Future Scenarios for Green Chemical Supply Chains

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Abstract

We live in an age where industrial chemicals are central to the modern economy serving as the basis for all man-made fibers, life-science chemicals and consumer products. Owing to globalization, the industry has grown to extend its presence all over the world. Given the heavy manufacturing base and large distribution networks, the underlying supply chains are a critical component for the chemical industry.

The chemical industry is capital intensive and most strategic decisions taken by firms in this industry have long-term impacts. As such, any uncertainty in the environment that affects these strategic decisions in supply chains needs to be understood before committing to the assets. In particular, sustainability related concerns have risen in importance in the past decade, and are likely to be important in the next decade (and beyond).

In this thesis, we use scenario planning to understand the impact of sustainability related factors on Chemical supply chains for the year 2025. Using the literature in the field of long-range planning for the chemical industry, supply chain sustainability and scenario planning, and interviews with several experts in industry and academia, we developed three scenarios that we feel will be most applicable to understand the implications of a rather ambiguous issue of "sustainability" for chemical supply chains.

Each of the three scenarios offers our end users –planners in the corporate supply chain strategy group – a framework to think about a complete and consistent set of world views regarding sustainability in which the industry must thrive.

Acknowledgements

We would like to express our gratitude to our supervisor Dr. Shardul Phadnis for his guidance and engagement through the last year in spite of his demanding schedule. We greatly benefited from his deep knowledge of scenario planning and learnt valuable lessons in asking the right questions and being independent and original in our research. We'd also like to thank our thesis sponsor at BASF, Dr. Inga-Lena Darkow, who showed immense patience in guiding us through the scenario brainstorming sessions over several teleconferences from Germany. We remain very grateful for all we have learnt from both of them. We would also like to thank the participants in our survey, who have willingly shared their precious time during the process of interviewing.

Sekhar & Vibhu

I wouldn't be here at MIT if not for the support of my young family, my parents and in-laws. Mom, Dad, Uncle and Aunty - I will forever be thankful for the sacrifices you made the past year to be with us and support us during this time. I cannot thank Aparna enough for her superhuman effort during my absence to keep the family afloat – I am eternally grateful. To my son Gautham, I am sorry I was away during such a wonderful phase of your life – you were always in my thoughts. Finally, thanks to all my friends and well-wishers who cheered for me and helped me along the way. It was an amazing journey!

Sekhar Putcha

None of this would have been possible without the unconditional support of my parents and my sister. They have been standing like a rock through the years and I will always be grateful for their untiring efforts and sacrifices.

Vibhu Arora

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1 Introduction

Strategic planning is a key requirement for a business to survive and thrive well in the future (Porter, 1996). However, a major challenge in formulating such a strategy is that it needs a reasonably accurate mechanism for predicting the future. This is difficult to do so as the key business drivers for organizations are becoming harder to predict in the fast changing global economy. In particular, the issue of sustainability is rapidly evolving and would be critical for future business decisions. Despite the popularity of the topic, the business implications of "sustainability" are still not understood completely, and its future influences are even more unpredictable. Given this prevailing ambiguity and uncertainty, it is difficult for businesses to plan a long-term supply chain strategy that supports the business' 'sustainability' goals.

One of the techniques used by business leaders across the world for long-range planning is 'scenario planning'. Although scenario planning has been used successfully in the military, it has only recently (since early 1970s) emerged as an important thinking tool for businesses to visualize a picture of the future and plan proactively for it (Wack 1985; Linneman & Klein 1983). Scenario thinking is different from the usual short-term forecasting that managers use for day-to-day business decisions, in that short-term forecasting aims to predict the future by linearly interpolating from the past events. On the other hand, scenario thinking allows one to think beyond the usual linearity bias that guides most routine business continuity decisions (Figure 1).

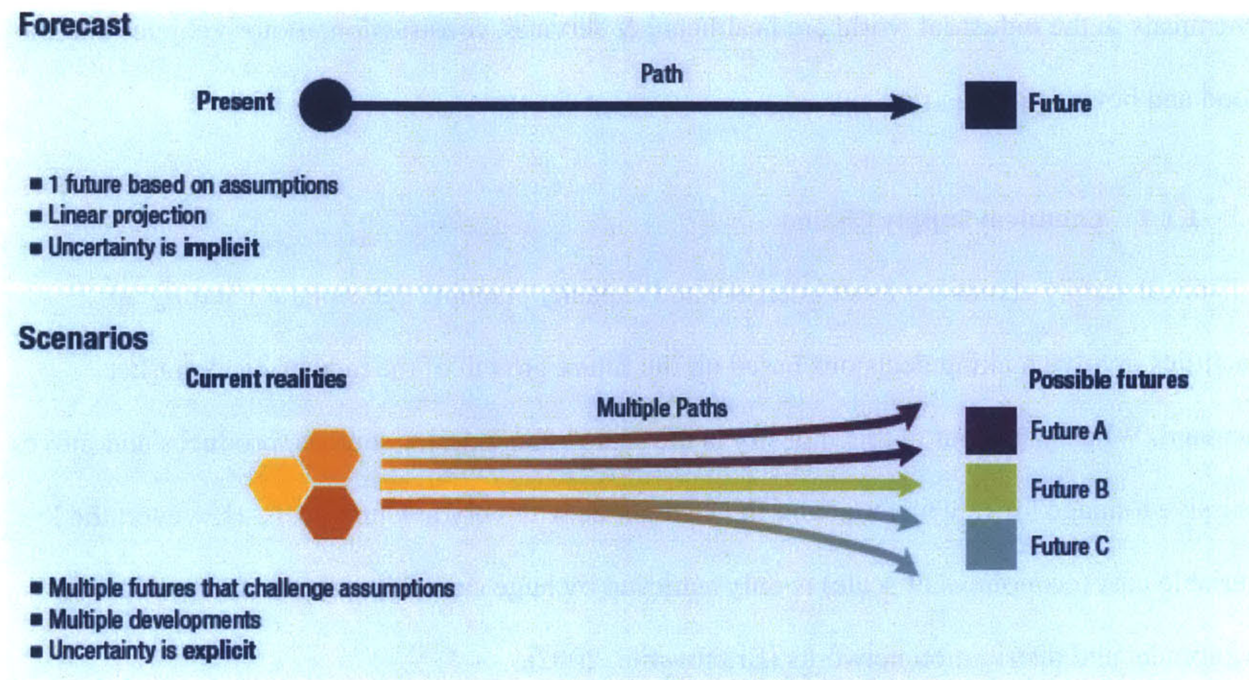

Figure 1: Forecasting vs. Scenario Thinking

[Source: WEF Metal Mining Scenarios 2030]

The key objective of this thesis is to use scenario techniques for characterizing the uncertainty in sustainability related factors for chemical supply chains. The time horizon for creating the scenarios is 10-15 years into the future or a time close to 2025.

1.1 The Chemical Industry

One of the fundamental drivers of the modern economy, the chemical industry has been growing at a healthy rate of approximately 7% since the mid 1980's to reach USD 3 trillion. In a recent report on Chemical Industry, AT Kearney (2012) projects that the total size of the global chemical industry will double and cross USD 6 trillion by 2030. It is hard to find any industry which is not served by the chemical industry in some manner. The biggest consumers of chemicals in the industrial world are healthcare & services, construction, motor vehicles and the food and beverage industries.

1.1.1 Chemical Supply Chains

Chemical supply chains are asset intensive and capacity planning decisions for setting up facilities involve making decisions based on the future growth of the industry and market demand. What stands out in this industry is the scale – the industry sources, produces and moves massive tonnage for raw material and finished goods with very low unit costs. However, the low variable cost (economies of scale) is only achieved by huge capital investments in production equipment and distribution networks (Braithwaite, 2002).

1.2 Sustainability considerations in chemical supply chains

Given the scale of the chemical industry, it has a huge impact on the resources of this planet and thus has a very tangible impact on our natural environment. The European Chemical Industry Council outlined its vision (Mandery, 2012) where this sector will play a vital role in ensuring that by the year 2050, a projected 9 billion people live well within the resources of the planet. However, in the context of sustainability, the industry is heavily dependent on a non-renewable source – crude oil derivatives – as its principal raw material as well as the source of energy. Furthermore, occasional leaks and spills from chemical plants have a detrimental effect on the environment. At the same time, chemical companies are uniquely positioned to incorporate sustainable practices across their entire value chain from procurement to distribution to the entire life cycle of their product. Being a basic industry, it supplies the primary inputs that go into manufacturing most products. Thus, it has the potential for reducing the environmental impact of most value chains right at the very beginning by utilizing environment friendly production practices such as closed-loop manufacturing (Mandery, 2012).

1.3 Research Question

Most sustainability initiatives in the chemical industry tend to focus more on the products themselves – such as chemicals, paints, agro chemicals – and aim to reduce the environmental impact of individual products. Over the last decade, there has been a strong R&D focus on designing and manufacturing more environmentally friendly products throughout their cradle-to-grave lifecycle. While this is a good start, focusing sustainability efforts merely on product manufacturing cannot address the complete impact of chemical industry on the planet. It is important that sustainability efforts be focused on the *entire* supply chain in order to have the maximum overall impact since they extend across multiple product lines and run across the globe. For our research, we have focused exclusively on chemical supply chains. We have attempted to take a deeper look at sustainability in the chemical industry and to understand its impact on the design and evolution of future chemical supply chains.

The research question that we have aimed to answer is as follows –

"What scenarios can facilitate strategic thinking in the context of sustainability for global chemical supply chains for the year 2025?"

1.4 Thesis Outline

The research was carried out in three phases – literature review, methodology development and scenario creation.

For the literature review, two key aspects were studied. First, we attempted to understand the meaning of the term 'sustainability' within the context of our thesis. Second, we surveyed existing scenario planning techniques in order to identify the best suited approach for our research. Subsequently, in the methodology section we elaborate on our approach of identifying the key driving forces and developing multiple scenarios for the chemical industry in the context of sustainability. A total of seven key driving forces were identified. Based on our methodology, we chose *consumer behavior* and *transportation modality* as the two critical uncertainties for constructing the scenarios. Subsequently, the results of the scenario creation exercise are presented in the form of three plausible scenarios for 2025.

Finally, we have provided probable directions for future research and how our work can be applied to help formulate strategy for long range planning.

2 Literature Review

Long-range planning for sustainable chemical supply chains is a relatively nascent field. Most of the literature available explores both the short-term challenges facing the chemical industry and mega-trends that are likely to shape the industry in the coming years. While there is an abundance of literature acknowledging the importance of sustainability in an industry that has a direct environmental impact in terms of sourcing and production, there is relatively little attention paid to the supply chain as a whole and how it will evolve. In particular, there is a dearth of future scenarios that can help explore the question we started out to address.

In the next few sections, we survey the existing literature related to the issue of sustainability in chemical supply chains and long-term strategies to cope with uncertainties arising from the relevant factors. In addition, we also explore multiple approaches to scenario planning, with an emphasis on understanding different methods for developing scenarios.

2.1 What is Sustainability?

Sustainability can mean different things to different people. It is important for us, as researchers, to establish what we mean by the term "sustainability" in our thesis. We begin with a broad definition of sustainability and through the rest of this section we lay out our framework for understanding sustainability in the context of chemical supply chains.

In a broad sense, the notion of 'sustainability' refers to the capacity to endure or carry on for the future. One of the best examples of sustainable systems is tropical rainforests. As a system, they provide resources to sustain life for all the stakeholders (different species) in it for a very long period of time. The tropical rainforests have flourished on the planet and have been increasing their biodiversity for hundreds of millions of years. In other words, a sustainable system remains thriving and productive over a long period of time for all the participating stakeholders.

