #3: Ability to reduce production lead-time.** The ability of the supplier to reduce production lead-time using automation and advanced technologies helps in reducing work-in-process inventory and in offering better lead-time to customers.

- **Factor #4: Ability to reduce delivery lead-time.** The ability of the supplier to ship products faster to customer from closely located warehouses improves delivery lead-time.

- **Factor #5: Inventory flexibility.** Minimizing the finished goods inventory level during oil prices downturns by pushing inventory upstream will help suppliers to maintain better cash positions. Keeping a higher level of inventory in oil price upturns will help suppliers maintain better service levels.

- **Factor #6: Strong cash flow position.** Strong cash position gives suppliers more flexibility and helps suppliers survive oil prices downturns.

- **Factor #7: Business intelligence team.** Market insight team to study oil and gas industry cycles and trends can give suppliers faster access to information and enable suppliers to make plans in advance.
- **Factor #8: Experience of the management team.** Supplier management team’s in-depth understanding of the cyclical nature of the oil and gas industry can effectively help suppliers to navigate changing market conditions.

- **Factor #9: Flexible workforce.** Whether a supplier’s labor force is unionized and whether a supplier can quickly increase / decrease its labor force based on changing market conditions will impact the supplier’s flexibility.

- **Factor #10: Systematic hiring and training.** Well established hiring and training system to quickly bring new labor force up to speed will give suppliers more flexibility.

- **Factor #11: Capacity flexibility.** The ability of a supplier to keep buffer capacity and ability to run multiple shifts gives suppliers more flexibility.

- **Factor #12: Partnership with FieldServ.** Partnership with FieldServ provides a supplier with faster and accurate access to market outlook and order pipelines and a better platform for communication. This helps both customer and supplier to engage in joint business planning to reduce the mismatch between demand and supply.

- **Factor #13: Competitive compensation for work force.** Competitive pay will help suppliers attract and retain talent. Suppliers need to maintain a pool of workforce requiring specialized skills to manage during capacity ramp ups.

- **Factor #14: Partnership with sub-suppliers.** Partnership with sub-suppliers promotes communication and helps sub-suppliers to plan their capacity effectively to match customer demand.

- **Factor #15: Flexible agreements / contracts with sub-suppliers.** Flexible supply agreements with sub-suppliers ensure raw material supply at the minimum risk.

- **Factor #16: Risk sharing by FieldServ.** Existence of a risk sharing mechanism between the customer and supplier is important to ensure that supplier remains flexible during ups and downs of oil cycle. For example, suppliers pointed out that FieldServ’s willingness...
to compensate for the losses incurred by the suppliers when FieldServ cancels orders in turbulent times would help suppliers to mitigate their financial risks.

- **Factor #17: Manufacturing flexibility.** The existence of versatile manufacturing facilities (i.e. capable of manufacturing most of the products) provides suppliers the capability to shift production among different facilities.

- **Factor #18: Flexibility to switch production strategies.** Suppliers mentioned that in good times, they would like to manufacture products for FieldServ using make-to-stock (MTS) strategy and ensure inventory availability. In bad times, suppliers would like to stick to a make-to-order (MTO) strategy to minimize their risks. The ability of the supplier to switch between these production strategies is crucial for suppliers in oil and gas industry.

- **Factor #19: Ability to reduce prices through innovations and technology.** The ability of the supplier to constantly innovate and reduce costs by using alternate materials and advanced technologies help them to extend price discounts to FieldServ in both good times and bad times.

  We learned from an industry expert who has more than twenty years of experience in oil and gas industry that the risk appetite of the management and culture of the organization would also be a significant factor of flexibility of suppliers.

- **Factor #20: Culture of the organization and management:** The culture of the organization and management influences the risk taking appetite of the company and hence will have an impact on the flexibility.

  Also, during the review process with our thesis supervisor, he pointed out – after examination of the mini-case for Supplier G that an additional factor contributing to the flexibility of a supplier may be a workforce with transferable skills.
• **Factor #21: Transferable skills.** The ability of the supplier’s workforce to perform multiple roles by having transferable skills may increase the supplier’s flexibility.

**Section 4.4 - The master list of factors of flexibility**

In previous sections, we have listed factors that are seen as contributing to the flexibility of a supplier, from three sources: (1) interviews with FieldServ commodity managers, (2) a systematic literature review, and (3) interviews with “high-performing” suppliers of FieldServ. It is now possible to prepare a consolidated list that combines the factors from all three sources.

The list attached below summarizes all unique factors of flexibility we identified from FieldServ’s commodity manager interviews, literature review and FieldServ’s supplier interviews. To make a unique list of factors, we combined some of the factors that are similar in nature. For example, manufacturing flexibility, volume flexibility, capacity flexibility and flexibility to switch production strategies represent similar ideas and hence are combined as production flexibility. Similarly, some other factors that represent similar ideas are also combined to get a unique list of factors as attached below.

- Factor #1: Business portfolio diversification
- Factor #2: Strong financials/ positive cash position
- Factor #3: Private vs. public company
- Factor #4: Labor flexibility
- Factor #5: Degree of vertical integration
- Factor #6: Sub-supplier flexibility
- Factor #7: Variety of product offering
- Factor #8: Negotiability / Ability to reduce prices through innovations and technology
- Factor #9: Production flexibility
• Factor #10: Distribution flexibility
• Factor #11: Logistics flexibility
• Factor #12: Joint planning and partnership with FieldServ and sub-suppliers
• Factor #13: Trust and shared vision / supplier relationships
• Factor #14: Procurement flexibility
• Factor #15: Delivery flexibility
• Factor #16: Maturity and formalization
• Factor #17: Contract flexibility
• Factor #18: Ability to reduce raw material purchasing lead-time
• Factor #19: Ability to reduce production lead-time
• Factor #20: Ability to reduce delivery lead-time
• Factor #21: Inventory flexibility
• Factor #22: Business intelligence team
• Factor #23: Experience of the management team
• Factor #24: Systematic hiring and training
• Factor #25: Competitive compensation for work force
• Factor #26: Risk sharing by FieldServ
• Factor #27: Work force with transferable skills
• Factor #28: Culture of the organization and management
• Factor #29: Information sharing
Chapter 5 Validation

Section 5.1 - Design

The master list from section 4.4 summarizes the list of factors of flexibility we arrived at through the research methodology. To test the validity and relative importance of these factors, we designed a short survey, including the 18 factors that had been identified at the time the survey instrument was prepared. Although ideally all 29 factors presented in the master list should be validated, the pace of the SCM Program required the survey to be prepared and deployed before all factors had been identified. On the plus side, there is a methodological advantage to using a smaller number of factors: a shorter survey is likely to have a higher response rate. An additional consideration is that the factors that were identified earlier in the process, and included in the survey are those that we believe are more relevant and applicable to companies in the oil and gas industries.

