How to Identify Leading Indicators for Scenario Monitoring

By

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Submitted to the Engineering Systems Division in Partial Fulfillment of the Requirements for the Degree of

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ABSTRACT

Being able to quickly adapt to changes in the business environment has been widely acknowledged as essential for sustainable success by business leaders. Scenario planning is recognized as an effective tool used to explore ambiguous business environment dynamics over a long time horizon and identifying ways to translate uncertainty into potential future strategies. After the potential scenarios are developed and formulated into business strategies, the practical decision-making process then requires continuous review. Existing literature suggests that companies must actively monitor the business environment using appropriate indicators and understand their implications. This research specifically aims to develop a systematic, quantitative approach to identifying potential *leading indicators* for scenario monitoring. This approach is a framework that calculates correlation between various datasets from public databases, identifying, screening then consolidating the key driving forces of particular business scenarios. This process, in concert with a thorough qualitative assessment by business leader practitioners, enables an effective practice of scenario planning that allows the business to adapt its strategic long term plans in a constantly shifting global environment.

Thesis Supervisor: Shardul Phadnis
Title: Postdoctoral Associate

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1. INTRODUCTION

The introduction section provides context on scenario planning and scenario monitoring. A brief explanation of the benefits, history and challenges of scenario planning will help frame the research problem of scenario monitoring and the approach behind quantifying it. This section also outlines the research scope and thesis structure.

1.1 Background & Motivation

The business environment has seldom been as complex as it is today. Factors such as rapidly advancing technology, constantly changing regulations, increasingly stringent environmental restrictions and unpredictable social upheavals expose companies to an impossibly challenging and seemingly unpredictable operating environment. The challenge is even greater from a long-term perspective, in that firms can't simply predict what will happen 30 years from now. Take the early 21st century energy industry for instance: new technologies such as fracking, solar, wind were developed, abundant reservoirs of natural gas and oil in U.S. shale were discovered, and a different demand landscape emerged in China. Even more unpredictably, the state of global politics has changed dramatically for oil-producing states, such as growing tensions between the West and Russia and the relative level of stability in Iraq and Libya. This example illustrates how in just a few years the global landscape for a particular industry can unpredictably change over time, and companies must consider a wide range of scenarios and devise an appropriate range of responses. Many efforts have been made to predict the future environment, such as forecasting models that use historical data, simulation tools which analyze patterns, and contingency plans for discontinuity. However, all of these methods are relatively ineffective when looking over a long-range time horizon because they are largely based on a narrow range of data that is most relevant to the status quo.

The challenge of addressing uncertainty in the distant future stems mainly from two causes. First, predictions of the long-term future may be suspiciously regarded as imaginative wild guessing that casts doubt and thus indecision in navigating such predictions. Secondly, a long-term prediction that is based on actual evidence is likely to be rather scant, weak evidence, in which case is equally as challenging to interpret and make as a basis for critical business decisions. A good example is Nokia's pitfall in the smartphone business in which they witnessed the early nascent growth of smartphone technology yet were not able to fully determine its impact on their business, resulting in Nokia's fall from the top of the mobile industry as smartphones took off. Missing or misinterpreted signals are too big a price to pay for businesses that cannot afford poor foresight and bad luck.

Scenario planning originated from military use, but has gained popularity in industry as the business environment has experienced greater volatility in recent decades, particularly after Shell's success in surviving the oil shortage crisis of the 1970s (Bradfield, et al., 2005). As a long-term planning tool, scenario planning is a "disciplined method for imagining possible futures that companies have applied to a great range of issues" (Schoemaker, 1995, P. 25). Unlike the traditional approach of generating a precise forecast based on operational data, scenario planning aims to understand the underlying drivers behind market shifts (Schoemaker, 1995). There are at least three major schools of scenario planning: Probabilistic Modified Trends, the La Prospective methodology and Intuitive Logic, which is the most widely used (Bradfield, et al., 2005).

While these methods provide strategists with flexibility to formulate appropriate strategies for specific scenarios, they need to periodically revisit these strategies in order to ensure sound decision making. Strategy is in concern with future uncertainties, whether acting with uncertainties or waiting until they are determined is the decision a company should make (Wernerfelt & Karnani, 1987). This monitoring process is imperative in that it detects those critical signals that indicate impending changes to inform decision makers about the timing of the changes. To facilitate this monitoring, it is necessary to build a tool that effectively identifies the key leading indicators that may most significantly impact the operating environment. This tool must be a practical platform where quantitative data is captured, analyzed, subjected to interpretation, and then finally validated through the qualitative perspectives of a diverse set of stakeholders across various levels and functions of the organization. Such a tool would be a vehicle for transparent communication, debate, and careful analysis of both the quantitative and qualitative inputs to scenario planning. The tool would also serve as a foundation toward establishing and monitoring the constantly evolving indicators that drive scenario planning.

1.2 Research Scope

This research aims to develop a methodology and a practical tool to identify leading indicators for scenario monitoring. First, the tool would first determine statistical correlation and identify whether a given indicator is a *leading* indicator – a sensor of future change in a driving force that shapes an impactful phenomenon. Those leading indicators would provide the basis for validation sessions, where managers vet, discuss and provide qualitative input in order to determine causation. If causation is agreed upon, those managers would then determine the potential scope and impact of the driving force on the business.

1.3 Thesis Structure

This thesis is organized as follows: Chapter 2 reviews literature related to business scenario planning to establish the context of my specific research. Chapter 3 outlines and discusses the methods by which data was gathered, analyzed and summarized; this section also provides the justification for the methodologies employed. Chapter 4 details the results derived from the correlation of indicators and applies the scenario monitoring tool to an actual case study with the sponsor company, Visionary Chemical, an alias given for non-disclosure purposes. Chapter 4 then presents an informed interpretation of the results and evaluates potential applications given the findings. Chapter 5 offers a summary of the research and key observations, as well as suggestions on how scenario planning can be implemented and improved upon for future use.

2. LITERATURE REVIEW

This section first reviews the historical development of scenario planning. Second, it summarizes the reasons why business strategy can benefit from scenario planning in terms of its decision-making process and organization learning. Third, it introduces the necessities of monitoring efforts after scenarios are created, such as the procedural shift from sluggish reflection toward action-oriented planning. Finally, this section identifies how my proposed framework fits into the existing scenario planning methodology.

2.1 What is Scenario Planning?

Scenario planning is a method and process that organizations adopt in an attempt to develop long-term strategies (Bradfield, et al., 2005). The process employs a planning framework used to identify assumptions and drivers of change and then identifies practical scenarios used to guide business strategy. Scenario Planning as an organizational tool has its roots in the U.S. military and has been applied in business applications over the past few decades.

2.2 Why Perform Scenario Planning?

Decision-making is subject to several activities among which information gathering and interpretation play a key role. Human psychology plays a critical role in both aspects. Scenario planning corrects human bias in decision-making, improving the quality of final decision (Schoemaker, 1995). It also promotes organizational learning, which is essential to a company's sustaining development (de Geus, 1988). Examples of this are explained in further detail below.

2.2.1 The Trap of Human Psychology in Decision Making

The human psychology of tunnel vision and narrow-mindedness can inadvertently induce overconfidence and thus negatively impact long-term decision-making (Schoemaker, 1995). In this "confirmation bias," people habitually look for confirming evidence that affirms their pre-existing beliefs, subconsciously ignoring alternative perspectives, which can sometimes turn out to be costly surprises(Schoemaker and Day, 2009, p.44). Therefore, seemingly confident decisions can appear clearly unwise in hindsight. Likewise, executives are more willing to accept those business decisions that intend to tackle cost reduction or quality improvement in order to feed their insatiable desire for instant, visible results. Such projects do not challenge managers' assumptions about the nature of the business environment, and thus only solve myopic issues, ignoring the distant, unforeseen challenges that can easily blindside the firm (Wack, 1985). Nevertheless, when the operating environment changes on the firm and existing assumptions collapse, managers still living in their old mindsets will respond poorly. Moreover, the individual and organizational biases lead individuals to misinterpret the critical signals that indicate fundamental changes in the business environment (Schoemaker and Day, 2009). Decision makers often believe that their misjudgment is due to a lack of information; however, the real problem is more likely one of a narrow perspective. The information to make sound decisions is typically available, but managers often struggle to notice their confirmation bias and fail to determine which information is and is not relevant (Schoemaker and Day, 2009).

Scenario planning is argued to be an effective tool to correct such biases by stretching the decision makers' thinking in depicting alternate, detailed future scenarios to them(Schoemaker, 1995). In the Shell example, scenario planning is viewed as "the gentle art of re-perceiving," aiming more to challenge managers' mental models than the actual planning in itself (Schoemaker, 1995, p. 39). Compared with other tools such as contingency planning which typically focuses on one aspect of the business environment, scenario planning has the ability to consider several attributes of the environment simultaneously. Scenario planning also incorporates factors that cannot be modeled by complex computing simulations such as government regulations and social awareness (Schoemaker, 1995). When organizations are planning over a long time horizon, they need to account for various kinds of uncertainty that scenario planning is particularly appropriate for.

2.2.2 Better Supply Chain Planning and Organizational Learning

Sodhi (2003) argues that scenario planning can facilitate the alignment between strategy and tactical planning at of the highest level of supply chain planning. Though tools such as optimization are commonly used in tactical supply chain planning, executives unfortunately ignore their insights during strategic planning, instead primarily relying on accounting and economic metrics that are in the best interests of shareholders. The isolation between these two levels of thinking (tactical and strategic) creates conflict in the decision-making process (Sodhi, 2003). Sodhi claims that by introducing scenario planning, organizations can foster a common platform for senior decision makers and supply chain planners to communicate, enabling a formation of strategy that is both grounded in fact and also in line with shareholders' interest. As scenarios are developed by combining inputs from various functions across the company, these exercises promote an organization's learning by facilitating communication across all levels (de Geus, 1988). Such strategic conversations aid the individuals' learning, which ultimately changes their mental models establishing a common organizational vocabulary in which they can clearly convey their perspectives (de Geus, 1988).

2.3 The Importance of Scenario Monitoring

Once scenarios have been created, the practice of continuously monitoring the underlying driving forces needs to be established (Gregory et al, 2005). Scenario monitoring is an important tool for executives because it enables the effective review of long-term strategies with an early awareness for changes in the business environment, ensuring the strategies stay relevant. This process allows subordinate managers to adapt their business processes to these evolving strategies in order to align with the organization and be prepared for future uncertainty.

