How Should Indicators be Found for Scenario Monitoring ?

by

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Abstract

Scenario planning is a widely used approach for developing long-term strategies. The typical scenario process involves developing scenarios, identifying strategies whose success is contingent on the scenario, and monitoring the environment regularly to know which scenario(s) may become more likely. Hence it becomes necessary to find a way to monitor the business environment in order to inform the process of making strategic decisions under uncertainty. This thesis proposes to use a set of nested indicators to monitor environment. The approach consists of a seven–step process to build composite indicators and link them with scenarios. Individual indicators are selected based on intuitive theoretical frameworks. Different weights are assigned to individual indicators using factor analysis. And then composite indicators are built by linear aggregation of individual indicators. The composite indicators are used to assess the changes in the driving forces over time. Such changes serve as the basis for judging whether the level of the driving forces is high or low. Those levels are then used to infer which scenario is likely to come to pass.

This thesis used a set of four scenarios to illustrate the application of the approach. Those scenarios were built for a chemical company's supply chain in Asian/Pacific region in 2025. The result suggested that the environment of the sub-region in the monitoring year was more like a "Collaborative World" or a mix of "Collaborative World" and "Demanding World". And it is more possible that the environment was evolving into those two scenarios instead of the others.

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Finally, thank my parents for your love. I miss you and will soon be back.

To my Parents

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Chapter 1 Introduction and Motivation

1.1 Background

Strategy is an important factor in the success of firms. It means the firm has to find its unique position in the industry and establish a set of activities that not only fit its own system but also can continuously differentiate it from its rivals (Porter, 1996). As the business environment changes rapidly, it is hard to have a clear understanding of the current situation, not to say the situation in the far future. And it is even harder for business leaders to develop strategies that could be proven to be correct in a long-range. Too many companies failed despite of their former glories due to lack of a clear vision of how the business environment is changing. If only Kodak had seen the inevitable trend of digital camera in the early stage of this revolution, it could have continued to exist instead of going bankrupt. Had IBM known the potential of personal computers in the eighties, it wouldn't have totally lost this big market to Microsoft and Intel (Schoemaker, 1995). There're a lot of other examples about how bad long-term strategies brought doom to companies. To be sustainable in the long run, companies must develop right strategies.

Knowing the current situation and thinking about the future are equally important for making right strategies for the company. However, both of them are tricky. Even if with good situation awareness, poor decisions could still be made. On the contrary, if lucky enough, it is possible to make good decisions knowing nothing about what is going on around(Endsley, 2000). For another, thinking about the future is easy, but it's difficult to envision or predict it correctly. In the beginning of the 20th century, many professionals didn't believe that the airplanes would have huge impact on naval warfare(Schoemaker, 1995). And in 2007, the CEO of Microsoft claimed that "there's no chance that the iPhone is going to get any significant market share" (Lieberman, 2007) . In both cases, things turned out to be completely different. There are lots of such examples.

In order to make better plans for the future, various planning methods have been developed. The first example is contingency planning, which is used for examining one uncertainty that deviates from the baseline. It is useful for the company to quickly recover from certain changes in the environment. The second example is sensitivity analysis. It checks the impact of the change in one variable holding other variables unchanged. This method is only viable when the change is small. Third, with the help of computer, simulation models could be used to imitate the results of the strategies(Schoemaker, 1995). Fourth, backcasting is also used for making plans for future. This method first generates a desirable future and then looks back from it to see what can be done at the present to arrive at the desired future (Vergragt & Quist, 2011) . However, all the above-mentioned methods have limitations due to complex interactions among many factors that shape the environment and future. Specifically, contingency planning cannot deal with joint impact of various uncertainties; sensitivity analysis cannot handle big changes; not every element can be modeled in a simulation(Schoemaker, 1995); and backcasting mainly focuses on the solutions to a specified problem. Strategies in the undesirable developments are not considered(Dreborg, 1996).

Scenario planning is introduced as a different approach for making long-term strategy. It was originally developed for U.S. military applications; the first famous successful application in business was demonstrated at Shell. A group of planners at Shell had been using scenario planning since 1967, and they had been using a scenario that had the same effects as those later experienced in the 1973 Oil Crisis(Schwartz, 1996). This method has become popular in large corporations since early eighties (Linneman & Klein, 1983) .

Scenario planning takes a wide variety and range of driving forces into consideration. It organizes all those driving forces into several scenarios and expresses them as qualitatively different views of the future. Scenarios are written as stories – with or without supporting quantitative data. The use of scenario planning helps the decision makers look through possible futures and switch their mindsets among different scenarios(Schoemaker, 1995). This practice can help the decision makers get better sense of the environmental forces that shape the present and the future reality(Schwartz, 1996). After the scenarios are built, possible strategies are put into each scenario to check their validity. Then the decision makers can decide whether to implement the strategy or not in the future. This planning method does not assign probability to each scenario. On the contrary, its philosophy is that since in reality scenarios often overlap each other, it's not necessary to memorize different plans for different scenario (Schwartz, 1996).

1.2 Problem Statement

With all those unique treats, scenario planning could be one of the most appropriate tools for making long-term decisions. Scenario planning is time-consuming and involves many people. When scenarios are built, it becomes necessary to monitor the progress of environment to check if it matches the developed scenarios. By doing so, companies can promptly revisit their strategies. This arose the research question of this thesis: how can we know which scenario may unfold? The thesis aims to find a way to recognize the unfolding scenario so that companies using scenario planning can make better preparation to the scenario.

Indicators, which means "a variable, index, etc., which is considered to provide information about a sector, market, or economy; spec. which is used to predict future outcomes or trends" in the dictionary(Oxford, 1989), are commonly used to monitor the status of certain situation. Composite indicators, on the other hand, are variables that synthesize main information about driving forces. Driving forces are environmental factors that shape the scenarios. Organizations such as World Bank, OECD, WTO, UN etc. have developed many indicators to reveal the status of economic, political, technical or environmental situations. Quite a few sophisticated methods have been developed for building indicators and a lot of literature can support the use of indicators. Indicators serve as a direct way to help people understand underlying development of the scenario. Yet there is no published systematic way with logical argument in support of finding them. Hence this paper will describe a systematic process for identifying indicators to monitor a specific set of scenarios and the research question is further revised as follows:

"How should indicators be found for scenario monitoring?"

For clarity, the thesis defines the meaning of indicator as the observable variables that can show the changes in the scenario.

1.3 Research Plan

This project consists of three parts. (1) A review of the existing methods for scenario monitoring and possible indicators. (2) The development of a new method. (3) A case study of scenario monitoring, where the method is applied.

The thesis began with the exploration of the existing literature. In this step, the thesis surveys the existing common methods for constructing indicators. And then it came up with the methods designed for finding indicators for scenario monitoring. Furthermore, the methods for scenario monitoring were applied to a set of four scenarios to demonstrate the use of them.

During the process, theoretical frameworks for indicators were established by interviews, brainstorming or literature review. Then the database of World Development Indicators provided by World Bank were explored to find out the viable indicators for scenario monitoring. The methods to combine those indicators to show the trend of the environment were built.

The goal of the thesis is to find ways to construct a series of indicators that are convenient for continuously monitoring specific scenarios. By doing so, companies can promptly know what scenario is likely to come to pass. The final result would be a methodology that can help companies to build their own indicators for scenario monitoring.

Regularly monitoring the changes of the environment is a necessary step after scenarios are developed. Without knowing the changes, the companies would not know when to connect specific scenarios to their day-to-day business. Establishing a set of practical methods for scenario monitoring would help the companies solve the problem. As long as companies can recognize the scenario conveniently, over time, they can be aware of whether their strategy is appropriate and when to implement new strategies or change existing strategies. As a result, the practice of scenario planning can be incorporated into everyday business of the companies and better help the company to achieve long-term success in the fast changing business environment.

Furthermore, the developed process has the potential to be developed as an artificial intelligence system. So the whole process can be automated, thus making the practice of scenario monitoring more convenient. Moreover, the practice of finding the indicators can also help the decision makers have a richer understanding of the important factors in the environment and make sense of the evolution of the scenarios.

1.3.1 Research context

BASF is the sponsor of this research. With a revenue of ▪ 78.7 billion and net income of ▪ 8 billion in 2012, it maintains its leading position in the world chemical industry(BASF, 2013). Having the purpose of "we create chemistry for a sustainable future", BASF has set itself ambitious goals including adding value as one company, innovating to make customers more successful, driving sustainable solutions and forming the best team(BASF, 2013). Nowadays, BASF has its operations all over the world and is investing heavily in Asian/Pacific area. 19% of its sales were generated in this area in 2012. Excellent strategy is considered one of the core competences of the company. In 2011, BASF finished developing scenarios in 2025 for Supply Chain in Asia/Pacific area to facilitate long-term decision-making. Realizing "companies cannot do a scenario planning exercise on a continuous basis", BASF sponsored the project to "incorporate the monitoring of scenario development and revisit the supply chain strategy based on the ongoing evaluation of developed scenarios" (BASF, 2012) . Throughout the research, the author worked closely with a liaison from BASF. The thesis used the scenarios developed by BASF to demonstrate the application of the method of scenario monitoring. This project can help BASF use the methods to develop its own indicators for scenario monitoring. And it will further help BASF better implementing its strategies with the feedback from scenario monitoring.

Chapter 2 Literature Review of Scenario Monitoring

Individual literature that focuses on scenario monitoring is relatively rare. Sometimes this topic is also included in the discussion about scenario planning. However the discussions are often not sufficient.

Nevertheless, literature from two sources is most relevant to the topic. First, literature about scenario planning could show why scenario monitoring is necessary and what objective should scenario monitoring achieve. Second, literature about indicators could illustrate how the indicators are developed and what potential indicators would be. All those two areas attracted a number of researchers and the literature is abundant. In this literature review, the thesis attempts to document the literature related to scenario monitoring from above two sources.

This literature review first assessed the value of scenario monitoring in scenario planning, and then explored the use of indicators in other researches. Different methodologies were analyzed and compared. In the end, the OECD approach of constructing composite indicators was discussed.

