Product and Marketing Strategy Study in China

by

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Abstract

This thesis attempts to provide a framework for US companies to analyze the Chinese market, and to enhance their competitive strength in the market. The thesis captures ideas, thought processes, and knowledge developed during a 6 month Leaders For Manufacturing Program internship with Teradyne, Inc. of Boston, Massachusetts. This thesis also shows how a particular type of probability model, signal flow diagram, can be applied to the analysis of the telephone repair service operation. The thesis is developed in three major sections.

The first section reviews the current trend of the economical globalization and the increasing importance of the Chinese economy in this global economy. The conclusion is that, although US companies are entering China at a record rate, there is generally a lack of cohesive market study before most of them enter the market. This has resulted in failures and frustrations. A framework is proposed to help a company study the Chinese market in a thorough, cohesive, and quantitative manner.

In the second section, a detailed analysis is conducted on the telecommunications market in China, based on the market data collected and on a market analysis model, the Tavassoli model. The Chinese market is found to be an attractive market for Teradyne, and Teradyne is discovered as being weak in the Chinese market. Teradyne's major weaknesses in the Chinese market are identified and analyzed.

The third section documents a major effort by the project group to enhance Teradyne's competitive position in the Chinese market. The project group addresses one of Teradyne's major weaknesses, lack of understanding of telephone repair process, by conducting an in-country analysis of the Chinese telephone repair process. The inherent inefficiencies of the Chinese repair process is analyzed both qualitatively and quantitatively, and how Teradyne is able to add value to its Chinese customers is discussed in detail. The quantitative model taken to analyze the Chinese telephone repair operations is the signal graph analysis.

This thesis documents the application of an structured framework in studying the Chinese market. It may provide some insight into the problems faced by many rapidly globalizing US companies as they enter emerging markets like China.

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I wish to thank both of my advisors at MIT for the patience, guidance, leadership, and wisdom they have shared with me in this endeavor. It was Anna Thornton's participation that was instrumental in shaping this project and this thesis. It was Don Rosenfield's experience and process knowledge that helped me greatly in resolving the process analysis side of this project. I would also like to thank Steve Eppinger, Professor of the MIT Sloan School, for his insight and guidance in helping me through the process analysis. Finally, much of my appreciation goes to Charlie DeWitt, a LFM alum and a good friend, for the much needed discussions and help.

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CHAPTER 1: INTRODUCTION AND OVERVIEW

If a person hurries too much, things will not be done well or thoroughly.
---- Confucius[1]

1.1 Introduction and Literature Review

The objective of this thesis is to address the issue faced by many US companies today - how to study and analyze emerging markets. The increasing globalization and the increasing importance of emerging markets have offered interesting challenges for many US companies as they explore opportunities beyond their traditional domestic and western European markets. The thesis captures ideas, thought processes, and knowledge developed during a 6 months internship conducted jointly by the Leaders For Manufacturing Program at MIT and Teradyne, Inc. of Boston, Massachusetts. The focus of this internship is to study the Chinese Telephone market. A framework is developed in the course of the internship to help US companies study the Chinese market in a thorough, cohesive, and quantitative manner.

1.1.1 China: the Future Economic Giant

The economic center of the world is shifting to the Asia Pacific region, and there is growing possibility that China will emerge as the centerpiece of that region.

There are many reasons for this gravitational shift. China's size, natural resources, and huge population give it an overwhelming edge in the future; China's continuous attempt to modernize its industrial base and to open up its economy attracts more and more investment. In addition, China shares much of the traditional culture and civilization with other Asia Pacific economic powerhouses like Japan, Korea, and Hongkong, including their Confucian-Oriented social and moral systems. This gives these countries a special

[1] De Mente, Boyce. " Chinese Etiquette & Ethics in Business." NYC Business Books, 1989.

intellectual and emotional bond with China that, coupled with their proximity, makes them natural trading partners.

Technology, management expertise, and capital are flowing into China from both the East and the West, fueling the political, social, and economic revolution now transforming the country. There are many who believe that this joining of East Asian countries into a new economic community that dwarfs the West is the wave of the future. The only question seems to be the continued willingness of the Chinese leadership to let market forces shape the national economy.

For now at least, the answer to the question seems to be a yes. Since the inauguration of the Open Door policy in 1978, the economic reform in China, albeit ups and downs, has sustained its momentum. The Open Door policy started in the vast rural area in China where peasants took possession (although not legally) of land and were free to grow what they liked to, after meeting the government quota. It was followed by opening up a special economic zone, Shengzhen City, where foreign investment was given preferential treatment to encourage exporting by utilizing the labor resources in China. Currently, the effort is spent on upgrading the technology base of the country, on continuing to move state enterprises into semi-private organizations, and on revising the legal and policy systems to catch up with the economic growth.

1.1.2 China: the Gold Rush

It is probably not exaggerated to compare the current rate at which the Western businesses move into China with the "gold rush to the west" 100 years ago. The companies entering China cover a wide spectrum of companies from manufacturing to service. The infiltration takes all shapes and forms from joint venture to wholly owned. The number of projects involving US companies, for example, grew from 139 in 1982 to 5,779 in 1989, while the total investment increased from $649 million to $3.8 billion[2].

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[2] US - China Business Council. "US investment in China." China Business Forum, 1990.

Not all these ventures have had successful records. According to the 1990 US-China survey of US companies, only 12 out of 28 companies surveyed reported a profitable operations in terms of hard currency[3]. Some companies are enormously successful. Motorola has grasped a dominant market share in paging and cellular telecommunications while becoming a household name in China. McDonald's famed restaurant in Tiananmen square has become the weekend resort for many children in Beijing City. Other successful examples include KFC and UTC.

Some are not so successful, however. One of the major US telecommunications companies is still losing money after investing in China heavily for the past ten years. Several companies have scaled back their investments in China, and many, especially midsize companies, withdrew from the market after initial investments and subsequent failures.

One of the major reasons resulted in this high failure rate of investing in China is the "Gold Rush" mentality and the lack of detailed study before entering China. When asked the question "what would you have done differently (when investing in China)?", in 3 out of 20 responses[4], companies wished for better feasibility study; more than half of the responses reflected poor planning before investing.

1.1.3 China: the Mine Field

There are plenty of companies in the pipeline who are thinking of "giving China a try." In fact, the fever of getting into the Chinese market has grown exponentially since 1989, and many companies are starting to feel the pressure to get in (for the sake of getting in). There are even estimates that China will become the largest economy in the world by 2050. Yet only those who have tested the "China" water appreciate the fact that the

[3] US - China Business Council. "US investment in China." China Business Forum, 1990
[4] US - China Business Council. "US investment in China." China Business Forum, 1990

Chinese market is at the extreme of the risk-reward scale. The huge culture difference, the complex Chinese business system, and the uncertain political future are all possible mines that have or will hurt companys' future in China.

For large companies, it is feasible to have a presence in China first and to learn second. Indeed, many companies have done[5] just that and have been successful in doing so. For midsize and small companies, learning from "trial and error" does not seem to be an option because of resource and time constraints. Yet there lacks a tool for them to conduct careful market studies to aid their market entry decisions, or, to, at least, make them aware of what they get into.

The author believes that it is imperative, for large or small companies, to study the Chinese market in a thorough, cohesive, and quantitative manner, and to position themselves strategically before they commit to the Chinese market. Rushing into the market without a good understanding of it is the source of frustrations and failures. It is the objective of this thesis to provide a tool or a framework to facilitate such a study and strategic decision making.

1.2 Literature Review and Framework of Thesis

Two most prominent factors that influence the entering into the Chinese market is the market entry strategy and the Chinese culture. In his classic strategy paper[6], Porter pointed out that in studying a market, one must consider the interaction of five market forces: suppliers, buyers, substitutes, entry (exit) barriers, and industry rivalry. For an existing player, the most attractive market is one where entry barrier is high, industry rivalry is low, supplier and buyer power is low, and threat of substitution of low. All these conditions, except one, apply to a new entrant: the new entrant wants the entry

[5] Yoshino, Y., Lam V. M., and Malnight T. W., "Otis Elevator Co. (A): China Joint Venture," *Harvard Business School Case 9-391-062*, 1984.
[6] Porter, Michael. "How competitive forces shape strategy." Harvard Business Review, March-April 1979.

barrier to be low. It is the collective strength and interactions of these five forces that determines the attractiveness of a market to a potential entrant.

Tavassoli[7] proposed a more practical model: it aims at helping a company evaluate not only the attractiveness of the existing and potential markets, but also its strength and weaknesses in these markets. According to Tavassoli, any market can be evaluated along two dimensions: the market attractiveness, which represents how much profit potential a company has in a market, and business strength, which indicates how strong a company is in a particular market. The challenge is to find a market which is attractive, and where the company is also strong. If such a market does not exist, the company needs to strategies its investment and energy to create such a market by building its business strength in some markets. A detailed description on the Tavassoli model is presented in Chapter 3.

Numerous literature sources have written on the Chinese culture, and a growing number of literature sources specifically focus on doing business in China. In his book, "Chinese Etiquette & Ethics in Business," Mente summarizes the cultural and political elements that affect the process of doing business in China, and provides some guidelines in assisting business people in dealings with the Chinese[8].

Wong[9] pointed out 10 common problems foreign investors encounter in China and provided recommendations for resolving them. He asserted that knowing the important culture elements such as face saving, trust, connections are often times essential for foreign businesses to succeed in China. He also provided analysis on each of these elements, and gave solutions to each of the 10 common problems.

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[7] Tavassoli, Nader. Class Notes, International Marketing Course, MIT Sloan School of Management 1995.

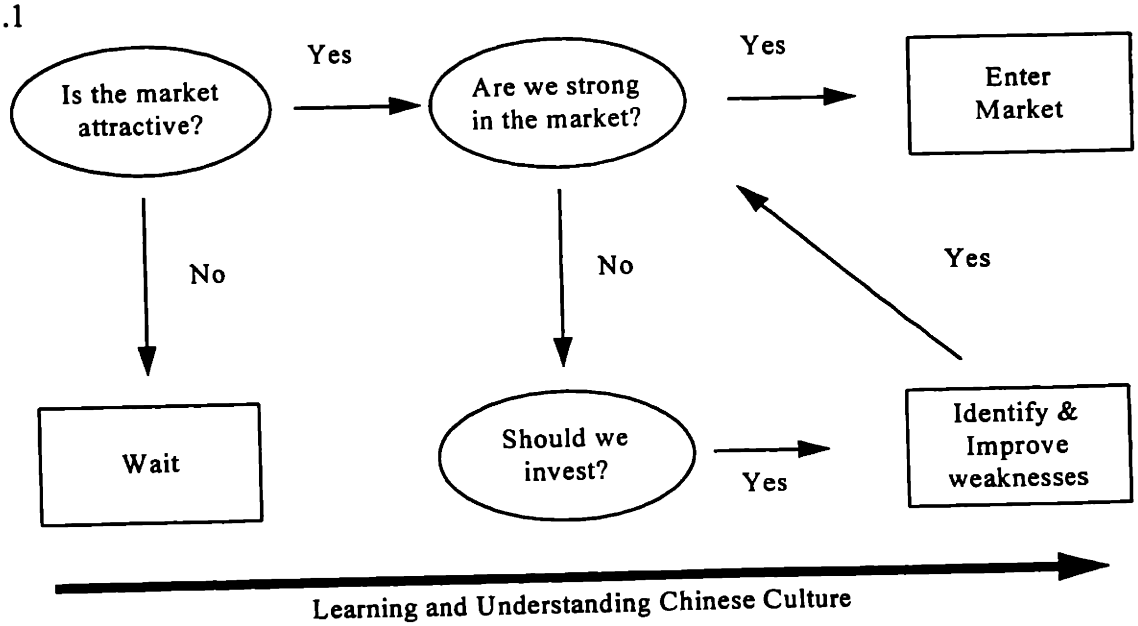
[8] De Mente, Boyce. " Chinese Etiquette & Ethics in Business." NYC Business Books, 1989.