In the context of a global economy, the idea of sustainable growth considers environment, society & economy to be three key elements of a concentric nested system. (Hutchinson, Mellor & Olsen, 2002)

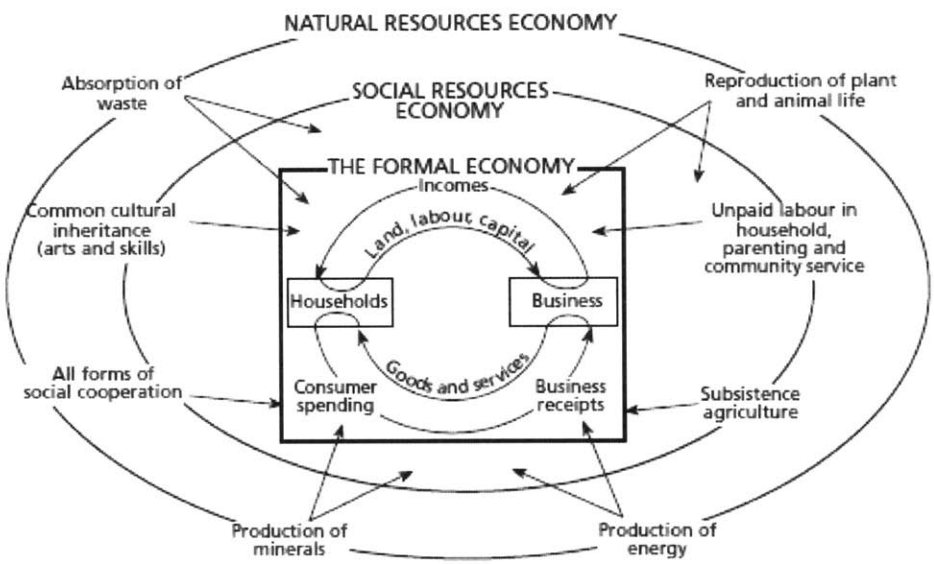

Figure 2: A Pictorial Representation of a Sustainable Ecosystem in the Modern Economy

[Source: Hutchinson, Mellor and Olsen (2002), The Politics of Money: Towards Sustainability and Economic Democracy]

Figure 2 illustrates how society and business are arranged hierarchically in a sustainable ecosystem. In such a system the formal global economy (trade & commerce) is considered to be enclosed in the envelope of 'society' which in turn is enclosed in the envelope of 'environment'. This simplistic model goes on to suggest that the working of the formal trade and commerce economy is dependent on the structure of the society which in turn is dependent on our natural environment. For our research, looking at sustainability from these three perspectives was crucial to zero down on the major driving forces. A brief discussion on these viewpoints is presented below.

2.1.1 Environment View of Sustainability

The most common perception of sustainability is that it is *most* related to our natural environment. One approach to study sustainability in this context is to observe the changes in the earth's environment over time to understand the evolution of our understanding of sustainability. In their research, O'Riordan and Rayner (1991) identify four categories to help better characterize the broad subject of global environmental change. These are: biospheric change, climate change, changes in basic human needs and changes caused by long-term effects of micro pollutants. In order to confront the issue of global environmental change they propose for *sustainable development* as the final recourse of a three stage process, the first two being damage prevention of change and adaptation to change.

Even though the concept of sustainable development sounds intuitive, it is often not easy to incorporate it into long range planning and policy decisions. Guest (2009) describes the problem of designing a future looking policy for sustainably using the joint environmental resources of the world, such as air or water, to be subjected to "prisoner's dilemma" effect. This means that even though all the players on the planet have a clear incentive to cut down on environmental damage, no one wants to risk being the only one.

2.1.2 Social View of Sustainability

From the perspective of society, the term 'sustainability' has largely been interpreted in the context of inter-generational equity. This interpretation of sustainability implies that opportunities and resources left for the future generations should not be any lesser than the preceding generations. Howarth (1995) explored this notion of inter-generational equity and suggests that when it comes to distributing the fruits of welfare amongst present and the future generations, sustainability considerations should be the key inputs to the decision making. Guest (2009) attempts at characterizing human welfare by two societal models: one with attempts to curb environmental damage and one with unhindered growth. In his analysis of these two models, he indicates that over a long time horizon, human well-being (y-axis in figure 3) is better when attempts have been made to curb or abate environmental damage. He shows that the human well-being reaches an inflection point if there are no efforts to mitigate the damage caused by the current state of global development.

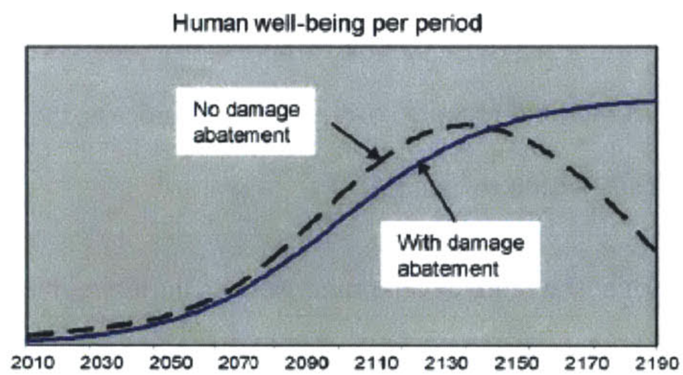

Figure 3: Choosing a Path for Well-being

[Source: Guest (2009), The economics of sustainability in the context of climate change: An overview]

2.1.3 Business View of Sustainability

As an entity working to serve people and the society, businesses are even more complex systems which are dealing with a dynamically evolving concept of sustainability. Diwekar (2005) describes that sustainable efforts start from 'green process design' (an environment friendly and waste minimizing approach) in individual business units which involve relatively simpler decision making (usually a single-objective optimization problem). As the scope of the system is increased to industry-level, the decision making, management and planning become difficult due to the increase in complexity. Finally at the global level, sustainable business systems encompass significant uncertainties and constraints and most single objective problems (such as maximizing profitability) to turn into multi objective problems (such as maximizing profitability, ensuring long-term growth and compliance with global regulations).

Attempting to address this structural uncertainty for sustainability, Bernal and Zografos (2012) propose an 'eco-integrated methodology for managing structural uncertainty'. They allude to a systems modeling approach for multi-objective decision making wherein describing the system itself is significantly more useful than the individual turn of events. Their research suggests that undertaking sustainability initiatives might be more complicated than anticipated since many aspects of business are inherently interlinked.

The preceding discussion leads to the question "If sustainable initiatives are so hard to understand and implement, is it really worth for businesses to invest in them?" In a recent survey of executives all around the globe, McKinsey & Company (2011) attempted to explore how firms are tackling the issue of sustainability. The survey reports that most companies are now addressing sustainability issues to reduce costs and to align efforts with the company's goal and vision as opposed to merely serving as an instrument for enhancing corporate reputation. The respondents to the survey also noted that 57% of companies are including sustainability considerations in their core business and strategic planning. According to their research, managers in companies that are leaders in sustainability believed that sustainability efforts strengthen the competitive position of their firms. In addition, 53% of the respondents stated that sustainability efforts are important in employee retention and engagement.

2.2 Uncertainty in Sustainability Related Factors

Not only does sustainability related factors and issues have long-term implications but also they are highly uncertain to characterize. Dovers and Handmer (1992) maintain that when dealing with the topic of sustainability, it is important to keep the "total system" notion in mind. Such allusions to systems thinking strongly indicate the ambiguous nature of measuring the impact of sustainability related policies and decisions.

The terms which are commonly related to or are used as a proxy for sustainability such as energy efficiency, carbon footprint, green production etc. are themselves quite broad and their long range impact on the overall issue of sustainability are difficult to quantify. In a more general sense, the expectations around the organization's responsibility towards sustainable practices have also been changing over time. Even for any organization interacting with our ecosystem (economy, society and environment) there is a great deal of uncertainty.

Asselt (2000), characterizes two particular sources of uncertainty: variability and limited knowledge (Figure 4) in his book *Perspectives on Uncertainty and Risk - The PRIMA Approach to Decision Support*.

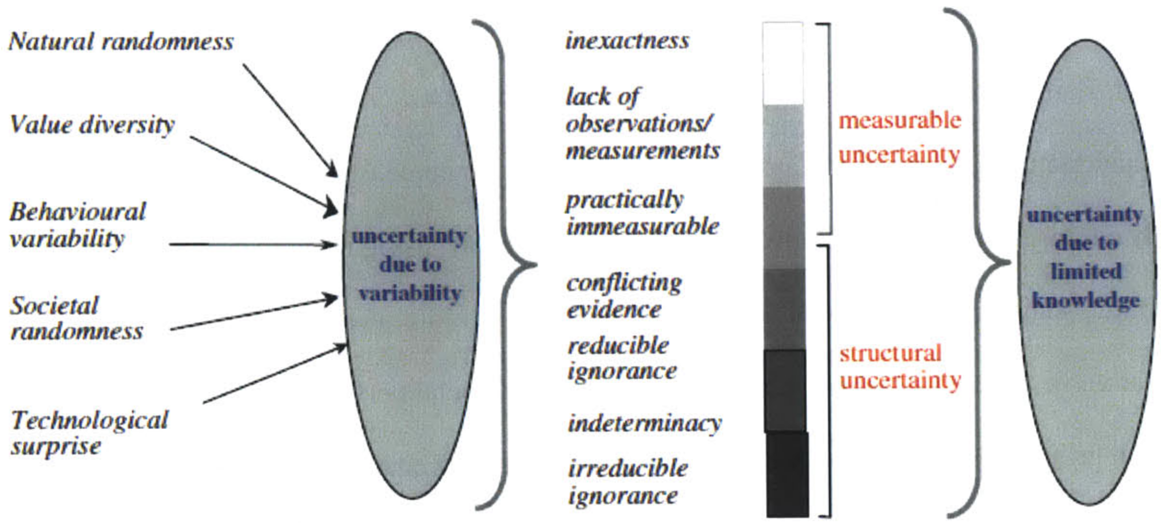

Figure 4: Sources of Uncertainty

[Source: Asselt (2000), Perspectives on Uncertainty and Risk - The PRIMA Approach to Decision Support]

2.3 Sustainable Supply Chain Management

The intersection of sustainability and supply chain management is the key theme of this research. Supply chains have a direct impact on the sustainability footprint of goods and products manufactured with core activities ranging from raw material procurement to final transportation of finished goods. In extension to the commonly held notion of a sustainable supply chain, Linton, Klassen and Jayaraman (2007) argue that the entire supply involved during the production, consumption, end-of-life disposal of products should be considered while designing a sustainable supply chain. More generally speaking, sustainable supply chain design goes beyond the 'current production costs' and incorporates the 'total lifetime costs' that are incurred over the entire lifetime of a product from manufacture to usage to disposal.

A logical concern that arises at this point is whether or not it benefits an organization to invest in sustainability. It is important to grasp this implication since a large number of benefits or gains of sustainable initiatives are perceived to be intangible or have very long-term payoffs. As a case in point, Zailani, Jeyaraman, Vengadasan and Premkumar (2012) conducted a survey amongst 400 manufacturing firms in Malaysia to understand the outcome of sustainable practices on supply chains. They found that environmental friendly purchasing in these firms increased the economic, social and operational performance and furthermore, investing in greener packaging alternatives improved the environmental, economic and social performance of these firms. Their research provides empirical evidence that sustainable supply chains can bring tangible value addition to an organization.