2.1 A brief review of scenario planning

2.1.1 What is scenario planning

In order to ensure long term success in the rapidly changing business environment, companies like BASF use scenario planning to help make strategic decisions. Strategy making often aims to develop sets of activities for decades or even longer(Porter, 1996). However, it is hard to predict the future in such a long term, not to say plan activities based on it. Studies showed that traditional statistical forecasting methods are not perceived as trustworthy tools in long-rang forecasting (Linneman & Klein, 1983) . Therefore, scenario planning is considered an alternative method that overcomes some of the limitations of the statistical forecasting methods. Scenario planning was first used for military planning (Bradfield, Wright, Burt, Cairns, & Van Der Heijden, 2005) . Later, more companies started to use scenario planning. According to Linneman & Klein. (Linneman & Klein, 1983) , by 1981, more than 75% of Fortune 100 companies used scenario planning. And the percentage in Fortune 1000 at that time was 46%. Companies in high capital density industries were more likely to use scenario planning. Nowadays, scenario planning is recommended as a valuable tool for long range planning(Schnaars, 1987).

Scenario planning has two distinct features compared with other forecasting approaches. First, it's qualitative and usually in a descriptive format. Second, it identifies a set of futures but does not try to associate them with probabilities(Schnaars, 1987).

There are three major kinds of scenario schools, namely 'Intuitive Logics', 'the Probabilistic Modified Trends' and 'the La Prospective methodologies'(Bradfield et al., 2005). Among them, intuitive logics methodology mainly depends on the work of the individuals from within the company. It emphasizes more on the learning and insights derived from the process rather than on the reliability of the scenarios(Bradfield et al., 2005). This is the approach employed by BASF project and will be discussed in this thesis.

2.1.2 The need for scenario monitoring

There are three reasons that make scenario monitoring necessary.

First, after the scenarios are developed, strategic decisions can be made based on those scenarios. Some activities are good in all scenarios. They are called "No-brainer". Some activities are bad in all scenarios. They are called "No-gainer". And some are good in some scenarios but are not bad in any scenarios. They are called "No-regret". Those decisions can be easily made regardless of the scenarios. However, there are some activities which are good in some scenarios and bad in some other scenarios. The decision whether they should be implemented depends on which scenario will actually happen. Activities of these kinds are called "Contingent" decisions (Caplice & Phadnis, 2013) . To deal with the contingent decisions, people need to identify which scenario is likely to come to pass.

Second, since scenarios built by intuitive logics are quite descriptive, they are possible to be tailored to some special needs (Huss & Honton, 1987) . Monitoring scenarios can help people avoid being misguided by ill-developed scenarios in certain extent.

Third, if there are no explicit criteria to connect the environment with the scenarios, the users of the scenario will be upset when they do not know when to start to get benefits from the scenarios (Gregory, Harris, & Ogilvy, 2009) . Mornitoring scenarios can give them guidance about the timing of the scenario development.

To sum up, in order to make judgment on contingent decisions, avoid bad effects of tailoring and know when to reap the benefits of scenario planning, scenario monitoring becomes necessary.

2.1.3 Finding early indicators

Early indicators are used to discern the likely scenario. Early indicators are "signs in the environment that point to the possible futures described in the scenarios"(Gregory et al., 2009). By watching these signs, the unfolding future can be recognized. The ability to recognize and react to those indicators is crucial to the implementation of scenario planning (Weil & White, 1994) .

According to Gregory et al. (Gregory et al., 2009) , there are two different ways to find indicators. One is to scan all the aspects of the environment, hoping to find signs of new trend. The other is to monitor certain indicators that are chosen in advance. So that new indicators related to existing indicators could also be found when they emerge. Usually these indicators are monitored on a periodic basis. Gregory et al. (Gregory et al., 2009) also suggest three guidelines for choosing indicators. They are "think upstream", "identify the little signs of big changes" and "look to your customers' customer".

In addition, Schoemaker & Day (Schoemaker & Day, 2009) come up with another set of methods to find indicators that they call weak signals. The methods are "tapping local intelligence", "leveraging extended networks", "mobilizing search parties", "testing multiple hypotheses", "canvassing the wisdom of the crowd", "developing diverse scenarios", "seeking new information to 'confront reality'", "encouraging constructive conflict" and "trusting seasoned intuition".

Most of these methods are qualitative. Although each individual method seems to be practical, yet there's no systematic way to evaluate and interpret the early indicators. Comprehensive study using above-mentioned methods for monitoring scenarios is still rare.

2.2 Developing Indicators

Indicators are also widely used in areas other than scenario monitoring. International comparison, sustainability evaluation, financial soundness measurement, performance metrics etc. are areas that use indicators commonly. In studies of these fields, indicators often serve as quantitative tools. Usually they are developed from original data.

2.2.1 The methodologies for developing indicators used in other researches

In order to "provide users with a rough idea of the soundness of the financial sector as a whole", Geršl & Heřmánek (Geršl & Heřmánek, 2008) constructed a simply aggregate banking sector stability index. Based on international practice, they selected individual partial indicators. Then they asked experts to set weights for each partial indicator. Next, they converted the indicators so that the increase of the indicator means improvement and the decrease of the indicator means deterioration. Linearly adding the weighted partial indicators together, they got the aggregate financial stability indicator (Geršl & Heřmánek, 2008).

In 1999, Nicoletti et al. (Nicoletti, Scarpetta, & Boylaud, 1999) used a multi-stage approach to develop summary indicators of product market regulation and extended it to employment protection legislation. They followed four steps. First, they collected and put the original data into different categories. Second, they constructed detailed indicators using a hierarchical scoring procedure. Third, they used factor analysis to estimate the summary indicators in each domain and sub-domain. Fourth, the overall indicators were estimated also using factor analysis. The first two steps involved some subjective judgment and the last two steps relied on statistical property of the data. (Nicoletti et al., 1999)

In a 2011 report, Finne et al. (2011)developed a composite indicator for knowledge transfer. They mainly followed the advice of a handbook on construction of composite indicators, which is published by OECD (Nardo et al., 2005). First, they divided knowledge transfer into three fields. Second, they listed potential indicators for each field. Third, they chose proposed component indicators based on the criteria they set. Fourth, they normalized each component indicator and then constructed the composite indicator by averaging the normalized component indicator for each country. Thus the complexity of giving weight to each component indicator was avoid and the other advantage was that they could calculate the composite indicator even if some component indicators are missing.

In the Innovation Union Scoreboard 2011 published by European Union, the authors built summary innovation index to help monitor the implementation of the Europe 2020 Innovation Union flagship. They followed seven steps to calculate composite scores. First, they identified and replaced outliers. Second, they set reference years that usually lag 1 or 2 year behind the target year. Third, they handled missing values. Fourth, they identified maximum and minimum scores. Fifth, they transformed skewed data. Sixth, they normalized scores using maximum and minimum scores. Seventh, the composite innovation indexes were calculated by averaging the normalized scores of indicators without giving different weights to them. (European Commission, 2011)

The project report of European Common Indicators followed a different approach. The report first defined the indicators that were important for sustainable policy making. Second, the authors sent out web survey questionnaires to ask people their feelings about the indicator. People who participated in the survey should rate the indicators in a rating scale from 1 to 7. Third, a table was developed base on the survey results to show the percentage of each rating scale. And a general comment was also put on the results. (Ludlow, Mitchell, & Webster, 2003)

The first four studies are similar in the sense that they all aimed to build composite indicators to represent the target phenomenon. The most salient difference among those studies is their ways to assign weights. The first study used the weights assigned by experts. This method is susceptible to the biases of the experts. The third and fourth studies gave up assigning different weights to individual indicators and used simple average to get the composite indicators. This approach is easy to implement but ignores the different importance of indicators. The factor analysis approach that is used by the third study may also be the most plausible one for scenario monitoring. In the method section, the thesis will discuss factor analysis in detail.

The last research was different from the previous four because it directly asked respondents to evaluate the indicators. This approach is simpler and more qualitative. However, the downside is that it could suffer from the biases of the respondents and fail to incorporate information from other sources.

2.2.2 The approach proposed by OECD

In 2008, OECD(Nardo et al., 2005) published a handbook that gives detailed instructions on how to build indicators. This book summarizes the commonly used methods for constructing composite indicators. It can serve as a good reference book. Basically, it lists ten steps. Those ten steps are shown in the following graph:

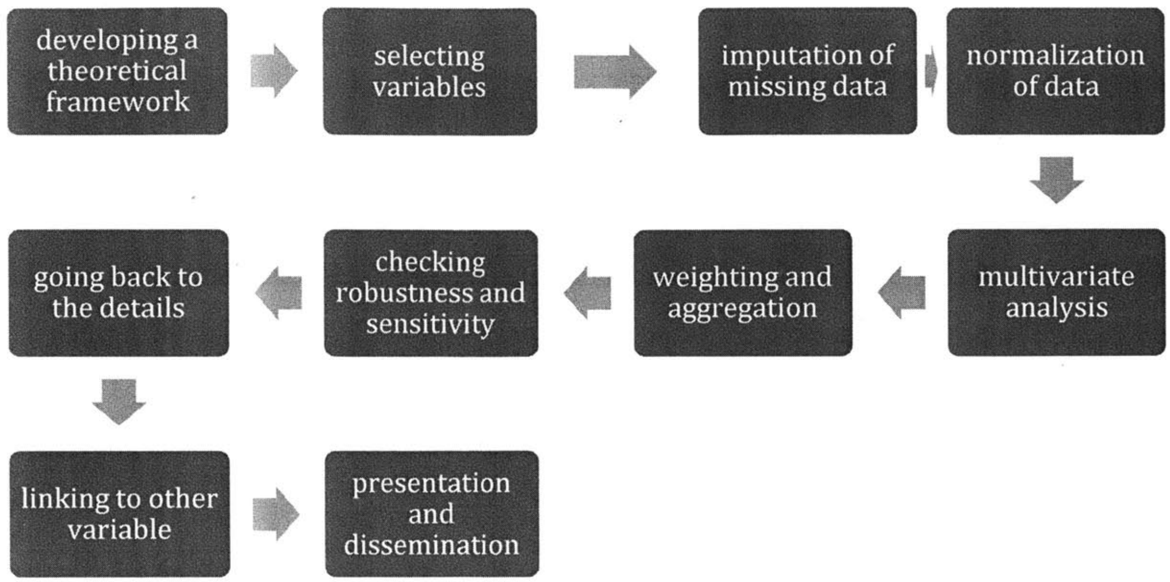

Figure 1: Ten Steps for Constructing Composite Indicators

In each step, the book listed various methods that could be used to accomplish the step. Those methods cover most technics of constructing indicators.