2.3.1 Scenario Monitoring Linked to Practical Strategy

Monitoring the business environment through the lens of one or more scenarios is an important element of making informed projections about future scenarios—making scenario planning most beneficial to the tactical operations of a business. After all, organizations can only have one strategy to guide their business (van der Heijden,1996). This requires companies to identify which scenario is most likely to unfold, and frequently reassess alternative scenarios as time progresses. Wack (1985) notes that scenario planning has succeeded in transforming managers' thinking, helping managers better understand the future in order to be more prepared, but it is not prescriptive; in other words, it cannot single-handedly provide the solution to a problem. Though learning through scenario planning is important, practical implementation is where the value is realized. There tends to be a gap between planning and implementation in that managers are typically focused on short-term execution and real-time problem solving, where scenario planning features long-term, alternate universe thinking. As Wack (1985) claimed, "the interface between scenarios and decision makers is often missing in scenario planning" (p.139).

Therefore, developing scenarios is not enough, they need to extend beyond blue-sky thinking and translate into practical operational action. If companies monitor the business environment through the lens of each defined scenario, decision makers can steer their organization toward a future that appears most likely to occur over time. The monitoring process thus becomes so critical that it expands scenario planning from being only a thinking tool into a practical decision-making tool.

2.3.2 Look Out and Adapt

According to de Geus's (1988) survey, those companies with longevity of more than 75 years share a common characteristic of success, which is paying great attention to the business environment and adapting themselves to its changes. In this way, monitoring the external environment is an integral prerequisite step of adaptation. Scenario creation and scenario monitoring have different roles in terms of preparing for the future. While creating scenarios prepares a management team to be mindful toward the future, the addition of continuous monitoring can lead to a comprehensive, action-based strategy. Instead of becoming victims of the crisis and always fighting fires, sustainable companies tend to opt toward actively identifying external changes and proactively reacting though organization learning (de Geus, 1988). Companies promote this group learning by depicting a business environment contrary to the existing one; bringing employees together to discuss their approach to changes and aligning their individual mindsets (de Geus, 1988).

According to Lee (2004), closely watching the external environment aids in building a more adaptive and agile supply chain strategy, which is essential to long-term growth. Companies endeavoring to build an efficient and cost effective supply chain, as is the common practice now, cannot ensure sustainable business growth solely through the joint efforts of upstream and downstream parties. In order to enable the supply chain designs to contribute to the ultimate business goal of competitive advantage and sustainable growth, the three qualities of Agility, Adaptability and Alignment should be incorporated into supply chain strategies (Lee, 2004). Lee also points out that adaptability enables a firm to consider long-term trends in demographics, economics and politics as it shapes markets. It requires that a company pay attention to the outside changes in the business environment especially in developing countries where there is more uncertainty. Unfortunately, Lee does not provide approaches for monitoring the environment.

2.4 Methods of Scenario Monitoring

While a great deal of research describes the benefits of scenario planning in decision-making and organization learning, very little literature sheds light on systematic, quantitative approaches to scenario monitoring. Gregory, Harris and Ogilvy (2009) argue that after the scenarios are built, strategic conversations, early indicators, and communication to the organization, gains significance. The two basic search methods of early indicators are scanning, which is broad and aimless, and monitoring, which has more quantifiable targets (Gregory, et al, 2009). Gregory et al (2009) also proposed some general guidelines on how to identify leading indicators:

- Consider upstream actors and their impact on each scenario
- Identify weak signs of great changes
- Look downstream to your customer's customers

Additionally, Gregory et al point out that due to the nature of identifying early indicators, an excessively mechanical approach, or an extreme focus on precise figures, raises a number of concerns to be considered:

1. Cause and effect trap: arguing that a certain event can actually cause a certain change.
2. Exhaustive in-searching process: not being content once a few indicators have been discovered. Gregory et al recommend staying alert to other emerging trends that could affect the original evaluation of the environment.

In conclusion, the literature suggests that firms must prepare for uncertain future environment through scenario planning activities. Firms that have any hint of critical thinking toward the future tend to sustainably perform better than those who do not. Finally, companies that constantly monitor the business environment are better prepared for changes to it. However, much of the published material on the subject matter tends to focus in a general way and lacks quantitative, substantive methods to execute such activities. In contrast to the aforementioned research, my thesis introduces a systematic, quantified framework that detects early warning signals and is a practical tool for businesses to conduct scenario planning activities.

3. METHODOLOGY

The research aims to develop a method of identify leading indicators for scenario monitoring. In this section, I qualitatively analyzed this research question and explained the overall logic to develop the solution to the problem. I illustrated a five-step filtering process to screen out leading indicators from a public database. The core of the method is constructing correlation test with time lag between driving force and potential indicators. Based on this filtering process, an Excel-model can be ultimately created to identify leading indicators in practice, which is discussed in Section 4.

3.1 Problem Analysis

In the current scenario planning practice, scenarios are mostly developed following the previously discussed *intuitive logic school* approach, which relies on the qualitative input of internal individuals within an organization as well as external subject matter experts. In this way, the strategic conversations among organizational stakeholders are the essence of scenario formation. Qualitative depictions of the driving forces behind scenarios can help these stakeholders picture the scenarios intuitively, tailoring specific strategies to those scenarios. However, when it comes to monitoring the system, the seemingly boundless descriptive information makes it difficult to systematically track changes to the driving forces. An ideal situation would be a monitoring system that translates qualitative, categorical data into quantitative, numerical information. This requirement leads to the challenge of actually transforming the driving forces from categorical to quantitative data sets. Another challenge stems from firms' inability to interpret information from such a broad spectrum of disciplines (i.e. politics, economics, etc.). In order for this monitoring system to be robust, the firm must understand the driving forces behind their business environment. Doing so involves a vast range of economic, social and political expertise. Though being equipped with such advanced knowledge resources is feasible for large firms, it is practically impossible for smaller ones.

In order to develop a monitoring system with the aforementioned constraints, it is necessary to build a framework that quantitatively transforms the driving forces. Once transformed, this framework can then statistically process and identify the leading indicators that forecast future scenarios. In this thesis, I use the framework defined by Zheng He's (2013) thesis "How Should Indicators be Found for Scenario Monitoring" to provide a quantitative approach to interpret driving forces. In his paper, Zheng constructs theoretical frameworks for driving forces following the Organization for Economic Co-operation and Development (OECD)[1] approach of building composite indicators.

3.2 Overall Approach

He (2013) argues that driving force indicators can be identified using OECD's framework. Given this, it is an appropriate framework to transform categorical driving forces into present-day quantitative values. However, the indicators identified by He do not adequately provide *future* warning signs because his framework does not consider the forward looking attributes of indicators. He chooses indicator intuitively relevant to and determining driving forces. For example, the indicators for energy cost are from the dimension of energy production and

[1] The Organization for Economic Co-operation and Development (OECD), "Provides a forum in which governments can work together to share experiences and seek solutions to common problems. We work with governments to understand what drives economic, social and environmental change. We measure productivity and global flows of trade and investment. We analyze and compare data to predict future trends. We set international standards on a wide range of things, from agriculture and tax to the safety of chemicals"(www.oecd.org/about).

consumption. In order to build a more robust predictive monitoring system, additional steps should be taken. Therefore, my framework uses correlation values from a more comprehensive set of indicators with time lag. This approach identifies what may ultimately prove to be *leading* indicators, rather than only present indicators. If there exist excessive highly correlated leading indicators candidates, filters can be applied to refine and narrow the list. This process is thoroughly discussed in Sections 3.2.2.4 and 3.2.2.5.

A leading indicator is an indicator that changes in unison or opposition to object variables (or driving forces), prior to those variables' occurrence. Therefore, an ideal leading indicator will be highly correlated with the object variables with a clear backward time difference. The below figure visualizes the relationship between a driving force and a positive leading indicator.

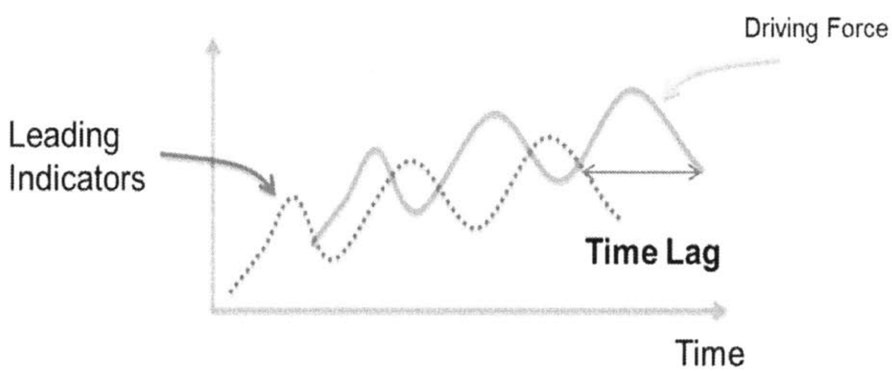

Figure 1: Illustrative Diagram of Leading Indicators

Based on the research of leading indicators, the fundamental approach adopted in this research is to identify the leading indicators via a correlation test. Correlation in statistics reveals "the degree and direction of association of variable phenomena; how well one can be predicted from the other." A leading indicator is simply one that correlates in an anticipatory fashion. Therefore, using a correlation test with a time lag is an appropriate approach to identify the leading indicators for scenario monitoring.

Correlation with time lag means to calculate the correlation value between two data sets using different time series. In this research, I used the most current data to build a "driving force matrix" that identifies potential leading indicators, using a one to three year time series. Leading indicators are characterized by both the strength of the correlation and its time lag. Strength of leading indicators is measured by the coefficient of correlation (R). Time lag is defined as the amount of time elapsed between predicted and observed data, where the correlation occurs in a foretelling way. The longer the time lag, the earlier a firm can forecast a particular trend.

The driving force indicators used to identify correlation with all potential leading indicators have been predefined based on previous research on the topic "How indicators should be found for scenario monitoring (Zheng, 2013). Further, only two of the ten driving forces of the scenario case, political stability and energy costs are analyzed by case study in Section 4.

3.2.1 Data Source

One of the challenges of the topic is to find the data source to perform the analysis because scenarios can be attributed to an infinite number of external environmental factors. I chose to continue to use the database in He's (2013) thesis, which is the World Development Indicators (WDI) from the World Bank[2]. Using the same data set provides consistency in the analysis and is

[2] World Development Indicators (WDI) is the primary World Bank collection of development indicators, compiled from officially recognized international sources. It presents the most current and accurate global development data available, and includes national, regional and global estimates. [Note: Even though Global Development Finance (GDF) is no longer listed in the WDI database name, all external debt and financial flows data continue to be included in WDI.

the most accessible public database, providing a wide range of statistics on various topics, ranging from the public sector, to finance, education, etc.