2.4 Supply Chain Strategy for Chemical industry

Supply chain costs in the chemical industry represent a larger share of net value added than do costs in other industries like building materials, automobiles, or paper (McKinnon, 2004). As such, the short-term strategy has focused on addressing cost pressures arising from fluctuations in commodity and energy prices, which in turn, have a direct impact on sourcing and logistics costs. More recently, supply chain strategy papers have centered on mitigating transportation risks to the distribution network arising from environmental catastrophes, security breaches, political unrest and labor issues (US Resilience Project, 2011). In addition, recent industry survey participants have cited volatile customer behavior, security of supply, consumer growth in developing economies as important trends that warrant attention (Baker 2012).

Long-term strategy has also highlighted concerns in the environmental, political, technological and social spheres such as tightening of environmental controls, availability and price of oil and consumer perception of the chemical industry (McKinnon, 2004).

While we derived a lot of our data from existing scenario studies related to sustainability and supply chain strategy, we did not encounter any scenario studies that focused exclusively on sustainability related factors and their impact on supply chains. The final output of our study is a framework to think about not just the risks but also the opportunities that arise from uncertainty related to sustainability factors.

2.5 Scenario planning

Scenario planning techniques have recently grown in popularity among academic and industrial practitioners. As we seek to establish the current state of techniques for long-range strategic planning, we explore the evolution of scenario planning as one of the more popular long-range planning tools in use today. We begin with a history of scenario planning over the last few decades and move on to examine best practices which increase its utility within a large organization.

There have been several variations of scenario planning related methodologies including scenario building and scenario thinking. Some extensive reviews of the literature in this field acknowledge a 'methodological chaos' related to scenario studies (Varum and Melo, 2010). Given the plethora of methods to approach scenario planning we aimed not only for an academic rigor in our methodology but also sought for a useful result which has practical utility for the industry.

Bradfield, et al., (2005) detail broad definitions and different methodologies that make up the field of scenario planning. In their review paper, they classify scenario planning into two major schools - intuitive-logics and probabilistic modified trends (PMT).

Both these papers, (Bradfield, et al., 2005; Varum and Melo, 2010) present recent attempts at surveying the state of the scenario planning landscape. In these studies, some of the main motivations behind scenario planning are to aid managers in decision making and to help understand a firm's interaction with the external environment. The authors performed an extensive review of the scholarly scenario planning literature to draw conclusions about which way the field was gravitating. They note a trend towards empirical research in the field indicative of strong real-world experiences of many of the participating authors.

Pierre Wack, who was one of the staff members at Royal Dutch Shell (RDS) created the pioneering scenario studies for the company. In addition to detailing the scenario creation process, Wack focuses on how to derive the most value out of scenarios for the company (Wack, Sep-Oct 1985). In this paper, he addresses the mechanics of scenario creation process such as the level of detail contained within a scenario and sorting out pre-determined elements from uncertainties. More importantly, there is a strong focus on tuning the scenario creation process to make it useful to senior leadership. For example, Wack talks about the importance of the "surprise-free" scenarios – its sole purpose being to sound less threatening to members of a management audience. He describes that at Shell, the scenario creation process had two phases – an exploratory phase and a subsequent phase that involved creating two families of polar scenarios. Recognizing that each individual operated in his or her own micro world, Wack advocates the importance of securing a buy-in for the scenarios within that micro context. Only then could that individual appreciate and utilize the power of scenarios. Thus, in a nutshell, the goal of scenarios is not necessarily to test their 'accuracy' but to use them as tools to challenge managerial thinking – especially in large organizations that usually see only small incremental changes over time ~~but~~ and are susceptible to seismic shifts from internal or external factors.

In a follow-up paper in Harvard Business Review, Wack delves further into the topic of ensuring that scenarios become ultimately useful as decision making tools (Wack, Nov-Dec 1985). He focuses on the "interface" between decision makers and the scenarios themselves. He observes that merely quantifying alternative outcomes is not enough. The idea is to gather factual information of strategic significance that can ultimately affect the perceptions of a manager operating in a given environment. Scenario thinking requires understanding the impact of driving forces on the business rather than the prediction itself. While it is important for managers to understand the forces underlying the business environment to protect against risk of failure, the greater utility is in using scenarios to make clear previously unrecognized growth opportunities.

2.6 Summary and Key Definitions

Over the course of last two chapters we have laid out the problem definition and a brief overview of the current state of literature on sustainability, supply chains and scenario planning. We have discussed the principle idea behind the use of scenarios – as "thinking tools" – which served as a guide throughout.

Before moving ahead to subsequent sections, we want to simplify a few definitions which are frequently encountered in our dissertation.

2.6.1 Definitions

Scenario: Carefully constructed plots that make the significant elements of the world scene stand out boldly. (Shwartz 1991)

Focal Issue: This is the key question that drives the entire scenario creation process. (Bradfield, et al.,2005)

Scenario Creation: This refers to the mechanics of creating scenarios for use in long-term planning.

Scenario planning: This includes creating and monitoring scenarios and using scenarios as thinking tools in strategic planning.

Driving Force: A dominant influence in the social, technological, political, economic or environmental arena that helps shape the future.

Key Local Factor: Decision levers that are found closer to the internal business – external surroundings boundary

Polarity: An extreme manifestation of a particular driving force. Example: High political stability vs. low political stability.

Uncertainty: A measure of unpredictability about what polarity a driving force may take in the future under consideration.

Scenario Axes/Critical Uncertainty: A driving force that is high in impact and uncertainty and likely to play a major role on the evolution of the focal issue.

Impact: The importance level of a particular driving force in determining the future.

Scenario Set: A set of 3-4 scenarios that are internally consistent and based upon two critical uncertainties. All Scenarios in a set are related because they all are built using the same set of driving forces (Phadnis, 2012).

Stakeholders: Participants from the industry and academia who are directly impacted by changes in the global realities with respect to the focal issue.

3 Methodology

In this section, we present an overview of existing scenario creation techniques, their advantages and disadvantages within the context of this study and finally, details of our adopted methodology and its evolution with respect to mainstream practices. The final output of this study (presented in the next chapter) is a set of scenarios that can help answer our research question.

3.1 A basis for adopting a methodology

As mentioned in section 2.6, we intend our scenarios to be a management tool to 'better understand how the future may unfold in different ways in order to inform strategic planning (Wright, Bradfield and Cairns, 2012). Our research question addresses a specific sliver of the chemical industry – that of sustainability in chemical supply chains. Accordingly, our methodology evolved with the goal of enabling future scenario users to focus on the sustainability aspects of divergent futures. To that end, we avoided traditional approaches based exclusively on quantitative data or on qualitative interviews. Instead, we settled on a hybrid methodology (Kalmbach, Bernhart, Kleimann and Hoffmann, 2011) based on research and interviews with experienced professionals in industry and academia followed by iterative cycles to review and refine scenarios with experts in the field of scenario development.

3.2 Popular Scenario Creation Techniques

Creating future scenarios can be deceptively simple but in practice is a complex and rigorous process. Since both the future and the mechanics that drive it are 'unknown and unknowable'

(Klooster and Asselt, 2005), it is relatively easy to come up with scenarios that can essentially never be deemed improbable or unreasonable. This can severely undermine the goal of scenario creation as an aid in strategy development. We surveyed prevailing scenario development techniques to find the most appropriate for our research. The most commonly used scenario creation method is based on the Intuitive Logics School (ILS), which attained popularity when used successfully by Shell Corporation (Bradfield et al., 2005). The ILS approach has been credited with having "the right mix of technical sophistication and ease of use for a professional audience" (Bishop, Hines and Collins, 2007). In the ILS method, scenarios are part of a *set* and are not just stand-alone interpretations of the future. Our methodology is adaptation of a generic outline for creating scenarios for strategic planning (Schwartz, 1991) also known as the scenario axes technique (Klooster and Asselt, 2005).

3.3 Methodology Outline

In surveying prevailing techniques, we found that the scenario axes technique offered a reliable and straightforward high-level framework for building future images of a world in a "coherent and systematic way" (Klooster and Asselt, 2005). This approach requires the scenario creator to identify two "critical uncertainties" from among a set of important driving forces most relevant to the focal issue (Figure 5). These two identified critical uncertainties will become the backbone or the axes that define a scenario set. Since each critical uncertainty can assume two polarities, each combination of the two – which compute to four – becomes the basis for one of four possible scenarios.

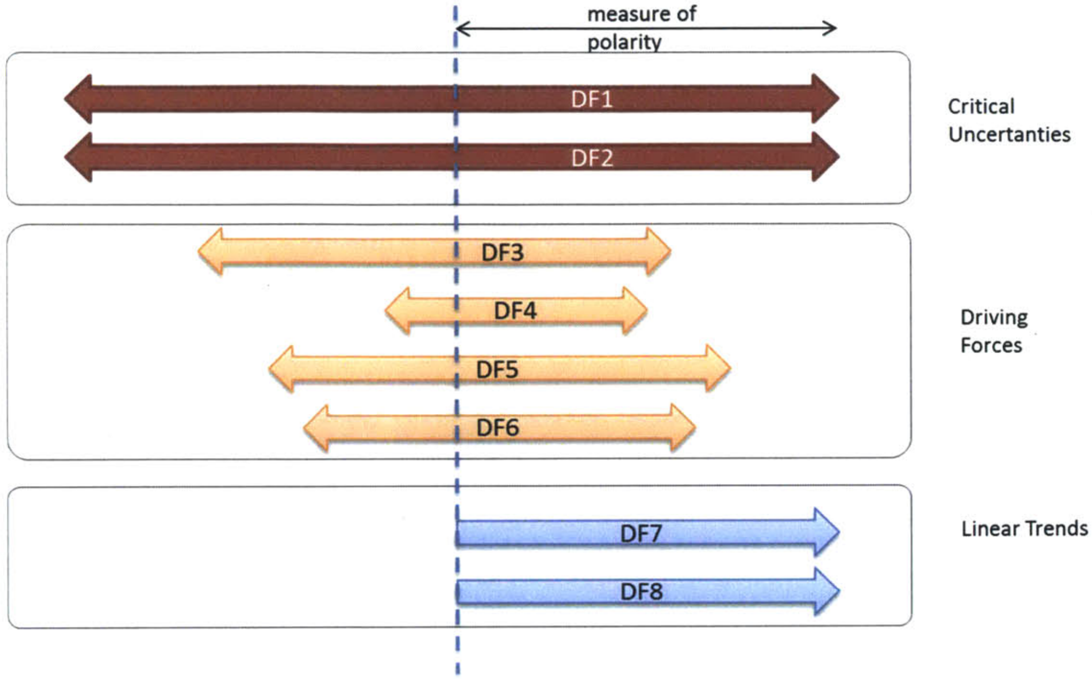

Figure 5: Elements of a Scenario
Critical Uncertainties, Driving Forces & Linear Trends

While this framework is very useful at a high-level, there are many low-level details for the choice of driving forces that are left to the practitioners' discretion. Klooster and Asselt note how the approach is in theory "only functional if two overwhelming driving forces can be identified". They also go on to note a lack of explanation for standard processes or methods for identifying the axes pairs. This is understandable since at its core, scenario creation is a qualitative reasoning exercise. At the same time, this aspect is critical to the quality of the output; especially when looking for driving forces in the "fringe" categories (Schwartz 1991). Schwartz refers to humans' tendency to think in terms of mainstream ideas – that track along popular belief rooted in the past and present – as susceptible to losing sight of innovative ideas at the edges.

One of the suggested methods to alleviate this concern is to shortlist the driving forces by incorporating the opinion and feedback of a "broad range of users and stakeholders" who are invested in the focal issue (Klooster and Asselt , 2005). They note the usage of successive rounds of consultation and stakeholder brainstorming workshops to narrow down from an initial inventory of driving forces.