We sent the survey across FieldServ’s commodity managers, FieldServ’s suppliers and a group of supply chain professionals from the MIT Supply Chain and Logistics Excellence (SCALE) Network. FieldServ’s commodity managers and suppliers constituted 30% of the survey recipients and MIT SCALE students and alumni constituted the remaining 70%. The target population for the survey can be broadly classified into two categories, namely: (i) population with confirmed oil and gas industry experience, and (ii) population without confirmed oil and gas industry experience.

The survey had two parts, with the first part consisting of structured questions and the second part being more open-ended. In the first part we asked each respondent to rank the 18 factors of flexibility in the order of importance using a 5-point Likert scale 3 (with the extreme points being 1=Unimportant and 5=Very important). For example, one question

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3 Likert scale is a psychometric scale commonly involved in research employing questionnaires.
asked the respondent to rate the importance of “business portfolio diversification” in the order of the importance from “unimportant”, “of little importance”, “moderately important”, “important” to “very important”. In the second part, we asked each respondent to list factors of flexibility, which they believe are important, but were not appeared in the first part. The survey questions used in the study are presented in Appendix 9.

Section 5.2 - Analysis and results

The survey received a total of 35 usable responses, 23% of which had work experience in the oil and gas industry. We analyzed the survey results using a weighted average method. First, we assigned each level in 5-point Likert scale a numerical value. For example, we assigned 1 to “unimportant”, 2 to ‘of little importance’, 3 to ‘moderately important’, 4 to ‘important’ and 5 to ‘very important’. The weighted average method helps us understand the relative importance of flexibility factors from the perspective of the respondents.

Figure 2: Ranking of supplier flexibility factors

<table>
<thead>
<tr>
<th>Ranking by importance (5-most important, 1-least important)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint planning/ Partnership with customer</td>
</tr>
<tr>
<td>Strong financials/ Positive cash position</td>
</tr>
<tr>
<td>Production flexibility</td>
</tr>
<tr>
<td>Joint planning/ Partnership with sub-suppliers</td>
</tr>
<tr>
<td>Trust and shared vision across supply chain...</td>
</tr>
<tr>
<td>Ability to reduce lead-time</td>
</tr>
<tr>
<td>Experience of the management team</td>
</tr>
<tr>
<td>Culture of the organization and management</td>
</tr>
<tr>
<td>Inventory flexibility</td>
</tr>
<tr>
<td>Business portfolio diversification</td>
</tr>
<tr>
<td>Contract flexibility</td>
</tr>
<tr>
<td>Labor flexibility</td>
</tr>
<tr>
<td>Information sharing (EDI)</td>
</tr>
<tr>
<td>Ability to reduce prices through innovations...</td>
</tr>
<tr>
<td>Systematic hiring and training</td>
</tr>
<tr>
<td>Logistics flexibility</td>
</tr>
<tr>
<td>Business intelligence team</td>
</tr>
<tr>
<td>Procurement flexibility</td>
</tr>
</tbody>
</table>

1  2  3  4  5
The relative ranking of all factors based on data analysis are shown in Figure 2. The weighted average score of all factors turned out to be greater than 3 indicating that all factors are at least moderately important. Respondents rated joint planning and partnerships with customer and suppliers, financial health, production flexibility and trust and shared vision across supply chain partners as the top five most important factors influencing flexibility of suppliers.

We also analyzed the spread of responses from various respondents to understand the overall pattern of responses. The box plot in figure 3 shows the distribution of responses for each survey question. The box plot analysis indicates that some factors have lower spread or variability while others have higher spread. For example, three out of the top five factors, namely joint planning and partnership with customer, financial health, and production flexibility, have lower spread- indicating most of the respondents ranked these factors similarly. On the other hand, two out of the top five factors, namely joint planning and partnership with suppliers and trust and shared vision, have greater spread indicating that respondents have varied opinions regarding the factors. However, we believe this spread does not detract from the significance of the findings, since even their lower quartiles fall at or above the 3 (“moderately important”) mark.

To further understand the dynamics of difference in ranking between respondents, we analyzed the survey results separately by different target groups. Figure 4 shows the box plots of survey responses from both respondents with confirmed oil and gas experience and respondents without confirmed oil and gas experience.

We found that both groups gave approximately the same ranking for labor flexibility, need for a business intelligence team, manufacturing flexibility and culture of the organization (refer to figure 4).
Figure 3: Box-plot analysis of overall survey responses
Figure 4: Box-plot analysis of different target groups
Within groups, the top factors are as follows. For the 8 respondents in the group with confirmed oil and gas experience, the top five factors are as follows: (i) business portfolio diversification, (ii) strong financial and positive cash position, (iii) ability to reduce prices through innovation and technology, (iv) experience of the management team, and (v) production flexibility.

For the 27 respondents in the group without confirmed oil and gas experience, the top factors are as follows: (i) joint planning and partnerships with customers, (ii) strong financial and positive cash position, (iii) joint planning and partnership with sub-suppliers, (iv) trust and shared vision across supply chain partners, and (v) production flexibility.