To select a meaningful sample of countries to be studied, I sought four factors: 1. a high relevance to the business of Visionary Chemical; 2. a high degree of representativeness of the region; 3. differing stages of economic development; 4. high data availability and the existence of multiple bi-directional, fluctuating trends. As the scenarios developed by Visionary Chemical are mainly Asia-based, the research ultimately focused on Japan and Thailand. Data from these countries are readily available and both have sustained historical data demonstrating multi-directional fluctuations in political and financial stability since the year 2000. The fluctuations in politics or finance of the two countries can be supported by the influential events regarding this matter happened in the history. As shown in Table1, Thailand endured high occurrence of violent political events after 2008. However, during the Tenure of Thaksin Shinawatr, Thailand enjoyed relatively stable politics, emphasizing its economics recovery from 1997 financial crisis. Table 2 shows the unstable financial performance of Japan in its near history. Additionally, the two countries represent both developed and developing economic profiles and provide a diverse depiction for analysis. Finally, these two countries, when combined, are fairly representative of the Asian economy as a whole. Initially, China had been an obvious choice for analysis, but was disqualified for correlation as a result of its unidirectional positive growth rate. The lack of fluctuation in its development would result in spurious correlations.

The GDF publication has been renamed International Debt Statistics (IDS), and has its own separate database, as well.

Table 1: Political and Financial Events in Thailand's Recent History

Approximate Date Range	Political or Financial Event
2001–2006	The Tenure of Thaksin Shinawatr, emphasizing on economic recovery.
2008	Political crisis
2009–2010	Protests and crackdowns

Table 2: Political and Financial Events in Japan's Recent History

Approximate Date Range	Political or Financial Event
2001	Reformist Junichiro Koizumi is nominated prime to fight the 10-year old stagnation
2003	The Japanese NIKKEI stock market average bottoms up at 7699 after falling 80% from its 1989 peak, and skyrockets 41% from April to October
2005	Real-estate prices have fallen 75% from their 1990 peak

3.2.2 Data Analysis

After selecting the appropriate dataset from WDI, I used a filtering process featuring a correlation test with backward difference in time serial to define the applicability of indicators to specific driving forces. The following five steps outline the detailed processes employed.

3.2.2.1 Step 1 Check Multi-trend Features of Driving Force Indicators:

In the first step, trends over the time horizon were investigated by graphing all of the driving force indicators. If a driving force indicator only displays a trend in only one direction, the correlation test may yield a high coefficient of correlation. However, it is not certain whether those indicators can predict the driving force, because one cannot know how the seemingly correlated indicators may behave when the driving force changes direction. The Graph below (Figure 2) shows after time T the trend of driving force starts to diverge from the trend of a leading indicator at T-n. Therefore, testing with an indicator that demonstrates trend in only a single direction may lead to spurious correlations and is thus filtered out of the data set.

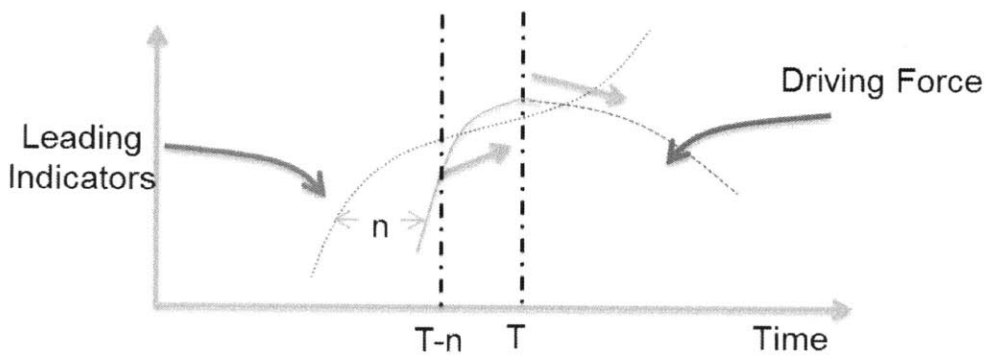

Figure 2: Spurious Correlation

Additionally, I used both a composite indicator that combines a group of indicators under the driving force frame defined by He (2013) and these individual indicators standalone to represent driving forces. The method of combining individual indicators is developed by He (2013) using factor analysis to assign weight to each indicator in the group.

3.2.2.2 Step 2 Data Filtering:

The WDI database features a long time span from 1960 to 2012 and a broad data of around 1350 indicators. However, a great deal of data is missing for various years and indicators. Intuitively, it is tempting to clean out a large portion of missing data to get a smaller yet more complete sample but it is not appropriate to do so. Though some datasets are currently small they are always expanding as statistics continue to be captured. If these data are excluded from the observation list, it is likely that signals may be missed. However, when there is not enough data to justify a high correlation, such indicators can then be filtered. In this research, data filtering is not meant to simply clean out data, but use the degree of data availability as a criteria for screening out indicators.

A minimum requirement of data was determined for potential indicators before performing the correlation test. The data set of the driving forces should conform with the following criteria: it should contain trends in both positive and negative directions, should have multiple instances of trends, Therefore, the data set of indicators should match to those timeframes where those trend criteria are met. For example, consider that political stability for Japan was constant during the 1970's, then begins fluctuating from the 1980's through the 2010's. A graph of the entire timeframe would be mapped, identifying the 1970's as a data subset that would not contribute to the correlation test, and is thus not required. Additionally, considerations are given towards blank data when conducting the correlation test.

3.2.2.3 Step 3: Develop a Correlation Matrix

The third step was to construct the correlation matrix between each driving force indicator and other indicators within a one-to-three year time lag (T-1, T-2, and T-3, respectively). It is demonstrated in the figure 3 below.

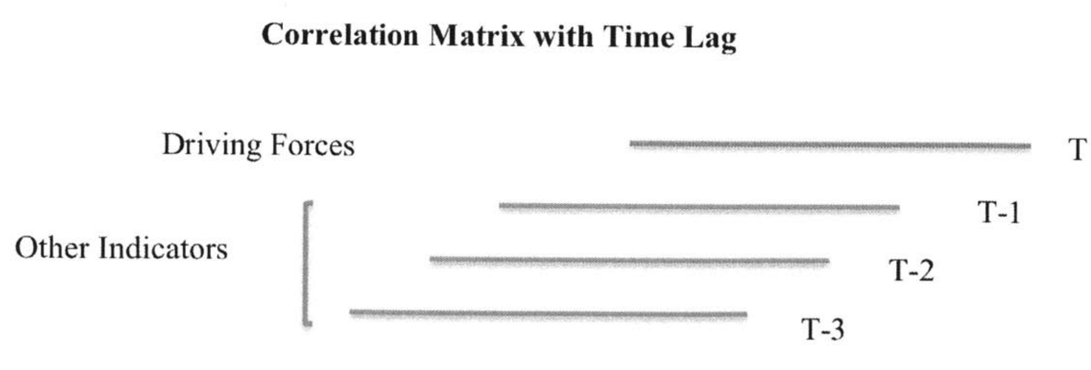

Figure 3: Correlation Matrix with Time Lag

Data from years one, two and three were used because of its availability and relevance. Correlations were calculated using Microsoft Excel and the *CORREL* function, which calculates the relationship between two random variables. The correlation coefficient is defined by the formula below and represents the relationship between two data sets, expressed as a coefficient ranging from 0 to 1.

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

3.2.2.4 Step 4 Filtering on Correlation Values:

Generally speaking, the higher the correlation coefficient value, the stronger the correlation. An absolute correlation value above 0.5 or higher is considered to be a good correlated pair. Correlation values from 0.5 to 1.0 are considered strong correlations, values from 0.3 to 0.5 are considered moderate correlations and values from 0.0 to 0.3 are weak. Given this, the lower limit for filtering is set to 0.5, while the higher limit is set to 0.95 (a correlation of 1.0 is highly unexpected and would indicate an issue in the data or the calculation). In terms of the amount of indicators, the ideal size of the final result is around ten for each driving force, which is suggested by Visionary Chemical. Once the correlation test is completed, there are two possibilities to define the number of leading indicators at the desirable correlation level: one is that too few potential indicators have yielded a strong enough correlation level (greater than 0.5), requiring the use of sub-standard correlated variables. The second possible situation is the opposite where an excessive number of potential indicators are found at the highest correlated level. If so, stronger criteria need to be developed to trim down the number of the indicators.

3.2.2.5 Step 5: Applying Other Filters

Besides applying a correlation filter, other criteria to screen out potential indicators are data availability, bi-directional and multi-dimensional profiles, and the time lag variety. Each of these four filters is explained in detail below:

Time lag variety refers to indicators with varying amounts of early-warning power. For example, a T-3 indicator indicates that the driving force will occur earlier than a T-2 indicator. Having a group of different time lag indicators, decision makers can be informed of the predictive timing of a certain driving force.

Bi-direction profile means the group of indicators should have a comparable amount of positive and negative correlated indicators to avoid the potential bias of indictors with a single direction profile. Greater diversity in the polarity of correlation may help provide a more robust outcome.

The multi-dimension filter requires that the group of indicators be from statistics of varying aspects. For example, both absolute and relative statistics of one single indicator are considered redundant and should be filtered from the group. In this situation, when choosing which indicator to retain and which to exclude, there are two general guidelines employed. First, indicators in the form of a relative index are better than absolute statistics which exclude the impact of growing scale. For example, GDP per capita (or any statistic per capita for that matter) is stronger than the general GDP statistic. Secondly, generalized indicators are superior to overly specific indicators. For example, an indicator such as Japan's gross national expenditure is a more valuable statistic than their gross household expenditures.

If applying these three criteria still does not effectively filter out the lesser indicators, then I chose the one with the highest data availability. In summary, the four filters are a structured mechanism to support the identification of leading indicators.

3.3 Expected Results

The expected output of this research is an Excel-based framework allowing Visionary Chemical to update the data over time and potentially change the criteria applied according to its own business considerations.

3.4 Quantitative Correlation Validation

In statistics, a correlation test can be validated by calculating the coefficient of correlation, which measures the degree of linear dependence of x and y. In other words, the coefficient shows how close two variables lie along a line. Calculating the coefficient is important for this research since it specifically indicates to what extent the driving force will move in line with the indicator variables - in order for the relationship between driving force and indicator to be valid, I would expect a relatively high correlation coefficient.

3.5 Qualitative Validation: Expert Assessment

Another method of validation is to utilize the expertise of company experts, in this case Visionary Chemical . As an analytic tool, the correlation test method helps develop a sense of what indicators are like from a mathematical perspective. A high correlation value can be seen as a necessary but not singularily sufficient condition to be classified as a leading indicator. A qualitative assessment and judgement is needed to compensate for the bias or misunderstandings inherent in data analysis.

In conclusion, though drawbacks inherent in using a statistical tool are important to acknowledge with scenario planning where qualative analysis currently dominates most of the process, using the correlation test and filtering approach to analyzing the data was fairly robust and can be recreated by other practitioners relatively easily. The five-step process allowed me to standardize the way in which categorical data can be converted into numeral data in a methodical way. Thus, mathematic analysis could be utilized to explore leading indicators of the initially un-calculatable categorical data.