However, the notebook does not have detailed guidance on how to choose these methods. Neither does it provide example to demonstrate the implementation of the whole process. Besides, some of the steps are not necessary for scenario monitoring and new steps should be added in order to use the indicators to monitor scenario. Furthermore, the steps seem to be in sequence. But in practice, this is not true. These steps should be adapted for the cognitive process in scenario monitoring.

The thesis will develop a new systematic approach to build indicators for scenario monitoring based on the steps proposed by OECD. The new approach will solve the problems that are not covered by OECD notebook and give a practical example of how to implement the methods.

Chapter 3 Methods

In this section, the thesis set up an approach to find indicators for scenario monitoring. The thesis first defined the terms used in scenario monitoring and discussed the sources of the data. Following this, the thesis presented the steps for constructing indicators and the method to monitor the business environment with the indicators.

3.1 Definition

The scenarios are fleshed out with driving forces (Phadnis, Caplice, Singh, & Sheffi, 2012) . Thus, monitoring scenario is a synonym for recognizing the changes of the driving forces. In many cases, the changes of driving forces cannot be directly observed. So indicators are used to show the changes. In order to capture complex effects of the driving force, usually more than one indicator are used to show the changes in one driving force. Composite indicators are built upon individual indicators so that the relationships among individual indicators can be included in the analysis. Another reason of using composite indicators is that their meanings to the changes can be directly interpreted. This kind of relationship provided the basis for the terms that are used in scenario monitoring. The thesis borrowed some basic definitions from existing thesis and defined terms that have special meanings in this thesis.

- **Driving force:** "An element of the organization's external environment (thus, not amenable to the organization's control), which the organization cannot influence."(Phadnis et al., 2012)

- **Individual indicator:** the variable that reflects an aspect of "five domains of the environment-Society, Technology, Economy, Environment and Politics" (Phadnis et al., 2012) .
- **Composite indicator:** an indicator aggregated from individual indicators. It shows the changes of the driving forces.
- **Dimension:** the layer under which some indicators are grouped and above which the composite indicator is constructed. Dimensions reflect both the meaning of the theoretic framework and the results of multivariate analysis of the individual indicators.
- **Objective:** the desired change direction of the indicator. To help the composite indicator get the highest value, the objective of the indicator could be either maximizing or minimizing itself.

3.2 Overall research approach

To build the composite indicators, the thesis first reviewed the methods proposed by OECD. As have mentioned in previous section, OECD proposed ten steps for building composite indicators. Since those are general technical guidelines, the thesis selected six steps among them as reference to build composite indicators for scenario monitoring. The other four steps including checking robustness and sensitivity, going back to the details, linking to other variables and presentation and dissemination(Nardo et al., 2005) are important steps for further understanding and effectively utilizing composite indicators but are not essential for building composite indicators. These steps were eliminated so that the thesis could focus solely on the goal of finding indicators for scenario monitoring.

Other than those six steps, based on The Data/Frame Theory of sensemaking (Klein, Moon, & Hoffman, 2006) , a loop between developing a theoretical framework and multivariate analysis was added. Furthermore, one last step that shows how to use composite indicators to monitor scenario was added. In the following paragraphs, the thesis will explain the seven steps in order. An example of using these steps and methods to construct composite indicators for monitoring scenarios developed by BASF will be shown in the 4th part.

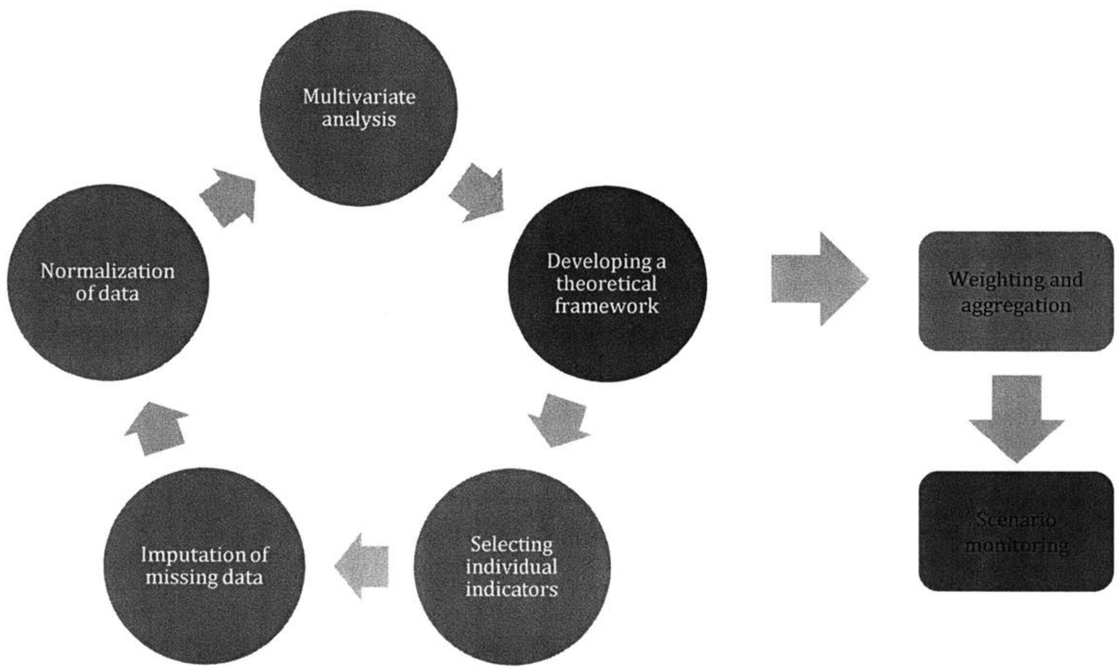

Figure 2: Steps for Constructing Composite Indicators

3.3 Developing a theoretical framework

Theoretical frameworks are used to select and aggregate individual indicators. They "should clearly define the phenomenon to be measured and its sub-components, selecting individual indicators and weights that reflect their relative importance and the dimensions of the overall composite"(Nardo et al., 2005).

They are the foundation to construct composite indicators. First, they serve as the guidelines for selecting individual indicators. Those that are not fit the theoretical frameworks will be eliminated. Second, it gives meaning to the results of multivariate analysis, so as to make the combination of the individual indicators sensible. Thus the user of the composite indicators can interpret the meaning of its components and can trace back the composite indicator to get more understanding of what it implicates. Third, in the weighting and aggregation step, they help to choose the method used for weighing individual indicators. The objectives of individual indicators defined in the theoretical framework determine how they will be weighted. Moreover, when using nonlinear method to build non-compensatory composite indicators, which are used when only the weights are interpreted as "importance coefficients", the theoretical framework should make sure "symmetrical importance" of each individual indicator exists (Munda & Nardo, 2009) .

3.3.1 Steps for building framework

The steps involved in defining a theoretical framework are described below:

1. ***Define composite indicator***: to develop theoretical framework, the definition of the composite indicator should firstly be given(Nardo et al., 2005). In this research, this definition is as same as that of driving force.
2. ***Define components of composite indicator:*** The second step is to determine sub-groups of multi-dimensional concepts of composite indicator (Nardo et al., 2005). Those concepts include dimensions, individual indicators and objectives of individual indicators.

In the hierarchical structure of composite indicator, the first layer consists of dimensions and the second layer consists of individual indicators. The theoretical selection criteria are given in the definition of individual indicators.

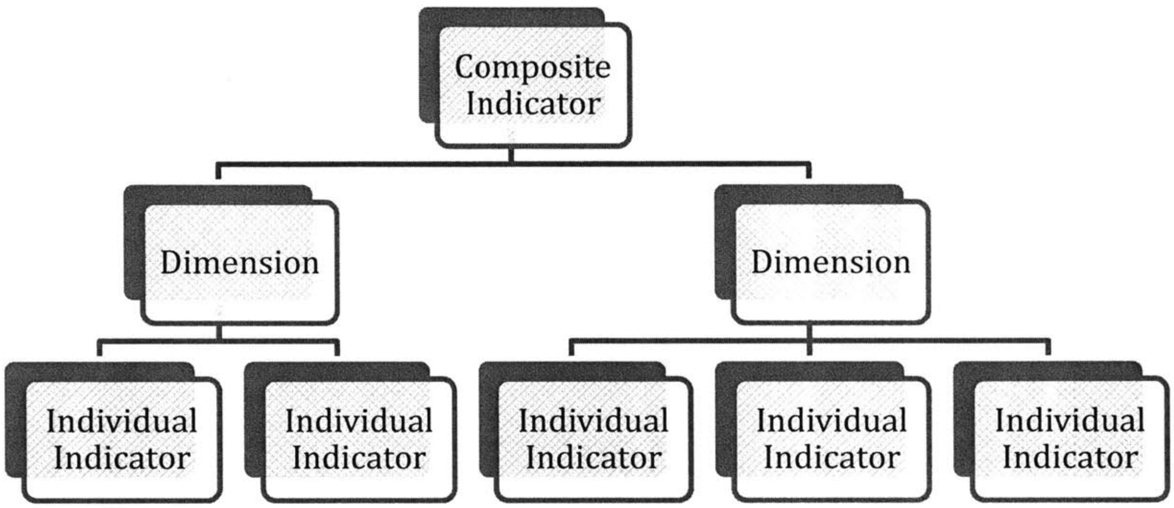

Figure 3: Construction of Composite Indicators

An example can better explain the above terms. Let's take energy cost as the composite indicator. It could have two dimensions. One is the production of energy; the other is the consumption of energy. In the consumption dimension, there could be an individual indicator called the losses in electric transmission. The variable of this indicator could be percent of total electric output. And if higher energy cost were to be achieved, the objective of the indicator would be to maximize the losses in electric transmission.

3.3.2 Method for building framework

Usually there are several driving forces in a scenario plan. For each driving force, the thesis came up with a theoretical framework to catch the main aspects of it. The ideas of the frameworks were from existing literatures or intuition. If there are sophisticated theories or researches that can explain the driving force well, the thesis borrow their ideas. If such theory or research was not found, the thesis would conduct brainstorming to generate original ideas about the composite indicator. The brainstorming process is to first write down 30 possible indicators and then pick up those which better represent input or output side of the driving force to form the theoretical framework.