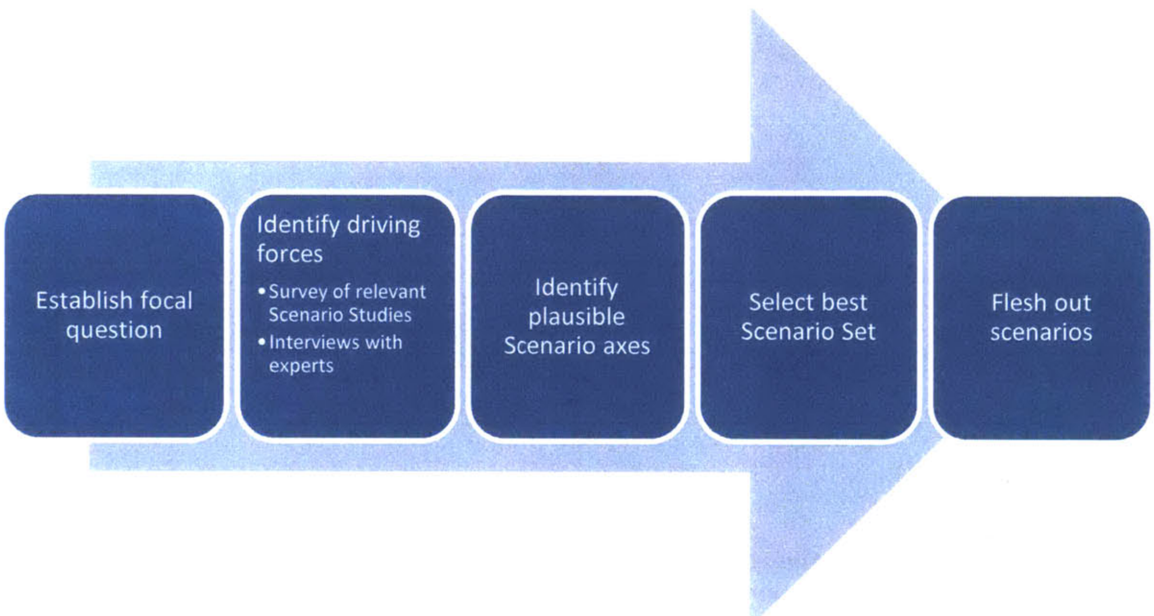

Figure 6: Different Stages in Creating a Scenario

In our study, we used two stages of analysis to arrive at a shortlist of driving forces that will be detailed later in this section. The first stage involved using keyword-frequency counts of all driving forces across our scenario study set to yield a comprehensive inventory of driving forces. In the second stage, interviews with a broad base of experts from industry and academia were used to create a smaller list of key driving forces. At each stage, the results were reviewed independently by scenario experts at CTL and the industry to rule out possible bias. Figure 6 outlines our process at a high-level. In the next few sections, our methodology is explained in detail.

3.3.1 Establish Focal Issue

We arrived at our central topic – "strategic thinking in the context of sustainability across chemical supply chains for the year 2025" – through a series of discussions with academic and industry experts in scenario planning. This helped us formulate our research question mentioned earlier at the end of Chapter 1.

3.3.2 Identifying Driving forces

3.3.2.1 Create driving force inventory

There are two different approaches that experts have used as a starting point to identify the key driving forces for scenario creation -

a. Inside-Out: Start with interview with stakeholders inside the company to get a list of key local factors and map to driving forces (Schwartz 1991)
b. Outside-in: Start with driving forces based on related literature or interviews with external experts.

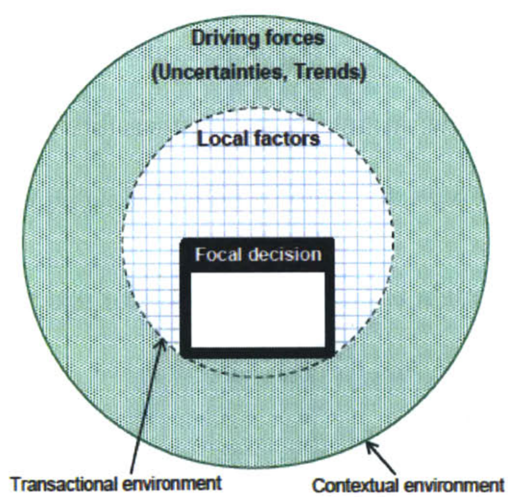

Figure 7: Driving Forces and the Focal decision

[Source: Phadnis (2012), PhD Dissertation, Center for Transportation and Logistics, MIT]

While it is common for company sponsored studies to adopt the first method, for broader industry-wide studies – a category to which this study belongs – the latter method is better suited. We are looking at the wider set of trends or developments that are likely to affect supply chains for an industry as a whole. The choice for this step lays the foundation for future course of research.

We surveyed 22 articles in academic journals and industry publications covering scenario studies and future trends across the chemical industry, sustainability, supply chains and logistics. In each article, we extracted the *driving forces* and noted their *polarity* if used in a scenario. When aggregated across all the literature that we surveyed, this yielded 19 driving forces with a clear count of frequently occurring driving forces and the aggregate polarities they assume.

For example, if an industry study mentions "consumer preference for sustainable products" as one of the key factors that will affect future chemical supply chains, it increases the frequency count of the driving force - 'consumer behavior' - by one. In this manner, the total number of such occurrences across all of the reviewed literature becomes the frequency for that driving force. Through this approach, we are measuring consensus among scenario creators and domain experts about the importance of that driving force. We therefore use the frequency as a proxy for the impact of that driving force. We felt this to be better than a purely qualitative approach.

In addition to impact, we also sought to capture the degree of uncertainty of a driving force. In order to characterize a particular driving force as uncertain we counted the number of times that specific driving force was chosen as one of the axes in a relevant scenario study. Our rationale for this choice was that a particular driving force would be chosen as an axis for a scenario set only if its creators considered that driving force to have a high degree of unpredictability in the future. One issue is that a driving force may have been uncertain when the study was conducted in the past and may not be uncertain now. We performed qualitative checks during the interview process to ensure that the uncertainty remained unchanged.

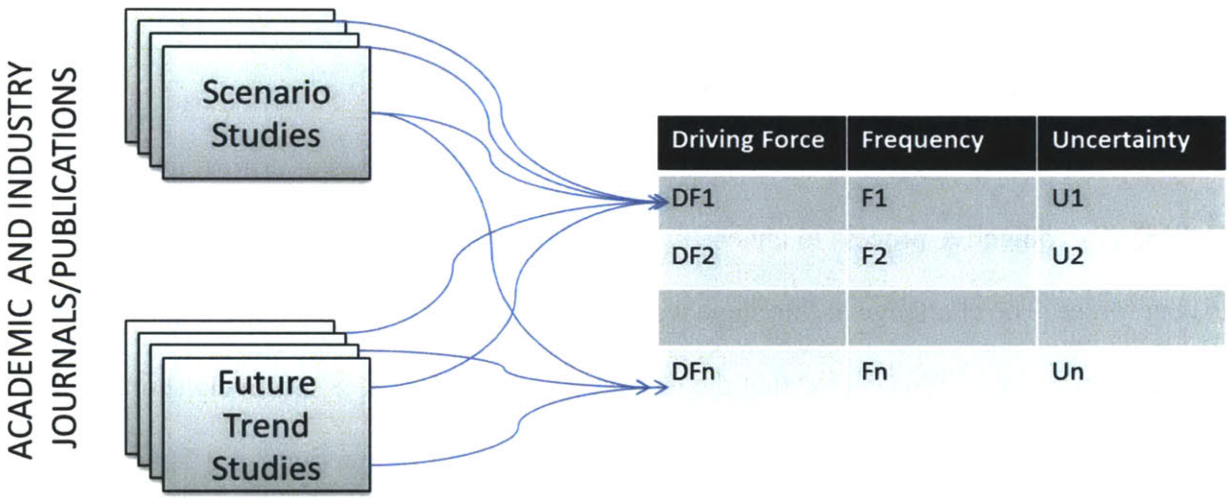

Figure 8: Identifying and Characterizing the Driving Forces

We identified nineteen driving forces with different frequencies and uncertainty measures. From among these driving forces we shortlisted six for the next stage of analysis.

3.3.2.2 Augment studies with expert opinions to cross-check selections

In the second stage of the analysis, we identified experts from industry and academia in sustainability, supply chains and the chemical industry. We emailed a brief questionnaire (Appendix A) describing the project and requested an interview to get their opinion on how relevant the shortlisted driving forces were to the focal issue. The interview questions were deliberately left open-ended so that any driving force not in the shortlisted set could also be recorded in our driving force inventory. This ensured that our selections made through a literature review were in line with expert opinion. The interviewers were also encouraged to take a position on the likely polarity of a particular driving force in the future - for instance, the different opinions on how consumer behavior shifts or even a lack of opinion for that matter. This response data (Appendix B) helped verify those driving forces with a high degree of uncertainty. The set of driving forces resulting from this stage served as the final consolidation cum validation of the initially selected driving forces.

3.3.3 Identify Plausible Scenario Axes

As mentioned previously, one of the challenges in identifying the axes or critical uncertainties is the lack of an objective process to choose two critical uncertainties from the final shortlist of driving forces. The challenge at this stage was to come up with two most critical uncertainties in an analytical manner. We decided that the best way forward was by exhaustively (but at a high-level) reviewing all possible pairs of driving forces (resulting from section 3.3.2.2) as axes for the final scenario set. This involved pairing up the driving forces in all possible combinations, much like the pool matches of a sports event. Subsequently, two experts along with the two authors of this study (four people), independently graded the plausibility or each driving force pair combination as possible candidates for the two critical uncertainties (or the 2 axes for the base scenarios). In general, the driving force pair which was deemed to have a high impact on the industry coupled with a high degree of variability in terms of possible future manifestations was ranked higher.

The following is a brief overview of how the results of individual axes 'grades' were aggregated:

$Let\ there\ be\ n\ driving\ forces, denoted\ by\ DF_i(i{:}\ 1..n)$

$Let\ there\ be\ m\ participants.$

$The\ plausibility\ matrix\ for\ participant\ j\ is\ denoted\ by\ M_j$

$M_j(x,y)\ denotes\ the\ participant's\ grade\ for\ a\ scenario\ set\ whose\ axes\ are\ DFx\ and\ DFy.$

$$M_j(x,y) = \begin{cases} 1\ if\ participant\ considers\ DFx\ and\ DFy\ to\ be\ a\ suitable\ pair \\ 0\ if\ participant\ is\ unsure \\ -1, if\ participant\ considers\ DFx\ and\ DFy\ to\ be\ an\ unsuitable\ pair \end{cases}$$