4. RESULTS

In this section, I use the data from the scenarios provided by Visionary Chemical to illustrate the tool's use of identifying leading indicators for two key driving forces —Political Stability and Energy Cost, using the data sample of two Thailand and Japan. I ran two qualitative-to-quantitative transformations: one using a group of individual indicators under a driving force framework and the other using a single composite indicator that combines the individual indicators in the case when composite indicator is not appropriate for analysis.

As each scenario could theoretically occur, a predictive model that understands the behavior of key driving forces will allow Visionary Chemical to emphasize the importance of one or more particular scenarios, helping shape its strategy and the mindset of their employees. Moreover, a straightforward monitoring system consisting of visible indicators makes the company more aware of the changes to the business environment, enhancing the adaptability of the company to external conditions.

4.1 Summary of Visionary Chemical's Scenarios and Driving Forces

The Scenario Planning Project of Visionary Chemical explored alternative futures in 2025 for the Asia Pacific (A/P) Area; a region perceived as both the most uncertain and most impactful on its business while simultaneously offering the most potential market upside. A set of four scenarios were built from external market research and internal interviews conducted following the intuitive logic methodology.

The four scenarios identified by Visionary Chemical are each summarized below. In each scenario, investment in transportation infrastructure and environmental regulation are key drivers in the logic that drives the remaining driving forces. Consistently across all scenarios, demand is strong for the chemical industry across the A/P region. These scenarios provide an example of the driving forces which can be further studied in order to identify the leading indicators. Of the ten provided, I studied in detail only two, political stability and energy costs.

1. **The collaborative world**: This is the "Asia becomes an advanced economy" scenario where demand continues its explosive growth in countries like China, India and ASEAN, national governments invest in appropriate infrastructure improvements, and companies such as those in the bulk chemicals business see little constraint to drive growth. Simultaneously, the national governments have implemented stringent environmental regulations that may create some scarcity in energy resources, while the overall industry growth has inhibited the availability of basic raw materials.

2. **The lean world**: The "Asia sees uninhibited and unregulated growth" scenario is similar to the first, without the environmental regulation. High growth is seen across the region with cooperative governments supporting infrastructure investments. Again, with the strong growth has created some scarcity in basic raw materials as more competitors have entered a generally larger market.

3. **The demanding world**: This "worst of both worlds" scenario is one in which demand still grows, however governments have failed to provide improved infrastructure, and have also instituted strict environmental regulations. This forces companies to be creative and responsive in supporting customer demand. Transportation is the most challenging aspect in this world due to the lack of logistics networks and high cost of energy.

4. **The low cost world:** In this "no infrastructure no regulation" scenario, governments have failed to provide infrastructure to support the tremendous growth in Asia, but have also not strictly regulated environmental measures, allowing energy and transportation to be relatively cheap. However this lack of logistics network in some countries may inhibit the ability for Visionary Chemical to meet demand.

There are ten driving forces behind these four scenarios, listed below (Table 3). As mentioned, this thesis only focuses on political stability and energy costs. There are clearly other driving forces that Visionary Chemical may need to further study in order to identify the scenario which is should most closely align with.

Table 3: Driving Forces and Scenarios

Driving Forces	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Investment in transportation infrastructure	High	High	Low	Low
Environmental regulation	High	Low	High	Low
Political stability	High	High	High	Low
Tariff barriers, and customs regulations and free trade agreements with other regions	High	Low	High	Low
Stability of financial systems	High	High	High	Low
Availability of qualified employees	Low	Low	Low	High
Transfer and application of global knowledge (patents, innovations, processes)	High	Low	High	Low
Awareness towards sustainability of the society	High	Low	High	Low
Energy costs	High	Low	High	Low
Mobility of people (freedom to live and work anywhere)	High	High	Low	High

4.2 Driving Force Framework and Driving Force Indicators

In this research, I used He's (2013) approach in defining the driving force framework and building composite driving force indicators. He built composite indicators linked with driving forces to assess their variations over time. In his methodology, He (2013) first identified individual indicators based on intuitive theoretical frameworks and then used factor analysis to assign weight to each individual indicator. Finally, a composite indicator is formed by aggregating the weighted individual indicators.

Not every case used the composite driving force indicator to perform the correlation test. In some instances, the aggregate composite indicator may only demonstrate a unidirectional single trend without fluctuation, making the composite indicator ineligible for the correlation test. In these instances, I used only the underlying individual indicators in the correlation test to ensure valid results. Similarly, even at the granular individual indicator level, there may still be non-fluctuating, unidirectional trends that are ineligible for correlation test. In this case, I simply excluded that indicator entirely from the analysis.

4.3 Leading Indicators for Political Stability in A/P Countries

In Asia, political stability of each country varies greatly. Countries like China and Japan enjoy a relative stable political environment, while Southeast Asian countries like Thailand are still enduring political turbulence. It is fair to pre-judge that indicators will vary by country due to their complexities. The most important factor in selecting a country's dataset is its relevance to the company's business. Another main factor to consider is statistical robustness which requires fluctuations in the object data sample. Therefore, statistical robustness is more important than the country's relevance. However, as pointed out by Gregory et al (2009), the search for indicators should not be overly mechanical; a practitioner should conduct a widely inclusive search for many indicators rather than be overly selective. To compensate for any potential noise in the data, I chose two diverse countries for analysis: Japan, which has a strong political influence in the region, and Thailand, which has a politically turbulent history.

4.3.1 Driving Forces Framework for Political Stability

In He's (2013) thesis, the theoretical framework of political stability consists of the five most relevant indicators—out of a list of 78 from WDI's public database—that is a direct or indirect result of political stability's influence (Shown in Table 4 and Figure 4). Once indicators are selected, their weights are assigned using factor analysis in order to combine them into a composite indicator. Thus, political stability can be represented by a single indicator as in shown in Figure 5. Calculation of the relative weights derived from factor analysis is shown in appendix A.

Table 4: Indicators within the Driving Force Framework of Political Stability

1. Intentional homicides (per 100,000 people)
2. Armed forces personnel (% of total labor force)
3. Arms imports (constant 1990 US$)
4. Foreign direct investment, net inflows (BoP, current US$)
5. Military expenditure (% of GDP)

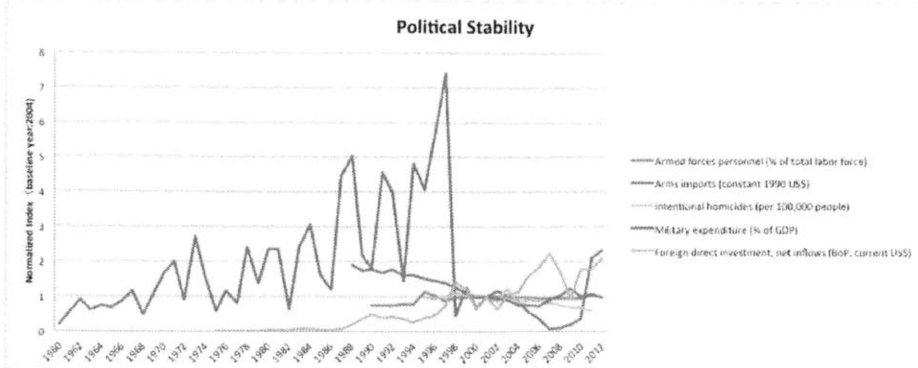

Figure 4: Individual Indicators Reflecting Thailand's Political Stability

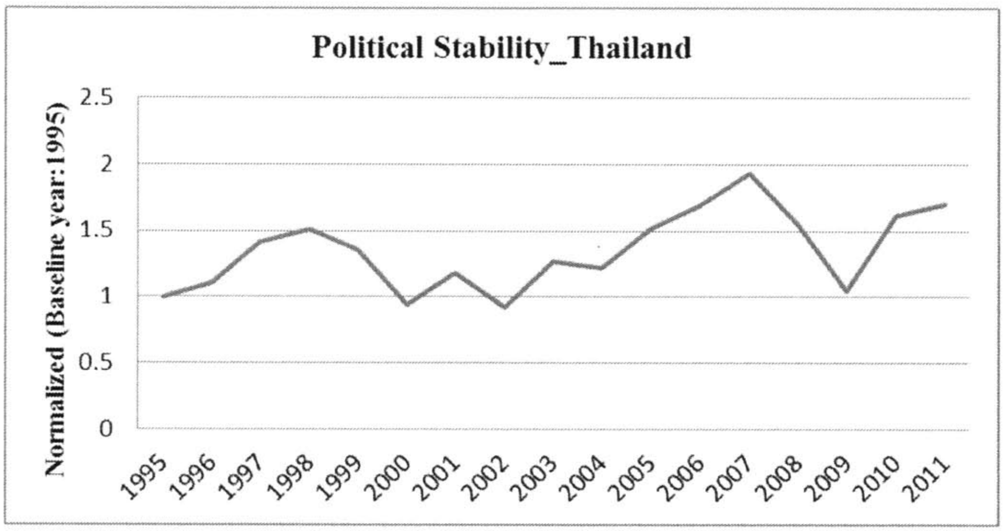

Figure 5: Composite Indicator for Thailand's Political Stability

4.3.2 Leading Indicator Selection by Correlation for Thailand

Based on the observations in Figure 2, the composite driving force indicator is suitable for the correlation test given it has considerable fluctuations over time. Recalling the methodology, the first level filter is data availability. As seen in Figure 6, the dataset of political stability covers a total of 17 years beginning in 1995. However, the fluctuations that enable valid correlation tests only happen in the most recent 10 years. Thus, the first level filter was set to the most recent 10 years, matching appropriate time spans between the driving force and the broad set of indicators.

Additionally, the timeframe of the datasets should be as recent as possible. Fulfilling these filter requirements enabled me to properly detect the hidden interrelationships between driving force and indicators.

After the first level filter was set, there were still 854 qualified indicators remaining. Recalling the methodology, the second filter is used to identify a significant level of correlation between the driving force and the remaining indicators (3.2.2.4). I set the initial requirement for correlation coefficient to 0.95, however no indicators qualified. Once I relaxed the filter to 0.7, 28 indicators sufficiently qualified (for all time lag categories). Table 5 shows the number of qualified indicators at each correlation coefficient threshold step. Next, applying the third filter (3.2.2.5) which screens for multi-dimension and bi-direction, there were then 14 qualified indicators remaining (Figures 6 and 7 depict the filtering process). As there are a sufficient number of qualified indicators, there is no need to apply any further filters. Figure 7 demonstrates how each stage of the filtering process provides the most relevant indicators related to Thailand's political stability.