[9] Wong, Yim Yu. "Succeeding in China in the 21st century." SAM Advanced Management Journal, 1995.

The thesis author believes that the objective of a company, when considering whether to enter the Chinese market, is to have a cohesive feasibility method that guides and drives their decision making process. Although both the strategy literature and the Chinese culture literature can be of help in this regard, it is not immediately obvious that how a company can combine these two bodies of knowledge and utilize them to drive the market entry decision making. The strategy work tends to stay at a fairly general and generic level; the culture analysis, while very specific to China, does not provide a linkage between business decisions and the Chinese culture. In short, there is generally a lack in current literature on how to combine the knowledge in existing strategy and culture analysis to deduce a practical guide for a company to study emerging markets like China.

This thesis attempts to achieve this objective by synthesizing the strategy theories, the Tavassoli model in particular, and the culture knowledge in China. Figure 1.1 outlines the framework of the thesis.

Figure
1.1



The question “is the market attractive?”, i.e., the market opportunity question, should always be the first question to ask when considering entering the Chinese market. The Chinese market is often times a high risk market, and therefore, the reward needs to be high. The opportunities, both at present time and in the future, should be quantifiable profit potential for the company. Rushing into the market without considering the market opportunities should be avoided - if Chinese don’t buy widgets, a widget manufacturer should not get into the market regardless how large the Chinese population is. To answer this question, casual examination of the existing reports is often not enough; instead field study is often times needed.

An attractive market is a necessary but not sufficient condition for investing in China. A company should next understand the needs of the market and exam how well it can meet the market needs, i.e., should answer the question “are we strong in the market?”. If the market is attractive and the company meets the market needs better than its competitors, an immediate entry into the market is warranted. If it is not strong in the market, the company should examine the opportunity cost of investing in the Chinese market versus the cost of investing in elsewhere. If investment is justified, the next step is to identify and improve major weaknesses. Investment in improving its capability should be made until company is strong enough to enter the Chinese market.

The process of studying the market is also a process of learning: learning the Chinese culture, the political system, and the Chinese people. It is important to not only understand but also be able to operate within the Chinese culture context. The level of understanding of the Chinese culture determines the ultimate level of success a company can achieve in China. Yet it is a hypothesis of this thesis that the studying of culture and system can not be separated from the studying of market. The sub-culture, pertaining to the particular market in which the company operates, instead of the general Chinese culture, should be the focus of the company’s study. The Chinese culture is a such an encompassing subject that one can easily get lost by learning it in a general sense.

The framework was first applied to a 6 month project conducted in the Chinese telecommunications industry. This project was funded by a US company - Teradyne Inc. of Boston, Massachusetts, and conducted jointly by the Leaders for Manufacturing Program at MIT and Teradyne. The industry segment where the study was conducted is the Automatic Line Testing (ATE) sector in the telephone market. The framework proposed here is in its final form; in actuality, the concepts and structures evolved in the course of the project. Therefore, the author will not only describe the analytical results from using the framework, but more importantly, document the actions and strategies taken during the project to demonstrate the continuous effort to identify opportunities, tackle weaknesses, and refine the framework.

1.3 Structure of Thesis

The chapter 2 introduces Teradyne, its products, and its market position in the automatic line testing market. First an description on the technology is provided: both the telephone technologies and automatic line testing technologies. It is followed by a detailed discussion on the world wide automatic line testing (ATE) market, and on the product comparison between Teradyne and its competitors.

The third chapter attempts to answer the first and the second question of the proposed framework in the context of the Chinese ATE market. First the Tavassoli model, which examines a potential market in two dimensions, market attractiveness and business strength, is introduced. Then the Chinese market is analyzed using this model with data collected from a two months in-country market study. Finally, the attractiveness of the Chinese market and strength (weaknesses) of Teradyne are identified and discussed, based on the model's framework and on the Chinese market.

Chapter 4 describes a method used by the author and the project group to improve Teradyne's market strength. The focus is on analyzing the existing telephone repair process in China and on identifying Teradyne's ability to providing improvements onto this process. The existing phone repair process in China is first presented and studied, both qualitatively and quantitatively, with data drawn from an extensive field study in B City Telephone Company. A mathematical model, using a Markov chain approach, is developed to analyze the expected cycle time of the process. Next, a more efficient repair process is proposed. The expected improvements, both qualitatively and quantitatively, of this proposed process over the existing process, are presented.

1.4 Data Source and Methodology

One of the data sources is the existing research materials, publications, and statistics. While information and data sources are numerous, they are also extremely uneven. One of the reasons for this unevenness is different terminology. Chinese reports often use "local telephone switch capacity", for example, as an indicator for the size of the Chinese telephone industry. In the US, the term "line count" - meaning number of telephone lines at the station level - is often used. As a result, the size of the Chinese telephone is bigger in the Chinese terms than it is in the US terms. This different usage of terms is factored in when data is presented in this thesis.

The Chinese government's aggregate data often provides accurate portrayal of growth trends in the Chinese telephone, although the numbers may be overstated. This may be a result of the following two phenomenon. First, local government officials have the incentive to exaggerate their statistics, such as reporting a telephone cable (~200 pairs of telephone wires) under construction as having added 200 new users, because they are often rewarded for growth and size. The second reason may be the lack of standard reporting procedure to follow and the lack of independent third party monitoring system (except for occasional audit by the central government).

Statistics reports by third parties provide good checks on the Chinese official data. These third parties include World Bank, US-China Business Council, US China Embassy, and several independent Business Consulting Firms. Although they still tend to err the plus side (many still use the official data as a base), they are often less optimistic than the Chinese government reports. An attempt is made to utilize this level of data whenever they are available.

The second channel of data source is from direct interviewing operating people during in-country site study. The site study covered five large local telephone markets in China, and in each of these sites, a sampled group of managers, engineers, and technicians were interviewed. Independent checks by members of the project group were made whenever possible, and these checks indicated that data obtained from these interviews were at higher level of accuracy than those from research materials. Since the combined market size of these five markets accounts for 15% of the total Chinese market, this study assumes that the data from these markets is representative of the Chinese market.

The third channel of data collection is from direct field study. The author worked in a local telephone market for three weeks as a telephone repairman, documenting the repair process and timing each step of the process. At least ten data points were collected at each work station; four processes, in the same local telephone market, were observed in detail; 8 receptionists, 4 dispatchers, and 5 repairmen worked with and were interviewed by the author. These data constitutes the data base and process base for the process study (Chapter 4) with two underlying assumptions: (a) the processes observed by the author is representative of that in this local market, and (b) the process from this particular market is representative of that in the Chinese market.

The data collected and results obtained from the study are disguised due to business sensitivity. The following names are also disguised for the same reason: the Chinese cities where this project was conducted, and the names of Teradyne's markets (current or potential), and Teradyne's competitors.

CHAPTER 2: AUTOMATIC LINE TESTING TECHNOLOGY AND MARKET

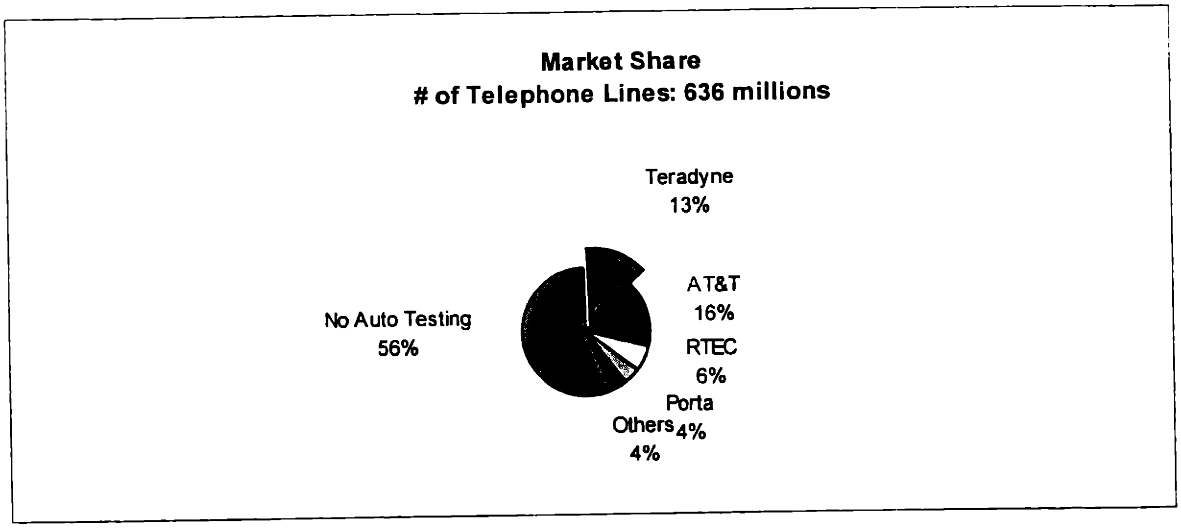
This chapter lays the technical foundation for the thesis. It first gives a brief introduction to Teradyne and its Telecommunications Division and to the background of this study. This introduction is followed by a description of the telephone technology which enables modern telephone communications. Finally, the automatic line testing segment of the industry is discussed with the emphasis on Teradyne's product and its comparison with competitive products. The content in this chapter, unless specified otherwise, is based on the US telephone market.

2.1 Teradyne and its Telecommunications Division

With sales of $1.4 billion and with 3,900 employees world wide in 1995, Teradyne is the world's leading supplier of automatic test systems to the electronics and telecommunications industries. Founded in 1960, Teradyne started the automatic test equipment (ATE) industry with the first automatic diode test system. By 1970, Teradyne was a leading merchant supplier of these systems.

In 1975, Teradyne's Telecommunications Division (TD) designed and manufactured the first automatic test system to help local telephone companies improve service while reducing cost. TD research shows that the ATE sector within the world wide telephone industry has growth to a $300 million industry. The customers are local telephone companies; the suppliers to this industry include Teradyne and its competitors, most of whom are US-based companies. Figure 2.1 shows major ATE suppliers and their respectively market share in 1994. The number of telephone lines currently under test is 312 million, 90 million of which is under test by Teradyne's equipment.

Figure 2.1



Teradyne designs and manufactures testing and surveillance systems to help telephone companies maintain the lines emanating from the local exchanges toward the customers. These systems help a telephone company achieve objectives of improving customer satisfaction, productivity, and efficiency. Teradyne systems accomplish this by detecting degradation through surveillance, facilitating fault correction through advanced troubleshooting and integrating the results into maintenance operations support systems.

After many years of success, the Telecom Division is facing new challenges. Its traditional Western European and North American markets are maturing. Most of the telephone lines in these markets are being tested by automatic testing equipment. The available market for test equipment in the US and Europe is small and is growing slowly. One of TD's means to meet its long term growth objective is to explore new market opportunities, especially large emerging markets in Asia-Pacific and in Eastern Europe.

One of the potential markets is China. With its number of telephone lines growing at an average annual 30% rate in the past ten years, China is one of the largest and fastest growing telephone markets for TD. Yet, Teradyne's knowledge about the Chinese telephone market is limited. It is therefore imperative for Teradyne to (1) understand the opportunities in China compared with other emerging market, and (2) understand where Teradyne can position its product given the maintenance operations in China.

2.2 Digital Telephone Technology

A telephone system is an electrical system. It is powered by batteries installed in Central Offices (CO), which are owned by local telephone companies. The dialing is originated on the key pad on the telephone set. The call is routed by switching equipment in the CO to another CO (if appropriate), which serves the called party. From there, the call is directed to a pair of wires which connects the telephone of the called party to that CO.

2.2.1 Telephone and Digital Switches

Simply put, a telephone is made up of a key pad, a receiver, and a transmitter. Both receiver and transmitter are pressure transducers. A typical transmitter is the carbon transmitter. Carbon is a nonmetallic element and is an electrical conductor. When under pressure, the carbon resistance changes, resulting in variation in current flow in the telephone circuit. When one speaks into the transmitter, a sound wave is created, whose pressure varies depending the volume of the voice. This varying pressure causes the carbon resistance to change, resulting the amount of current flowing through the telephone circuit to change. The receiver is also a simply carbon transducer, except that it translates the variation in the current it receives back to pressure, and then to voice.