Although the steps proposed by OECD seem to be quite straightforward, building theoretical framework usually is not a waterfall process. Constructing theoretical framework is a kind of sensemaking activities. Sensemaking means "how people make sense out of their experience in the world" (Duffy, 1995) . Usually, the beginning and the end of sensemaking activities are not clear. For example, people usually come up with their theoretical frameworks with minimal perspective or viewpoint. Frames decide what indicators are chosen, and then the chosen indicators are used to check the validity of frames(Klein et al., 2006). This loop may continue several times until frames and data agree with each other.

Therefore, the first theoretical framework should later be tested by the data. If the data are inconsistent with it, new framework should be proposed until no evidence is contradicted with it.

3.2 Selecting individual indicators

This step aims to pick out individual indicators from the data sources. Those individual indicators are basic elements for constructing composite indicators.

3.2.1 Selecting potential indicators

Based on the theoretical framework, potential indicators are selected from datasources. In this process, the criteria of selection are:

- **Relevance:** indicators should be relevant to the theoretical framework.
- **Availability:** data of the target country in the desired time period are available from the data sources. Since most scenario users were big companies that aimed to establish long strategic position (Malaska et al., 1984), the time period should be set long enough. In this thesis, the lower bound was set at seven years, which is typically considered a long term in chemical industry. If the data are not available continuously in the time period, the indicator has to be abandoned.

The number of potential indicators should be as many as possible so as to give room for the next step.

3.2.2 Selecting individual indicators

After getting all the potential indicators, the second round of selection should be conducted. In this round, the purpose is to select individual indicators that can be used for building composite indicators. The following criteria are for selecting indicators at this stage:

- **Non-repetition:** Different individual indicators should not repeat the same or similar content. For example, a concept can be measured either by percentage or amount. In this case, only one individual indicator with one measurement should be chosen.

- **Coverage:** Chosen individual indicators should cover all the dimensions proposed by theoretical framework. If the theoretical framework is not fully covered, the final composite indicator may lose its theoretical justification and be misleading. Each dimension should have at least one individual indicator. Usually there are multiple individual indicators for each dimension.
- **Data availability:** in the given time period, the missing data should be as less as possible.

3.3 Imputation of missing data

There are many different ways to deal with missing data. The simplest way is to ignore the missing data in the analysis. However, since the composite indicator is actually a ranking result between each year, omitting some numbers may have big effect on the ranking. So in this research, the thesis used imputation to handle missing data.

Imputation could be either single or multiple. Single imputation includes mean/median/mode substitution, regression imputation, hot-and-cold-deck imputation, expectation-maximization imputation etc. Those methods use the existing data to generate a predictive distribution, and then the missing values are filled by values drawn from the distribution. Multiple imputation does not require to know the overall distribution of the data. Instead, it dissects the data into smaller sets and estimate missing values in each set. Following this, the results are combined to get the whole data set(Nardo et al., 2005).

Since scenario monitoring is a constant activity, new data will be often incorporated into original ones. Thus complex imputation based on the overall distribution of the data should be avoided. Also, the thesis intends to develop methods to help supply chain managers to construct indicators. To keep things simple, complicated multiple imputation is not plausible either. Therefore, the thesis chose to use the data of the closest previous year from the same country to substitute the missing data, assuming nothing changed during the period. After this step, a full set of data should be prepared.

3.4 Normalization of data

The original data usually have different measurements. The next step is to normalize the data, so that different units will not affect the impacts of the individual indicators.

There are a lot of methods to normalize data. In this study, the thesis needed to compare indicators of the country in different times so as to get a sense of the environment. Some normalization methods such as ranking, categorical scales lose too much information. Others such as cyclical indicator are not easy to calculate.

Among all the commonly used methods, normalizing to the base year is a simple but reliable way. One method to choose the base year is to use group leader. Group leader could be the year with the highest value of a certain indicator. However, group leader may change over time. If people have to find out the group leader whenever they want to calculate the composite indicators with new data, it would be too troublesome. China is the biggest country in terms of its territory size and population in Asian/Pacific area. It has also been the largest economy in terms of GDP in this area since 2010(World Bank, 2013) and continuous growth of China can be expected. Therefore, the thesis advised to take China as a benchmark group leader in this area.

3.5 Multivariate analysis

The purpose of this step is to use multivariate analysis to group the individual indicators. In doing so, the original theoretical frameworks can be checked by data and revised according to the analysis results. The results of this step are also the sources for calculating the weights in the next step.

Among all the available multivariate analysis methods, the thesis chose to use factor analysis. Factor analysis gives weight to each component of composite indicator according to its contribution to the total variance in the data(Nicoletti et al., 1999). It assumes that under the surface attribute of each indicator there are three kinds of factors that actually affect the surface value. They are: common factors, specific factors and error of measurement factors. Factor analysis clusters individual indicators together in big groups and shows at what percent common factors explain the indicators (Tucker & MacCallum, 1997). The square foot of the percent of variance in each individual indicator explained by the factor is called factor loading. Factor loadings will be used to generate the weights for each individual indicator and dimensions.

There are two reasons for conducting factor analysis. First, the results of factor analysis are based on data. Hence they are not affected by analysts' subjective opinions. Second, the factors can explain the largest part of the variances among indicators. Therefore, the composite indicators built on them can be well used to compare the changes in each year(Nicoletti et al., 1999).

The thesis chose factors that have eigenvalues greater than one 1. In factor analysis, "the factor with the largest eigenvalue has the most variance and so on, down to factors with small or negative eigenvalues that are usually omitted from solutions" (Tabachnick, Fidell, & Osterlind, 2001) . So eigenvalue is used as a popular criterion, which is know as "Guttman-Kaiser criterion", to choose the number of factors (Yeomans & Golder, 1982) . However, researchers found that Guttman-Kaiser criterion only works well when the number of variables is much higher than the number of factors and the communality is also high (Yeomans & Golder, 1982) . Communality is the variance that is explained by all factors.

So, beside the factors with eigenvalues higher than one, the thesis also chose factors that contribute to a variance greater than 10%. When there is only one factor satisfies the previous conditions, the thesis added another factor which contributes the most to the variance in the remaining factors.

If the factors calculated from data are not in accordance with the theoretical framework, the theoretical framework will be modified.

3.6 Weighting and aggregation

In this step, the weight assigned to each individual indicator and dimension is determined and all the components were aggregated. Weighting is usually performed in an arbitrary way. However, this part also has significant impact upon the final composite

[1] In SPSS, varimax rotation should be chosen to maximize the highest factor loading of each indicator.

indicator(Nardo et al., 2005). Inappropriate weighting may be misleading in terms that it enlarges components that are relatively not important and ignores significant components.

Equal weighting may be the most frequently used method to build composite indicators(Nardo et al., 2005). However, the shortcoming of equal weighting is also obvious. It does not have sound statistical or empirical basis and double counting of the correlated parts of two components may occur.

This thesis used the rotated component matrix got from the factor analysis as a start point to calculate weight for each indicator. The factor loading was first squared and scaled into unity sum(Nardo et al., 2005). It is easy to know that "the squared factor loadings represent the proportion of the total unit variance of the indicator which is explained by the factor" (Nicoletti et al., 1999). And then the individual indicators are put into factors in which they have the highest factor loading. The thesis then multiplied the squared factor loading of each indicator by the percent of variance explained by the factor that includes the indicator. The result of the multiplication should also be scaled so that they can add up to one. Finally, the weight for each indicator can be determined(Nardo et al., 2005).

Compared with equal weighting, this weighting method is more reliable because it takes the statistical attribute of data into account. Each indicator only represents its part in the common factor in which it has the most significant impact. Therefore double counting is avoided. And the behaviors of those common factors are exactly what the thesis wants to monitor through composite indicator.

After getting the weights, all the components should be put together to construct composite indicators. The individual indicators are firstly aggregated to dimensions and then dimensions are aggregated to composite indicators. There're two different ways to aggregate individual indicators into composite indicators: linear and non-linear. Linear aggregation is simple and easy to implement. It adds up the weighted and normalized value of indicators linearly. The equation of linear aggregation is:

$$I = \sum_{i=1}^{N} w_i x_i \quad (1)$$

where x_i is a scale adjusted variable normalized between zero and one and w_i a weight attached to x_i, usually with $\sum_{i=1}^{N} w_i = 1$ and $0 \leq w_i \leq 1$,i=1,2,...,N(Nardo et al., 2005)

Linear aggregation assumes the variables can compensate each other. This is not desired in some cases. Therefore, non-linear aggregation was introduced. Instead of adding indicators linearly, non-linear aggregation compares the variables in a pair-wise manner. It gives the winner a score that is equal to the weight of the indicator. And then it adds up all scores of each year and ranks them accordingly (Munda & Nardo, 2009) .

The problem of this non-linear aggregation was addressed by Moulin(Moulin, 1991):"only drawback of this aggregation method is the difficulty in computing it when the number of candidates grows".

Since the calculation of non-linear aggregation is difficult, in order to keep the aggregation straightforward, the thesis used linear aggregation. The downside of compensation in linear aggregation can be avoided by choosing theoretical framework carefully so as to eliminate the possibility of inappropriate compensation.

3.7 Scenario Monitoring

The last step aims to use composite indicators to monitor the environment. The following definitions are used in this step.

- **Starting year:** the year in which scenarios are developed
- **Monitoring year:** the year in which the environment is monitored
- **Boundary:** a number that helps to judge whether the trend in the driving force is certain. If the difference between the composite indicator of the monitoring year and the composite indicator of the starting year exceeds the boundary, the trend can be considered determined. The value of the boundary could be various for each composite indicator. To be simple, the thesis chose 0.5 as the uniform boundary.

To monitor the environment, first calculate the composite indicators of the starting year and the monitoring year in the same area.

Second, compare the value of composite indicators of the monitoring year and that of the starting year. If there is an increase higher than the boundary, then it is certain that the level of the driving force in the monitoring year is high. If there is a decrease larger than the boundary, then it is certain that the level of the driving force in the monitoring year is low. If the difference is within the boundary, then the trend of the driving force is still uncertain.

Third, put these levels together and compare them with the description of scenarios, the more levels match the description, the higher possibility the corresponding scenario is unfolding.

In the next section, an example about how to implement the methods described in this part to find indicators for scenario monitoring will be given.