Table 5: Outcome of different Correlation Threshold

Correlation Threshold	Number of indicators
0.95	0
0.9	0
0.85	0
0.8	6
0.75	18
0.7	28
0.65	40

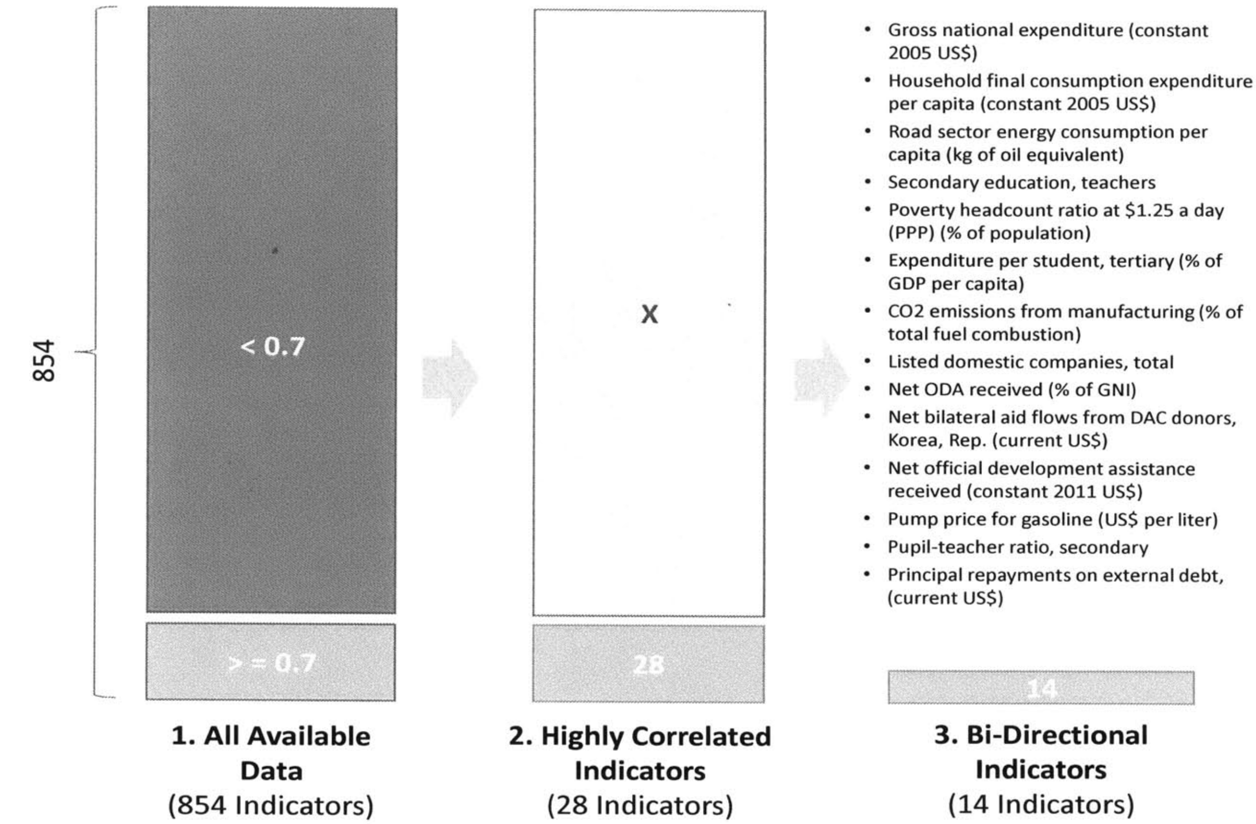

Figure 6: Example of Filtering Process

Thus, 14 indicators are the final candidates for "Political Stability," which are shown in full detail in Figure 7; the positive indicators are highlighted in red, while the negative indicators are shown in green.

Political Stability_Thailand			Count:	854	28	14	
Indicator Information	**Predictive Power**			**Potential Indicators**			
Indicator Name	**T-1**	**T-2**	**T-3**	Filter1 Data Availabili	Filter2 Correlati	Filte3 Indicator Profile	Filter4 Time Lag
Gross national expenditure (constant 2005 US$)	0.71	0.57	0.35	1	2	3	
Household final consumption expenditure per capita (constant 2005 US$)	0.70	0.59	0.48	1	2	3	
Road sector energy consumption per capita (kg of oil equivalent)	0.76	0.47	0.27	1	2	3	
Secondary education, teachers	0.56	0.61	0.78	1	2	3	
Poverty headcount ratio at $1.25 a day (PPP) (% of population)	-0.74	-0.49	-0.30	1	2	3	
Expenditure per student, tertiary (% of GDP per capita)	-0.88	-0.69	-0.56	1	2	3	
CO2 emissions from manufacturing industries and construction (% of total fuel combus	0.74	0.58	0.58	1	2	3	
Listed domestic companies, total	0.74	0.46	0.25	1	2	3	
Net ODA received (% of GNI)	-0.58	-0.65	-0.70	1	2	3	
Net bilateral aid flows from DAC donors, Korea, Rep. (current US$)	0.76	0.55	0.18	1	2	3	
Net official development assistance received (constant 2011 US$)	-0.52	-0.63	-0.71	1	2	3	
Pump price for gasoline (US$ per liter)	0.71	0.22	0.60	1	2	3	
Pupil-teacher ratio, secondary	0.30	0.35	0.83	1	2	3	
Principal repayments on external debt, public and publicly guaranteed (PPG) (AMT, curr	0.18	0.51	0.72	1	2	3	

Figure 7: Leading Indicators of Politics Stability for Thailand

In this research, it is important to mention that these individual leading indicators were not consolidated into a single indicator, but left as standalone. This was done in order to avoid the inherent inaccuracies of being over mechanical, possibly risking distorting reality.

4.3.3 Leading Indicator Selection by Correlation for Japan

Using the same approach of factor analysis to combining driving force indicators using Japan data sample (See Appendix A for the calculation of weights), the composite driving force indicator is shown in the following figure(Figure 8), this indicator has several fluctuations over time, thus suitable for correlation test.

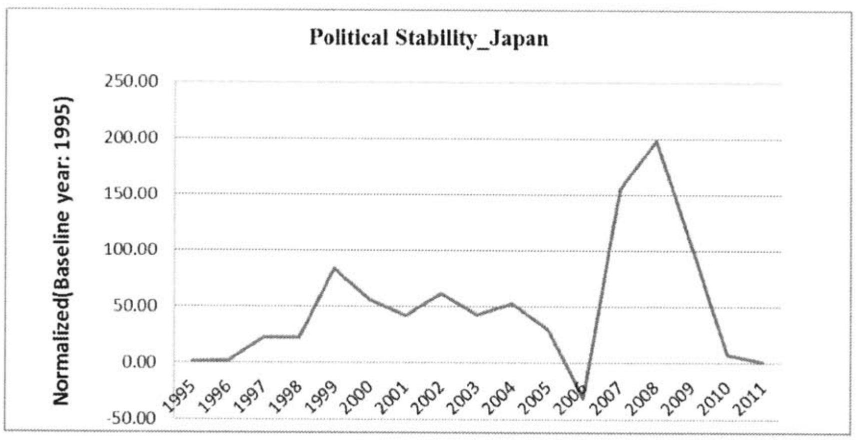

Figure 8: Composite Indicator of Political Stability for Japan

The steps taken to seek leading indicators for Japan are identical to Thailand's analysis. The correlation coefficient falls at 0.6 to get a desirable size of potential leading indicators. The result of leading indicators in the case of Japan is shown in the following Table (Figure 9).

Political Stabilitly_Japan			Count:	627	21	15	0
Indicator Information	Predictive Power			**Potential Indicators**			
Indicator Code	**T-1**	**T-2**	**T-3**	**Filter1 Data Availability**	**Filter2 Correlatio**	**Filte3 Indicator Profile**	**Filter4 Time Lag**
Adjusted savings: carbon dioxide damage (% of GNI)	0.60	0.48	0.23	1	2	3	
Armed forces personnel (% of total labor force)	-0.38	0.35	0.67	1	2	3	
Armed forces personnel, total	-0.38	0.38	0.66	1	2	3	
Bank liquid reserves to bank assets ratio (%)	-0.74	-0.26	0.48	1	2	3	
Exports of goods and services (current LCU)	0.62	0.48	0.20	1	2	3	
Gross domestic income (constant 2005 US$)	0.35	0.64	0.68	1	2	3	
Health expenditure, public (% of total health expenditure)	-0.70	-0.46	0.06	1	2	3	
Household final consumption expenditure (current LCU)	0.61	0.54	0.37	1	2	3	
International tourism, expenditures (current US$)	-0.48	-0.07	0.62	1	2	3	
Refugee population by country or territory of origin	0.71	0.28	-0.23	1	2	3	
School enrollment, preprimary, female (% gross)	0.84	0.42	0.00	1	2	3	
Telephone lines (per 100 people)	-0.68	-0.26	0.09	1	2	3	
Unemployment with tertiary education, male (% of male uner	0.63	0.45	0.21	1	2	3	
Vulnerable employment, male (% of male employment)	-0.70	-0.43	-0.22	1	2	3	
Water pollution, other industry (% of total BOD emissions)	-0.27	0.55	0.70	1	2	3	

Figure 9: Leading Indicators of Political Stability for Japan

4.4 Leading Indicators for Energy Costs in A/P Countries

Energy cost has more visibility due to the international crude oil price. However, varying regional regulations, renewable energy technologies etc. affect the regional energy costs. Thus, the energy leading indicator is a key success factor for Visionary Chemical, as they are a leading chemicals manufacturer and a key reason why I chose energy to demonstrate the tool's effectiveness. I continue to use Thailand and Japan's database to identify leading indicators for the reasons given in section 4.3.

4.4.1 Driving Forces Framework for Energy Costs

Zheng (2013) developed the indicator framework of energy cost based on two dimensions: energy consumption and production. Highly relevant indicators in terms of consumption and production in the WDI database form the basis of the framework for the driving force of energy cost, as presented in the below table (Table 6).

Table 6: Indicators within the Driving Forces Framework

1. Electric power transmission and distribution losses
2. Electricity production from renewable sources
3. Energy production
4. Energy use
5. GDP per unit of energy use

However, I found the aggregate composite driving force indicator for Thailand presents a single upward trend over the timeframe (seen in Figure 10), thus the synthesized indicator for Thailand is not suitable for correlation test. Instead, individual driving force indicators are used for Thailand to perform the correlation test, while Japan was capable of using the composite leading indicator.