$Let\ the\ aggregated\ matrix\ for\ all\ participants\ be\ denoted\ by\ AM$

$$AM(x,y) = \sum_{1}^{m} M_j\,(x,y)$$

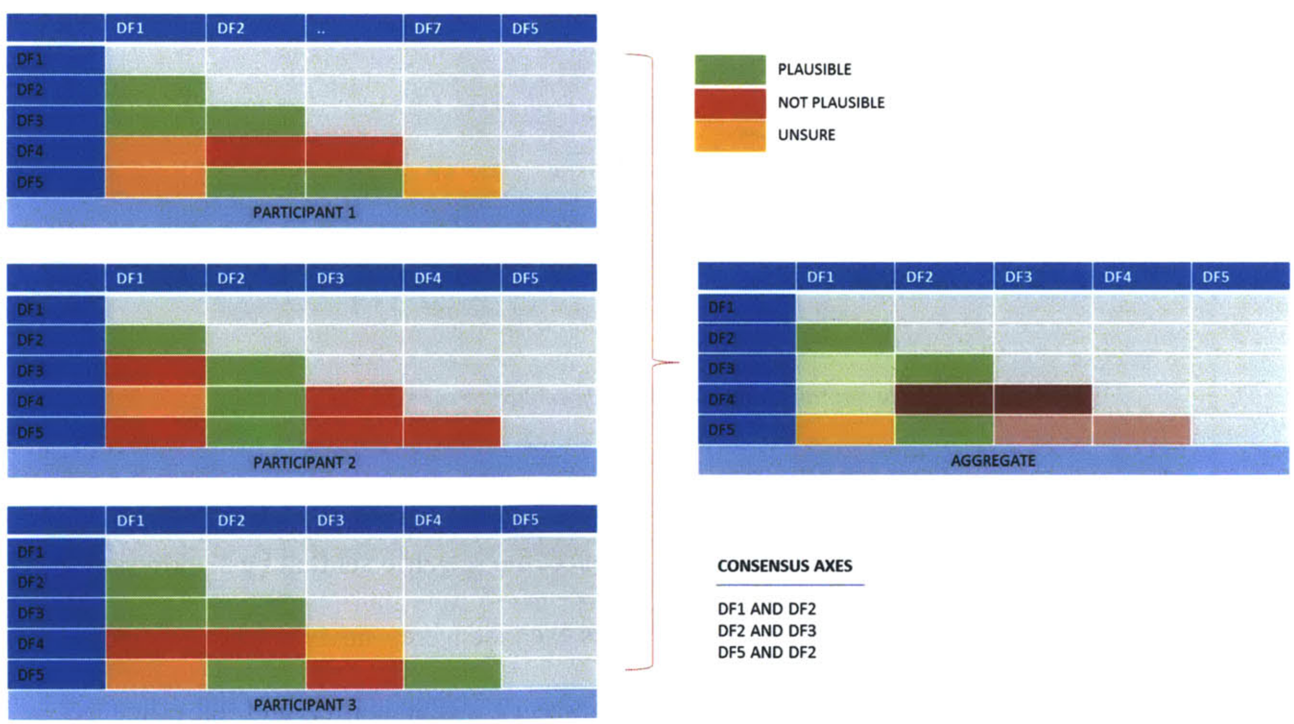

Figure 9: Selecting the 2 axes of critical uncertainties as the scenario baselines

3.3.4 Select Best Scenario Set

The previous exercise allows us to distill the inventory of shortlisted driving forces to find a set of candidates for the 2 axes or the baseline for scenarios. At this stage, a deeper scenario creation exercise was performed where the remaining supporting driving forces (those that are not the axes of the base scenario) were assigned polarities to create complete scenario sets. Each baseline axes pair yielded a set of three plausible scenarios.

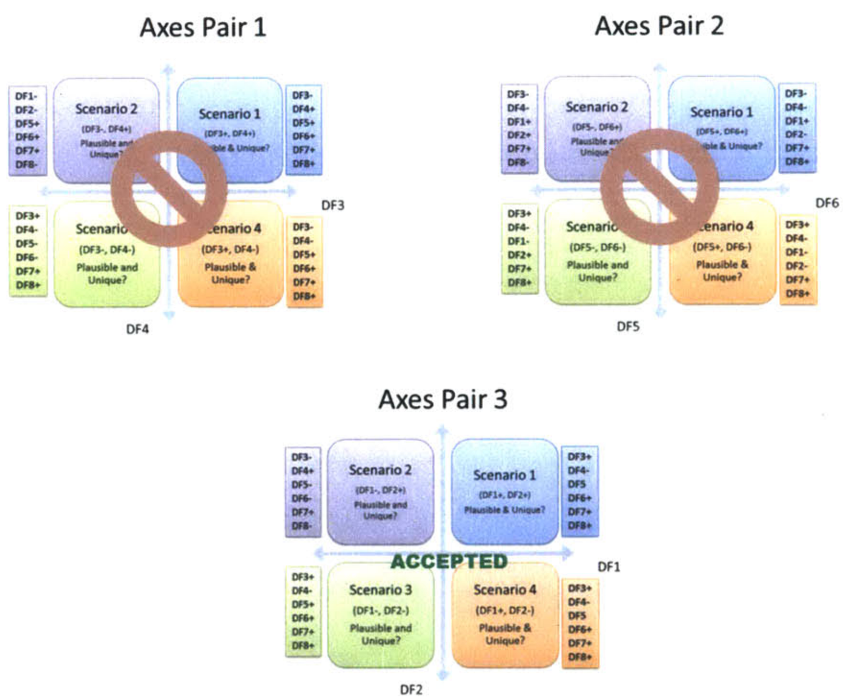

Figure 10: Selecting the Most Meaningful Scenario Set

These scenario sets were individually evaluated to select the scenario set that best addresses the focal issue. Among the factors considered during this exercise were - novelty when compared to other scenario studies, applicability to the chemical industry, sustainability, and relevance to supply chain strategy discussions. This exercise was performed independently by the authors and reviewed with multiple stakeholders. After this review, one scenario set was selected.

3.3.5 Developing the scenario stories

With the axes and supporting driving forces in place, we have a framework or a skeleton to support a more detailed story of the future each scenario must depict. Over numerous iterations, we refined and reviewed the scenarios to add details for each scenario. The authors used information from industry trend articles, executive interviews on long-term concerns, future outlooks on climate & technology during this process.

In a rapidly evolving modern world, the next two decades will produce many surprises. Our hope is that this detailed scenario set helps our end users envision and plan for these divergent futures.

4 Three Scenarios for Green Chemical Supply Chains

In this section, we present three divergent scenarios of the world based on our discussions with experts in industry and academia. Each of these scenarios help the reader imagine long range views of the business environment for chemical supply chains by the year 2025 with a focus on sustainability related developments.

The two critical uncertainties (or the two axes) for the chosen scenario set that was created following the approach highlighted in Section 3.3.4 were:

a. Consumer behavior with respect to sustainability
b. Transportation Modality

For the rest of the chapter, we start by presenting intermediate results which led to the selection of the key driving forces and the construction of the corresponding scenario set. Finally, we present detailed stories for each of the three scenarios that were created during the study.

4.1 Initial Driving Force Inventory

We reviewed a total of twenty one industry white papers and scenario studies (Appendix A). A database as described in Section 3.3.2 was created. A snapshot of the database is shown in fig 11.

Title	Page/Para	Trend Description	Driving Force	Polarity
(2011) Roland Berger Automotive landscape 2025	19, 2	Dependence on oil	Energy Price and Mix being used	High
(2011) Roland Berger Automotive landscape 2025	20, 1	Growing market share of renewable energy	Energy Price and Mix being used	High
(2011) Roland Berger Automotive landscape 2025	28, 1	Trend towards demotorization	Logistics and Transportation, Infrastructure	High
(2011) Roland Berger Automotive landscape 2025	34, 3	Emergence of natural gas, biofuels	Energy Price and Mix being used	

Figure 11: Driving Force Database Snapshot

Each entry in the database corresponds to the occurrence of a driving force within that article or study. For example, in the snapshot above, we reviewed a scenario study by Roland Berger on Automotive Landscape 2025. In that study, 'dependence on oil' and 'growing market share of renewable energy' were mentioned as important trends that could determine the future. The page and paragraph were noted for cross-reference. These trends were put under the broader category 'Energy price and mix being used'. These broader categories become the eventual list of driving forces (Table 2).

In Table 1, we show the counts against the top driving forces and their uncertainty.

Table 1: Driving Forces - Impact and Uncertainty

Driving Force	Impact	Uncertainty
Technological Innovations	27	High
Transportation Modality	24	High
Consumer Behavior	22	High
Environmental Regulation	21	Medium
Level of Climate and Environmental Change	20	Medium
Economic Dynamics	19	High
Geo-Political Stability	15	High
Population Growth	14	Low
Demographic Trends	12	Low

Trends such as population growth, growth in demand for and scarcity of natural resources, aging workforces and demographic shifts were categorized as linear trends (Table 4) because there is wide agreement among experts from different fields that these trends will continue.

After analysis and ranking by impact (Section 3.3.2.1), we used the top six forces (Table 3) when soliciting feedback from our interviews with experts. We added a seventh driving force - Geo-political Stability - to the list after interviews with experts.

Table 2: Initial Driving Force Inventory

Driving Force Inventory
1. Level and Distribution of income
2. Consumer Behavior
3. Level of Urban Development
4. Population growth
5. Energy Price and Mix being used
6. Availability and Price of Raw Materials
7. Level of Climate and Environmental Change
8. Transportation Modality
9. Geo-Political Stability, Cooperation
10. Economic Dynamics
11. Information and Communication Systems
12. Materials Technology
13. Infrastructure for International Trade
14. Environmental Regulation
15. Demographic Trends
16. Corporate Commitment to Sustainability
17. Technological Innovations
18. Emerging Market Dynamics
19. Labor Shortage

Table 3: Shortlisted Driving Forces

High Impact/Uncertainty Driving Forces
1. Consumer Behavior
2. Level of Climate and Environmental Change
3. Transportation Modality
4. Economic Dynamics
5. Environmental Regulation
6. Technological Innovations
7. Geo-political Stability*

* Added after interviews with experts

Table 4: Linear Trends

Linear Trends
Population Growth
Demographic Trends
Labor Shortage

The next step was to assign extreme polarities to each shortlisted driving force (Table 3) in order to proceed with the scenario creation exercise. These polarities are presented in Table 5. They were derived based on the literature as well as interviews with experts.

Table 5: High-Low polarities of Shortlisted Driving Forces

Driving Force	High	Low
Consumer Behavior	Sustainable sourcing and logistics are a requirement for buying a product	Primary decision based on price. Sustainability footprint a nice-to-have.
Economic Dynamics	Continuing globalization with manufacturing centered around Asia	Predominance of local (closer to consumers, raw materials) manufacturing capabilities
Environmental Regulation	Increased implementation of environmental regulations and treaties	Continued divide between developing and developed worlds over fighting climate change
Climate Change	Sharp increase in global temperatures and frequency of climate induced disruptions	Mild increase in global temperatures and frequency of climate induced disruptions
Technological	Commercially viable non-carbon energy	Fossil fuels continue to dominate energy

Innovations	alternatives for freight transport	supply
Transportation Modality	Multi-modal (air, rail, water) are all utilized in equal proportions for freight movements	Road transport dominates most of the inland freight movements
Geo-political Stability	Geo-political stability in strategically important regions (South Asia, East Asia, Europe, Africa)	Conflicts in strategically important regions (South Asia, East Asia, Europe, Africa)

4.2 Plausible Scenario Axes

In order to pick the two critical uncertainties from the above seven driving forces, we use an axes plausibility matrix as illustrated in Section 3.3.3. We had four participants (both the authors and one expert each from industry and academia) fill out the plausibility matrix. The goal of having multiple participants in this exercise was to reduce individual biases and ensure reasonable consensus levels for the shortlisted pairs. The four plausibility matrices are shown below in Figure 12 (detailed responses are in Appendix D).