Chapter 4 Data Analysis

This part will use the scenarios developed by BASF to demonstrate how should the indicators be found to monitor those scenarios. In the beginning, the data sources will be introduced. And then the construction of each composite indicator for uncertain driving force will be demonstrated. Finally, the monitoring result will be illustrated.

4.1 Data sources

First, the scenarios provided by BASF, which are the target of monitoring, will be briefly described. And then, the sources of original data will be explained.

4.1.1 Scenarios and driving forces

Through its scenario planning project, BASF developed four scenarios for Asian-Pacific area in 2025. The four scenarios are:

1. The collaborative world

2. The lean world

3. The demanding world

4. The low cost world

Those four scenarios are developed from ten driving forces whose development in the future was uncertain at the time the scenario plan was made.

The driving forces are:

1. Political stability in A/P countries

2. Tariff barriers, and customs regulations in A/P countries and free trade agreements with other regions

3. Stability of financial systems in A/P countries

4. Availability of qualified employees in A/P

5. Investment in transportation infrastructure in A/P countries

6. Transfer and application of global knowledge (patents, innovations, production, supply chain and information technologies etc.) to A/P countries

7. Awareness towards sustainability of the society in A/P countries

8. Energy costs in A/P countries

9. Environmental regulation in A/P countries

10. Mobility of people (freedom to live and work anywhere) in A/P countries

4.1.2 Data

The domains of environment can be divided into five aspects. They are society, Technology, Economy, Environment, and Politics(Phadnis et al., 2012). Since driving forces are developed from them(Phadnis et al., 2012), the thesis looked into the data from those aspects. Many international organizations provide databases that contain social, economic, environmental, technological and political data. For example, the website of World Bank provides World Development Indicators, Education Statistics, Poverty and Inequality Database etc. on its website for downloading. Other organizations such as OECD, UN, WTO etc. also provide similar services. Among those databases, the World Development

Indicators of World Bank covers all the aspects the thesis concerned with and the data are abundant. Therefore, the thesis chose to use data from the World Development Indicators.

The thesis will construct composite indicators for a selected sub-region in Asian-Pacific area and use them to monitor the scenarios in this sub-region. The scenarios were developed in 2011. In order to demonstrate the methods, the thesis only chose and calculated data of China from 2004-2010. 2004 was set as the starting year and the base year as well. And 2010 was set as the monitoring year.

In China's case, only six driving forces are uncertain at the starting year[2](BASF, 2011). They are:

1. Political stability in A/P countries

2. Tariff barriers, and customs regulations in A/P countries and free trade agreements with other regions

3. Stability of financial systems in A/P countries

4. Transfer and application of global knowledge (patents, innovations, production, supply chain and information technologies etc.) to A/P countries

5. Awareness towards sustainability of the society in A/P countries

6. Energy costs in A/P countries

In the following part, the composite indicators of the above six uncertain driving forces will be calculated and the environment in 2010 will be monitored.

[2] The actual starting year is 2011. For demonstration purpose, the thesis assumes 2004 is the starting year.

4.2 Political stability in A/P countries

4.2.1 Theoretical Framework

Political stability referred to stability of power relations between state and various non-state actors(BASF, 2011). According to intuition and preliminary analysis, there were two dimensions for political stability. One was named direct result, and the other was called secondary results[3]. The concepts and their relationships were shown as follows:

- **Composite indicator:** Political Stability. It increases when politics becomes more stable.
- **Dimension one:** direct result. Objective: minimize
- **Dimension two:** secondary results. Objective: minimize

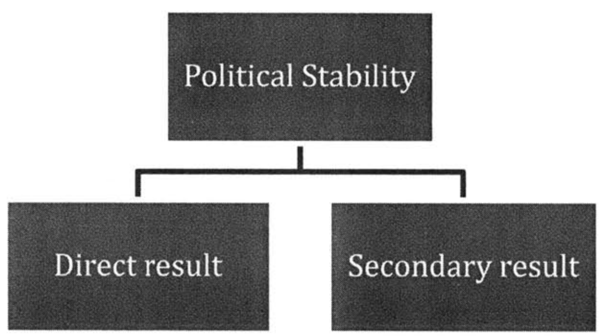

Figure 4: Theoretical framework of political stability

4.2.2 Selecting variables

There were 78 indicators under "Public Sector" of the database. However, only 9 indicators were related to political stability. Some of them were not available in case of China. Finally, the thesis opted to concentrate on 5 individual indicators for monitoring political stability.

[3] There was a spiral process to get the framework as mentioned in section 3. The detail of this process was left out in order to avoid redundancy.

Table 1: Individual indicators of political stability(World Bank, 2013)

Indicator	Definition	Dimension	Objective
Intentional homicides (per 100,000 people)	Intentional homicides are estimates of unlawful homicides purposely inflicted as a result of domestic disputes, interpersonal violence, violent conflicts over land resources, intergang violence over turf or control, and predatory violence and killing by armed groups. Intentional homicide does not include all intentional killing; the difference is usually in the organization of the killing. Individuals or small groups usually commit homicide, whereas killing in armed conflict is usually committed by fairly cohesive groups of up to several hundred members and is thus usually excluded.	Secondary result	Minimize
Foreign direct investment, net inflows (BoP, current US$)	Foreign direct investment is net inflows of investment to acquire a lasting interest in or management control over an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvested earnings, other long-term capital, and short-term capital, as shown in the balance of payments. Data are in current U.S. dollars.	Secondary result	Maximize
Armed forces personnel (% of total labor force)	Armed forces personnel are active duty military personnel, including paramilitary forces if the training, organization, equipment, and control suggest they may be used to support or replace regular military forces. Labor force comprises all people who meet the International Labour Organization's definition of the economically active population.	Secondary result	Minimize
Arms imports (constant 1990 US$)	Arms transfers cover the supply of military weapons through sales, aid, gifts, and those made through manufacturing licenses. Data cover major conventional weapons such as aircraft, armored vehicles, artillery, radar systems, missiles, and ships designed for military use. Excluded are transfers of other military equipment such as small arms and light weapons, trucks, small artillery, ammunition, support equipment, technology transfers, and other services.	Secondary result	Minimize

Military expenditure (% of GDP)	Military expenditures data from SIPRI are derived from the NATO definition, which includes all current and capital expenditures on the armed forces, including peacekeeping forces; defense ministries and other government agencies engaged in defense projects; paramilitary forces, if these are judged to be trained and equipped for military operations; and military space activities. Such expenditures include military and civil personnel, including retirement pensions of military personnel and social services for personnel; operation and maintenance; procurement; military research and development; and military aid (in the military expenditures of the donor country). Excluded are civil defense and current expenditures for previous military activities, such as for veterans' benefits, demobilization, conversion, and destruction of weapons. This definition cannot be applied for all countries, however, since that would require much more detailed information than is available about what is included in military budgets and off-budget military expenditure items. (For example, military budgets might or might not cover civil defense, reserves and auxiliary forces, police and paramilitary forces, dual-purpose forces such as military and civilian police, military grants in kind, pensions for military personnel, and social security contributions paid by one part of government to another.)	Direct result	Minimize

4.2.3 Imputation and normalization

There was no missing data in this case. In order to normalize the data, the thesis set 2004 as the base year. The data of the other years were all divided by the data of 2004. The normalized data were shown in the following table.

Table 2: Normalized Individual Indicators of Political Stability

Indicator Name	2004	2005	2006	2007	2008	2009	2010
Intentional homicides (per 100,000 people)	1	0.84	0.72	0.64	0.59	0.58	0.53
Foreign direct investment, net inflows (BoP, current US$)	1	1.90	2.26	2.84	3.12	2.39	4.44
Armed forces personnel (% of total labor force)	1	0.99	0.94	0.75	0.74	0.75	0.74
Arms imports (constant 1990 US$)	1	1.12	0.91	0.55	0.52	0.33	0.22
Military expenditure (% of GDP)	1	0.99	1.01	0.99	0.98	1.08	0.99

4.2.4 Multivariate analysis

According to factor analysis, there were two components that had eigenvalues bigger than one. Those two components together could explain 94.8% of the total variance of the data. So the thesis chose them as two dimensions of the composite indicator.

Table 3: Total variance explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	3.6	72.1	72.1
2	1.1	22.7	94.8
3	0.2	3.2	98.0
4	0.1	1.9	99.9
5	0.0	0.1	100.0

The factor analysis also listed rotated component matrix. Varimax rotation was used to "minimise the number of individual indicators that have a high loading on the same factor" (Nardo et al., 2005) . The result matrix showed the loading of each individual indicator in each factor. Those loadings were then squared and scaled to unity sum. The squared loadings represented how much variance each individual indicator explained. Thus the sum of these squared loadings were total explained variance. The weight of each component, namely dimension, was the ratio of explained variance of each component divided by total explained variance. For example, the weight of dimension 1 was 3.59/(3.59+1.16) = 0.76.

Table 4: Loading Matrix of Political Stability

	Factor loadings		Squared loadings		Squared loadings (scaled to unity sum)	
	CMPT 1	CMPT 2	CMPT 1	CMPT 2	CMPT 1	CMPT 2
Intentional homicides (per 100,000 people)	0.96	-0.10	0.93	0.01	**0.26**	0.01
Armed forces personnel (% of total labor force)	0.95	-0.13	0.91	0.02	**0.25**	0.01
Arms imports (constant 1990 US$)	0.94	-0.23	0.89	0.05	**0.25**	0.05
Foreign direct investment, net inflows (BoP, current US$)	-0.92	-0.31	0.85	0.09	**0.24**	0.08
Military expenditure (% of GDP)	-0.07	0.99	0.00	0.98	0.00	**0.85**
Explained Variance	3.58	1.15	3.58	1.15		
Explained Variance/ Total Variance	0.76	0.24				

4.2.5 Weighting and aggregation

Knowing the weight of each dimension, the weight of each individual indicator could be calculated. Frist, each individual indicator should be put into the dimension in which it had the highest loading. Second, the thesis used the squared and scaled loadings to multiply the weight of the corresponding dimension. Third, the thesis scaled up the results to unity sum. These new results were weights of the individual indicators.