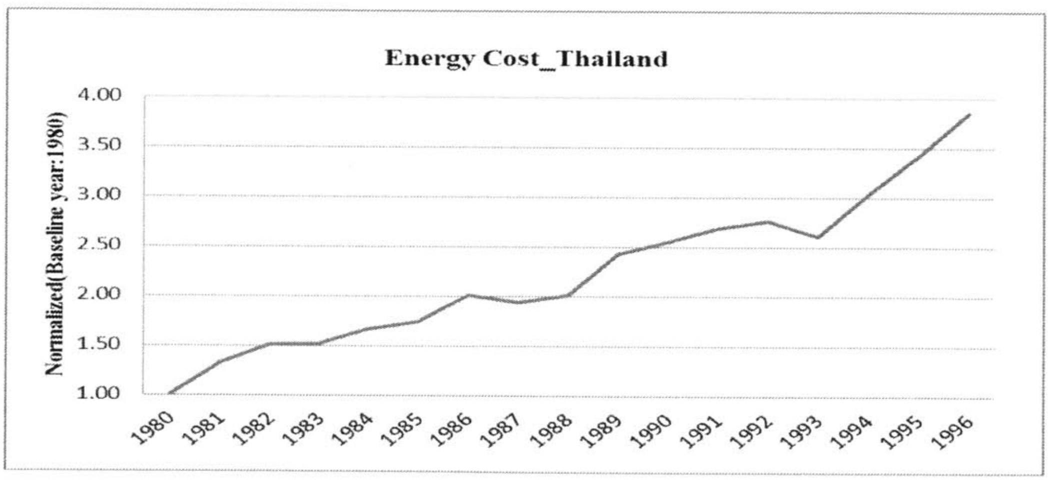

Figure 10: Composite Indicator of Energy Cost for Thailand

4.4.2 Leading Indicator Selection by Correlation for Thailand

The process of obtaining leading indicators for individual driving force indicators follows the methodology discussed in Section 3. Upon inspection of energy production and energy use

(Figure 11, Figure 12), I discovered these indicators lack multi-directional trends, disqualifying them from correlation tests with Energy Cost.

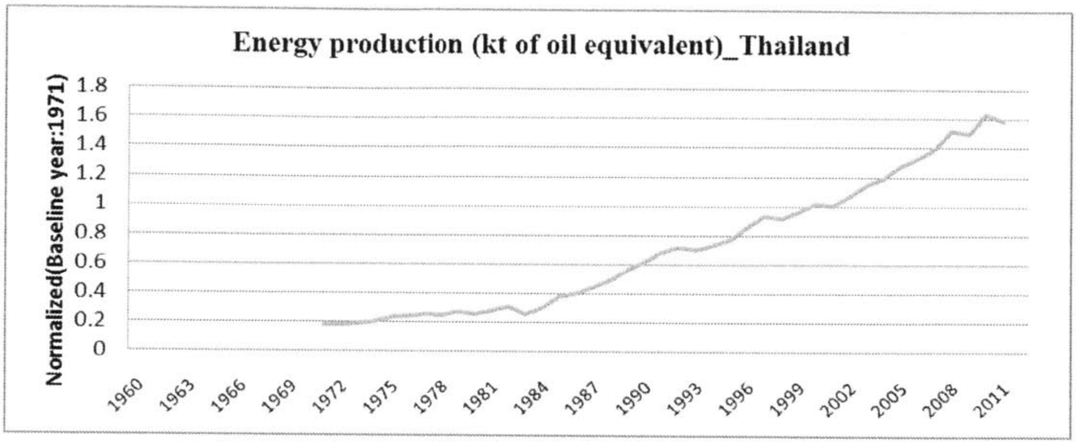

Figure 11: Individual Driving Force Indicator of Energy Production for Thailand

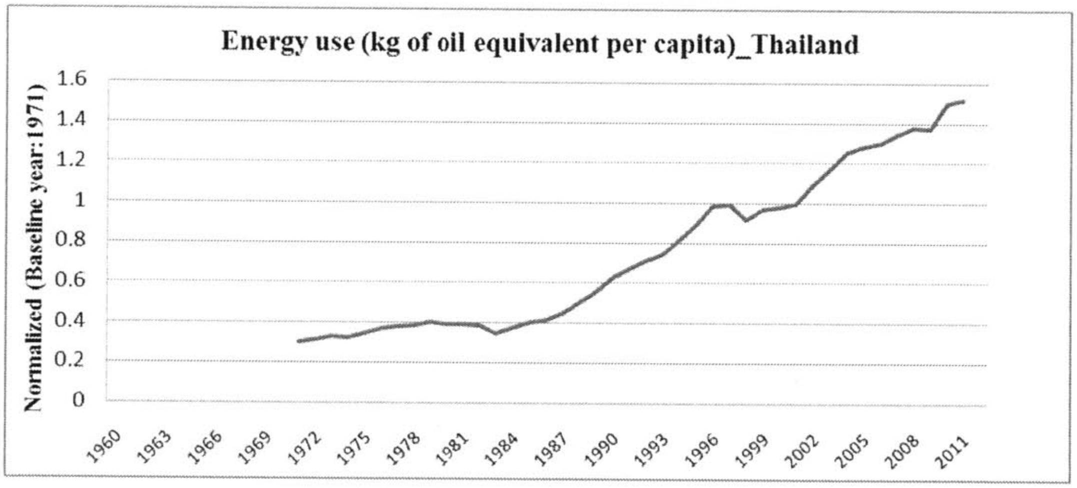

Figure 12: Individual Driving Force Indicator of Energy Use for Thailand

Therefore, I performed correlation tests with the remaining individual driving forces, which are electric power transmission and distribution losses, electricity production from renewable sources and GDP per unit of energy use. The filtering parameters of Filter 1—Data Availability and Filer 2—Correlation Value for Thailand are summarized in the following table.

Table 7: Filtering Parameters of Individual Energy Cost Indicator for Thailand

Driving Force Matrix	Filter1 Data Availability	Filter2 Correlation Value
Electric power transmission and distribution losses	Recent 18 Years	0.95
Electricity production from renewable sources	Recent 22 Years	0.90
Energy production	Not suitable(single trend)	
Energy use	Not suitable(single trend)	
GDP per unit of energy use	Recent 30Years	0.90

After the filtering process, three sets of leading indicators corresponding to individual driving force indicatorsas listed in the Figures below(Figure13,14,15).

Electric power transmission and distribution losses (kWh)			Count	740	113	28	0
Indicator Information	Predictive Power			Potential Indicators			
Indicator Name	T-1	T-2	T-3	Filter1 Data Availability	Filter2 Correlation	Filte3 Indicator Profile	Filter4 Time Lag
Adolescent fertility rate (births per 1,000 women ages 15-19)	-0.98	-0.98	-0.98	1	2	3	
Age dependency ratio, young (% of working-age population)	-0.96	-0.96	-0.97	1	2	3	
Agriculture, value added (constant 2005 US$)	0.95	0.96	0.96	1	2	3	
Air transport, freight (million ton-km)	0.96	0.96	0.96	1	2	3	
Arable land (hectares per person)	-0.96	-0.95	-0.94	1	2	3	
Broad money (% of GDP)	0.97	0.97	0.98	1	2	3	
CO2 emissions (kg per 2005 US$ of GDP)	0.95	0.94	0.92	1	2	3	
Combustible renewables and waste (% of total energy)	-0.97	-0.98	-0.97	1	2	3	
Consumer price index (2005 = 100)	0.97	0.97	0.97	1	2	3	
Crop production index (2004-2006 = 100)	0.96	0.96	0.96	1	2	3	
Energy production (kt of oil equivalent)	0.96	0.95	0.95	1	2	3	
Exports of goods and services (% of GDP)	0.95	0.94	0.93	1	2	3	
External debt stocks, concessional (DOD, current US$)	0.94	0.96	0.96	1	2	3	
Final consumption expenditure, etc. (constant 2005 US$)	0.98	0.97	0.96	1	2	3	
GDP per capita (constant LCU)	0.98	0.97	0.97	1	2	3	
Imports of goods and services (% of GDP)	0.95	0.93	0.92	1	2	3	
Industry, value added (% of GDP)	0.98	0.98	0.98	1	2	3	
Livestock production index (2004-2006 = 100)	0.96	0.96	0.98	1	2	3	
Manufacturing, value added (% of GDP)	0.98	0.98	0.98	1	2	3	
Physicians (per 1,000 people)	0.95	0.95	0.95	1	2	3	
Population in the largest city (% of urban population)	-0.96	-0.96	-0.96	1	2	3	
Road sector energy consumption per capita (kg of oil equivalent)	0.98	0.97	0.95	1	2	3	
School enrollment, preprimary (% gross)	0.98	0.98	0.97	1	2	3	
Services, etc., value added (constant 2005 US$)	0.98	0.97	0.97	1	2	3	
Telephone lines (per 100 people)	0.95	0.94	0.93	1	2	3	
Trade (% of GDP)	0.96	0.94	0.94	1	2	3	
Trademark applications, total	0.96	0.95	0.93	1	2	3	
Vulnerable employment, total (% of total employment)	-0.95	-0.91	-0.88	1	2	3	

Figure 13: Leading Indicators of Electric power transmission and distribution losses for Energy Cost for Thailand

Electricity production from renewable sources (kWh)			Count	672	129	20	0
Indicator Information	Predictive Power			Potential Indicators			
Indicator Name	T-1	T-2	T-3	Filter1 Data Availability	Filter2 Correlation	Filte3 Indicator Profile	Filter4 Time Lag
Adjusted savings: education expenditure (current US$)	0.93	0.91	0.89	1	2	3	
Air transport, passengers carried	0.93	0.91	0.90	1	2	3	
Broad money (current LCU)	0.92	0.91	0.92	1	2	3	
CO2 emissions from electricity and heat production, total (million metri	0.91	0.89	0.90	1	2	3	
Consumer price index (2005 = 100)	0.91	0.91	0.92	1	2	3	
Crop production index (2004-2006 = 100)	0.92	0.91	0.91	1	2	3	
Energy production (kt of oil equivalent)	0.92	0.91	0.91	1	2	3	
Energy use (kg of oil equivalent per capita)	0.92	0.90	0.90	1	2	3	
Exports as a capacity to import (constant LCU)	0.92	0.91	0.92	1	2	3	
Final consumption expenditure, etc. (constant 2005 US$)	0.93	0.92	0.91	1	2	3	
Food production index (2004-2006 = 100)	0.92	0.91	0.91	1	2	3	
GDP per capita (current LCU)	0.93	0.92	0.92	1	2	3	
Household final consumption expenditure per capita (constant 2005 US	0.92	0.91	0.90	1	2	3	
Imports of goods and services (current US$)	0.93	0.88	0.88	1	2	3	
Industry, value added (constant 2005 US$)	0.93	0.92	0.92	1	2	3	
Money (current LCU)	0.92	0.92	0.92	1	2	3	
Population ages 65 and above (% of total)	0.92	0.92	0.92	1	2	3	
Trade (% of GDP)	0.90	0.90	0.92	1	2	3	
Trademark applications, total	0.92	0.92	0.92	1	2	3	
Wholesale price index (2005 = 100)	0.93	0.92	0.93	1	2	3	

Figure 14: Leading Indicators of Electricity production from Renewable Sources for Energy Cost for Thailand

GDP per unit of energy use (PPP $ per kg of oil equivalent)			Count:	436	50	11	0
Indicator Information	Predictive Power			Potential Indicators			
Indicator Name	T-1	T-2	T-3	Filter1 Data Availability	Filter2 Correlation	Filte3 Indicator Profile	Filter4 Time Lag
Age dependency ratio (% of working-age population)	-0.94	-0.94	-0.93	1	2	3	
Agriculture value added per worker (constant 2005 US$)	0.87	0.89	0.91	1	2	3	
GDP per capita (constant 2005 US$)	0.91	0.89	0.87	1	2	3	
Household final consumption expenditure per capita (constant 2005 US	0.90	0.88	0.87	1	2	3	
Industry, value added (% of GDP)	0.92	0.91	0.89	1	2	3	
Mortality rate, under-5 (per 1,000 live births)	-0.93	-0.93	-0.93	1	2	3	
Population (Total)	0.93	0.93	0.94	1	2	3	
Population in largest city	0.95	0.95	0.95	1	2	3	
Services, etc., value added (constant 2005 US$)	0.91	0.90	0.88	1	2	3	
Urban population (% of total)	0.93	0.94	0.95	1	2	3	

Figure 15: Leading Indicators of GDP per Unit of Energy Use for Energy Cost for Thailand

4.4.3 Driving Forces Framework for Energy Costs for Japan

Japan's composite indicator for Energy Cost has some fluctuations, as chart below (Figure 16).