The purpose of telephone key pad is for dialing. Pushing any one of the key buttons produces a tone, an electrical signal, made up of two assigned frequencies. This electrical signal is sent to the switch equipment in CO, and a combination of several (in US, 7 for local and 10 for long distance) tones gives instructions to the switch equipment to locate the address of the called party. When a phone call is originated from a calling party, his/her voice (sound wave) is converted in the telephone set into an analog electrical current which travels into the Central Office (CO). This analog electrical signal is converted into digital signal and routed through interoffice network (trunks) to the

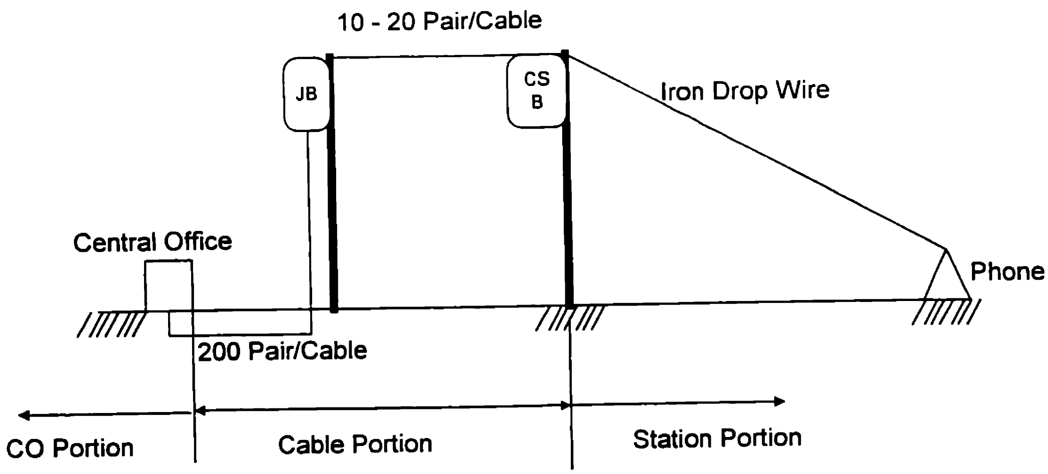
Central Office at the proximity of the called party. There the digital signal is converted back to analog signal and runs through the local transmission facilities, which is discussed in the following paragraphs.

2.2.2 Transmission Facilities (Cable Plant)

The transmission facilities start with large primary feeder cables running from the end of CO out to cross-connect terminal cabinets (known as Junction Boxes or JBs) mounted on poles. These feeder cables usually run in underground tunnels. A feeder cable consists of 200 pairs of telephone lines. At Junction Boxes the feeder cables is divided into smaller bundles known as distribution cables, which in turn are made up of 10 to 20 pairs of telephone lines. A distribution cable runs from one pole to another until it reaches the proximity of the user location. There the distribution cable, through another connection box called Cable Splice Box, splits into individual phone lines. The section of telephone line from Cable Splice Box to customer premise equipment (CPE) is called drop wire. To make a complete electrical circuit, each telephone line is made up of two copper wires, one for battery and the other at ground.

In the telephone US network, telephone drop wire is normally copper twisted pair wire (CTP) and is usually short (<100 feet). In China, on the other hand, the drop wire is iron wire and is normally very long (500 meters to 1,000 meters), running from one pole to another until reaching end users. A drop wire of this type represents highly problematic maintenance situation because the wire is susceptible to external environment factors (weather change, sunshine, etc.) as well as internal factors (large gravitational force due to long distance, etc.). Figure 2.2 shows a typical layout of a telephone network in B city, China.

Figure 2.2



2.3 Line Faults

When a telephone user is not able to communicate well over his/her telephone, the telephone is at "fault." Problems such as cross talk (over hearing others talking), noise, and lost dial tone are all classified as "faults."

There are three types of possible causes of resistance fault in a telephone line - short, ground, and cross. Short refers to one wire of a telephone line electrically connecting with the other wire of the same telephone line. This is mainly resulted from the poor inside insulation. Ground is the one wire touching ground, stemming from a poor insulation situation of both the inner insulation and outside insulation. Cross is one wire of a telephone pair touching the battery wire of another telephone line. Short, ground, and cross can be characterized by different and measurable electrical characteristics.

A fault can either occur in the CO, Cable, or Station, and different fault locations require different repairing skills. The frequency of types of faults and their locations depends on a particular network. Correspondingly, a maintenance organization is divided into three repair groups: CO, Cable, and Station. Table 3.1 provides a breakdown of problems and their locations for telephone network in Tokyo, USA, and B City, China. In China, the higher fault rate at the cable seems to indicate the poor installation and construction quality.

Table 2.1

	CO Fault	Cable Fault	Station Fault
USA	10%	20%	70%
Tokyo, Japan	3%	24%	73%
B City, China	5%	35%	60%

2.3.1 Telephone Repair Process

The telephone repair process is defined as the system and procedure by which telephone companies repair line problems. In a broad sense, the process can be divided into proactive and reactive processes. The reactive process refers to the type of repairs initiated by telephone user's complaints. Proactive maintenance process is a process in which telephone companies initiate the repair of a phone line, usually before the end user ever notices problems. This thesis focuses on reactive improvement process, although results can be easily applied to both processes.

In both the US and in China, a reactive repair process is roughly a four step process. The first step is reception. When a telephone user calls the telephone company to complain about a phone problem such as no dial tone, noise, etc., he/she is received by a telephone operator who documents the complaints. The second step is dispatch. The dispatcher, after confirming that there are indeed problems in the telephone line, updates and generates a trouble report and sends this report to the appropriate repair group. The next step is repair, where the group (or person) goes out to the field and repairs the telephone line. The last step is retest. The telephone company retests the telephone line, either through testing or through calling end users directly, and confirms the successful repair of the telephone line. A detailed description, analysis, and discussion of the Chinese telephone repair process is provided in Chapter 4.

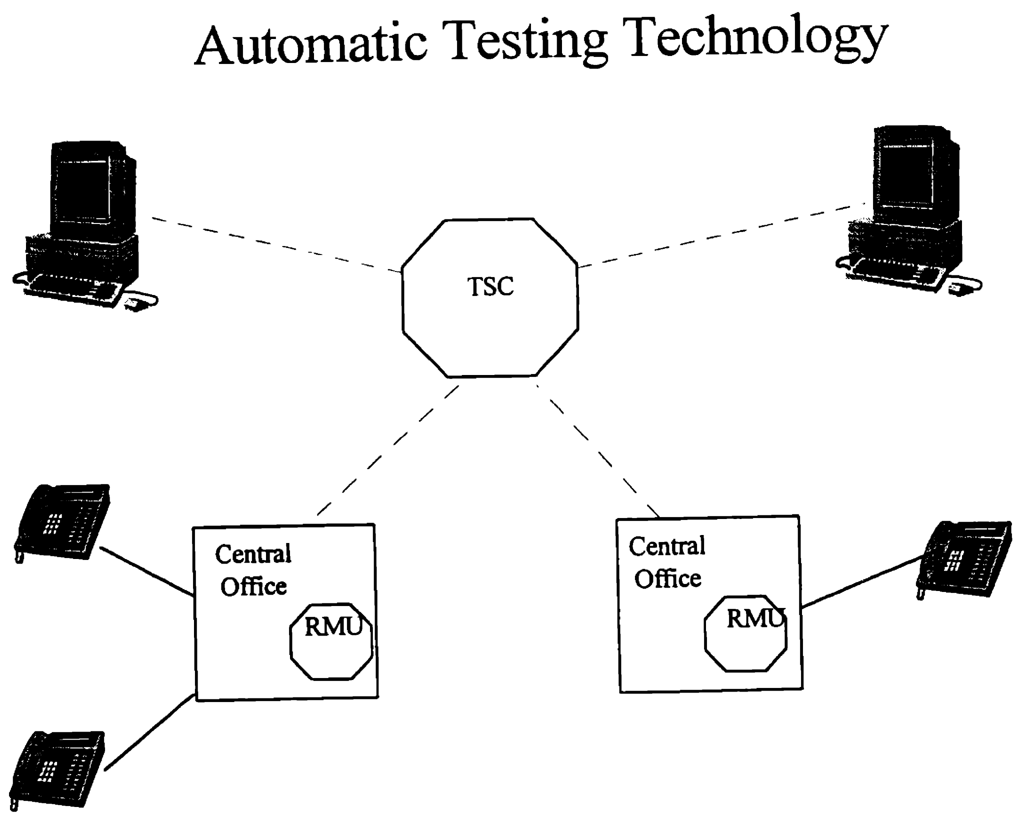
2.4 Automatic Line Testing (ATE) Technology

In North America and in Western Europe, automatic testing machines are integral part of the telephone service process. The repair dispatchers use the automatic testing equipment to find out what problems the line has, which repair group they should dispatch to the line, and, in some cases, where the fault locations are. By using automatic testing, the telephone companies repair telephone lines in an accurate and efficient manner. A typical ATE system consists of two major functional components: testing and data processing.

The "testing" part of ATE is completed by a system called Remote Measurement Unit. This is basically a sophisticated electrical meter which tests basic electrical characteristics of a telephone line. For example, Teradyne's RMU is able to test 23 electrical parameters in a telephone line such as system voltage, line resistance, line capacitance, etc.

The "processing" part of ATE can either be done locally in each Central Office, or centrally in a centralized service location. Figure 2.2 shows how a typical Teradyne ATE system, which relies on central data processing, is used within a telephone network. The system is composed of many Remote Measurement Units (RMUs) and a Test System Controller (TSC). RMUs are located in the telephone central offices (COs). When a test command is initiated by the telephone company operator, the RMU function as a sophisticated testing meter which captures electronic parameters of a copper telephone line. These captured data is fed back, through a special communications link, to a central location where the TSC is located. TSC is the "brain" of automatic testing. It processes the data numerically and displays fault types and locations for the telephone operator. The telephone company dispatcher is then able to use the result to dispatch to appropriate repair groups to the field.

Figure 2.2



The centralized processing capability of the TSC dictates the economics of automatic testing equipment - it is most effective in a centralized repair center, which monitors and repairs large number of telephone lines. One of service centers which use Teradyne testing equipment, for example, is able to monitor and repair 7 million phone lines throughout 7 states in continental America.

2.5 Product Features: Teradyne vs its Competitors

Teradyne is often considered the "Cadillac of the industry." Its product is comparable with its competition in terms of speed and reliability, offers better performance in accuracy and features, and charges higher price than competitive products.

The accuracy of the Teradyne product stems from two facts. One is more sophisticated RMUs. Teradyne's RMUs test 23 independent electrical parameters. Most competitors test 12 or less. Secondly, Teradyne's analysis algorithm in the TSC is perhaps the most comprehensive software in the industry. By combining these two factors, the Teradyne system is able to consistently identifies line faults and locations accurately.

Because of the RMUs' ability to collect more data and the TSC's ability to do more manipulation, Teradyne's product has more features than its competition. For example, batch testing enables telephone companies to routinely test a predetermined group of lines. The following table summarizes some of the key Teradyne product features that are superior to the competition.

Function Type	**Teradyne**	**Competition**	**Teradyne Benefits**
Dispatch	Detect line fault types and dispatch directly to Station, CO, or Cable	Dispatcher performs analysis on electrical parameters	Accurate results Less skilled required
Fault Detection	Detect multiple faults per test	Single fault detection per test	More accurate initial dispatch
Fault Location	<200 feet at cross faults; <300 feet at short and opens	Fewer measurements Less accurate	Competition requires skilled labor
Special Customer Equipment (Fax, PBX, etc.)	Detect special equipment by Teradyne developed features	Buyer developed features; less reliable	Decrease unnecessarily dispatch
Voice Response System	Field crew able to call back CO to initiate testing and obtaining results	Not all test features available to the field crew	Faster repair and minimum redispatched repairs

*: Competition refers to RT, PT, and MCS. Based on product knowledge obtained from Teradyne and on customer perceptions in several large local markets in China.