Table 5: Weights of Political Stability

Individual indicators	Original loading	Scaled loading
Intentional homicides (per 100,000 people)	0.20	0.20
Armed forces personnel (% of total labor force)	0.19	0.20
Arms imports (constant 1990 US$)	0.19	0.20
Foreign direct investment, net inflows (BoP, current US$)	0.18	0.19
Military expenditure (% of GDP)	0.21	0.22

With the weights and the normalized data, the composite indicator could then be computed using simple linear regression.

Table 6: Composite Indicator of Political Stability

Indicator Name	Weights	Objective	2004	2010
Intentional homicides (per 100,000 people)	0.20	Minimize	1	0.53
Foreign direct investment, net inflows (BoP, current US$)	0.19	Maximize	1	4.44
Armed forces personnel (% of total labor force)	0.20	Minimize	1	0.74
Arms imports (constant 1990 US$)	0.20	Minimize	1	0.22
Military expenditure (% of GDP)	0.22	Minimize	1	0.99
Value of Composite Indicator			-0.63	0.32
Change				0.95

The change between the composite indicator of 2010 and that of 2004 was 0.32-(-0.63)=0.95. Since 0.95 was higher than the boundary, which is 0.5, the level of political stability in 2010 could be regarded as "high" compared with that in 2004.

4.3 Tariff barriers, and customs regulations in A/P countries and free trade agreements with other regions[4]

4.3.1 Theoretical Framework

The scenarios described this driving force as consisting of three parts. They are existence of tariff barriers and customs regulations in A/P; Free Trade Agreements between A/P and other regions of the world; regional co-operation to create uniform regulations for trade, environment, technology, legislation (BASF, 2011) . For convenience, the thesis used the acronym TCF to name the composite indicator.

[4] From this section, only theoretical framework and individual indicators are explained. The calculation of the composite indicator is omitted in order to reduce redundancy.

The above-mentioned policies could be seen as Costs. They determined how efficiently the international trade can be conducted and finally affect the trading results. So the thesis used Cost and Output as two dimensions to show the change of TCF. The concepts and their relationships were shown as follows:

- **Composite Indicator:** TCF. It increases when international trade becomes more difficult
- **Dimension One:** Cost. Objective: maximize
- **Dimension One:** Output. Objective: minimize

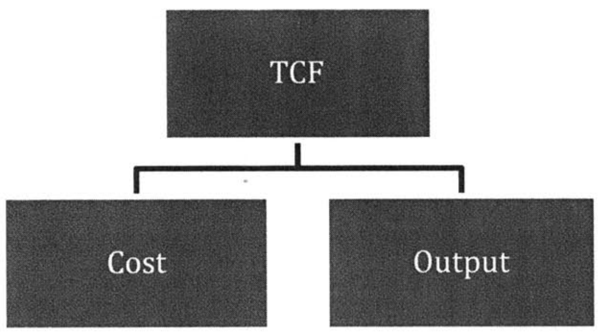

Figure 5: Theoretical framework of barriers and regulations

4.3.2 Selecting Variables

There were 148 indicators in the "Private Sector & Trade" section in the database. According to the criteria mentioned in 3.2, the thesis extracted indicators relevant to the framework and were available. The following 16 indicators were chosen for monitoring TCF.

Table 7: Individual indicators of TCF (World Bank, 2013)

Indicator	Definition	Dimension	Objective
Cost to export (US$ per container)	Cost measures the fees levied on a 20-foot container in U.S. dollars. All the fees associated with completing the procedures to export or import the goods are included. These include costs for documents, administrative fees for customs clearance and technical control, customs broker fees, terminal handling charges and inland transport. The cost measure does not include tariffs or trade taxes. Only official costs are recorded.	Cost	Maximize
Cost to import (US$ per container)	Cost measures the fees levied on a 20-foot container in U.S. dollars. All the fees associated with completing the procedures to export or import the goods are included. These include costs for documents, administrative fees for customs clearance and technical control, customs broker fees, terminal handling charges and inland transport. The cost measure does not include tariffs or trade taxes. Only official costs are recorded.	Cost	Maximize
Commercial service exports (current US$)	Commercial service exports are total service exports minus exports of government services not included elsewhere. International transactions in services are defined by the IMF's Balance of Payments Manual (1993) as the economic output of intangible commodities that may be produced, transferred, and consumed at the same time. Definitions may vary among reporting economies.	Output	Minimize
Commercial service imports (current US$)	Commercial service imports are total service imports minus imports of government services not included elsewhere. International transactions in services are defined by the IMF's Balance of Payments Manual (1993) as the economic output of intangible commodities that may be produced, transferred, and consumed at the same time. Definitions may vary among reporting economies.	Output	Minimize
Binding coverage, all products (%)	Binding coverage is the percentage of product lines with an agreed bound rate.	Cost	Minimize
Bound rate, simple mean, all products (%)	Simple mean bound rate is the unweighted average of all the lines in the tariff schedule in which bound rates have been set.	Cost	Maximize
Share of tariff lines with international peaks, all products (%)	Share of tariff lines with international peaks is the share of lines in the tariff schedule with tariff rates that exceed 15 percent.	Cost	Maximize

Tariff rate, most favored nation, weighted mean, all products (%)	Weighted mean most favored nations tariff is the average of most favored nation rates weighted by the product import shares corresponding to each partner country.	Cost	Maximize
Documents to export (number)	Documents to export are all documents required per shipment by government ministries, customs authorities, port and container terminals, health and technical control agencies, and banks to export goods. Documents renewed annually and not requiring renewal per shipment are excluded.	Cost	Maximize
Documents to import (number)	Documents to import are all documents required per shipment by government ministries, customs authorities, port and container terminals, health and technical control agencies, and banks to import goods. Documents renewed annually and not requiring renewal per shipment are excluded.	Cost	Maximize
Time to export (days)	Time is recorded in calendar days. The time calculation for a procedure starts from the moment it is initiated and runs until it is completed. If a procedure can be accelerated for an additional cost, the fastest legal procedure is chosen. It is assumed that neither the exporter nor the importer wastes time and that each commits to completing each remaining procedure without delay. Procedures that can be completed in parallel are measured as simultaneous. The waiting time between procedures--for example, during unloading of the cargo--is included in the measure.	Cost	Maximize
Time to import (days)	Time is recorded in calendar days. The time calculation for a procedure starts from the moment it is initiated and runs until it is completed. If a procedure can be accelerated for an additional cost, the fastest legal procedure is chosen. It is assumed that neither the exporter nor the importer wastes time and that each commits to completing each remaining procedure without delay. Procedures that can be completed in parallel are measured as simultaneous. The waiting time between procedures--for example, during unloading of the cargo--is included in the measure.	Cost	Maximize
Export value index (2000 = 100)	Export values are the current value of exports (f.o.b.) converted to U.S. dollars and expressed as a percentage of the average for the base period (2000). UNCTAD's export value indexes are reported for most economies. For selected economies for which UNCTAD does not publish data, the export value indexes are derived from export volume indexes (line 72) and corresponding unit value indexes of exports (line 74) in the IMF's International Financial Statistics.	Output	Minimize

Export volume index (2000 = 100)	Export volume indexes are derived from UNCTAD's volume index series and are the ratio of the export value indexes to the corresponding unit value indexes. Unit value indexes are based on data reported by countries that demonstrate consistency under UNCTAD quality controls, supplemented by UNCTAD's estimates using the previous year's trade values at the Standard International Trade Classification three-digit level as weights. To improve data coverage, especially for the latest periods, UNCTAD constructs a set of average prices indexes at the three-digit product classification of the Standard International Trade Classification revision 3 using UNCTAD's Commodity Price Statistics, international and national sources, and UNCTAD secretariat estimates and calculates unit value indexes at the country level using the current year's trade values as weights. For economies for which UNCTAD does not publish data, the export volume indexes (lines 72) in the IMF's International Financial Statistics are used.	Output	Minimize
Import value index (2000 = 100)	Import value indexes are the current value of imports (c.i.f.) converted to U.S. dollars and expressed as a percentage of the average for the base period (2000). UNCTAD's import value indexes are reported for most economies. For selected economies for which UNCTAD does not publish data, the import value indexes are derived from import volume indexes (line 73) and corresponding unit value indexes of imports (line 75) in the IMF's International Financial Statistics.	Output	Minimize

Import volume index (2000 = 100)	Import volume indexes are derived from UNCTAD's volume index series and are the ratio of the import value indexes to the corresponding unit value indexes. Unit value indexes are based on data reported by countries that demonstrate consistency under UNCTAD quality controls, supplemented by UNCTAD's estimates using the previous year's trade values at the Standard International Trade Classification three-digit level as weights. To improve data coverage, especially for the latest periods, UNCTAD constructs a set of average prices indexes at the three-digit product classification of the Standard International Trade Classification revision 3 using UNCTAD's Commodity Price Statistics, international and national sources, and UNCTAD secretariat estimates and calculates unit value indexes at the country level using the current year's trade values as weights. For economies for which UNCTAD does not publish data, the import volume indexes (lines 73) in the IMF's International Financial Statistics are used.	Output	Minimize

4.4 Stability of financial systems in A/P countries

4.4.1 Theoretical Framework

The meaning of this driving force was straightforward. It meant stability of financial system, currency exchange rates, etc. in A/P countries (BASF, 2011).

The thesis used a spiral way to group the factors that affect this driving force into two dimensions: monetary and managerial. Monetary dimension measured the performance of financial system. It mainly consisted of financial indicators of the state. And the managerial dimension showed the robustness of the financial system and the ability of the state to leverage it. It reflected the institutional arrangement of the financial system.

- **Composite Indicator:** Financial System. It increases when financial system becomes more stable.

- **Dimension One:** Monetary. Objective: maximize
- **Dimension two:** Managerial. Objective: maximize

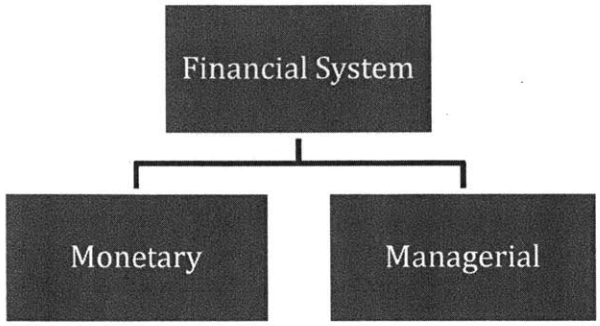

Figure 6: Theoretical framework of financial system

4.4.2 Selecting Variables

There were 49 indicators in the "Financial Sector" in the database. According to the criteria mentioned in section 3.2, the thesis extracted indicators that were relevant to the framework and available. Finally, the thesis opted to concentrate on 9 indicators for monitoring financial system.