Some similarities across the groups are obvious. For example, production flexibility and strong financial and positive cash position are in both lists. However, there is potential disagreement between ranking of some factors such as ability to reduce price, business diversification, joint planning with sub-suppliers and ability to reduce lead-time between the groups. When respondents with confirmed experience in oil and gas ranked the ability to reduce price and business diversification as major factors affecting flexibility of suppliers, the respondents without confirmed experience valued these factors lower in their ranking. Similarly, when respondents without confirmed oil and gas experience ranked joint planning with sub-suppliers and ability to reduce lead-time as major factors, respondents with confirmed oil and gas experience ranked them relatively lower.

The differences in ranking of the factors by the two groups could be attributed to multiple factors such as familiarity with the industry and its challenges, potential biases of the respondents, and ability of the respondents to look at the issue from a fresh perspective. As an example, the respondents with background outside the oil and gas industry can provide some fresh perspective on factors of flexibility that could be different from the factors as perceived by the respondents with background in oil and gas industry.
Chapter 6 Instrument development

Section 6.1 - Objectives

In the previous section, we validated the factors of flexibility through survey and classified them in the order of importance. Although this validation should not be considered final, it provides us a starting point to develop the first draft of an auditable self-assessment tool or instrument for FieldServ. That is the purpose of this chapter. The instrument will serve two major purposes. First, the instrument will help suppliers of FieldServ to assess their flexibility through self-evaluation. Second, the instrument will help suppliers to understand better what factors contribute to flexibility.

Section 6.2 - Flexibility evaluation framework, questions and weightage

Section 6.2.1 - Flexibility evaluation framework

We first analyzed the similarities and relationships among the 29 flexibility factors in our master list. We classified the factors into two categories, namely (i) core supply chain functions, and (ii) key support functions. Core supply chain functions are sub-divided into four sub-groups, namely (i) procurement, (ii) manufacturing and operations, (iii) distribution and logistics, and (iv) collaboration and integration. Key support functions are sub-divided into: (i) finance, (ii) human sources, (iii) research and development, (iv) knowledge and expertise, (v) business portfolio, and (vi) ownership and culture.

For most of the factors, it is rather clear to which sub-group they belong. For example, factors such as labor flexibility, competitive compensation for work force, hiring and training plan and, work force with transferable skills are associated with the Human Resources function, and are therefore included in the human resources subgroup. However, for a few factors, assigning them to a sub-group was a bit more of subjective call, since they fall on a gray area. For example, consider the factor that we have called delivery flexibility,
which – depending on the company’s inventory policy – may be more closely associated with either manufacturing or distribution. If the company keeps the goods in stock, delivery flexibility is a question of distribution. But if the company does not have a policy to keep the goods in stock, delivery flexibility may involve a make-to-order case and hence related to manufacturing.

The grouping of these factors is shown in Figure 5.

Section 6.2.2 - Questions

For each flexibility factor we have identified, we developed a set of questions using the definition of each flexibility factor. We believe these questions could help companies effectively gauge how well their suppliers are performing on that particular dimension of flexibility. For example, to evaluate manufacturing flexibility, we ask the following seven questions to assess suppliers’ performance:

- **Question #1:** What is your production strategy? Engineer-to-Order, Make-to-Order, Assemble-to-Order, Make-to-Stock or Make-to-Forecast (Martínez-Olvera & Shunk, 2006), or a hybrid one.
- **Question #2:** Do you switch from one production strategy to another to cater to customer demand? Give examples.
- **Question #3:** What is your average capacity utilization rate last year?
- **Question #4:** How much time do you need to double your production capacity?
- **Question #5:** Do you have multiple manufacturing facilities to make the same products? Give examples.
- **Question #6:** How many production shifts do you have?
- **Question #7:** On a scale of 1 to 5 (where 1 is “least difficult” and 5 is “most difficult”, how do you rate the difficulty of adding an extra shift of production?
Figure 5: Grouping of flexibility factors

**Core supply chain functions**

- **Procurement**
  - Ability to reduce raw material purchasing lead-time
  - Contract flexibility
  - Procurement flexibility
  - Sub-supplier flexibility
- **Manufacturing and Operations**
  - Ability to production lead-time
  - Capacity flexibility
  - Delivery flexibility
  - Flexibility to switch production strategies
  - Launch flexibility / order customization
  - Manufacturing flexibility / interchangeable locations
  - Volume flexibility / capacity to respond to unexpected demand
- **Distribution and Logistics**
  - Inventory flexibility
  - Ability to reduce delivery lead-time
  - Distribution flexibility
  - Logistics flexibility

**Key support functions**

- **Finance**
  - Strong financials/Positive cash position
- **Human Resources**
  - Competitive compensation for work force
  - Labor flexibility
  - Systematic hiring and training
  - Transferable skills
- **Research and Development**
  - Negotiability / Ability to reduce prices through innovations and technology
- **Knowledge and Expertise**
  - Experience of management team
  - Maturity and formalization
  - Business intelligence team
- **Business Portfolio**
  - Variety of product offering
  - Business portfolio diversification
- **Ownership and Culture**
  - Private vs. public company
  - Culture of the company

**Collaboration and Integration**

- Risk sharing by customer
- Trust and shared vision
- Joint planning and information sharing with customer
- Joint planning and information sharing with sub-suppliers
- Degree of vertical integration
From our research we understand that suppliers with manufacturing flexibility are more likely to have capabilities, such as multiple interchangeable facilities, the ability to add or remove capacity, and the capability to switch production strategies with minimum costs. The responses from suppliers for the above questions would provide a good indication of manufacturing flexibility of suppliers. Similarly, we developed questions to measure each of the 29 factors from the master list.

Section 6.2.3 - Weights

Using the result of our validation survey, we assigned initial weights for the 29 factors. The higher rating a factor received in our survey, the more weight we will assign to this factor. For example, joint planning and partnership with customer is rated the most important factor in our validation survey, so we will assign the highest weight to that factor. The weight of each factor can be modified in the instrument to reflect any variation that different commodities or industries may have. Notice that, when a more formal validation of these factors is conducted, these weights should be revised accordingly.

Section 6.3 - Instrument structure

We developed an instrument based on Microsoft Excel. The instrument contains series of questions we developed in the previous section to measure each factor of flexibility. The instrument has four sections4. A preview of the sections is shown in Appendix 10.

- **Instrument section #1**: The first section introduces the instrument and explains how to use it.