CHAPTER 3: MARKET ATTRACTIVENESS AND BUSINESS STRENGTH

This chapter answers the first and the second question of the proposed framework (Figure 1.1) in the context of the Chinese ATE market. First the Tavassoli model, which examines a potential market in two dimensions - market attractiveness and business strength, is introduced. Then the Chinese market is analyzed using this model with data collected from a two months in-country market study. Finally, the attractiveness of the Chinese market and strength (weaknesses) of Teradyne are identified and discussed, based on the model's framework and on the Chinese market.

3.1 Tavassoli Model[10]

3.1.1 Introduction

A market is a place where suppliers interact with customers. One aspect of this interaction is the supplier's evaluation of the potential attractiveness of the market. In deciding whether to enter a particular market, a supplier evaluates, either consciously or subconsciously, a list of key factors that are important to its business. Is there a need for its particular product? Is the market large enough or growing fast enough to warrant its investment? Will it do better or worse than its competitors in the market? Will the market be more or less profitable than other potential markets? In essence, the supplier evaluates how attractive the targeted market is, both in absolute terms and in comparison with other alternatives. Also, different suppliers may ask different questions in this evaluation process, i.e., different suppliers may use different criteria in evaluating markets.

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[10] The model is developed by Professor Nader Tavassoli of MIT Sloan School of Management for one of his class exercises in the International Marketing class.

The second aspect of the market interaction is the market's evaluation of suppliers. For a particular product segment, the market evaluates potential suppliers with a set of criteria. Is one supplier's product less expensive than others? Who has good product features and functionality? Who responds quicker to customer's requirements? Normally the market values the supplier with the strongest collective business strength in meeting this set of criteria.

The interaction in the context of the Teradyne project is shown in Figure 3.1a and 3.1b (ranking in these charts serves as an example only). Teradyne is a potential supplier of automatic line testing equipment to China; the Chinese telephony market is one of Teradyne' potential markets. On one hand, Teradyne is comparing the attractiveness of the Chinese market with its other market alternatives: *A*, *P*, *S*, *U* (disguised names. see **section 1.4**). On the other hand, the Chinese telephone market is evaluating Teradyne's business strength - how well Teradyne meets the market needs compared with Teradyne's competitors. The Tavassoli model proposed here intends to provide a systematic approach to enhance Teradyne's understanding of the Chinese market and of its own strength (weaknesses) in the market, and to enable Teradyne improve itself in a particular market. A Chinese telephone company is here referred to as a city level telephone operating company, where the purchase decision of automatic testing equipment is made.

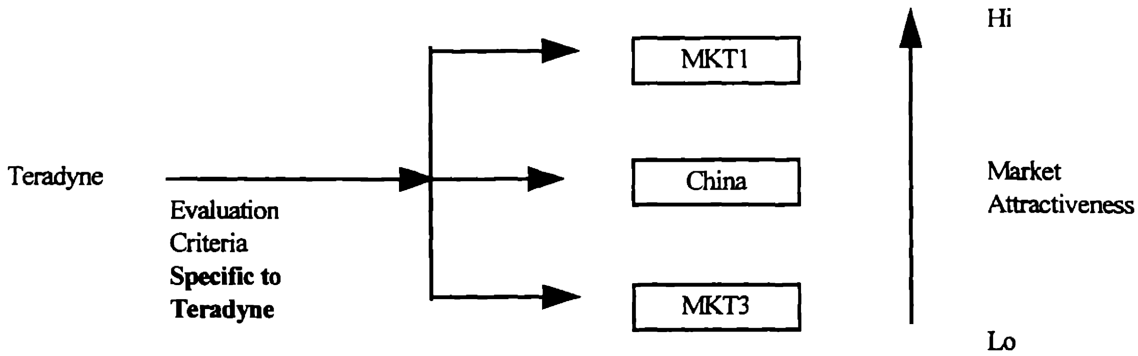


Figure 3.1a: Market Attractiveness

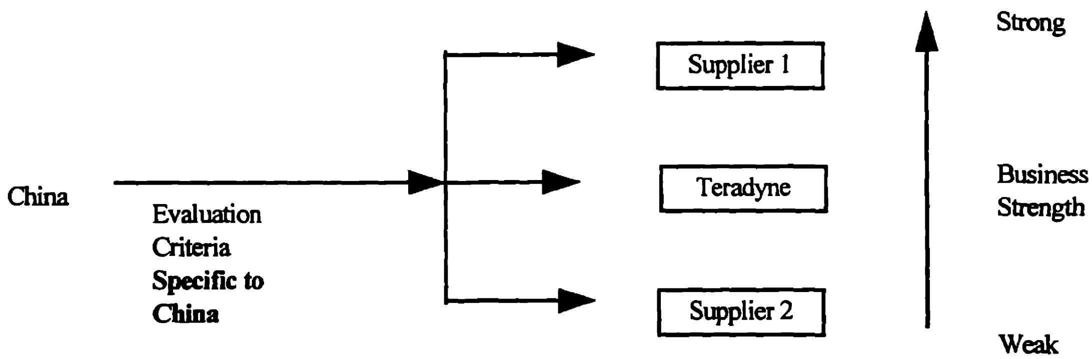


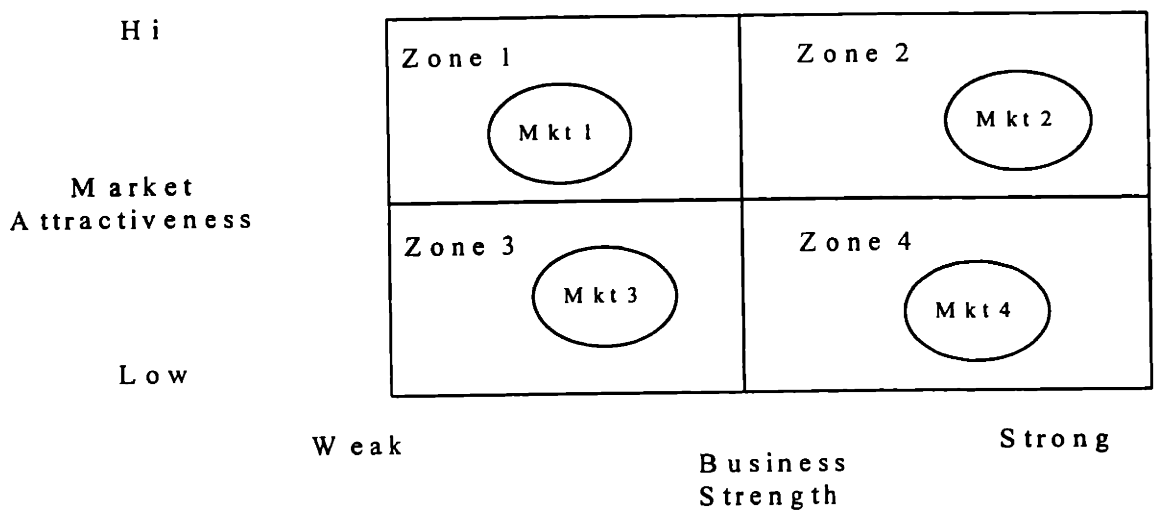
Figure 3.1b: Business Strength

This model examines supplier-market interaction in two dimensions, market attractiveness and business strength, each of which comprises a set of criteria. Next step is to discuss these two dimensions in the context of automatic testing equipment market.

3.1.2 Strategic implication of the model

Figure 3.2 gives an example in order to illustrate the strategic implications of the model. Suppose a company is evaluating four markets: market 1 to market 4. Each of these markets is mapped out according to two dimensions: market attractiveness and business strength, shown in Figure 3.2.

Figure 3.2



Market 2 is the ideal market for the company. The market is attractive, and the company is strong in meeting the market needs. If the company has operations in Market 2, the operations will be very profitable; if the company doesn't have operations in Market 2, the company needs to enter Market 2 soon before its competitive edge is lost.

Market 4 represents a mature market for the company. If the company is operating in Market 4, actions need to be taken to move Market 4 upwards to Zone 2 by introducing new products, exploring new opportunities, etc. If attempts of moving Market 4 back to Zone 2 are not successful, the company should considering exiting this market. If the company is not operating in Market 4, it should not enter. Neither should the company enter Market 3, where the market is not attractive, and the company is not strong in the market. If the company is operating in Market 3, it should considering exiting.

There are three steps the company should take when considering Market 1. Obviously, the company likes to move Market 1 into Zone 2 by building up its business strength in Market 1. The first step is to find out what makes the company weak in the market. This requires in depth examination of the business strength criteria and what, if anything, the company can do to improve its performance on these criteria. The second step is to determine how much the company needs to invest to achieve the desired improvements, and if this investment can produce a good return in long term. If the investment proves to be acceptable, then the third step is to work out an action plan to improve the company's performance in Market 1.

The main body of this chapter discusses an application of the Tavassoli model in the context of the Teradyne project. Basic information about the Chinese market is presented next.

3.2 Information on the Chinese Market

3.2.1 History of Growth

Early in its "open-door" reform in late seventies and early eighties, China recognized that the telecommunications infrastructure was a key to its economic development. The China Ministry of Posts and Telecommunications (MPT), China's governmental agency in charge of developing telecommunications industry, has since put in serious effort into developing its telecommunications sector. By the end of 1993, China's telecommunications network has become one of the ten largest in the world. This effort in telecommunications is likely to continue in the foreseeable future. The emphasis of the national economy in the near future, according to Chen Jinhau, China's Minister of State Planning Commission, in his report on 1994-95 plans to the Eighth National People's Congress, is "strengthening key construction in such basic (infrastructure) industries as energy, communications, telecommunications, raw and processed materials."

The development statistics of the China telecommunications industry has supported Mr. Chen's claim. Starting from early 1980s, the growth rate of telecommunications has consistently outpaced that of the national economy. The annual growth rate from 1980 to

1993, in terms of telephone line capacity, is approximately 30%, while during the same period, the annual growth rate of the national economy is 10%.

It is also interesting to note that the past growth rate has consistently beaten the government forecast. This has resulted in the Chinese government's frequent revising of their own forecasts. The projection of telephone line capacity by the end of this century has been changed four times, from 31 million of the original projection to 60 million, 100 million, 140 million, and then to 170 million of the most recent projection. The most recent projected growth means an average annual growth of over 10 million lines from 1995 to 2000 - the size of a United Kindom's telephone network in every three years.

The telephone exchange capacity increases from 8.4 million in 1986 to 32.7 million in 1993. Nation wide telephone penetration has reached 2.2%, and urban penetration 9%. Table 2.6 shows the size of some local telephone markets for coastal provinces and large Chinese cities. Based on Teradyne research, at least 50 millions of these lines are without automatic line testing.