As a result, the correlation test was performed on the composite indicator.

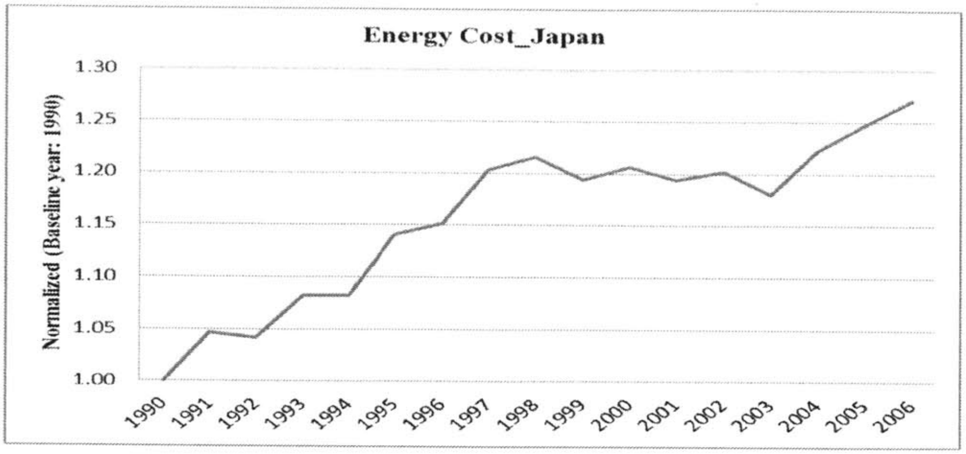

Figure 16: Composite Indicator of Energy Cost for Japan

4.4.4 Leading Indicator Selection by Correlation for Japan

Because the process of filtering leading indicator for Energy cost is similar to aforementioned for Political Stability, I omit the discussion here. The result shows that there are 19 potential leading indicators are found with correlation level of 0.9 as is shown in the figure below.

Energy Cost			Count:	478	33	19	0
Indicator Information	Predictive Power			**Potential Indicators**			
Indicator Code	**T-1**	**T-2**	**T-3**	Filter1 Data Availability	Filter2 Correlatio	Filte3 Indicator Profile	Filter4 Time Lag
Adjusted net national income (constant 2005 US$)	0.84	0.91	0.88	1	2	3	
Age dependency ratio, young (% of working-age population	-0.92	-0.92	-0.92	1	2	3	
Air transport, freight (million ton-km)	0.91	0.75	0.84	1	2	3	
CO2 emissions from residential buildings and commercial a	0.77	0.87	0.92	1	2	3	
Electric power consumption (kWh per capita)	0.87	0.92	0.90	1	2	3	
Electricity production (kWh)	0.88	0.92	0.90	1	2	3	
Exports as a capacity to import (constant LCU)	0.82	0.90	0.85	1	2	3	
Fertility rate, total (births per woman)	-0.88	-0.90	-0.91	1	2	3	
Forest rents (% of GDP)	-0.88	-0.89	-0.92	1	2	3	
GDP (constant 2005 US$)	0.84	0.90	0.86	1	2	3	
Gross national expenditure (constant 2005 US$)	0.89	0.92	0.88	1	2	3	
Gross value added at factor cost (constant 2005 US$)	0.83	0.90	0.86	1	2	3	
High-technology exports (current US$)	0.78	0.92	0.79	1	2	3	
Merchandise imports from developing economies in Latin A	-0.83	-0.89	-0.92	1	2	3	
Military expenditure (current LCU)	0.90	0.91	0.90	1	2	3	
Population density (people per sq. km of land area)	0.91	0.90	0.89	1	2	3	
Road sector gasoline fuel consumption per capita (kg of oil	0.89	0.90	0.91	1	2	3	
Scientific and technical journal articles	0.86	0.89	0.90	1	2	3	
Services, etc., value added (current LCU)	0.92	0.93	0.92	1	2	3	

Figure 17 Leading Indicators of Energy Cost for Japan

4.5 Summary

After undergoing the analysis of political stability and energy cost in Japan and Thailand, it is clear that individual indicators under the driving force framework are better suited to be consolidated into one composite indicator via factor analysis. However, when composite indicators are not eligible for a correlation test (due to unidirectional trends), individual indicators are better suited for the correlation test. The following table (Table 8) highlights the respective approach used for each test in this thesis.

Table 8: Outline of Leading Indicators Filtering in Different Cases

Driving Force	Driving Force Indicator	Thailand	Correlation Coefficient	Driving Force Indicator	Japan	Correlation Coefficient
Political Stability	Composite Indicator	14 leading indicators	0.7	Composite Indicator	15 leading indicators	0.6
Driving Force	**Driving Force Indicator**	**Thailand**	**Correlation Coefficient**	**Driving Force Indicator**	**Japan**	**Correlation Coefficient**
Energy Costs	Electric Power Transmission and Distribution Losses	28 leading indicators	0.95	Composite Indicator	19 leading indicators	0.9
	Electricity Production from Renewable Resources	20 leading indicators	0.9			
	Energy Production	Not Applicable				
	Energy Use	Not Applicable				
	GDP per Unit of Energy Use	11 leading indicators	0.9			

5. DISCUSSION

In this section, I summarize and evaluate the results of the leading indicators by comparing two different countries' datasets. I conclude by exploring the results' findings and limitations, present recommendations to Visionary Chemical and finally offer suggestions for future research.

5.1 Evaluation of the results

The following section highlights unique findings from the correlation tests.

5.1.1 Characteristics of the correlation tests

Overall, the public data used was generally quite reliable. Once the dataset was fully prepared, the correlation test generally yielded significant results, with most coefficients ranging from 0.7 to 0.9 with a maximum of 1.0. Some correlations were not as strong, such as the relationship between political stability and homicide rate indicators. Most indicators had positive correlations with political stability, whereas there were many negative correlations with energy costs. It is important to note that a driving force with a unidirectional trend will yield stronger results in the correlation test, but due to lack of fluctuation it is more difficult to infer causation. This exemplifies that each correlation test for a specific indicator may have a completely unique effect on a particular driving force.

5.1.2 Special leading indicators

5.1.2.1 Common/similar leading indicators for individual driving force indicators

As seen in the results, some leading indicators correlate with more than one driving force indicator, and are thus *common* leading indicators (Table 8). As common leading indicators can be used to predict multiple individual driving forces, they may prove more valuable than others. For instance, in the case of Thailand's Energy Cost, Consumer Price Index is a common indicator for Electric Power Transmission and Distribution Losses and Electricity production from renewable sources.

Likewise to *common* indicators, there are *similar* leading indicators, where the indicators themselves are related to each other. These indicators also tend to have a strong correlation with various driving force indicators (Table 8), but due to their similarities, it is best to consolidate them in order to decrease the range of the observation spectrum. For example, if there are two leading indicators that both relate to some aspect of Air Transport, it's best to use the single one that most managers are agree is the most relevant. Doing this makes for lean yet robust set of indicators for use in planning sessions amongst the company's management.

Table 9: Common/Similar Indicators for Energy Cost

Potential Leading Indicators	Individual Driving Force Indicators for Energy Cost
Age dependency ratio (% of working-age p	GDP per unit of energy use (PPP $ per kg of oil equivalent)
Age dependency ratio, young (% of workin	Electric power transmission and distribution losses (kWh)
Agriculture value added per worker (const	GDP per unit of energy use (PPP $ per kg of oil equivalent)
Agriculture, value added (constant 2005 U	Electric power transmission and distribution losses (kWh)
Air transport, freight (million ton-km)	Electric power transmission and distribution losses (kWh)
Air transport, passengers carried	Electricity production from renewable sources (kWh)
Broad money (% of GDP)	Electric power transmission and distribution losses (kWh)
Broad money (current LCU)	Electricity production from renewable sources (kWh)
CO2 emissions (kg per 2005 US$ of GDP)	Electric power transmission and distribution losses (kWh)
CO2 emissions from electricity and heat p	Electricity production from renewable sources (kWh)
Consumer price index (2005 = 100)	Electric power transmission and distribution losses (kWh)
	Electricity production from renewable sources (kWh)
Crop production index (2004-2006 = 100)	Electric power transmission and distribution losses (kWh)
	Electricity production from renewable sources (kWh)
Energy production (kt of oil equivalent)	Electric power transmission and distribution losses (kWh)
	Electricity production from renewable sources (kWh)

5.1.2.2 Remote Indicators

In addition to *common* and *similar* indicators, there are also indicators which may show strong correlation, but qualitatively appear to be unrelated to the driving force. We classify these types as *remote* indicators. For example, "Scientific and Technical Journal Articles" and "Energy Cost" have a 0.9 correlation coefficient but there no intuitive causation at first glance. However, this does not necessarily mean causation doesn't exist. When this sort of trend is encountered, the relationship should be explored for the potential development of additional leading indicators. However, except in cases where an extraordinarily high level of correlation is encountered, developing *remote* indicators should not be considered of primary importance.

5.1.2.3 Comparison by country

Many modern corporations operate in a multi-national environment, and thus their scenario plans must stretch across borders. When comparing correlation test results between countries, it is important to understand country-specific cultural biases, geographic factors, and simple statistical anomalies. For instance, where a strong correlation exists for Thailand, there may be none for Japan. In such an instance, a firm that operates in both of these countries would want to be aware of this disparity. As is seen in the result of leading indicators for political stability of Japan and Thailand, most indicators found are different, except for "Household final consumption" (seen in Figure 7,9 in Section 4).

5.1.3 Summary of Correlation Tests

By using universal correlation tests, the indicator identifier tool is both scalable and flexible in that it can be tailored to organizations which may have different driving forces and multiple regions of operation. The tool is able to select those indicators that pass the correlation test, establish groups of indicators that best correlate with driving forces, and visually present the results across a wide variety of scenarios, driving forces, indicators and geographies.