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior							
Economic Dynamics	-1						
Environmental Regulation	-1	-1					
Climate Change	-1	+1	-1				
Technological Innovations	+1	+1	-1	-1			
Transportation Infrastructure	+1	-1	-1	+1	+1		
Political Dynamics	+1	+1	-1	+1	+1	-1	

AUTHOR 1

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior							
Economic Dynamics	-1						
Environmental Regulation	-1	-1					
Climate Change	-1	-1	-1				
Technological Innovations	0	-1	-1	-1			
Transportation Infrastructure	+1	-1	+1	+1	0		
Political Dynamics	+1	-1	-1	+1	+1	-1	

AUTHOR 2

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior							
Economic Dynamics	-1						
Environmental Regulation	-1	-1					
Climate Change	-1	+1	-1				
Technological Innovations	+1	-1	+1	-1			
Transportation Infrastructure	+1	-1	-1	+1	-1		
Political Dynamics	+1	-1	+1	+1	-1	-1	

EXPERT 1

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior							
Economic Dynamics	+1						
Environmental Regulation	-1	+1					
Climate Change	-1	+1	-1				
Technological Innovations	+1	+1	+1	+1			
Transportation Infrastructure	+1	+1	+1	+1	+1		
Political Dynamics	+1	-1	+1	+1	+1	+1	

EXPERT 2

Figure 12: Results of Individual Plausibility Matrix Analysis

In the next step, the aggregate plausibility matrix is computed (as described in section 3.3.3) and the following pairs of driving forces emerge as the ones with the greatest consensus among participants.

1. Consumer Behavior and Technological Innovation
2. Transportation Modality and Consumer Behavior
3. Geo-political Stability and Consumer Behavior
4. Climate Change & Consumer Behavior
5. Climate Change and Geo-political Stability
6. Technological Innovation and Transportation Modality

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior							
Economic Dynamics	0						
Environmental Regulation	-4	+2					
Climate Change	-4	+2	-4				
Technological Innovations	+3	0	0	-2			
Transportation Infrastructure	+4	-2	0	+4	+1		
Political Dynamics	+4	-2	0	+4	0	-2	

AGGREGATED PLAUSIBILITY MATRIX

Figure 13: Aggregated Results of All Plausibility Matrices

At this stage, we decided to drop the axes associated with two driving forces: 'Geo-political Stability' and 'Climate Change'. The impact being caused 'Geo-political Stability' in our study was largely related to the stability in the East-Asian and South-Asian regions that are currently unstable due to long standing conflicts. Since the scope of our scenarios was global, we felt that this force ~~is~~ would be better suited as a *supporting* driving force rather than a critical uncertainty. Next, it can be argued consumer attitudes toward sustainability are influenced by unseasonal climate changes. Thus, even while there is a high degree of uncertainty associated with 'Climate Change', we found that this driving force had a strong correlation with 'Consumer Behavior' toward sustainability. Furthermore, from a supply chain perspective, dealing with the effects of climate change – environmental catastrophes – now tends to be associated more with mainstream risk mitigation for which elaborate planning is done in most organizations.

Therefore, we proceeded with creating scenario sets based on the following three pairs of axes:

1. Consumer behavior and Technological Innovation
2. Technological Innovation and Transportation Modality
3. Consumer Behavior and Transportation Modality

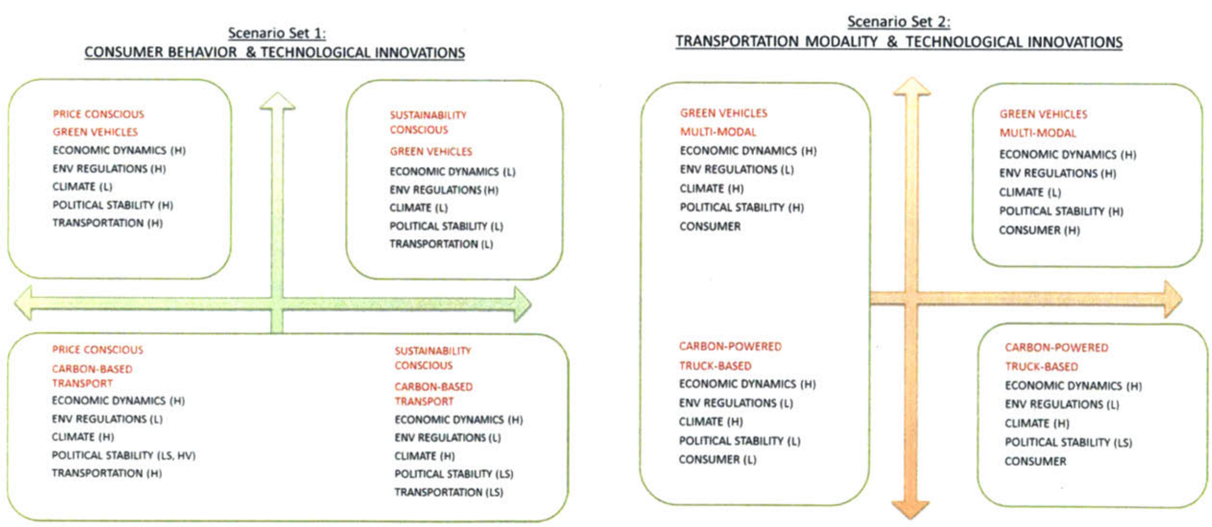

Figure 14: Scenario Sets for Pairs 1 & 2

The baseline scenario sets for pairs 1, 2 are presented above. For all combinations of polarities of the critical uncertainty pairs, polarities were assigned for *each* driving force, thus resulting in three scenarios per pair of critical uncertainty. There were two common characteristics across all the three scenario sets. One, all the scenarios that we created were very similar across the three scenario sets. And two, all the three scenario sets yielded in only three scenarios per set. Even though a maximum of 4 scenarios per set could have been potentially created, the internal consistency of the driving forces resulted in only three uniquely different scenarios per set of critical uncertainties. In all three scenario sets, we found that there was not much difference between two scenarios when polarities were assigned for the supporting driving forces. In all three scenario sets, only three scenarios were plausible based on

Based on our discussions with two scenario experts, we felt that the most useful perspective for our research question could be gained from scenario set 3 and was thus adopted as our final chosen scenario set.

4.3 Final Scenario Set

The final scenario set was created using 'Consumer Behavior' and 'Transportation Modality' as the critical uncertainties for the two axes. The authors worked in conjunction with a scenario expert to assign polarities to the remaining driving forces. For example, if consumer is sustainability conscious, it is more likely that environmental regulations are high than the other way around.

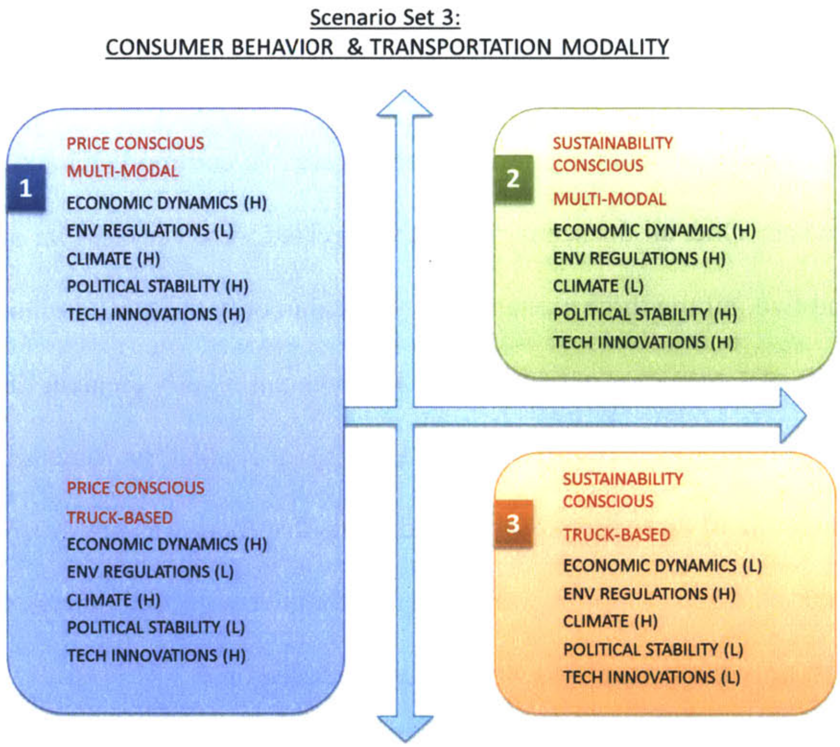

Figure 15: Final Chose Scenario Set – Consumer Behavior and Transportation Modality

We present each of the three scenarios in detail in the following pages.

Green Chemical Supply Chains - 2025

Scenario 1: *The hyper globalized world*

Scenario Logic

Price Conscious Consumers

Predominantly Truck Based Transportation

Supporting Driving Forces & Linear Trends	**Polarity**
1. Continuing globalization with manufacturing centred around Asia	High
2. Lax regulation and continued divide between developing and developed world over environmental treaties	Low
3. Sharp increase in global temperatures and frequency of disruptions	High
4. Geo-political conflicts in key trade corridors	Low
5. Commercially available non carbon alternatives for freight transport	High
6. Availability of Labor	Low
7. Population growth	High

Scenario Description

Greater political stability enables increased global trade. Many multinationals have strongly established footholds in major developing economies and exercise increasing influence in regulatory decisions. Most economic policies are designed for the short to medium (10 year) time horizon. This creates an unsuitable backdrop for strong environmental regulations that need a longer planning time horizon.

A strong growth is observed in the variety and volume of consumer products that are manufactured and consumed in Asia Pacific. This leads to a high growth in demand for industrial chemicals in Asia Pacific.

Inland transportation continues to be dominated by trucks as multi-modal infrastructure development fails to keep up pace with the growing consumer demand.

This is an era of reduced energy prices driven by cheap availability of shale gas. The level of technological innovations in fuel technologies has not kept pace since low cost alternatives such as Liquefied Natural Gas (LNG) and Compressed Natural Gas (CNG) offer a good alternative to gasoline and diesel.

There is a shift towards shale gas as feedstock for crackers. Shale gas becomes a primary source replacing naptha and crude oil residue. With the emergence of shale gas as a feedstock for crackers, there is gradual movement of base chemical manufacturing towards the west.

High carbon chain derivatives and specialty chemical manufacturing move to Asia Pacific since the abundance of shale gas feedstock is not suitable for high carbon chain end products.

Increased fluctuations in climate changes lead to water scarcity in many regions. This causes a change in products manufactured, for instance – detergents that use lesser water. Also, water as a raw material becomes expensive. Chemical companies start producing potable water (water treatment).

Green Chemical Supply Chains - 2025

Scenario 2: *The Efficient World*

<u>Scenario logic</u>

Sustainability conscious consumers

Multi modal transportation is predominant

	Supporting Driving Forces and Linear Trends	**Polarity**
1.	Continuing globalization with manufacturing centred around Asia	High
2.	Implementation of environmental regulations and treaties	High
3.	Mild-increase in global temperatures and reduced environmental disruptions	Low
4.	Geo-political stability in strategically important regions (South Asia, East Asia, Europe, Africa)	High
5.	Commercially available non-carbon alternatives for freight transport	High
6.	Availability of Labor	Low
7.	Population growth	High

<u>Scenario Description</u>

Asia is the centre for low-cost manufacturing but there is improvement in labor conditions. Labor rates have become more equitable with other professions and this has driven the prices of commodity goods up. Most organizations are mandated to maintain public carbon footprint information across the value chain. Sophisticated IT systems and measurement techniques are developed to capture the carbon footprint.

Rail and water infrastructure coverage improves - making it a viable alternative in routes previously served by road-based transport. Low emission ocean transport options are adopted (e.g. Skysails, slow steaming and super slow steaming). Rise in global temperature flatlines and thus there are fewer environmental catastrophes. Environmental regulations on production facilities and vehicles become more stringent.

Dependence on crude oil based transport systems is reduced. This results in a decrease in oil production and exploration. Breakthroughs in alternative energy sources such as economical and large-scale manufacturing of batteries result in reduced carbon emissions and drive new chemical supply chains.