Table 3.1 Selective key markets in China: coastal cities and provinces

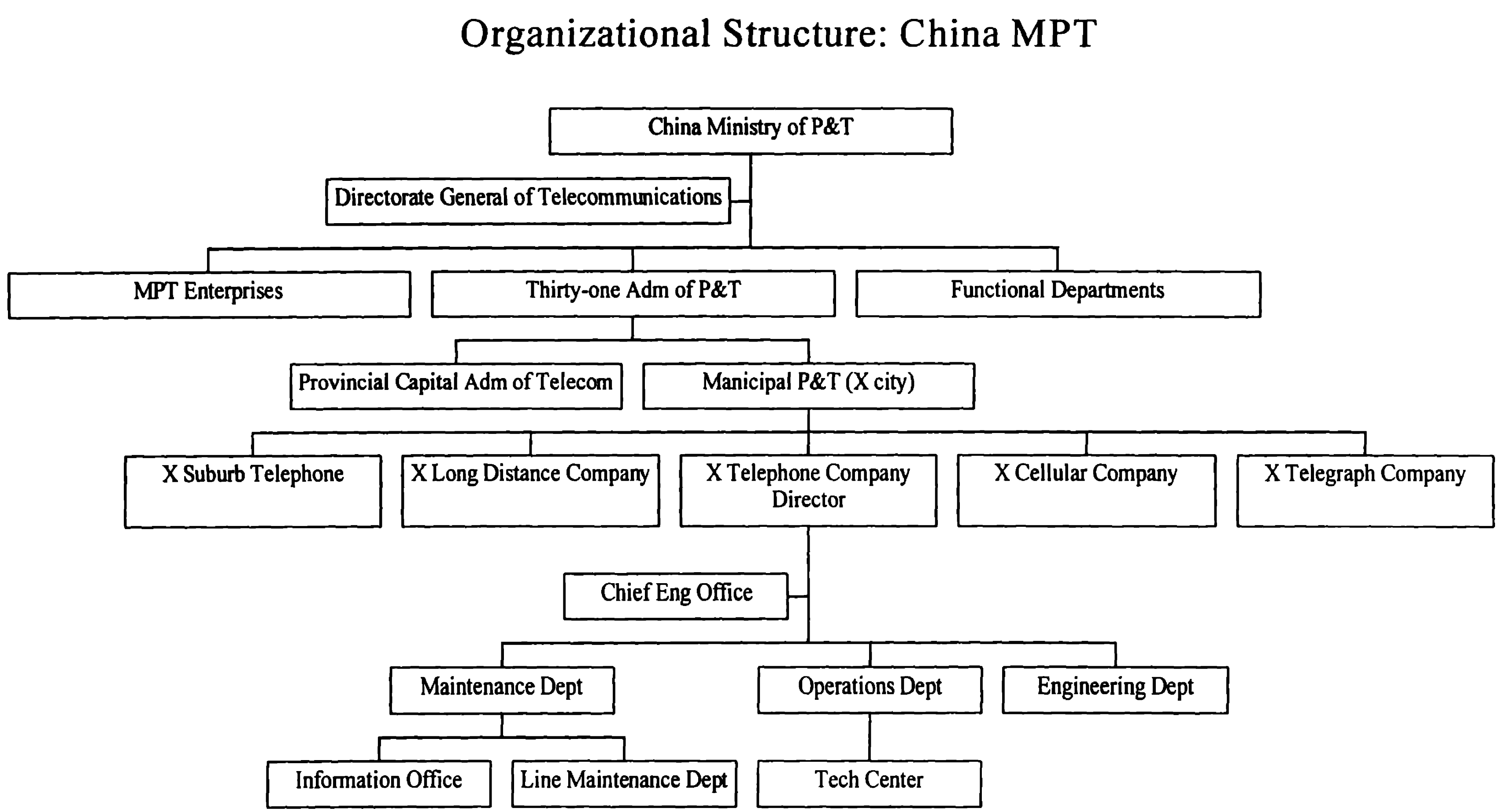
Province Name	SW Cpt, Province	Major cities	SW, city	Subscriber	Decision maker (est)
		Beijing*	2.5 m (5/95)	1m (5/95)	city
		Shanghai*	2.3m (5/95)	1.5m (5/95)	city
		Tianjin*	1.1 m (5/95)	.57m 95/95)	city
Liao Ning	3.3 m (8/95)	Shengyang*	0.71 m (12/94)	.41 m (12/94)	prov
		Dalian			
Guang Xi	1.1 m (6/95)	Nanlin	0.2m (12/94)		prov
		Guilin			
Jiang Su	4.84 m (9/95)	Nanjin*	.62m (12/94)		prov
		Xuzhou			
Shan Dong	3.18 m (7/95)	Jinan	0.35 m (5/95)	.22m (5/95)	prov
		Qindao			
Hu Nan	7 m * (2000)	Changsha*	.67m (12/94)		prov
Guang Dong	8.3 m (8/95)	Guangzhou	1.4 m (9/95)	1m (9/95)	city/prov
		Shengzhen*	1 m (12/94)	1m (9/95)	
Hu Bei	2 m (11/95)	Shigaizuan	.25m		prov
Zhe Jiang	3.09 m (7/95)	Hangzhou	0.52m (12/94)	.35m (12/94)	prov
		Linbo			
Hubei		Wuhan*	.57m (12/94)	.38m (12/94)	prov
Shichuan		Chendu*	.38m (12/94)	.23m (12/94)	?
		Chongqin*			
Fujian		Fuzhou	0.35m (12/94)		prov
Total (China)	60 m				

* SW CPT refers to switch capacity in local telephone companies

3.2.2 China MPT

The telecommunications industry is overseen by China Ministry of Posts and Telecommunications (China MPT). The organizational Chart is shown in Figure 3.3.

Figure 3.3


Organizational Structure: China MPT
China Ministry of P&T
Directorate General of Telecommunications
MPT Enterprises
Thirty-one Adm of P&T
Functional Departments
Provincial Capital Adm of Telecom
Manicipal P&T (X city)
X Suburb Telephone
X Long Distance Company
X Telephone Company Director
X Cellular Company
X Telegraph Company
Chief Eng Office
Maintenance Dept
Operations Dept
Engineering Dept
Information Office
Line Maintenance Dept
Tech Center

Through its functional departments, enterprises, and research institutes, China MPT plays a three fold role in the telecommunications industry. First, it has its own operations. Its research institutes develop or introduce important technologies to the market; its functional departments and enterprises run large scale projects such as building a national-wide fiber network. Secondly, China MPT supervises and coordinates activities for local telephone companies. It allocates state funding to different local telephone companies for capital equipment purchasing and technology upgrading; it appoints key personnel to local telephone companies. Thirdly, China MPT serves as a regulatory body. It sets operating policies for local telephone network; it sets customer service criteria that local telephone companies have to meet. Each province has its own Provincial Ministry of Posts and Telecommunications (Provincial MPT), which play a role similar to that of China MPT, except at a provincial level.

3.2.3 Local Telephone Companies

Below China MPT and Provincial MPTs are local telephone companies, the actual operating units of local telephone network. There are over 2,000 local telephone companies in China. A local telephone company's operation includes, but not limited to, activities such as installation, network expansion, maintenance, repairing problematic lines, and billing.

Traditionally, telephone companies are organized as any state owned enterprises: no responsibility and no accountability. They operated under rigid state-set guidelines; they were 100% funded by China MPT; they turned in all their profits and were reimbursed for all their losses. This situation is quickly changing, however, as telecommunications has become the most dynamic and forward thinking state-own sector in China. Currently, local telephone companies operate as "quasi profit centers." They are now allowed to keep the after tax profits; they do not get funding for their daily operations any more. They are still funded, through mainly tax benefits, for their capital equipment spending and for their technology upgrading.

This change of operating relations between China MPT and its local telephone companies has strong implications. One on hand, China MPT still has strong influence on telephone companies. It sets the overall policies for telephone companies. It specifies technical criteria for them to meet. It has right to approve or to veto for large capital spending. Most importantly, China MPT retains the right to ultimately appoint or dismiss key officials in telephone companies.

On the other hand, while still adhering to the broad guide lines by China MPT, local telephone companies are making more autonomous decisions, resulting in the market moving towards decentralization. As the level of complexity grows with the growth of telephone network, local telephone companies are increasingly making their own decisions, and the controls by China MPT are becoming increasingly ineffective. Conflicts often arise as a result of this . An example of this conflict occurred in Jiangsu province. When local telephone companies in Jiangsu tried to get approval for a joint venture with Fujitsu company, a Japanese manufacturer of switch equipment. China MPT did not approve this deal on the basis that Fujitsu was not on MPT's preferred manufacturers list. Jiangsu persisted, only to encounter more rejections and eventually threats from China MPT. The conflict escalated. Jiangsu went ahead with the project without the approval, and China MPT decided to forbid the joint venture products to be marketed in other provinces.

3.2.4 Deteriorating Service

In the past few years, it has become more and more evident that the telephone network in China has outgrown telephone companys' service capability. As the number of subscribers increased exponentially over the past ten years, the quality of the telephone service, especially line maintenance, has taken a nose dive.

This problem is a direct result of China MPT's early policy, which stresses growth versus network management. Local telephone companies have been focusing on adding new subscribers, and buying more switch equipment and telephone cables. Little effort has been given to building up a quality installation and maintenance system. B City Telephone Company, for example, has growth from 20,000 line capacity in 1982 to 2.0 million in 1995. Yet maintenance organization is essentially staffed by same number of personnel; the maintenance method is still largely manual "trial and error" type. As a result, the queue of telephone lines waiting to be repaired and cycle time to repair a telephone line have growth exponentially. A random sampling of telephone users in B City has revealed that the average waiting time for a telephone repair is 4 days.

3.2.5 Monopolistic Operations

China MPT and its telephone companies are enjoying monopolistic status in the wire line telephone market. This status has helped the telephone market in many ways. First, it has allowed the concentration of financial and technological resources on key projects and developments. Second, it has given MPT unparalleled power in negotiating with foreign suppliers for low equipment price, generous technology transferring, and favorable financing (soft loans), all of which have resulted in the rapid development of the telephone infrastructure. Finally, it enables China MPT to set the price of installation and service to maximize the return of cash flow and to sustain continuous huge investment in infrastructure.

In other sectors of the telecommunications industry, China MPT is not that lucky. In the cellular communications sector, China MPT is facing fierce competitors from two state owned companies, UNICOM and Jitong, both of which enjoy strong political support from the government. The competition is even more intense in paging, where there are estimated 4,000 operators in the country.

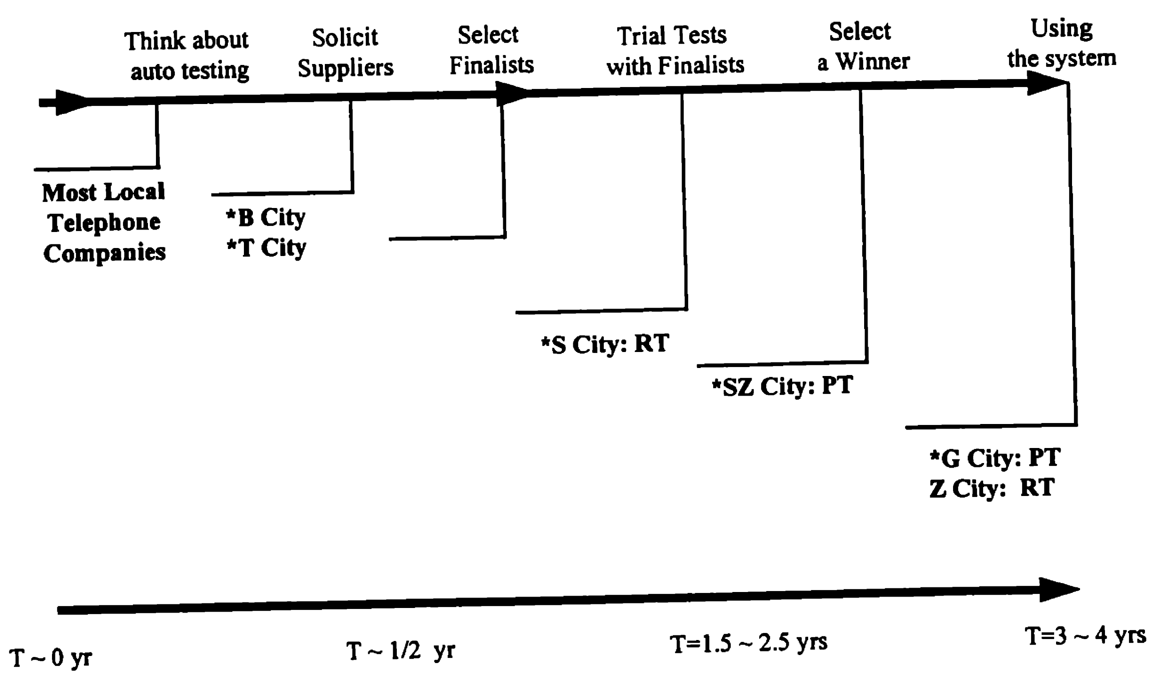
Jitong and UNICOM do not pose a threat to China MPT in the telephone market in the short run. Nevertheless, the fierce competition from them has forced China MPT to prepare itself to compete in the telephone market. One of the most notably moves is the initiation of Project 97, which finally aims at improving China MPT's deteriorated service level to telephone customers. Project 97 formulates a set of long term service criteria which local telephone companies must agree to meet in 1997. The aim of Project 97 is to improve telephone operation efficiency, which includes installation, phone line repair, billing, directory assistance, and service center consolidation.