- **Instrument section #2**: The second section is the self-reporting section where a supplier rates itself in terms of each factor in the questionnaire. The second section first explains each flexibility factor. It will then ask suppliers to rate their flexibility

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4 The Excel file for the instrument is available for download here: mcmxvi.com/tool.zip
performance for each factor on a scale of 1 to 5, where 1 means “least flexible” and 5 means “most flexible”. After providing a self-reported score for each factor, suppliers have to further answer the corresponding questions for each factor and provide evidence whenever they are required. After receiving the responses from suppliers, the instrument will automatically calculate suppliers’ overall flexibility performance score by considering each factor’s weight and score.

- **Instrument section #3:** The third section is the auditable section and is designed to be used exclusively by purchasing category managers of FieldServ. Purchasing category managers will have the option to validate suppliers’ responses in this section. Purchasing category managers will be asked to provide their own judgment of flexibility performance of suppliers against each factor according to suppliers’ responses and evidences. Purchasing category managers are also recommended to conduct sample on-site audits to evaluate the validity of suppliers’ responses.

- **Instrument section #4:** The fourth section contains the results dashboard, which compares the self-reported scores of suppliers with the scores given by category purchasing managers. In the future, suitable reference scores – either based on other suppliers or on the expectations from FieldServ for this supplier – could be added for comparison as well.

**Section 6.4 - Limitations of instrument**

There several limitations of the instrument we have developed. One of the limitations is subjectivity in the assessment of factors of flexibility. As mentioned in the literature review, self-assessment reports are subject to social desirability (tendency to respond in a socially acceptable way) and acquiescence (tendency to agree). One might argue that supplier representatives taking the flexibility assessment might try to rate the factors
favorably to create a positive impression. We believe this drawback can be overcome by incorporating independent assessments of purchasing commodity managers.

Another limitation is the effectiveness of the questions we developed to evaluate the flexibility factors. We developed questions for each factor based on the data available to us, from the existing literature and the interviews we conducted. However, we did not have enough time in our project to systematically validate the questions. A direction for future research is to formally validate these questions, using sound principles from measurement theory.

We believe that the supplier flexibility performance score derived from the instrument is a good indication of a supplier’s flexibility. However, the absolute value of the score is less informative than the relative comparison among different scores from different suppliers. To be able to conduct this relative comparison, however, scores from different suppliers in the supplier base must be collected, and analyzed – among other things – on the basis of whether they belong to a supplier that is perceived by FieldServ as “high performing”.
Chapter 7 Conclusions

Section 7.1 Conclusion

In this thesis we first conducted interviews with FieldServ’s commodity managers and then looked at the existing literature to understand what companies in volatile industries do to increase their flexibility to cope with the rapid changes in demand. Later we conducted interviews with “high-performing” suppliers of FieldServ and arrived at factors of flexibility using techniques from the grounded theory methodology. Finally, we conducted a preliminary validation of the flexibility factors using a survey and arrived at first draft of the instrument that can be self-administered by suppliers of FieldServ.

Through interviews and systematic literature review methodology, we managed to develop a thorough – albeit not final – understanding of the factors that contribute to the flexibility of suppliers in the oil and gas industry. Our research has both managerial and academic implications. The research is relevant for all companies in the volatile industries such as oil and gas, construction, and fashion. Our research offers insights to supply chain managers in these industries regarding the factors affecting the flexibility of their suppliers. These managers can use the knowledge of these factors in the process of supplier selection and evaluation mechanisms and also in educating their suppliers to develop capabilities to be flexible to meet the demands of oil and gas industry.

Section 7.2 Limitations

We acknowledge that there are several limitations to the approach. First of all, due to time constraints, we conducted interviews only with a small sample of suppliers that were deemed as “high-performing” by FieldServ. Interviewing a larger sample size of suppliers may result in more insights into the flexibility factors and will help to develop statistically significant results.
In addition, the research was also limited by looking at the characteristics of only the “high-performing” suppliers. A systems research process should incorporate both good performers and bad performers to understand better what they do differently.

We also acknowledge that there is some limitation in the process we used to validate the factors of flexibility. We used only 18 factors out of 29 to elicit a faster response from survey respondents. In a more systematic process, we could use all factors in the survey and send it across a larger sample size of suppliers and commodity managers of FieldServ. This would help to validate the factors statistically.

Similarly, there are also limitations associated with the proposed draft tool on the need to validate the questionnaire as we discussed in the previous section. However, incorporating an auditable segment of the tool can mitigate the limitations on subjectivity of the instrument.

Section 7.3 Opportunities for future research

The limitations outlined above open up new opportunities for future researchers. Our research offers several opportunities for future researchers. To the best of our knowledge, the literature offers very little in terms of studies on the flexibility of suppliers in the oil and gas industry. Future researchers could work towards developing an analytical expression of flexibility of suppliers in this industry using multiple regression analysis from the validated factors of flexibility. For arriving at the model, they need to survey a large enough sample from the supply base of FieldServ and similar companies.

A larger sample would allow future researchers to apply statistical methods. A technique that, in our view, seems promising is the use of structural equation modeling (SEM) to analyze the nature of the relationships among flexibility factors, both those we have identified and hypothesized ones. This is a clear opportunity for a new research project between MIT CTL and FieldServ.
As a general conclusion, this study provided important insights on sources of supplier flexibility in the oil and gas industry. Nevertheless, considerable research is necessary before arriving at a more general, empirically grounded understanding of the actions managers should take to improve the various dimensions of supply flexibility.
Appendix 1: Oil prices fluctuation from year 1986 to 2015

Daily spot prices of crude oil between 1986 and 2015

Source: EIA (US Energy Information Administration)

Appendix 2: Correlation between oil price and FieldServ’s revenue

Source: EIA (US Energy Information Administration), Bloomberg Inc.
Appendix 3: Major business divisions in FieldServ

![Diagram showing Reservoir Group, Drilling Group, and Production Group]

Source: FieldServ company presentation (October, 2015)
Appendix 4: Supplier interview protocol

Introduction (~3 mins)

Hi, ____________, this is ____________, calling from MIT (’s Center for Transportation and Logistics). How are you doing today?