5.2 Limitations of the Correlation Tests

The following sections highlights the limitations presented by the leading indicator and composite indicator methodologies.

5.2.1 Use of a Single Database

This thesis relied solely on the World Development Indicator (WDI) database, which is a comprehensive compilation of social and economic data. Many other datasets exist that focus on a particular discipline such as politics, military, etc. These datasets may be useful for obtaining more details on a particular area, but when combining multiple data sets the user must take steps to ensure consistency. This is especially true when undertaking comparisons between multiple countries, as country-specific datasets may have unique features and methods that make them difficult to directly compare to other datasets.

5.2.2 Reliability of Public Information

The research relies heavily on the integrity of public databases. In order to be a valid source of data, a dataset must have an extensive historical record, consistent methods of measurement, and be maintained by a trusted and reliable government or non-governmental agency. There were few instances where excluded some data subsets as a result of certain gaps. For instance, there is no data for energy cost during the 1970's oil crisis, which would have satisfied the multi-trend data requirement. The relative quality of public information is also an important consideration when using country-specific datasets, particularly when the analysis spans across multiple countries.

5.2.3 Value of Quantitative Versus Qualitative Information

Ultimately, the combination of both quantitative and qualitative information is far more powerful than either of them in isolation. It is not clear which of the two is more suitable for scenario planning, and this thesis does not attempt to provide an answer.

5.2.4 Inability to Run Correlation Test as a Result of Unidirectional Trends

The most significant limitation to the leading indicator methodology is that the dataset must indicate numerous multi-directional cycles over time. Examples of driving force indicators where this didn't exist were energy usage and energy production, potentially weakening the validity of the results. As the driving force indicator is the dependent variable of the correlation, it must show some unique quality to it in order to prove correlation.

5.3 Recommendations to the company

Based on the interpretation of the results from the analysis, the following recommendations can be made to companies instituting such a methodology.

5.3.1 How to implement within an organization

The primary recommendation when using this methodology is to use internal expertise from a variety of disciplines to interpret statistical correlations with publicly available data. When internal stakeholders are integrally involved in the process, they have a heightened sense of ownership in the results, as it is the product of their own efforts. Working closely with academia may help support this process, so long as all of the parties involved maintain a practical focus on the company's strategy.

5.3.2 How to interpret and respond to the tool's output

The filtering guideline proposed in methodology section 3.3 is a general recommendation that may not necessarily align with the driving force indicator being studied. A company may wish to adjust the methodology for Filters 2 and 3 or develop alternate filters in order to eliminate unrealistic indicators. Additional filtering criteria could also be developed based on the company's perspective on driving forces. For example, several indicators about population, shown in Table 10, are all found to be highly correlated to "GDP per unit of energy use." The guideline described in 3.3 recommends choosing "Population Total," which may be too broad a statistic in the specific context. Instead, a company practitioner may find indicators such as "population in the largest city" more relevant to "GDP per unit of energy use."

Table 10: Indicators of the same profile

Population (Total)
Population ages 0-14 (% of total)
Population in largest city
Population in the largest city (% of urban population)

Another recommendation is to use the findings from the countries studied in order to monitor other countries of interest. A leading indicator that can predict a driving force in Thailand or Japan may also be relevant for a more important country, such as China. For example, if a company can predict political instability in Japan, they may have the potential to foresee turbulence in China. However, the company should be cautious when extrapolating in this manner, as qualitative judgments will be necessary when validating these types of applications. This is a considerable implication of the tool that could be very valuable during a firm's scenario planning.

5.3 Suggestions on Future Work

Further work could explore the effects of scenario monitoring on the overall effectiveness of scenario planning. While it may seem futile to constantly monitor those signals that are highly correlated but have doubtful causality, scenario monitoring is a valuable way to validate scenarios and make sense of those signals which may or may not impact the business. As time progresses, those ambiguous leading indicators may in turn prove to actually be causal, enabling the company to predict those driving forces that it previously thought were undetectable. Future work could explore qualitative methods that interpret these types of variables which have strong correlation but questionable causality.

Another consideration is that the quality of the output of leading indicators is highly dependent on the driving force framework. The more reflective an indicator is on the real world, the more accurate potential indicators are. Therefore, future research can look into more specialized databases which may contain more detail on certain driving forces. One example of a specialized database is the World Bank's World Governance Indicator[3]for Political Stability, which provides six specific dimensions for political stability, where the WDI provides no specific measure.

Another limitation to this research that presents an opportunity for future research is the limited scope used in the driving force indicator framework. As this thesis explored only two of the ten driving forces that Visionary Chemical identified, further exploration of the other eight would further validate the framework. Additionally, other countries in A/P could be studied to further validate the model. I expect that application to other cases or scenarios would utilize the same general process (Chapter 3), with interesting implications for Visionary Chemical.

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[3] "The Worldwide Governance Indicators (WGI) project by World Bank reports aggregate and individual governance indicators for 215 economies over the period 1996–2012, for six dimensions of governance: Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption."(http://info.worldbank.org/governance/wgi/index.aspx#home)

Further research may also be done in conjunction with another partner company to validate the results. As it was not within the scope of this thesis, conducting a similar analysis for another company would be useful to further strengthen the tool's credibility.

5.4 Conclusion

5.4.1 A mathematical guideline for a performing art

Building scenarios is by and large a product of human brainstorming. Using a mathematical approach to formulate the monitoring process makes it easy for the audience to understand the process of scenario planning and allows them to offer their own perspectives. Instead of becoming overwhelmed with information and opinions, the quantitative approach provides a standardized, transparent framework for an organization to communicate and build consensus. Additionally, this approach provides another lens to look at a scenario's driving forces. Scenario planning combined with this quantitative framework is similar to the relationship between mathematics and art: some great artworks manifest themselves through mathematical law, while a mathematical law can help construct a beautiful piece of artwork. In this way, a quantitative approach to a historically qualitative process provides a balancing force to an inherently imperfect, human activity.

5.4.2 A standard tool can be utilized to any driving force for different scenarios

The leading indicator tool is particularly robust in that it is not limited to a restricted format and is not designed to serve any particular industry. The tool can analyze any statistically tracked driving force that features historical fluctuations over time in order to identify its key leading indicators.

5.4.3 Conclusion

In conclusion, companies that have introduced a robust scenario planning program can strengthen is capability by incorporating the quantitative methods introduced in this thesis. The process of converting qualitative categorical data into usable quantitative numerical information, and using the correlation matrix process to determine its potential as a leading indicator can help companies counteract the inherently flawed human approach to scenario planning. Thus, the combination of both quantitative analysis and human interpretation is similar to a mathematically inspired work of art. The global business landscape is an increasingly complex and unpredictable environment. Companies that design dynamic strategies that can both capitalize on unforeseeable opportunities while avoiding seemingly hidden risks are those that will be exceptionally successful in a sustainable, long-term way.

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APPENDIX A. Loadings of Individual Indicators of Political Stability (Thailand)

Component Matrix						
	Factor Loading		Squared Loadings		Squared Loadings (Scaled to unity sum)	
	Component1	Component2	Component1	Component2	Component1	Component2
Armed forces personnel (% of total labor force)	.492	.535	0.24	0.29		0.27
Arms imports (SIPRI trend indicator values)	.799	-.445	0.64	0.20	0.25	
Foreign direct investment, net inflows (BoP, current US$)	-.881	-.182	0.78	0.03	0.31	
Military expenditure (% of GDP)	.810	-.422	0.66	0.18	0.26	
Intentional homicides (per 100,000 people)	.455	.603	0.21	0.36		0.34
Explained Variance	2.52	1.06	2.52	1.06		
Explained Variance/Total Variance	0.70	0.30				

Individual Indicators	**Original Loading**	**Scaled Loading**
Armed forces personnel (% of total labor force)	0.21	0.28
Arms imports (SIPRI trend indicator values)	0.08	0.10
Foreign direct investment, net inflows (BoP, current US$)	0.19	0.25
Military expenditure (% of GDP)	0.15	0.20
Intentional homicides (per 100,000 people)	0.14	0.18
Sum	0.78	1.00

APPENDIX B. Loadings of Individual Indicators of Political Stability (Japan)

Component Matrix						
	Factor Loading		Squared Loadings		Squared Loadings (Scaled to unity sum)	
	Component1	Component2	Component1	Component2	Component1	Component2
Armed forces personnel (% of total labor force)	-.730	-.493	0.53	0.24	0.21	
Arms imports (SIPRI trend indicator values)	.773	-.208	0.60	0.04	0.24	
Foreign direct investment, net inflows (BoP, current US$)	.056	.948	0.00	0.90		0.72
Military expenditure (% of GDP)	-.858	.245	0.74	0.06	0.30	
Intentional homicides (per 100,000 people)	.782	-.053	0.61	0.00	0.25	
Explained Variance	2.48	1.25	2.48	1.25		
Explained Variance/Total Variance	0.67	0.33				

Individual Indicators	**Original Loading**	**Scaled Loading**
Armed forces personnel (% of total labor force)	0.14	0.16
Arms imports (SIPRI trend indicator values)	0.16	0.18
Foreign direct investment, net inflows (BoP, current US$)	0.24	0.27
Military expenditure (% of GDP)	0.20	0.22
Intentional homicides (per 100,000 people)	0.16	0.18
Sum	0.91	1.00

APPENDIX C. Loadings of Individual Indicators of Energy Cost (Japan)

Component Matrix						
	Factor Loading		Squared Loadings		Squared Loadings (Scaled to unity sum)	
	Component1	Component2	Component1	Component 2	Component 1	Component2
Electric power transmission and distribution losses (kWh)	.953	.050	0.91	0.00	0.40	
Electricity production from renewable sources (kWh)	.555	-.572	0.31	0.33		0.16
Energy production (kt of oil equivalent)	.260	.905	0.07	0.82		0.41
Energy use (kg of oil equivalent per capita)	.805	-.499	0.65	0.25	0.29	
GDP per unit of energy use (PPP $ per kg of oil equivalent)	.567	.769	0.32	0.59		0.30
Explained Variance	2.25	1.99	2.25	1.99		
Explained Variance/Total Variance	0.53	0.47				

Individual Indicators	Original Loading	Scaled Loading
Electric power transmission and distribution losses (kWh)	0.29	0.11
Electricity production from renewable sources (kWh)	0.64	0.23
Energy production (kt of oil equivalent)	0.78	0.29
Energy use (kg of oil equivalent per capita)	0.66	0.24
GDP per unit of energy use (PPP $ per kg of oil equivalent)	0.36	0.13
Sum	2.72	1.00

Original Loading=Max (Squared Loadings)/ corresponding (Explained Variance/Total Variance)

Max(Square Loading) is highlighted in yellow. Scaled Loading=Original Loading/Sum of original Loading

Scaled Loading is used for weight of each individual indicator.