3.2.6 Competition in the Chinese ATE Market

Compared with its main competitors PT and RT, Teradyne is in a weak competitive position in China. Figure 3.4 illustrates this from the point of market penetration.

Figure 3.4

China: purchasing cycle



As shown in Figure 3.4, the Chinese telephone companys' purchasing process can be broken down to six stages, from thinking about ATE to ATE installation. The five largest local telephone companies, city B, G, S, SZ, and T, have either started or have gotten close to the end of this process. Yet the rest of the local telephone companies, which collectively represent the majority of the Chinese market, have just started to consider the using of ATE. This contrast is not a surprise considering that the top five cities have always been the technological leaders in the Chinese telephone industry.

Teradyne's competitors have a head start over Teradyne in terms of market occupation. G City and SZ City both have purchased and installed automatic line testing system from PT. S City, the largest local market in China, has selected RT as its supplier. B City and T City are still in the stage of selecting suppliers, and only there Teradyne seems to have the last minute chance to compete.

Another feature of Figure 3.4 is that the whole purchasing cycle takes about 3 to 4 years to complete, according to empirical data from observing G, Z, and SZ cities. This cycle determines a particular supplier's capacity in China. For example, if the supplier's supply cycle is around 3 to 4 years (the total time it takes to market, sell, perform R&D and production, and finish installation), then the maximum capacity, the number of telephone companies this supplier is able to handle simultaneously, is 3 to 4 (time of purchasing cycle/time taking for an installation). The implication is that the quicker a suppler is able to respond to the market, the more customers it can target simultaneously.

The implication to Teradyne is more than just market penetration. By getting into the market earlier and occupying large local markets, PT and RT has laid their ground work in China. Both have established relationships or partnerships with local Chinese telephone companies; both have become intimately familiar with the Chinese telephone repair process and have configured systems for this specific process. Compared with Teradyne, both have come down their learning curve. As a result, both have been able to shorten their supplier cycle, thus becoming more responsive to the market needs.

3.3 Analysis of the Chinese Market

3.3.1 What is an Attractive Market to Teradyne?

The first step of determining the market attractiveness is deciding what defines market attractiveness, in other words, finding out the criteria comprising *market attractiveness*. To Teradyne, degree of a market's *market attractiveness* is high if:

- the size of the available market is large, i.e., the number of copper twisted pair (CTP) telephone lines without automatic line testing is large,
- the growth rate of the CTP is high,
- the degree of competition in telephone operations is high,
- there exists a set service criteria for the phone operating companies to meet,
- the purchasing decision is centralized in the market.

The source for this criteria is the direct interviewing of Teradyne people including one sales managers, one sales engineer, one marketing manager, and two engineers. Only the mostly mentioned criteria were selected, which are the ones shown above. The interview results were then summarized, and the top five criteria were selected.

It became apparent from the interviews that not all the criteria are at the same level of importance to Teradyne. In an attempt to quantify the relative importance of these criteria, the interviewees were then contacted again and asked to rate the relative importance of the selected criteria against one another. A complete list of market attractiveness criteria and their relative weight is given in the following table.

Table 3.2 Market Attractiveness Criteria

Market Attractiveness Criteria	**Weight (allocate 100 points)**
Number of CTP lines	40
Growth rate for next five years	25
Degree of competition in local market	15
Availability of set criteria	10
Degree of centralization in purchase	10

The size and growth rate are the most obvious factors. Size represents current business opportunities; growth and size combined represent future business opportunities.

The degree of competition in local telephone market is beneficial to Teradyne because of two reasons. First, telephone companies, when facing with competition, have more incentive to improve their telephone service. One of the most important measures of telephone service is efficiency - speed and accuracy - at which telephone companies repair problematic telephone lines. This is exactly the purpose of automatic line testing equipment - helping telephone operating companies repair their problematic lines more efficiently. Secondly, telephone companies under competition are motivated to reduce their cost. One way to achieve this goal is to have an efficient operation - a goal often times can be achieved by installing automatic line testing equipment, and at the mean time by benefiting from the process knowledge embodied in automatic testing operations.

The incentive to improve telephone repair service is critical to Teradyne: if a telephone company has this incentive, it will be likely to consider the purchase of process improvement equipment. Sometimes this incentive comes from competition in the local telephone market. Most of the times, however, this incentive comes from the regulatory pressure. For example, FCC, the regulatory body in the United States, publishes quantifiable measures of service criteria for telephone companies to meet. In the United States, the ability to meet the FCC's criteria directly links to a telephone company's bottom line such as getting approval for rate increasing.

The centralization of purchasing decision plays an important role in determining the attractiveness of a market. Automatic line testing equipment is highly customized equipment: sales and application engineering are both significant cost drivers. The more centralized the telephone companies purchasing decisions are, the more economies of scale Teradyne enjoys by getting large size order with uniform specifications. The role of competitive level in affecting a market's attractiveness is self-evident. With everything else being equal, Teradyne would enter the market with least competition presence.

3.3.2 What is Considered a Strong Supplier in China?

Compared with the determination of *market attractiveness*, the determination of *business strength* follows a similar process. The first step is deciding what defines *business strength*, in other words, what makes Chinese customers (telephone companies) prefer one supplier to another. *It is worth noting that business strength is market specific, and that rating of Teradyne is relative to its competition in the considered market.* To the Chinese market, a supplier is considered to have a strong *business strength* if the supplier

- has good understanding of existing process,
- has a low price,
- provides accuracy in testing, speed in testing, and a good product reliability,
- is flexible to the changes in customer specifications, and
- has a good understanding of the local business culture.

Similar to the determination of market attractiveness, the source for determining business strength is from interviewing. These interviews were conducted in China during the in-country study. The site study covered five large local telephone markets in China, and in each of these site, a sampled group of managers, engineers, and technicians were interviewed. The interview results were then summarized, and the top six criteria were selected.

Again, in an attempt to quantify the relative importance of these criteria, the interviewees were then contacted again and asked to rate the relative importance of the selected criteria against one another. A complete list of market attractiveness criteria and their relative weight is given in the following table.

Table 3.3 Business Strength Criteria

Business Strength Criteria	Weight (allocate 100 points)
Knowledge on process	30
Price	25
Local culture familiarity	15
Flexibility in responding to customers	10
Equipment reliability	5
Speed, accuracy	15

Whether an ATE system adds value or not hinges upon how well the ATE supplier understands the existing telephone repair process. In order to achieve the goal of an ATE system - process improvements, a supplier first needs to understand in great detail how the existing process works. This nature of ATE market determines that understanding of process plays a central role in evaluating technical capability of a potential supplier. It also challenges the supplier to convince the customer of this value (and paying a premium for it).

Another important consideration Chinese customers have in evaluating an ATE supplier is price. Chinese market is a highly price sensitive market, and when considering the purchase of capital equipment, much of telephone companys' effort is in reducing price. For a telephone company in China, funding for capital equipment purchase comes from two major sources: Capital Spending Fund and Technology Upgrade Fund. Both are allocated to telephone companies by the China central MPT, and are evaluated and renewed annually. Capital Spending Fund is normally used in large scale capital equipment purchase, such as switch and fiber network. The purchase of automatic equipment draws from the Technology Upgrade Fund, whose application process is more competitive and bureaucratic. Any spending from this fund over $500,000, one tenth of what a typical large city telephone company would have to spend on automatic testing for its network, has to get approval from the central MPT directly. The difficulty of securing funding forces telephone companies put much effort in negotiating for low price - an issue often dominants discussions even in early phases.

Like any other capital equipment supplier, an ATE supplier is also evaluated on its equipment functionality. Chinese telephone companies are concerned mainly with three dimensions of functionality - accuracy, speed, and reliability. It is rare, however, that functionality consideration dominates decision making. In China, it is usually overridden by price considerations.

Chinese telephone companies considers flexibility of their suppliers an important criteria. Chinese telephone companies often do not know exactly what they want at the onset - specifications change frequently. In addition, Chinese companies face many uncertainties themselves, among them the ability to obtain funding approval from China MPT, the addition of new switch equipment, etc. A flexible supplier who is quick to respond to technical and environment changes are highly valued by Chinese telephone companies. Finally, doing business in China requires the understanding of Chinese system: the local culture, the legal requirements, the business norm, etc. Appendix B discusses this issue at much greater detail.

3.3.3 How Attractive the Chinese Market is?

As mentioned earlier, determining the attractiveness of the Chinese market is determining the relative profit potential of the Chinese market when compared with other markets. Four markets (*P*, *U*, *A*, *S*) were chosen in the study to facilitate this comparison. Market data about these four markets are readily available in Teradyne either because Teradyne has presence already (2 out 4) or has done extensive research before (the other 2). These market data was taken as given, and is used to compare with the data obtained in China.

To compare China with these four markets in each attractiveness criteria, a rating system is established. An integer varying from 1 to 10 is assigned to each market under each criteria, with 1 given to the worst performer and 10 to the best. The best and worst performers serve as reference points, upon which the remaining three markets are scaled proportionally. Since the weight of each criteria is known, the combination of the total score for a particular market is obtained by summing the products of weight and score at each criteria. The market with the highest collective score represents the most attractive market; the market with the lowest score, the least attractive.

China rates highest in both size and growth. China is the largest market currently for line testing, accounting for 10% of the world wide market (60 million line capacity). Among the five countries studied, *A* and *P* have the lowest number of lines - 5 million. China line testing market is projected to grow rapidly (projected 30% a year), by far the fastest growing market in the several markets examined in this study. The *U* market seems to be the most matured market with 5% annual line growth rate. The rest of the rating is shown in the following table.

There is little market pressure on Chinese telephone companies to improve their services partly due to the monopolistic status, and partly due to the lack of organized consumer organizations. *A* is similar to China in this regard. In *U*, *P*, and *S* things are different. Although in all these countries, local telephone companies are still monopolistic companies, there exist powerful and well organized consumer watchdog organizations to keep the telephone companies in check. In terms of service criteria, *U* has the most stringent requirements and there the technical specifications are very well specified; China is in the process of making a service requirement (Project 97). There does not seem to exist any kind of service criteria in *A*, *P*, and *S* markets.

The Chinese telephone market is highly fragmented with over 2,000 local telephone companies making their own decisions in ATE equipment purchasing. The organizational structure, as discussed in the last section, is quickly moving towards decentralization. There is no centralized purchasing agencies for China MPT, and purchasing decisions are increasingly made at the local P&T level. Other markets fares better in this category also. Table 3.3 summarizes the rating of China vs other markets.

Table 3.3 Scoring Table, China vs Others

	China (rate)	US (rate)	PL (rate)	AG (rate)	SP (rate)
Number of TCP lines	60 (10)	10 (2.5)	5 (1)	5 (1)	12 (3)
Growth rate	30% (10)	5% (1)	15% (4.5)	10% (2.8)	10% (2.8)
Market pres. for service	No CP[a] ; No CG[b] (1)	CP; CG (10)	No CP; CG (5)	No CP; No CG (1)	No CP; CG (5)
Set service criteria	Weak Criteria (5)	No Criteria (1)	Strong Criteria (10)	No Criteria (1)	No Criteria (1)
Degree of centralization	15 (1)	10 (4)	1 (10)	1 (10)	1 (10)
Total Score[c]	725	425	200	235	380

3.3.4 How Strong Teradyne is in China?

The competitive data presented in **Section 3.2** and in **Chapter 2** is used to determine the collective business strength of Teradyne in China as compared with its competitors in China, PT and RC. These market data were taken as given.