Thanks for agreeing to talk with us, and thanks for your time. The purpose of this interview is to ask you some questions about the key practices of your position and your department. This interview is part of a research project we are conducting with FieldServ. We would like you to think of it as an open conversation, rather free flowing, about the things you do as part of your responsibilities. It won't take more than 1 hour.

Now, since it is an academic interview, you have some special rights as a respondent:

All the information you give us today will be treated confidentially. 1. We have signed a confidentiality agreement with FieldServ; 2. Your name will not be linked to any answer.

The interview is voluntary, which means: 1. you have the right to decline to answer any given question; 2. and you can stop the interview at any time.

We now request your permission to record the interview, if that's OK with you. 1. You have the right to revoke this permission at any time; 2. The recording will be kept in an encrypted digital file, guarded by us personally; 3. All copies will be destroyed once our research project is complete.

Do you have any questions? (Answer the questions, if any). Let's proceed.

Positioning questions (~5 minutes):

1. What is the name of your current position? (If not clear, ask for the department, and for clarification of any term that is not immediately intelligible. If the respondent
extends in the explanation, let him/her speak freely, taking notes. Use some clarifying questions until clear.)

2. What are your current responsibilities under this function?

Open section (~20 minutes):

Oil and Gas industry is characterized by the impact of the business cycles associated with fluctuating oil prices. Suppliers in the industry are not well aware of the business cycles and hence prone to get impacted by expansion and contraction cycles. Major players in the oil and gas industry face potential supply disruption due to supplier inflexibilities in adapting to changing market conditions. From our interactions with FieldServ, we understand that you are one of their “high-performing” suppliers during both good time and bad time. We want to understand what you have done well in the past to survive business downturn and flourish in good time. What do you think you have done well in the past, which makes you their preferred supplier?

The supplier may list down X, Y, Z factors. We will probe further to understand more about the effects of the factors by asking questions such as:

For interesting things, ask: “Tell me more about X”. When the respondent is getting vague, ask: “Can you give me an example of X?” If the conversation is getting lost in operational details, ask: "What is the purpose of this?", or "What is the philosophy/idea behind this?". If the conversation is getting too strategic, ask: "How do you implement this?", or "How do you ensure this happens", or "How do you enable this?", depending on the subject.

Structured section (~30 minutes)

In addition to the above factors suppliers’ point out, we would like to get their perspective on the below parameters, which we feel are important to supplier flexibility assessment.
- What's your management structure and talent base to support FieldServ's business demand?
- Are you a private or public company?
- What is average tenure of the management (through email)
- Tell us more about the hiring and training infrastructure in your company
- What are some of the key challenges you face to meet the demand from Oil and Gas industry?
- How do you address those challenges?
- How were able to go through Oil and Gas downturn and up cycle in the past?
- Is your work force unionized?
- How many suppliers do you have currently? Do you evaluate them in any way?
- What are some of the key challenges your suppliers face to meet the demand from Oil and Gas industry?
- How do your suppliers address those challenges?
- Do you have a formal supplier's risk evaluation and mitigation plan?
- What type of contracts do you sign with your suppliers? Fixed volume, optional volume, take and pay?
- What's your production lead-time for FieldServ products?
- How many manufacturing sites do you have? Are they dedicated for particular clients?
- What's your average capacity utilization level in the past 3 years? How do you manage your production capacity? Do you have buffer capacity?
- How do you handle order cancellations from clients?
- What's your ramp up period if you are about to set up a new manufacturing location?
- What distribution channels do you have deliver goods to customers?
• Do you have central/global distribution center? Where are them?
• What inventory policies do you use for raw materials and finished goods?
• Could we get a copy of your financial statements in the last 2 years? What’s your ROA and liquidity ratio in the past two years?
• What’s revenue last year and how’s the revenue allocation among clients?

(Note: All these questions are optional. Ask only those that seem relevant to the position and that have not been answered before during the course of the conversation.)

That's pretty much what we had to ask you. Thank you very much for your time. We really appreciate your answers and your time. We hope I can contact you with follow up questions after we have analyzed our conversation. Thanks again!
Appendix 5: Supplier interviews cross-validation

Supplier interview notes by researcher 1:

"It is a crazy business-its insane, anybody with right frame of mind, will not get into oil field. I will never do it again!"

- 100% dependency on oil and gas industry. 98% revenue from FieldServ.
- 104 employees. No contract employees. Work force non-unionized.
- Makes custom PCBs.
- Huge dependency in manual labor (80%)-less surface mounts technology (SMT). It is industry challenge.
- Expand and contract labor force- Flexible man power
- Keep people idle since training and learning curve is high-2 years
- 2009-70% down sizing (280 to 80). Ramped up later 100.
- Thorough hiring and train plan.
- Run company lean (management spends less time on meetings-max 1 meeting in a week)
- Both in good times ($130/barrel) and in bad times ($30/barrel)
- Negative- cant ramp up fast
- Positive- will not go out of business in bad times (2 competitor against 4)
- Manage inventory well-keep exposure to inventory a minimum like JIT system
- ERP system- MRP run like a job shop ordering components exactly to match the demand
- JIT – don’t bring all inventory at the same time- schedule their deliveries with sub-suppliers
- Ramp up challenges
• Labor: Need 2 years to train an assembler to speed (10 good people against 100 hires). Can’t make money on labor (during ramp up a new assembler can’t finish task in 10 hours as promised)
• Re-adjust router setting each year based on average routing hour.
• Material shortage
• Obsolescence is huge since technology is old (design 20 years ago)
• Sole sourced -Custom parts- due to FieldServ’s requirement
• Down size. Closed down.
• Have to place orders on Non-cancelable non-returnable basis.
• No flexible contact agreements
• FieldServ wont share any risks associated with sub-supplier PO.
• HST cant afford forecast
• FieldServ don’t gives forecast- even when given, very inaccurate
• Use VMI (6 months purchase agreements)-usage of last 4 months based algorithm
• Machine utilization/flexibility is not a concern.
• Capacity utilization – is very low. 15%.
• FieldServ can carry finish inventory on hand to respond to market demand quickly in good times. Suppliers can’t take that risk with out a reward mechanism.