Table 8: Individual indicators of stability of financial system (World Bank, 2013)

Indicator	Definition	Dimension	Objective
Bank capital to assets ratio (%)	Bank capital to assets is the ratio of bank capital and reserves to total assets. Capital and reserves include funds contributed by owners, retained earnings, general and special reserves, provisions, and valuation adjustments. Capital includes tier 1 capital (paid-up shares and common stock), which is a common feature in all countries' banking systems, and total regulatory capital, which includes several specified types of subordinated debt instruments that need not be repaid if the funds are required to maintain minimum capital levels (these comprise tier 2 and tier 3 capital). Total assets include all nonfinancial and financial assets.	Monetary	Maximize

Bank nonperforming loans to total gross loans (%)	Bank nonperforming loans to total gross loans are the value of nonperforming loans divided by the total value of the loan portfolio (including nonperforming loans before the deduction of specific loan-loss provisions). The loan amount recorded as nonperforming should be the gross value of the loan as recorded on the balance sheet, not just the amount that is overdue.	Monetary	Minimize
Credit depth of information index (0=low to 6=high)	Credit depth of information index measures rules affecting the scope, accessibility, and quality of credit information available through public or private credit registries. The index ranges from 0 to 6, with higher values indicating the availability of more credit information, from either a public registry or a private bureau, to facilitate lending decisions.	Managerial	Maximize
Private credit bureau coverage (% of adults)	Private credit bureau coverage reports the number of individuals or firms listed by a private credit bureau with current information on repayment history, unpaid debts, or credit outstanding. The number is expressed as a percentage of the adult population.	Managerial	Maximize
Public credit registry coverage (% of adults)	Public credit registry coverage reports the number of individuals and firms listed in a public credit registry with current information on repayment history, unpaid debts, or credit outstanding. The number is expressed as a percentage of the adult population.	Managerial	Maximize
Foreign direct investment, net inflows (BoP, current US$)	Foreign direct investment is net inflows of investment to acquire a lasting interest in or management control over an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvested earnings, other long-term capital, and short-term capital, as shown in the balance of payments. Data are in current U.S. dollars.	Monetary	Maximize
Stocks traded, turnover ratio (%)	Turnover ratio is the total value of shares traded during the period divided by the average market capitalization for the period. Average market capitalization is calculated as the average of the end-of-period values for the current period and the previous period.	Monetary	Maximize
Strength of legal rights index (0=weak to 10=strong)	Strength of legal rights index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate lending. The index ranges from 0 to 10, with higher scores indicating that these laws are better designed to expand access to credit.	Managerial	Maximize

Total reserves (includes gold, current US$)	Total reserves comprise holdings of monetary gold, special drawing rights, reserves of IMF members held by the IMF, and holdings of foreign exchange under the control of monetary authorities. The gold component of these reserves is valued at year-end (December 31) London prices. Data are in current U.S. dollars.	Managerial	Maximize

4.5 Transfer and application of global knowledge (patents, innovations, production, supply chain and information technologies etc.) to A/P countries

4.5.1 Theoretical Framework

This driving force meant transfer and successful application of sophisticated product and process technology, traditionally developed in the West, to companies in A/P (BASF, 2011).

The thesis grouped indicators that reflected the transfer of foreign knowledge to the country as dimension Transfer. This dimension directly measured the activity. The other dimension was the transfer and application result that was named as Output. Output is a more certain dimension that showed the achievements made by the transferring efforts.

- **Composite Indicator:** Transfer and Application of Global Knowledge. It increases when there're more transfer and application of global knowledge.
- **Dimension One:** Transfer, knowledge comes from other areas. Objective: maximize
- **Dimension two:** Output, the result of knowledge transfer. Objective: maximize

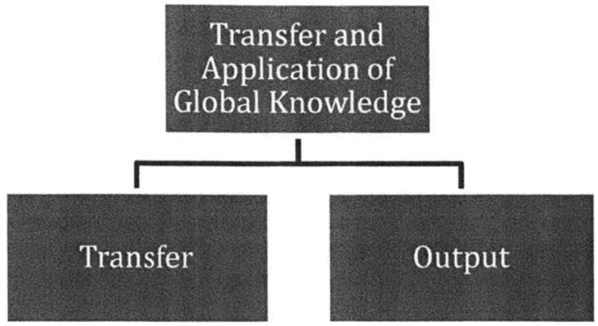

Figure 7: Theoretical framework of Knowledge Transfer

4.5.2 Selecting Variables

There were 13 indicators in the "Technology" section in the database. According to the criteria mentioned in section 3.2, the thesis extracted indicators that were relevant to the framework and available. Finally, the thesis opted to concentrate on 8 indicators for monitoring Knowledge Transfer.

Table 9: Individual indicators of knowledge transfer (World Bank, 2013)

Indicator	Definition	Dimension	Objective
Patent applications, nonresidents	Patent applications are worldwide patent applications filed through the Patent Cooperation Treaty procedure or with a national patent office.	Transfer	Maximize
High-technology exports (% of manufactured exports)	High-technology exports are products with high R&D intensity, such as in aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.	Output	Maximize
Scientific and technical journal articles	Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.	Transfer	Minimize

Technical cooperation grants (BoP, current US$)	Technical cooperation grants include free-standing technical cooperation grants, which are intended to finance the transfer of technical and managerial skills or of technology for the purpose of building up general national capacity without reference to any specific investment projects; and investment-related technical cooperation grants, which are provided to strengthen the capacity to execute specific investment projects. Data are in current U.S. dollars.	Transfer	Maximize
Researchers in R&D (per million people)	Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students (ISCED97 level 6) engaged in R&D are included.	Transfer	Minimize
Internet users (per 100 people)	Internet users are people with access to the worldwide network.	Output	Maximize
Research and development expenditure (% of GDP)	Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development.	Transfer	Minimize
ICT service exports (BoP, current US$)	Information and communication technology service exports include computer and communications services (telecommunications and postal and courier services) and information services (computer data and news-related service transactions). Data are in current U.S. dollars.	Output	Maximize

4.6 Awareness towards sustainability of the society in A/P countries

4.6.1 Theoretical Framework

This driving force meant awareness and behavior change according to ecological issues, environmental and social impact of businesses (BASF, 2011) .

To make the change happen, people in the country should be well educated and had reached certain degree of income so that they could afford to pay attention to ecological, environmental and social issues. The thesis assessed the trend of the driving force by two dimensions. One was education level in the country. The other was people's income.

- **Composite Indicator:** Awareness Towards Sustainability of the Society. It increases when the awareness increases.
- **Dimension One:** Education. Objective: maximize
- **Dimension two:** Income. Objective: maximize

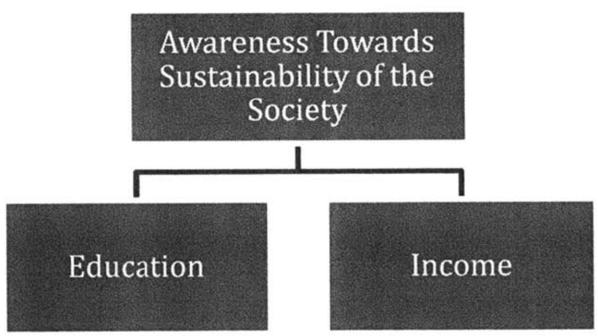

Figure 8: Theoretical framework of awareness towards sustainability

4.6.2 Selecting Variables

There were 89 indicators in the "Education" section and 102 indicators in the "Labor and Social Protection" section in the database. According to the criteria mentioned in section 3.2, the thesis extracted indicators that were relevant to the framework and available. Finally, the thesis opted to concentrate on 9 indicators for monitoring Knowledge Transfer.

Table 10: Individual indicators of awareness towards sustainability

(World Bank, 2013)

Indicator	Definition	Dimension	Objective
Literacy rate, adult total (% of people ages 15 and above)	Adult literacy rate is the percentage of people ages 15 and above who can, with understanding, read and write a short, simple statement on their everyday life.	Education	Maximize
School enrollment, preprimary (% gross)	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Preprimary education refers to the initial stage of organized instruction, designed primarily to introduce very young children to a school-type environment.	Education	Maximize
School enrollment, primary (% gross)	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science, art, and music.	Education	Maximize
School enrollment, secondary (% gross)	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers.	Education	Maximize

School enrollment, tertiary (% gross)	Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level.	Education	Maximize
Expenditure per student, primary (% of GDP per capita)	Public expenditure per student is the public current spending on education divided by the total number of students by level, as a percentage of GDP per capita. Public expenditure (current and capital) includes government spending on educational institutions (both public and private), education administration as well as subsidies for private entities (students/households and other privates entities).	Education	Maximize
Expenditure per student, secondary (% of GDP per capita)	Public expenditure per student is the public current spending on education divided by the total number of students by level, as a percentage of GDP per capita. Public expenditure (current and capital) includes government spending on educational institutions (both public and private), education administration as well as subsidies for private entities (students/households and other privates entities).	Education	Maximize
Expenditure per student, tertiary (% of GDP per capita)	Public expenditure per student is the public current spending on education divided by the total number of students by level, as a percentage of GDP per capita. Public expenditure (current and capital) includes government spending on educational institutions (both public and private), education administration as well as subsidies for private entities (students/households and other privates entities).	Education	Maximize

GDP per person employed (constant 1990 PPP $)	GDP per person employed is gross domestic product (GDP) divided by total employment in the economy. Purchasing power parity (PPP) GDP is GDP converted to 1990 constant international dollars using PPP rates. An international dollar has the same purchasing power over GDP that a U.S. dollar has in the United States.	Income	Maximize

4.7 Energy costs in A/P countries

4.7.1 Theoretical Framework

Cost of energy was determined by availability of energy, mix of energy sources, and demand (BASF, 2011). And those factors were a tradeoff between energy consumption and production. So consumption and production were considered two dimensions for energy cost. The thesis used the following theoretical framework to build the composite indicator for energy cost.