To compare Teradyne with its competitors quantitatively, a identical rating system to the one used in market attractiveness is established. An integer varying from 1 to 10 is assigned to each market under each criteria, with 1 given to the worst performer and 10 to the best. The best and worst performers serve as reference points, upon which the remaining three markets are scaled proportionally. Since the weight of each criteria is known, the combination of the total score for a particular market is obtained by summing the products of weight and score at each criteria. The supplier with the highest collective score represents the strongest supplier; the supplier with the lowest score, the weakest.

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[a] CP denotes competition in local telephone market.
[b] CG denotes consumer group.
[c] Total Score is calculated in the following manner. Score for Country A = Sum(Weight of each criteria X Country A's rating in this criteria).

Teradyne's knowledge about the Chinese repair process is limited compared with both PT and RC. Both RC and PT have had extensive installing experience in China, and both have Chinese partners to work with. This lack of process knowledge puts Teradyne at a serious competitive disadvantage: the designing and implementation of ATE is very much dependent upon the understanding of customer repair process. In addition, Teradyne's product is normally perceived to be more expensive than its competition. This perception holds true in the Chinese ATE market.

Familiarity with the Chinese business culture is often regarded as one of the most important factors for success in China. Compared with its competitors, Teradyne's TD is again weak in this dimension (rating =1). It is a newcomer to the market, it does not have experience installing a system in China, and it has few connections both at the local level and at the central level. Again, Teradyne is weak in this area compared with its the competition (rate = 1). The lack of local presence makes Teradyne's ability to respond to the market more difficult.

The only possible advantage Teradyne seems to have relates to product functionality. Interviews conducted during the site study revealed that the technical people in local telephone companies were aware of and had high regard to Teradyne technology, especially in terms of testing speed and accuracy. The final result is shown in the following table.

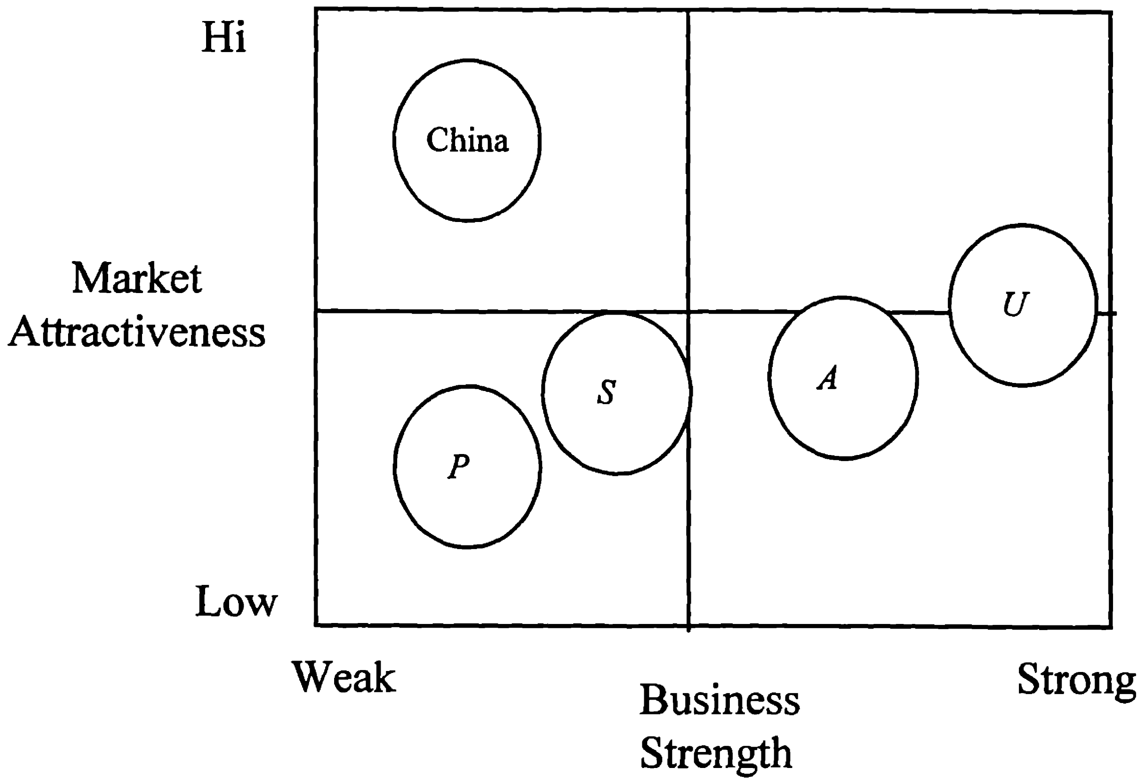
Criteria	**Knowledge on Process**	**Price**	**Culture familiarity**	**Accuracy, Speed**	**Flexibility**	**Total**
Teradyne	1	1	1	10	5	320
PT	5	10	10	5	1	660
RC	10	5	10	1	10	695

3.4 Conclusions: Answers to Questions 1 and 2

3.4.1 Model Results

The exercise of determining Business Strength vs Market Attractiveness can be carried out for other potential markets, details of which are not presented in this thesis. Figure 2.5 combines ratings from Table 3.3 and 3.4 and shows the final results.

Figure 2.5



Note that the precision of the score is not important - a score of 690 vs a score 650 reveals little, given that many assumption are made and that the market data is not accurate in the first place. What is important, however, is the relative position of each market in the above figure and the knowledge obtained in the process. This is the focus of the next few paragraphs.

3.4.2 *Is China Attractive?*

The Chinese market is an attractive market. Compared with other markets under study, the Chinese market is attractive mostly because of its size and growth potential. Its current size is about 10% of worldwide ATE market; it is expected to grow at 30% a year, a rate far better than most other ATE markets around the world.

Yet the breaking down and analyzing of each attractiveness criteria has revealed also some of the disadvantageous factors of the Chinese market, as compared with other more mature markets like the *U* and *S* markets. One of them is the apparent lack of market pressure to drive the service awareness on the part of local telephone companies in China. The Chinese telephone market is a monopolistic market: telephone companys' bottom line will not be in immediate danger if they ignore the service quality to their customers. The Chinese market is a fast growing market: telephone companies have traditionally focused their effort in expanding their installation base rather than maintaining a quality service. The marketing strategy for Teradyne needs to be adjusted accordingly. Recognizing that the main objective of telephone companys' purchasing ATE is to meet the service requirements imposed by China MPT, the focus of the Teradyne's marketing campaign should be in helping the telephone companies meeting their service criteria. It is the experience of the project group that a Chinese local telephone manager is more responsive to internal pressure (such as Project 97) than to external pressure from customers.

Another difficulty Teradyne will have in entering the Chinese market is the effect of decentralization and fragmentation. Facing such a fragmented market where purchasing decisions are largely made locally, Teradyne needs to adopt a different distribution strategy or product architecture so that it lends itself to a cost effective distribution strategy. In China, a rapid localization of the marketing, sales, and service engineering is needed in order to tackle multiple local telephone companies in parallel and to utilize the lower cost technical resources in China. In contrast, Teradyne has been relying heavily on bring in its existing technical and marketing resources in *A*, *U*, and *S*.

3.4.2 Is Teradyne Strong in China?

The results of the study reveal that Teradyne is in a weak position compared with its competitors. Perhaps more importantly, the process of collecting market data on the Chinese market and on Teradyne has helped Teradyne to identify the sources which have resulted this weak position.

The disadvantages in familiarity with the culture is a result of Teraydne's late entry into the Chinese market, and therefore, can only be resolved over time, and by effort and continuous commitment to the market. The project group discovered that culture familiarity is a factor of concern for customers. The awareness of this factor and its importance in customer's decision making process has prompted Teradyne to set up a China team, whose focus is to monitor and make connections within the Chinese market.

The most serious drawback for Teradyne, however, is the lack of knowledge about the telephone repair process in China. ATE is a system product: it is highly customized and sold on the bases of process improvements. The ability to design a good system directly links to a manufacturer's knowledge on customer's telephone repair process. Recognizing the importance of this factor, the project group cooperated with the telephone company in B city in a process study where the author conducted a 3-week field study to collect data on and analyze the telephone process in B city. The results of this study is the subject of Chapter 4.

3.4.3 How Useful is the Framework?

The framework is useful because, following its structure, the project study is able to determine, quantitatively, that the Chinese market is an attractive market and that Teradyne is weak in the Chinese market. The Chinese market represents a market where Teradyne needs to invest and build up its business strength.

Yet the results by this framework are far less important and revealing than the process of utilizing the framework. The discovery and verbalization of the market attractiveness and business strength tells not only what the attractiveness of the Chinese market is and what the business strength for Teradyne is, but, more importantly, ***why the Chinese market is attractive and why Teradyne is weak***. Knowing why is the most important step because only after knowing why can strategies be planned to address ***how to improve the weaknesses, how to maintain the strength, and what to expect from the customers and the market.***

The next step is to analyze why Teradyne is weak in the market. If investment is made, where should the investment be directed to? The attempt to improve in one of the major weaknesses, the lack of understanding of process, is captured in next chapter, **Understanding and Improving the Process.**

Chapter 4: Understanding and Improving the Process

This chapter addresses one aspect of the strategy planning: how to improve Teradyne's understanding of the Chinese telephone repair process, and how, based on this understanding, Teradyne can improve this process using its technology. First the existing process is described and analyzed, using process mapping techniques and a mathematical model, Markov chain[11]. Then a new process is proposed and same analysis is applied. The would-be benefits, reduction in repair cycle time and repair variation, from the proposed model are presented. The focus of this chapter is not the mathematical model; instead, the quantitative results from the model and how these results would help the telephone company in B city meeting their regulatory requirements.

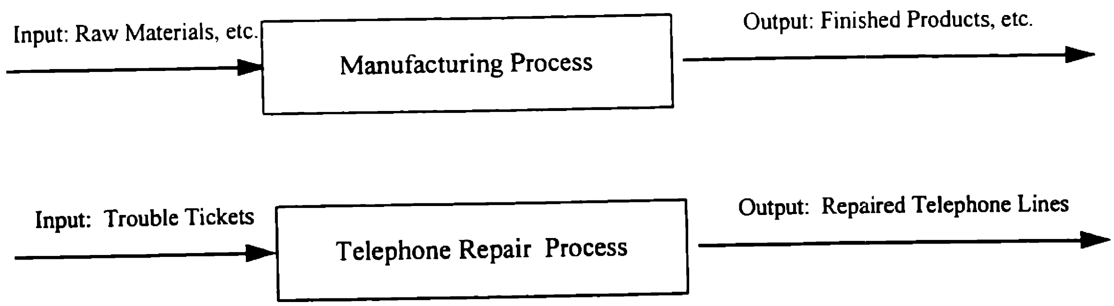
4.1 Background and Literature Research

One can easily understand a telephone repair process by considering its analogy to a manufacturing process. A manufacturing process, through a serious operational steps, converts input, raw materials, subassemblies, etc., into output, finished or semi-finished products. One of the most important measures of a manufacturing process is cycle time, how long it takes to turn input into output, and variability associated with this cycle time.

Telephone repair process can be viewed in a similar fashion (Figure 4.1). Input, instead of being raw materials, are now problematic telephone lines (trouble tickets) and output are repaired (good) telephone lines. The signal that triggers the operating of the process is an end user's telephone call. As is in the manufacturing process, the cycle time, how long it takes to repair a telephone line, together with its variability, is an important measure of the quality of the telephone repair.

[11] Hillier, Frederick; Lieberman, Gerald. "Introduction to Operations Research." Holden-Day, Inc., 1967. Chapter 13.