Supplier interview notes by researcher 2:

Interviewee: Operations head, has 30+ year experience in oil and gas industry.

Houston is a small manufacturer of electrical assembly board. Currently has 104 employees. 300 employees in peak time. 100% oil and gas dependent, 90% of business is from FieldServ.

Communication with FieldServ: telephone calls, emails, 4 different software packages to login to communicate, such as purchasing order. Key to survive oil price
downturn: 1. Manage inventory well, have JIT inventory policy, reduce exposure to inventory to a minimum level. Since FieldServ’s forecast is not accurate and can come in cancel POs anytime. As a small supplier, Houston Sigma has not much to do about order cancelation. So to make sure the raw material and finish goods won’t be wasted due to order cancelation. They will calculate the purchasing lead-time, production lead-time, to schedule purchasing and production just in time to delivery FieldServ products. 2. Reduce overhead spend and run very lean company. Increase the productivity of labor and effectiveness of managers. Eg. Manager do not spend much on meetings. However, the lead organization would have some trouble to ramp up in good time. Since their operations requires highly skilled workers, it takes up to two years to train them. The long lead-time to train workers made them very hard to have enough workers in good time.

Raw material purchasing: They will try not to order all raw material for one order. For example, if FieldServ orders 10 boards and requires different delivery date. They won’t buy all material needed at one time, but rather calculate the cost and delivery time to bring in raw material at the time needed.

It takes long time to train employees. Material supply is also an issue, but less critical. To manage sub-suppliers, they use VMI and will give vendor a forecast based on past usage. FieldServ’s forecast is not accurate and no one will rely on that to schedule production.

Workforce: 80% of the work is manual for circuit board used in oil and gas, because due to extreme condition requirements of these board, they tend to use old design and ceramic parts, which can’t use be used in automated surface mount technology process. For one board, it take around 8-10 hours for a skilled worked to make it. It hasn’t changed for the past 10-20 years. Since they don’t do any design, they are just a contract manufacturer,
they just follow the design of FieldServ. The product design of these FieldServ products require this kind of manual production process.

All workers will go through a 3 months training. They have an on-site trainer dedicated to provide that training. All workers are on contract base during the 3 months training period and will get paid. While they passed the training, they will be hired as full time. However, not much labor will turn into a skilled worker due to various reasons, roughly they pick 100 works and 10 will turn into someone they can use. Workers work on 10 hours per day, 5 days a week. Labor utilization is low. This year is around 10-15%, while last year is roughly 50%. 2009, they let 70% of employees go. No union

Approved Vendor List, they have a lot of suppliers. A lot of them are sole source supplier designated FieldServ; they do not manage designated suppliers by FieldServ, but rely on FieldServ to manage them. For non-FieldServ designated suppliers, they will require score card to manage quality, and delivery. Machines/equipment are not an issue for them. Can be turned off during bad time. Maybe these are old machines and have been fully depreciated.
## Appendix 6: Flexibility factor cross-case analysis result by research 1

<table>
<thead>
<tr>
<th>Factors mentioned in interviews</th>
<th>Supplier A</th>
<th>Supplier B</th>
<th>Supplier C</th>
<th>Supplier D</th>
<th>Supplier E</th>
<th>Supplier F</th>
<th>Supplier G</th>
<th>Supplier H</th>
<th>Supplier I</th>
<th>Supplier J</th>
<th>Significance (count of times mentioned)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dependency on oil and gas industry</strong></td>
<td>80% revenue comes from O&amp;G</td>
<td>100% O&amp;G</td>
<td>15% revenue from O&amp;G</td>
<td>Less than 10%</td>
<td>15% from oil and gas</td>
<td>100% oil and gas business</td>
<td>90% O&amp;G</td>
<td>33% O&amp;G</td>
<td>99% O&amp;G</td>
<td>99% O&amp;G</td>
<td>6</td>
</tr>
<tr>
<td><strong>Business diversification</strong></td>
<td>Diversified into different sectors of O&amp;G, some business from aerospace, transportation</td>
<td>15% revenue from O&amp;G</td>
<td>Less than 10%</td>
<td>15% from oil and gas</td>
<td>High level automation, shorter lead to 6-12 weeks</td>
<td>Yes</td>
<td>Automated process to cut lead time</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cut down lead time</strong></td>
<td>Invest in expensive cutting tools to shorten lead time</td>
<td>Invest in equipment, 10 years cut off period</td>
<td>High level of automation, shorter lead to 6-12 weeks</td>
<td>Yes</td>
<td>Keep minimum inventory</td>
<td>Does not carry much in bad time</td>
<td>5</td>
<td></td>
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</tr>
<tr>
<td><strong>Push inventory to vendors</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Do Not hold inventory</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Make to order</td>
<td>Make to order in bad time</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td><strong>Only start production until confirmed order (make to order)</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Make to order</td>
<td>Make to order in bad time</td>
<td>7</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Rely on Schlumberger to manager designated vendors</strong></td>
<td>Consider Schlumberger's forecast</td>
<td>Do Not rely on Schlumberger's forecast in bad time</td>
<td>Do Not rely on Schlumberger's forecast in bad time</td>
<td>Do Not rely on Schlumberger's forecast in bad time</td>
<td>Consider Schlumberger's forecast</td>
<td>Communicate about what to expect</td>
<td>7</td>
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<tr>
<td><strong>Leverage Schlumberger's forecast</strong></td>
<td>Consider Schlumberger's forecast</td>
<td>Do Not rely on Schlumberger's forecast in bad time</td>
<td>Do Not rely on Schlumberger's forecast in bad time</td>
<td>Do Not rely on Schlumberger's forecast in bad time</td>
<td>Consider Schlumberger's forecast</td>
<td>Communicate about what to expect</td>
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<tr>
<td><strong>Hedge on some specialty materials</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
</tr>
<tr>
<td><strong>Market insight team to understand market trend</strong></td>
<td>A few people</td>
<td>Rely on management team's experience to learn industry insights</td>
<td>Rely on management</td>
<td>Good understanding of the market dynamics</td>
<td>Business Intelligence team to monitor oil prices</td>
<td>Build up ability to understand market trend</td>
<td>Internal team will analyze oil indicator to ramp up</td>
<td>8</td>
<td></td>
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</tr>
<tr>
<td><strong>Flexible production shifts</strong></td>
<td>3 shifts, 24 hours a day, 6 days a week</td>
<td>Flexible shifts</td>
<td>4 shifts, factory runs 24 hours 7 days a week if needed</td>
<td>Flexible</td>
<td>4</td>
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<tr>
<td><strong>Systematic training program</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>On site trainer in place</td>
<td>On contract labor</td>
<td>Machinist are protected</td>
<td>5</td>
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<tr>
<td><strong>Competitive compensation to retain workforce</strong></td>
<td>Specialized product requires 10 years experience</td>
<td>On contract labor</td>
<td>Machinist are protected</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>3</td>
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<tr>
<td>Factors mentioned in interviews</td>
<td>Supplier A</td>
<td>Supplier B</td>
<td>Supplier C</td>
<td>Supplier D</td>
<td>Supplier E</td>
<td>Supplier F</td>
<td>Supplier G</td>
<td>Supplier H</td>
<td>Supplier I</td>
<td>Supplier J</td>
<td>Significance (count of times mentioned)</td>
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<tr>
<td>Direct shipping to customer</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Innovation</td>
<td></td>
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<td>Flexible workforce</td>
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<tr>
<td>Define core workforce which can Not be cut</td>
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<tr>
<td>Experienced management</td>
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<tr>
<td>Global manufacturing footprint</td>
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</tr>
<tr>
<td>Corporation history with Schlumberger</td>
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<tr>
<td>Manufacturing near shore</td>
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<td>6</td>
</tr>
<tr>
<td>Unionsized workforce</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>8</td>
</tr>
<tr>
<td>Manage supplier risks</td>
<td>Rely on Schlumberger to manage designated suppliers</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Increased coordination</td>
<td>Diversified into different sectors of O&amp;G, some business from aerospace, transportation</td>
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<td>4</td>
</tr>
<tr>
<td>Did not leave suppliers with excess raw material</td>
<td>Invest in expensive cutting tools to shorten lead time</td>
<td>Invest in equipments, 11 years cut off period</td>
<td>High level automation, shorten lead to 6-13 weeks</td>
<td>Yes</td>
<td>Automated process to cut lead time</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Keep low margin to attract volume</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Do Not hold inventory</td>
<td>Keep minimum level inventory</td>
<td>Does Not carry much in bad time</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ability to react on information</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Make to order</td>
<td>Make to order in bad time</td>
<td>7</td>
<td></td>
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</tbody>
</table>
### Appendix 7: Flexibility factor cross-case analysis result by research 2