- **Composite Indicator:** Energy Cost. It increases when energy cost increases.
- **Dimension One:** Consumption. Objective: maximize
- **Dimension two:** Production. Objective: minimize

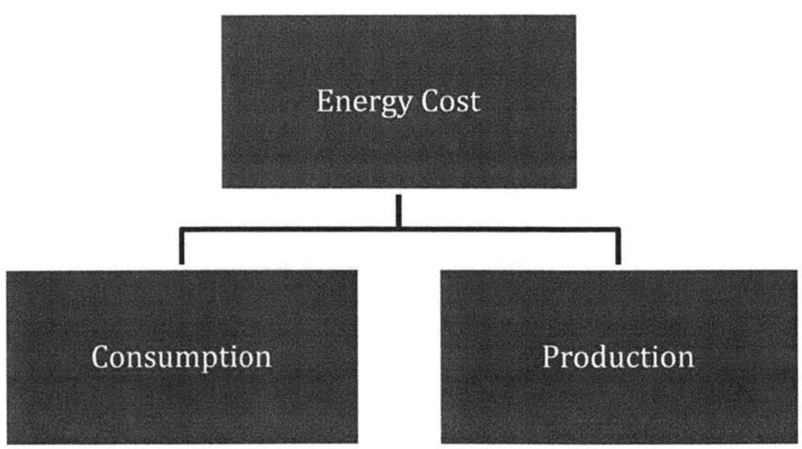

Figure 9: Theoretical framework of energy cost

4.7.2 Selecting Variables

There were 31 indicators in the "Energy production & use" section in the database. According to the criteria mentioned in section 3.2, the thesis extracted indicators that were relevant to the framework and available. Finally, the thesis opted to concentrate on 5 indicators for monitoring Knowledge Transfer.

Table 11: Individual indicators of energy cost (World Bank, 2013)

Indicator	Definition	Dimension	Objective
Electric power transmission and distribution losses	Sources of electricity refer to the inputs used to generate electricity. Hydropower refers to electricity produced by hydroelectric power plants.	Consumption	Maximize
Electricity production from renewable sources	Electricity production from renewable sources includes hydropower, geothermal, solar, tides, wind, biomass, and biofuels.	Production	Minimize
Energy production	Energy production refers to forms of primary energy--petroleum (crude oil, natural gas liquids, and oil from nonconventional sources), natural gas, solid fuels (coal, lignite, and other derived fuels), and combustible renewables and waste--and primary electricity, all converted into oil equivalents.	Production	Minimize
Energy use	Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.	Consumption	Maximize
GDP per unit of energy use	GDP per unit of energy use is the PPP GDP per kilogram of oil equivalent of energy use. PPP GDP is gross domestic product converted to 2005 constant international dollars using purchasing power parity rates. An international dollar has the same purchasing power over GDP as a U.S. dollar has in the United States.	Consumption	Minimize

4.8 Scenario Monitoring

The following table summarized previous analysis. It showed all the uncertain driving forces (composite indicators) and their hierarchical structures. The fist layer included 6 uncertain driving forces in the sub-region, namely China. The second layer consisted of 12 dimensions and the third layer was composed of 52 individual indicators. One example of driving forces was worked out in detail in 4.2.

Table 12: Summary of the hierarchical structures of driving forces

Driving Force (Composite Indicator)	Dimension	Individual Indicator
Political stability	**Direct result**	Military expenditure (% of GDP)
	Secondary result	Intentional homicides (per 100,000 people)
		Foreign direct investment, net inflows (BoP, current US$)
		Armed forces personnel (% of total labor force)
		Arms imports (constant 1990 US$)
TCF	**Cost**	Cost to export (US$ per container)
		Cost to import (US$ per container)
		Binding coverage, all products (%)
		Bound rate, simple mean, all products (%)
		Share of tariff lines with international peaks, all products (%)
		Tariff rate, most favored nation, weighted mean, all products (%)
		Documents to export (number)
		Documents to import (number)
		Time to export (days)
		Time to import (days)
	Output	Commercial service exports (current US$)
		Commercial service imports (current US$)
		Export value index (2000 = 100)
		Export volume index (2000 = 100)
		Import value index (2000 = 100)
		Import volume index (2000 = 100)

Stability of financial systems	**Monetary**	Bank capital to assets ratio (%)
		Bank nonperforming loans to total gross loans (%)
		Foreign direct investment, net inflows (BoP, current US$)
		Stocks traded, turnover ratio (%)
	Managerial	Credit depth of information index (0=low to 6=high)
		Private credit bureau coverage (% of adults)
		Public credit registry coverage (% of adults)
		Strength of legal rights index (0=weak to 10=strong)
		Total reserves (includes gold, current US$)
Transfer and application of global knowledge	**Transfer**	Patent applications, nonresidents
		Scientific and technical journal articles
		Technical cooperation grants (BoP, current US$)
		Researchers in R&D (per million people)
		Research and development expenditure (% of GDP)
	Output	High-technology exports (% of manufactured exports)
		Internet users (per 100 people)
		ICT service exports (BoP, current US$)
Awareness towards sustainability of the society	**Education**	Literacy rate, adult total (% of people ages 15 and above)
		School enrollment, preprimary (% gross)
		School enrollment, primary (% gross)
		School enrollment, secondary (% gross)
		School enrollment, tertiary (% gross)
		Expenditure per student, primary (% of GDP per capita)
		Expenditure per student, secondary (% of GDP per capita)
		Expenditure per student, tertiary (% of GDP per capita)
	Income	GDP per person employed (constant 1990 PPP $)
Energy costs	**Consumption**	Electric power transmission and distribution losses
		Energy use
		GDP per unit of energy use
	Production	Electricity production from renewable sources
		Energy production

The level of each indicator should be calculated and judged as illustrated in 4.2.5. If the levels of six uncertain driving forces were known, then they and the levels of other four certain driving forces of China together could be put into the following table.

Table 13: Scenario monitoring dash board[5]

DF*	collaborative world		lean world		demanding world		low cost world	
	High	Low	High	Low	High	Low	High	Low
1	x		x		x		x	
2	x		x		x		x	
3	x		x		x		x	
4	x		x		x		x	
5	x		x		x		x	
6		x		x		x		x
7	x		x		x		x	
8								
9	x		x		x		x	
10	x		x		x		x	

** 1. Political stability in A/P countries*
2. Tariff barriers, and customs regulations in A/P countries and free trade agreements with other regions
3. Stability of financial systems in A/P countries
4. Availability of qualified employees in A/P
5. Investment in transportation infrastructure in A/P countries
6. Transfer and application of global knowledge (patents, innovations, production, supply chain and information technologies etc.) to A/P countries
7. Awareness towards sustainability of the society in A/P countries
8. Energy costs in A/P countries

[5] Some values are fictional.

9. Environmental regulation in A/P countries
10. Mobility of people (freedom to live and work anywhere) in A/P countries

In the above table, the black boxes meant what kind of level of the driving force should be in each scenario and "x" meant the observed levels of the driving forces in the monitoring year. If the level in the monitoring year were still uncertain, then the row of the driving force would be left without any "x".

If there were an "x" in the black box, it would mean the level of the driving force matches the direction suggested in the corresponding scenario. Counting the number of "x"es that matches the scenario, the results were showed in the following table .

Table 14: Scenario Score Board

Scenario	The Number of Driving Forces Trending in the Direction Suggested in the Scenario
Collaborative world	7
Lean world	4
Demanding world	6
Low cost world	2

In this case, the year 2010 seemed to be more like a collaborative world. 7 driving forces had the levels that were suggested by the collaborative world. Besides, there were 6 driving forces had the levels that matched the requirement of the demanding world. Since the majority levels of the driving forces were in accordance with the description of those two scenarios, it was more possible that the environment would evolve into either of those two scenarios or become a mix of them. In other words, the chance might be remote for the environment to become a lean world or low cost world, unless there are dramatic reversals of levels of most of driving forces.

Chapter 5 Conclusion

Scenario monitoring is a necessary step for implementing strategies after scenarios are developed. Although scenario planning usually follows a qualitative approach, it does not mean scenario monitoring cannot follow a quantitative approach. The quantitative approach introduced in this paper is a direct and convenient way for scenario monitoring.

5.1 Key features of the work

This thesis developed a systematic approach to find out indicators for scenario monitoring. This approach includes seven steps. First, the theoretical frameworks are built. Second, individual indicators are chosen. Third step is imputation. Then the fourth step is to normalize data. In the fifth step, the factor analysis is conducted and the theoretical frameworks are revised according to the results of the analysis. Sixth, the weighting and aggregation are conducted and the composite indicators are developed. Moreover, the levels of the uncertain driving forces are recognized. In the last step, all the driving forces are put into a scenario monitoring dash board so that the scenario can be distinguished.

5.2 Advantages of approach

The advantage of this approaches are as follows:

1. The data are easy to get. The approach only concerns about five aspects that are used to construct scenarios. Those five aspects include social, economic, technological, environmental and political aspects. Many international organizations maintain the data in those five areas and offer the data freely to the public.

2. The most part of the process can be automated. Once the individual indicators are selected, the rest part of the calculation and comparison can be fully done by artificial intellectual without any human interference. Hence, the daily cost of implementing this approach would be low.

3. The results are simple and easy to understand. This approach is designed to satisfy the needs of supply chain managers. So it minimizes the use of complex mathematical methods and generates the composite indicator with only one number. Further more, the scenario monitoring results are showed visually by a table and the final results are also simple numbers that can be directly interpreted.

5.3 Limitations of approach

The shortcomings of this approach includes:

1. The choosing of the individual indicators is based on intuitive theoretical frameworks. Sometimes the frameworks may be biased due to personal prejudice.

2 If some data are not available, the affected composite indicators would need to be rebuilt. Rebuilding indicators may be time-consuming and make the result incompatible with the results form the previous work.

5.4 Future work

Further improvement of this method may include:

1. Import more experts' opinion on building theoretical frameworks. In so doing, the theoretical framework may be more reliable to various situations.

2. Sensitivity analysis could be included. Although sensitivity analysis is not a must step in finding indicators for scenario monitoring, using sensitivity analysis can help to gain more confidence in adding or subtracting indicators from the structure.

By and large, scenario monitoring will not replace scenario planning in terms that the process of scenario planning is actually a practice for decision makers to change their mind-sets. However, scenario monitoring method can serve as a economic tool to improve the implementation after developing the scenarios. In this way, it is a good complement of whole scenario planning project.

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