There are changes in capital infrastructure as greener choices in buildings, roads and industries become increasingly affordable over the asset lifetime. Asia-pacific leads the way as growing infrastructure demands are met with a growing environmental sensibility.

Due to greater stability and peace accords, trade opens up in key South and East Asian corridors. India-Pakistan see a huge increase in trade ties. Sanctions on North Korea and Myanmar have eased out.

Green Chemical Supply Chains - 2025

Scenario 3: *Green and dispersed world*

<u>Scenario logic</u>

Sustainability conscious consumers

Truck based transportation is predominant

<u>Supporting Driving Forces and Linear Trends</u>	**<u>Polarity</u>**
1. Continuing globalization with manufacturing centred around Asia	Low
2. Implementation of environmental regulations and treaties	High
3. Sharp increase in global temperatures and frequency of disruptions	High
4. Geo-political conflicts in key trade corridors	Low
5. Fossil fuels continue to dominate energy supply	Low
6. Availability of Labor	Low
7. Population growth	High

<u>Scenario Description</u>

Political instability leads to rising tensions between nations. Fresh water supply conflicts across the many countries.

Environmental regulation is geared mainly towards supporting regional supply chains (high import and export taxes at ports and airports). High MPG (Miles per Gallon) fleet average requirements mandated by Environment/Pollution control agencies

Chemical products evolve to cater very region-specific demand, they are less globally standardized products than those of today. Substitute materials to create new value chains in chemicals, where traditional material is not available locally in a region

Global temperatures projected to increase by 2 degrees, Heat Waves, Rising Sea Levels Very much regional supply chains. Carbon footprint information becomes compulsory in product information. There is a proactive investment in bio-based and green fuels that can be used viably for transportation.

Heavy investment in highway development especially in developing countries that leads to opening up of previously unreachable corners. In addition to trucks being powered by non-carbon fuel technologies, other changes such as high-capacity trucks, using motion and breaking energy for transmission, will increasing the efficiency of trucks significantly. An increased proliferation of high power batteries change the way we live and work (for example pure-electric sedans, energy for poor households).

5 Conclusion

With the scenario set developed in the last chapter, we have attempted to provide a guide to serve as a backdrop for formulation of long-term strategy decisions for chemical industries with the emergence of sustainability as major evolving theme of contemporary economy. In the following sections we summarize our research and outline the direction of future research in this area.

5.1 Summary

Formulating a long-term strategy is a complex exercise especially for large multinational corporations especially since the business environment is constantly changing and requires proactive decision making even in the wake of uncertainty associated with key decision variables. Through our study we have attempted to address the focal issue of sustainability for chemical supply chains. The meaning of the word sustainability itself is quite subjective and there is both uncertainty and ambiguity related to how this crucial parameter will impact future business decisions. While reviewing existing literature, we found that there is a dearth of research in the specific intersection area of *sustainability* and *chemical supply chains* even though a lot of research has been performed in sustainability and supply chains in general. We have tried to take the initial steps by laying down a thinking guide for strategy formulation with a forward looking time horizon of 12-15 years.

Early on, we reviewed that that there are two major prevalent approaches to scenario planning, viz. the ILS approach (Intuitive Logic School) and the PMT approach (Probabilistic Modified Trends). The ILS approach is an ideal mix between analytical rigor and the convenience in usage

(Bishop et al, 2007) and is the most commonly used approach. We have followed the same ILS approach in building our scenarios.

Even though a "step-by-step" approach to scenario building is articulated in Peter Schwartz's "The Art of the Long View" (1991), there is no specific methodology on how to proceed with *each* step in the scenario building process as outlined by Schwartz. In fact, Shwartz, argues that (pp 30) that scenarios cannot be created from a same set of techniques, hinting that each scenario creation exercise is unique.

In our approach we have taken a highly subjective focal question (sustainability) and developed a technique to implement the two-axes approach of scenario creation. We hope that our methodology in using this technique, as detailed in previous sections, would help future scenario practitioners to address similar subjective focal issues.

5.2 Applications of scenarios

The primary purpose of developing scenarios for us has been to provide a thinking tool to help formulate long-term strategy. The power of the scenario method lies in providing a view of future that is less dependent on the linearity bias based on past occurrences and immediately anticipated future events.

Chemical companies operating on a global scale can find these scenarios useful as sustainability considerations are going to gain increasing importance in the future and envisioning a corporate strategy around sustainable development would become a major business continuity requirement.

5.3 Limitations of our Approach

Even though scenario planning is a thinking guide for making future decisions it is important to bear in mind that there are several limitations and assumptions associated with the process. One major limitation of scenario building is the assumption that the scenario creators are well aware of all the possible outcomes in future. In other words, it assumes that scenario creators have possibly looked at all the *mutually exclusive and collectively exhaustive* versions of future before choosing a current set of scenarios.

For this research, we have followed an *outside-in* approach in our methodology since it was most relevant to us as academic researchers to understand a critical industry issue. It is also possible for key decision makers in the industry or organizations to follow an *inside-out* approach for answering the same focal question of sustainability for chemical supply chains. Since both methods would have different point of views, it can be argued that the resulting scenarios from the two methods could be different. Thus, there are two points to note here. One, at this stage in the field of scenario planning and future studies, it remains questionable which approach is better between the *outside-in* and *inside out*. And two, the two different approaches might potentially lead to different scenarios. Even though this observation does raise a question – "how accurate are the scenarios?" – it is important to realize that narrowing down the picture of future to a handful of permutations does involve some degree of subjectivity.

Finally, the power of using scenario sets is fairly limited in *actually* designing the strategy once the future outcomes have been anticipated. On one hand availability of scenario sets enables decision makers to use it as tools for strategy formulation, and on the other, the exact step by step process of formulating the strategy is not addressed by the scenarios.

Having provided most of the limitations of using scenario planning we would like to re-iterate that even with all these limitations the scenario planning exercise is an extremely powerful tool for business strategists and organizations which have used them in the past have significantly reaped the benefits of this exercise.

5.4 Future studies in scenario planning

One of the main concerns of strategists who use scenario planning is to become aware early when the world evolves towards a particular scenario and accordingly formulate a business plan around it. In other words, the question which many find themselves asking is *"How do we know we are there?"* Thus, a leading emerging research area in scenario studies is monitoring the indicators or signals that are constantly being sent from the business environment and then deciding when to develop a strategy when it appears that one of the scenarios would be more likely to occur. MIT's Center for Transportation and Logistics is currently doing research on this topic with a leading industry partner.

In most cases, scenario studies are performed for businesses that deal with complex dynamics. *Systems thinking* (need to reference) is a modeling tool that allows to characterize complex systems. A description on the field of 'System Dynamics' would be beyond the scope of this chapter however much of the key driving forces used to arrive at scenarios are also very likely to be key inputs to systems modeling. We believe that the intersection of system dynamics and scenario planning would not only be a very fruitful area of upcoming research but also a very interesting one. Research in this direction would especially be helpful in validating scenario creation exercises such as the one in this study.

Lastly, in our review of existing literature we found many scenario studies focusing on *specific* industries. While many individual industries such as automotive, transportation and logistics and manufacturing have been studied for the purpose of creating future scenarios, there is a pressing need to go a step further and examine the possibility of creating scenarios for industry *clusters* (for example automotive *and* transportation & logistics). Such future studies, we believe will become even more significant as a lot of businesses are moving in the direction of vertical integration across their value chain.

5.5 Conclusion

In our research, we have attempted to understand the question that *"how would factors relating to sustainability affect supply chain strategy for 2025?"* We have used scenario planning as our research methodology to address this question. Based on our literature review and analysis of industry papers we narrowed down seven key driving forces that were most important in the context of the research question. Next, we used 2-Axes scenario method to arrive at three scenarios viz.

1. Hyper Globalized World
2. The Efficient World
3. Green and Dispersed world

It is our hope that with the knowledge of these three scenarios, decision makers in the chemical industry would be better equipped to make effective long range decisions centered around sustainability.

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Appendix A – List of Industry Papers reviewed

No	Study Name
1	(2009) EBS PWC T&L2030_How will supply chains evolve in an energy constrained world
2	(2009) WEF Mining_Metals_scenarios
3	(2010) Deloitte Preparing for an unpredicatble future in the global chemical industry
4	(2010) EBS PWC T&L2030_Emerging_Markets
5	(2011) EBS PWC T&L2030_Transport Infrastructure
6	(2011) EBS PWC TandL2030_Securing the Supply Chain
7	(2012) DHL Z_Punkt Scenario study Logistics 2050
8	(2012) EBS PWC T&L2030_Winning_the_Talent_race
9	(2012) WEF EuroDollarYuanUncertainties - Scenarios on the future of the international monetary system
10	(2010) WEF_Construction_Enginieering_Scenario_2020_Report_50p
11	(2012) Accenture-Looking-Ahead-to-2030 - Trends in Chemical Industry
12	(2012) Accenture Global-Shift-Industrial-Investment - Chemical Industry
13	(AT Kearney on Chemical Industry Vision 2030)
14	(2012) WEF Deloitte Touche Tohmatsu The Future of Manufacturing
15	(2010) McKinsey Pricing the planet Scenario 2020
16	(2011) Deloitte Consumer 2020 - reading the signs
17	(2009) McKinsey roads_toward_low_carbon_future
18	(2012) WEF New Models Addressing Supply Chain Transport Risk
19	(2012) WEF New Models Addressing Supply Chain Transport Risk
20	Asia/Pacific Regional SCM Strategy 2025
21	(2011) Roland Berger Automotive landscape 2025
22	(2012) DHL Z_Punkt Scenario study Logistics 2059

Appendix B – Database of Industry Papers reviewed

No.	Driving Force	Description
1	Level and Distribution of Income	Average income level in a country and distribution across the population
2	Consumer Behavior	Consumer attitudes towards sustainability shaping buying behavior
3	Level of Urban Development	Extent of urbanization and movement of people to urban centers
4	Population growth	Growth in population across the planet. Increased demand for shrinking natural resource base.
5	Energy Price and Mix being used	Price of energy sources and main energy sources in use
6	Availability and Price of Raw Materials	Availability and Price of Raw Materials
7	Level of Climate and Environmental Change	Level of Climate and Environmental Change
8	Transportation Modality	Mix of air, rail, water and truck for freight movement
9	Geo-Political Stability, Cooperation	Geo-Political Stability and Cooperation between nations
10	Economic Dynamics	Distribution of production and consumption of products
11	Information and Communication Systems	Development of sophisticated information and communication systems
12	Materials Technology	Development of new materials
13	Infrastructure for International Trade	Efficiency and openness of supporting government structures that facilitate international trade
14	Environmental Regulation	Level of regulation and enforcement by environmental agencies
15	Demographic Trends	Population growth, demographic mix due to migration
16	Corporate Commitment to Sustainability	Corporate Commitment to Sustainability efforts
17	Technological Innovations	Technological innovations
18	Emerging Market Dynamics	Effect of changes in emerging markets
19	Availability of Labor	Aging and decreasing pools of supply chain workforces in developing and developed economies

Appendix C - Template of email interview request

Dear Sir or Madam,

By way of introduction, we are a team of two students at Massachusetts Institute of Technology (MIT) in Boston, US. Sekhar has previously worked in developing supply chain software and I have worked previously in the Oil & Gas industry. We have been working with <<*industry expert name*>> since last September on a very interesting project sponsored by BASF which will also be our thesis for the Master's program here at MIT. It is on advice from Dr. Inga-Lena Darkow that we are reaching out to you.