<table>
<thead>
<tr>
<th>Factors mentioned in interviews</th>
<th>Suppliers Interviewed</th>
<th>Significance (count of times mentioned)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supplier A</td>
<td>Supplier B</td>
</tr>
<tr>
<td>Oil dependency</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>Diversification to non-oil &amp; gas</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Diversification within Oil and gas</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Private vs Public</td>
<td>Private</td>
<td>Private</td>
</tr>
<tr>
<td>Experience of management team</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Flexibility (alternating facilities/outsourcing)</td>
<td>custom</td>
<td>custom</td>
</tr>
<tr>
<td>Custom/standard product</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Will you charge Schumacher for Order cancellation</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Capacity utilization - good times</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Capacity utilization - bad times</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Internal Ramp readiness plans</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Factors mentioned in interviews</th>
<th>Suppliers Interviewed</th>
<th>Significance (count of times mentioned)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Supplier A</td>
<td>Supplier B</td>
</tr>
<tr>
<td>Unionised</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Labor flexibility</td>
<td>Yes</td>
<td>yes</td>
</tr>
<tr>
<td>Partnership with suppliers</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Flexible contract with suppliers</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Negotiability (offer discounts)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Dependency on forecasts from Schikunberger</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Partnership with Schikunberger</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Inventory availability bad times</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Inventory availability good times</td>
<td>High</td>
<td>Medium (high lead times)</td>
</tr>
<tr>
<td>Business intelligence</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Training system for new hires</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Labor/Capital intensive</td>
<td>Labor</td>
<td>Capital</td>
</tr>
<tr>
<td>Lead time reduction</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Central Warehouse</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>S&amp;OP</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Appendix 8: Altman Z-score algorithm

\[ Z = 1.2X_1 + 1.4X_2 + 3.3X_3 + 0.6X_4 + 0.999X_5 \]

\[ X_1 = \frac{\text{Current Asset} - \text{Current Liability}}{\text{Total Asset}} \]

\[ X_2 = \frac{\text{Retained Earnings}}{\text{Total Asset}} \]

\[ X_3 = \frac{\text{Earnings before interest and tax}}{\text{Total Asset}} \]

\[ X_4 = \frac{\text{Market Value of Equity}}{\text{Total liability}} \]

\[ X_5 = \frac{\text{Sales}}{\text{Total Asset}} \]

In the Altman Z-score model, if a company scores lower than 1.8, it is in the “Distress” zone. While a company scores between 1.8 and 2.99, it is in “Grey” zone. A company scores higher than 2.99, it is in the “Safe” zone. By leveraging this model, we could effectively predict which suppliers have higher chance to suffer financial distress.
Appendix 9: Survey questions

*1. How do you rank the following factors in their order of importance that lead to an organisation's flexibility to adapt to changing market conditions?

<table>
<thead>
<tr>
<th>Business portfolio diversification to non-oil and gas sectors</th>
<th>Unimportant</th>
<th>Of Little importance</th>
<th>Moderately Important</th>
<th>Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to reduce raw material purchasing lead-time</td>
<td></td>
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<tr>
<td>Ability to production lead-time</td>
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<tr>
<td>Ability to reduce delivery lead-time</td>
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<tr>
<td>Inventory flexibility (policy to keep buffer inventory in good times vs. lean inventory in bad times)</td>
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<tr>
<td>Strong financials/Positive cash position</td>
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<tr>
<td>Experience of the management team</td>
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<tr>
<td>Labor flexibility (ability to hire and fire)</td>
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<tr>
<td>Systematic hiring and training infrastructure to bring workforce up to speed when needed</td>
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<tr>
<td>Dedicated business intelligence team to monitor oil and gas trends and macroeconomic factors</td>
<td></td>
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<tr>
<td>Information sharing and joint business planning with customers</td>
<td>Unimportant</td>
<td>Of Little importance</td>
<td>Moderately Important</td>
<td>Important</td>
<td>Very Important</td>
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<tr>
<td>---------------------------------------------------------------</td>
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<tr>
<td>Information sharing and joint business planning with sub-suppliers</td>
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<tr>
<td>Flexible contracts with sub-suppliers</td>
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<tr>
<td>Procurement flexibility</td>
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<tr>
<td>IT investments in supply chain-EDI, real time information sharing</td>
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<tr>
<td>Logistics flexibility( alternate transportation modes)</td>
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<tr>
<td>Production flexibility- ability to add shifts, presence of interchangeable resources and locations</td>
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<tr>
<td>Ability to reduce prices through innovations and technology</td>
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<tr>
<td>Culture of the organization and management</td>
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<td></td>
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<tr>
<td>Trust and shared vision across supply chain partners</td>
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</tr>
</tbody>
</table>

2. Could you think of any other factors, which you believe, are contributing to supply chain flexibility in your company which did not appear in the list in first question?
Appendix 10 Flexibility assessment tool

**Introduction**

**Background**

Oil and gas industry is a very volatile industry, characterized by unpredictable cycles of sharp rises and plunges in oil prices. This cyclical nature presents a huge challenge for companies that are operating in the industry. Companies have to be able to ramp up their production quickly so that they have enough capacity to meet increasing demand when oil prices go up and be able to survive when oil prices go down. In this context, understanding what factors contribute to flexibility is crucial.

To better understand what are the key flexibility factors and how to leverage these factors to improve suppliers' flexibility, FieldServ and MIT conducted a research project. This tool is designed to share the research findings of the project. The tool will provide an assessment regarding suppliers' flexibility performance. However, the result of the assessment will not be used to decide business allocation. It will serve the purpose of increasing suppliers' awareness of flexibility and ideally helps suppliers to work better in the oil and gas industry.

**Supplier flexibility framework**

Through the research project, 29 flexibility factors have been identified and are grouped into two categories, namely (i) core supply chain functions (ii) key support functions. Core supply chain functions are sub-divided into four sub-groups, namely (i) procurement (ii) manufacturing and operations (iii) distribution and logistics (iv) collaboration and integration. Key support functions are sub-divided into (i) finance (ii) human sources (iii) research and development (iv) knowledge and expertise (v) business portfolio (vi) ownership and culture.

These factors are considered critical for companies' flexibility. As shown on the right, we called this flexibility assessment framework House of Supplier Flexibility.

**How to use the tool**

This tool has four sections.

- The first section introduces the background of the tool and how to use it.

- The second section is the self-reporting section where a supplier rates itself against each factor in the questionnaire. It asks suppliers to rate their flexibility performance for each factor on a scale of one to five, where one means least flexible and five means most flexible. After providing a self-reported score for each factor, suppliers have to further answer the corresponding questions for each factor and provide evidence whenever they are required.

- The third section is the auditable section and is designed to be used exclusively by purchasing category managers of FieldServ. Purchasing category managers will be asked to provide their own judgment of flexibility performance of suppliers against each factor according to suppliers' responses and evidences. Purchasing category managers are also recommended to conduct sample on-site audits to evaluate the validity of suppliers' responses.

- The fourth section contains the results dashboard, which compares the self-reported scores of suppliers with the scores given by category purchasing managers. After sufficient amount of suppliers completed this survey. It is also valuable to compare different suppliers' performance on the dashboard in section four.
### 1. Supplier basic information

<table>
<thead>
<tr>
<th>Supplier name</th>
<th>Supplier Website</th>
<th>Supplier Address</th>
<th>Contact Person</th>
<th>Contact Email</th>
<th>Contact Phone</th>
</tr>
</thead>
</table>

### 2. Supplier flexibility information

<table>
<thead>
<tr>
<th>Flexibility Categories</th>
<th>Factor Name</th>
<th>Factor Description</th>
<th>Self-assessment Score (1-5)</th>
<th>Questions and evidences</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procurement</td>
<td>Procurement flexibility</td>
<td>The ability of the supplier to source a component from multiple suppliers increases its flexibility</td>
<td></td>
<td>What percentage of your total spend are sole-sourced?</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>What percentage of your total spend are sourced globally?</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>What percentage of your total spend are sourced locally?</td>
<td></td>
</tr>
</tbody>
</table>
Reducing raw material purchasing lead-time will improve suppliers' flexibility. Flexible supply agreements with sub-suppliers ensure raw material supply at the minimum risk.

<table>
<thead>
<tr>
<th>Ability to reduce raw material purchasing lead-time</th>
<th>Reducing raw material purchasing lead-time will improve suppliers' flexibility</th>
<th>Do you take initiatives to reduce raw material purchasing lead-time? Please give examples.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract flexibility</td>
<td>Flexible supply agreements with sub-suppliers ensure raw material supply at the minimum risk</td>
<td>Do you have a history of lead-time reduction with sub-suppliers? Please give examples.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What type of contracts do you employ with your suppliers?</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Do you have experience using flexible contracts, such as time-flexible contract, quantity-flexible contract, with your suppliers? Please give examples.</td>
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<tbody>
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<td>Contact Person</td>
<td>Contact Phone</td>
</tr>
<tr>
<td>Contact Email</td>
<td>Customer assessment score</td>
<td>Customer assessment score</td>
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</tbody>
</table>

Supplier Flexibility Evaluation-Customer Version
## 2. Supplier flexibility information

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Bibliography


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http://doi.org/10.1016/j.jom.2010.07.007