The main research question of our Thesis is – **"How could the uncertainty arising from factors relating to sustainability that affect supply chain strategy for the chemical industry in 2025 be captured through scenario planning?"**

As a key input to the research thesis, we are seeking to conduct short interviews with functional or domain experts within BASF. The goal of this interview is to help us understand the critical uncertainties that arise while considering planning for a long-term strategy around sustainability.

For instance, we are seeking to know questions such as "How would the environmental regulations have a bearing on the supply chain strategy for BASF ?"
More information on the project and the interview are contained in the flyer attached with this mail. Please do have a look at it.

For next step, we will request you to allocate a 30-minute time window in the coming week so that we may have a telephone interview for a discussion on the topic.

If there is any further information that we could provide with, please let us know.

Thanks very much & looking forward to talking to you soon!

Best Regards,

Vibhu Arora & Sekhar Putcha
MIT | Master of Engineering
Supply Chain Management Program | Class of 2013

Appendix D - Interview Responses

Reference for Driving Forces

DF1 – Consumer Behavior

DF2 – Economic Dynamics

DF3 – Environmental Regulations

DF4 – Climate/Environmental Change

DF5 – Technological Innovations

DF6 – Transportation Infrastructur

Respondent 1

DF1: Price-sensitive

All else equal consumers prefer sustainable but would not be willing to pay a price premium.

DF2: Stronger trend towards localization in food industry. In technology, there will be more globalization. Everything that you put into your body, local suppliers will be preferred for security reasons.

DF3: Enforcement will probably stagnate
Problem is not so much the enforcement mechanism but it just doesn't work. If you try to decrease carbon emissions, people will outsource to Asia. Growing markets - we throw away too much product. The shift needed is much more acute than political will.

DF4: Climate is changing and will continue to change
Wine example – taste has changed distinctly over the decades due to changing temperature patterns.

DF5: Non-carbon will be affordable and usable

DF6: Rail cannot carry capacity. You'd have to construct railway.

Other Notes:
Palm oil problem in chemical supply chain – publicity disproportionate to size in portfolio.
NGO-driven specific regulations/pressure on chemical companies.

Respondent 2

DF1: Price sensitive.
In the pharma industry, patients do not care about sustainability for these life-saving drugs. Commodity drugs might see some sustainability pressure for differentiation. The high margin on-patent drugs will most likely not be the first movers for sustainability. In general, individual customers are less price sensitive. In emerging market countries – individual customers are significant. Ex: China & India. In

countries with more developed health systems, institutional players like insurance firms put significant pricing pressures

DF2: Globalization
Pharma is high margin business. In general high quality and R&D products manufactured in developed countries. Commodity drugs manufacturing is shifting to developing countries.

DF3: Regulation/Enforcement is increasing and will tighten further
Regulations in EU will harmonize further. Developing countries will increasingly want to bypass Environmental regulations to catch up.

DF4: CO2 reporting is highly subjective and varies a lot from firm to firm

DF5: Technology -> There has been some shift in shifting to better technologies. EURO V trucks used with one business partner.

DF6: Transport -> Most Intra-EU transport is done in trucks. For cross continent transport air freight is used 99% times. Intermodal provides an inherent risk as monitoring high value shipments is hassle. Increase in road toll prices may shift some freight to train in EU. Cold-chain considerations as many drugs are refrigerated

Respondent 3

DF1: Direction towards sustainable, however price will be key for developing countries for next 10 years
70% weight on Price 30% weight on Sustainability

DF2: Commodity chems --> globalization
Specialty chems --> evenly distributed

DF3: Regulation/Enforcement is increasing and will increase further

DF4: Climate change → disasters will result in more flexibility and SAWP arrangements even between competitors

DF5: Technology -> Supply chain visibility is still needed and it can become a great lever for increasing efficiencies in the future

DF6: Transport Infrastructure --> Inter-modal presents a lot of challenges. For effectively using Rail, the infra has to be there. The customers should also be in a position to use the rail network. In the future, the trend towards inter modal and rail will be slow. It will be mostly road transport.

Most Important Two Factors: Consumer Behavior - PULL & Environmental Regulations - PUSH

Other points:
Chemical Industry in general needs to catch up on Sustainability. Things have only started.

Due to nature of B2B, not very close to the end consumer hence sustainability adoption is lagging.

Proactive customers like IKEA & P&G are increasingly conscious of carbon footprint and are pushing the industry forward.

Respondent 4

DF1. More price sensitive

DF2. Predominance of local manufacturing

DF3. More regulation

DF4. Mild increase

DF5. Oil will continue to dominate

DF6. Share of rail/water will increase but road will dominate

Other important factors:

Role of share-holders (besides buying public and political factors)

Measurement of Carbon Footprint: How do you report it? Waiting for the standard?

Demographic patterns (aging) are definitely a concern.

Respondent 5

DF1: Direction towards sustainable

DF2: commodity chems --> globalize
    Specialty chems --> developed
DF3: Regulation/Enforcement will increase
DF4: Inconclusive
DF5: Inconclusive
DF6: China --> Rail. Otherwise inconclusive.

Additional Factors:
Geo-Political Stability
Aging population - 'sustainable' supply chain workforce

Other notes:

Base Chems --> Low margin (1 gallon < $1), high logistics cost, upstream product
Specialty Chems --> 50% of sales (>50% of qty), downstream product (closer to end-user)
Regulation will increase <-- a lot of it coming from social pressure
How it affects logistics: In Japan, Production forced to move to the outskirts areas
Warehouse close to cities cause problems because
- they carry flammable product
- trucks always come into the warehouse. Causes higher traffic
Non-carbon fuels --> Nuclear – not very popular in Japan given the catastrophic accidents.
EVs are not solutions if if electricity for EVs is produced by fossil fuels
Raw material availability: Importance of govt agreement.

Appendix E - Plausibility Matrix Detailed Response

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior	X	X	X	X	X	X	X
Economic Dynamics	linked, but necessarily heavily correlated; in a very sustainability oriented consumer behaviour, global production might be a "no-	X	X	X	X	X	X
Environmental Regulation	linked, but necessarily heavily correlated; a very sustainability oriented consumer behaviour might lead to pressure on	highly correlated - low-high and high-low scenarios not plausible as non-prosering economies will not risk any additional regulation	X	X	X	X	X
Climate Change	this is a "pre-driver", which drives either environmental regualtion or /and consumer behaviour; I would not recommend to take it as an	linked, but not highly correlated; all scenarios plausible	rather correlated - theoretically all scenarios are plausible, but probably rahter "boring" to explain them	X	X	X	X
Technological Innovations	consumer behaviour probably triggers innovation, therefore, the topics are linked, but not correlated; even if technologiy is	highly correlated - low-high and high-low scenarios not plausible; for this kind of innovations high investments are necessary which	regulation can trigger innovation towards the environment - but can as well fail. I think, this would be an interesting	similar to combination with regulation, as innovation might be triggered by climate change, but there is a need for more	X	X	X
Transportation Infrastructure	similar to the arguments for the innovation, but probalby even more non-correlated, as infrastructure is mostly	highly correlated - low-high and high-low scenarios not plausible	correlated, as governments might finance infrastructure development in rail etc. with road tolls etc. based on	not correlated - all combinations plausible	if there is an innovation to enable road transport in a very sustainable way, then there might be no infrastructure	X	X
Political Dynamics	conflicts can lead to a non-sustainable behaviour, as people are focussed on more basic needs - there is no room for sustainability;	highly correlated - low-high and high-low scenarios not plausible	scenario with conflicts and high environmental regulation is not plausible - all the others yes. Therefore, we can choose these	climate induced disruptions can enforce conflicts, threrefore this as well as the non-climate disruption and stable scenario	disruptions might triffer and speed-up innovations; but they are probably not the only cause: therefore, not correlated and all	a low-high and high-low scenario are not plausible, as political stability leads to economic growth and at least	X

Detailed Response: Expert 1

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior	X	X	X	X	X	X	X
Economic Dynamics	Plausible	X	X	X	X	X	X
Environmental Regulation	Regulation may force companies to go beyond providing lip service on sustainability	Plausible	X	X	X	X	X
Climate Change	Consumers will prefer and start paying for green products, if they continue to experience adverse effects of extreme weather	Plausible	Sharp temp increase will expedite adoption of env regs (but we cannot discount man's stupidity)	X	X	X	X
Technological Innovations	Plausible	Plausible	Plausible	**Plausible.** Clean fossil fuel technologies	X	X	X
Transportation Infrastructure	Plausible	Plausible	Plausible	Plausible	**Plausible.** Trucks with high efficiency / low emission engines (natural gas, clean coal, etc.)	X	X
Political Dynamics	Plausible	Political conflict between West and Asia can hamper the amount of goods produced in Asia for the Western markets.	Political conflict can make homogenous regs difficult. But, still **plausible** to have high env regs everywhere	Plausible	Plausible	Plausible	X

Detailed Response: Expert 2

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior	X	X	X	X	X	X	X
Economic Dynamics	A higher degree of globalization decreases commodity prices and makes the choice of sustainability difficult for consumers.	X	X	X	X	X	X
Environmental Regulation	Increasigly sustainable behaviour can be induced by pro-active environmental regulations	Environmental regulations would affect the economic activity with respect to regionalization or globalization	X	X	X	X	X
Climate Change	Consumer choices will drive the levels of consumption which will drive climate change	In general globalization leads to increasing carbon emissions which increase climate change	Environmental Regulations will follow trends in climate change	X	X	X	X
Technological Innovations	Consumers will continue adopting new technologies but at slower rates	Increasing globalization encourages more technological innovations	Environmental regulations would strongly encourage technological innovations	Climate change will be a strong trigger to technological innovations	X	X	X
Transportation Infrastructure	Consumer Behavior patterns will generally not follow the transpost infrastructure progress	Strengthening economics lead to an investment in infrastructure	Environmental regulations and transport infrastructure are not very related.	Transportation Infrastructe and climate change do no seem to be related	Slight relation as transport improvements might drive technology innovations and vice versa	X	X
Political Dynamics	Political uncertainities and in efficiencies would stifle consumption to a certain extent but consumers would generally want similar things everywhere	Economic dynamics highly responsive to political dynamics	A stifling political situation would in general lead to lesser environmental regulations	Political dynamics and climate change do not seem to related.	Technological innovations are liked to political dynamics	Transporation infrastructure is higly linked to political dynamics	X

Detailed Response: Author 1

Detailed Response: Author 2

	Consumer Behavior	Economic Dynamics	Environmental Regulation	Climate Change	Technological Innovation	Transportation Infrastructure	Political Dynamics
Consumer Behavior	X	X	X	X	X	X	X
Economic Dynamics	Correlated (localization is driven by consumer tilt towards sustainability)	X	X	X	X	X	X
Environmental Regulation	correlated (environmental regulation is driven by consumer awareness)	correlated (environmental regulation will by definition have a -ve effect on globalization)	X	X	X	X	X
Climate Change	correlated (climate change influences consumer behavior)	Plausible	correlated (climate change will affect environmental regulation)	X	X	X	X
Technological Innovations	Plausible	Plausible	correlated (strong environmental regulation spurs innovation efforts and vice versa)	correlated (climate changes accelerate or decelerate efforts to innovate)	X	X	X
Transportation Infrastructure	Plausible	Non-Plausibility (transportation infrastructure doesn't make sense with a localized world)	Non-Plausibility (1 scenarios seems contradictory. Strong-Regulation & Truck-heavy infrastructure)	Plausible	Plausible	X	X
Political Dynamics	Plausible	Plausible	regulation enforcement across borders is tied to geo-political stability	Plausible	Plausible	infrastructure development without political stability is not plausible	X