Figure 4.1



There are numerous models developed by the operations research community in how to study a manufacturing process. According to Eppinger et al[12], process models can be grouped into two categories: performance evaluation models and optimization models. This thesis focus on performance evaluation. The factors to consider when modeling the telephone repair process are: the physics of the work flow (how design activities are executed and repeated - iteration), the topology of the network representing the process (how activities are interconnected), and the analytical technique used (how the network is solved).

Eppinger presented a sequential iteration model to model the design and development process. The design process is modeled as a Markov chain and the analysis can be used to compute lead time for the purely sequential case and to identify an optimal sequence of the coupled tasks to minimize iteration time.

This thesis adopts the Eppinger's signal flow graphs model to analyze the telephone repair process. The major assumptions in this work are three: (1) network is governed by a probabilistic rule, i.e., tasks are passed from one station to other stations based on known probabilities, which do not change over time, and are dependent only on the current state. (2) Task duration, i.e., the time a station spends on a task, is assumed to be

[12] Eppinger, Steve; Nekala, Muthy; Whitney, Daniel. "Generalized Models for Design Iteration Using Signal Flow Graphs." MIT Sloan School Working Paper, November, 1995.

deterministic in this thesis, although a changing task time can be easily incorporated into the study by allowing a probability for the task to be repeated. (3) The probabilities of iteration at each station are independent of each other. This approach capitalizes on the Markovian assumption (1) and is similar to the methods for analyzing a Markov process, as illustrated in Appendix A.

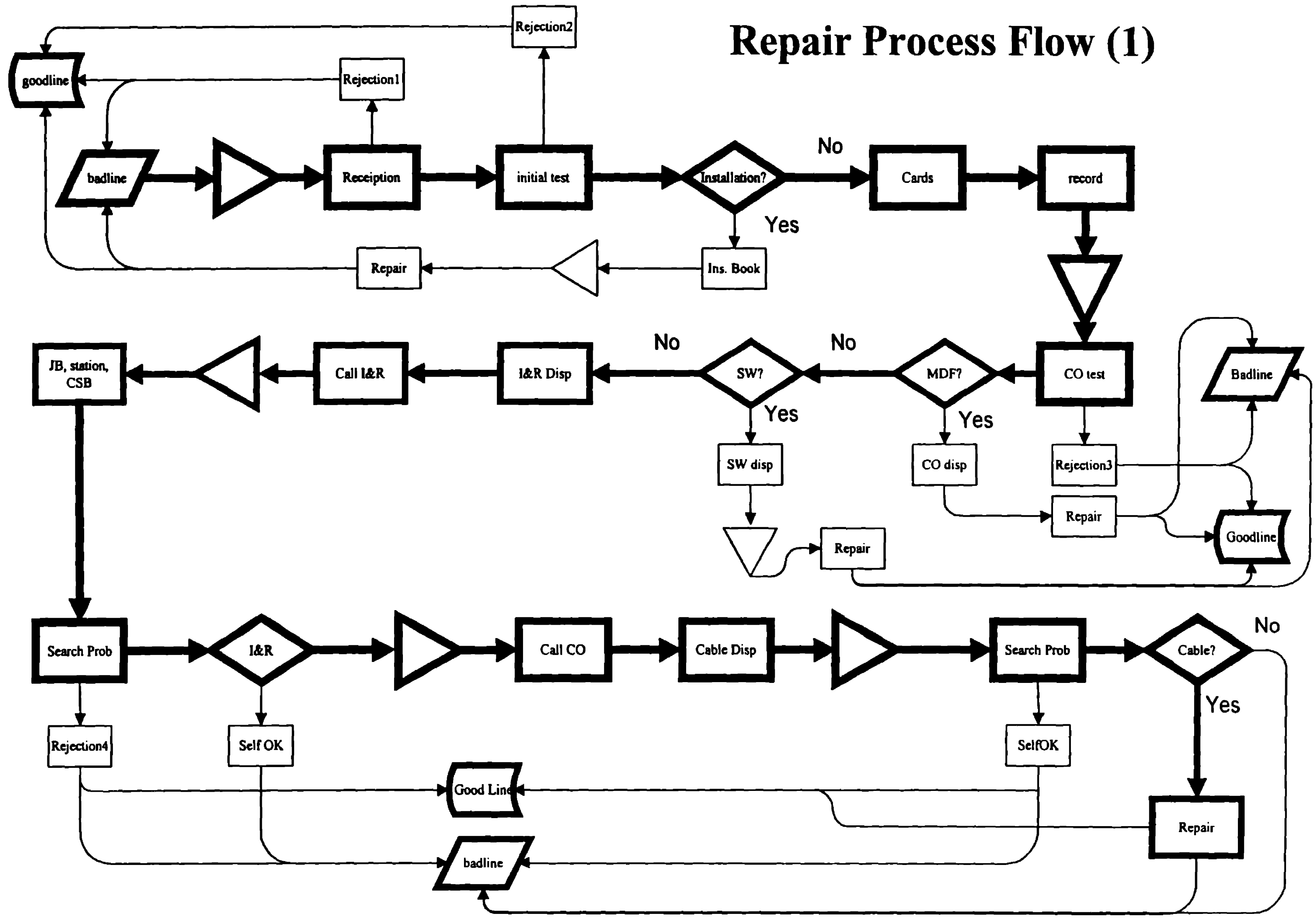
In actuality, both the task performance time and probabilities vary from one repair to another. However, the objective of this modeling is not to provide 100% accurate calculation of cycle time and its variance for the existing process. Instead it is to understand where the inherent inefficiencies are in the system, where the improvements can be made to the current process, and how to shorten lead times and variation in completing a repair task. Therefore, as a first order approximation, the author believes that these above assumptions will yield satisfactory results.

The data from the existing study came from a three week field study when the author worked as telephone repair person in B city. The telephone repair process was documented, both in terms of process steps and task completion time . At least ten data points were collected at each work station; four processes, in the same local telephone market, were observed in detail; 8 receptionists, 4 dispatchers, and 5 repairmen worked with and were interviewed by the author. These data constitutes the data base and process base for the process study with two underlying assumptions: (a) the process observed by the author is representative of that in this local market, and (b) the process from this particular market is representative of that in the Chinese market.

4.2 Existing Repair Process in China

Figure 3.4 is the process map of the existing repair process in B City Telephone Company. The process map consists of stations (rectangles), buffers (triangles), and decision points (diamond). In the service operations terminology, the time a trouble ticket spends in a buffer is characterized by "queuing time." In this thesis, "queuing time" and "buffer time" are used interchangeably for simplicity. The user of the telephone, when experiencing problems making or receiving phone calls, complaints to the telephone company. His/her complaint constitutes a *trouble ticket* which then serves as the input into the system. The process map starts with *fault line base,* which is the total stock of telephone lines with faults, and ends in *installation base,* which represents the total number of good telephone lines. When the phone line is successfully repaired, the trouble ticket goes to *installation base*; otherwise it goes back to *fault line base* where the telephone repair process is reinitiated again.

Repair Process Flow (1)



Note:
1. Data is for time period 8/21/95-9/20/95 2. SW capacity 106,000
3. Line capacity 80,000 4. # subscriber 60,000 5. BTC CO6

At each station, a trouble ticket goes into one of three routes - iterated, passed-through, or repaired. A ticket is iterated when it is routed back to *fault line base*, and iterates through the process again. A unsuccessful repair, one in which problems persist after a repair operation is conducted, is an example of iterated trouble ticket because the phone user will call again to complaint about the same problems. A passed-through ticket refers to ticket passing from one stage of the process onto the next stage. A hand over from the reception station to the buffer between reception and dispatch is an example of passed-through. A repaired ticket is one that goes to *installation base*, representing a successful repair.

The process starts when the receptionist receives a phone call from an end user complaining about a telephone problem - a trouble ticket. After documenting names, addresses, and problem descriptions, and performing an initial on-line test, the receptionist passes the trouble ticket onto the next station - a buffer between reception and CO dispatch station. There are very high iterations (90%) at this stage: customers hang up due to impatience of waiting; customers are informed that their phones are already dispatched; customers repeatedly call back after waiting for a long time to have their phones repaired.

The trouble ticket, after staying in a queue, is processed by the dispatcher station. The dispatcher manually tests each telephone lines at the cross connect point in CO, and determines whether the line needs to be dispatched. Only a small number of trouble tickets are dispatched. Others are either iterated and repaired at the dispatch station. When the dispatcher, through a manual testing, decides that the phone line is not a problematic line, he/she "repairs" the trouble ticket. Sometimes he/she is right, and the phone line is at normal working condition or the line has a problem due to the end user mistakes (such as leaving the phone off hook). Most of the times, however, the dispatcher is wrong and the end user calls back demanding another repair - an iteration occurs.

When a trouble ticket is dispatched, it is first dispatched to the station repair group. It takes a long time for a station repair person to locate and repair a problem, largely due to the complex and irregular layout of the phone network (Figure 2.2). Often times, the station repair person discovers that the line problem is a cable fault, and he/she then sends the trouble ticket back to the CO. Other times, he/she is able to locate and resolve the phone problems.

After queuing for a certain time, the trouble ticket bounced back by the station repair group is redispatched to the cable group. Some of these problems are fixed; others are again iterated back (termed as "fault-unknown" in B city's language) - the customers are likely to call again.

Table 4.1 gives the detailed data on each station and buffer. Task performance time is the average over the observed time.

Table 4.1

Station Name	**Tasks Performed**	**Avg. Task Time (hours)**	**Probability (Pass onto next station)**	**Probability of Iteration (back to first station)**	**Probability (resolve problems)**
a	Reception, initial test, information recording	0.5	0.1	0.9	0.0
b	Buffer between A&C	3.0	1.0	####	####
c	Dispatch, or/and CO repair	1.0	0.2	0.7	0.1
d	Buffer between C&E	6.0	1.0	####	####
e	Station Repair	6.0	0.4	0.2	0.4
f	Buffer between E&G	6.0	1.0	####	####
g	Redispatch	1.0	0.9	0.1	0.0
h	Buffer between G&I	6.0	1.0	####	####
i	Cable Repair	6.0	####	0.5	0.5

4.3 Modeling The Existing Process

4.3.1 Signal Flow Graphs

The signal flow graph is a well known tool for circuit and systems analysis in electrical engineering and for modeling discrete event systems. It begins as a diagram of relationships among a number of variables. When these relationships are linear, the graph represents a system of simultaneous linear algebraic equations.

The telephone repair process map can be rewritten in the format of signal flow graphs, which is composed of a network of directed branches and nodes. A branch jk, with $j = 1, 2, or 3$, beginning at node k and terminating at either next station when $j = 1$, first station when $j = 2$, or at finish state when $j = 3$. Each branch jk has associated with it a quantity known as the branch transmission P_{jk}.

For the modeling purpose, the branches represent the tasks being worked (an activity-on-arc representation). The branch values (or transmissions) include the probability and time to execute the task represented by the branch. That is

$$P_{jk} = \rho_{jk} z^{k}, \tag{1}$$

where ρ_{jk} is the probability of branch and k is the time to execute the task. z is the transform variable used to connect the physical system (time domain) to the quantities used in the analysis (transform domain). The z transform simplifies the algebra, as it enables us to incorporate the quantities to be multiplied (probabilities) in the coefficient of the expression, and to include the quantities to be added (task times) in the exponent.

4.3.2 Signal Graph Modeling of Existing Process

Appendix A presents a brief tutorial on signal flow graphs and explains the absorption of nodes in a graph, an algebraic technique for graph simplification. The path transmission is defined as the product of all branch transmissions along a single path. The graph transmission is the sum of the path transmissions of all the possible paths between two given nodes. (When there are cycles in the system due to iteration, the number of paths is infinite.) The graph transmission is also the resulting expression on an arc connecting the two given nodes when all of the other nodes have been absorbed. In particular, computing the graph transmission from the start to finish node is of the interest (for reason explained in next paragraph). Therefore, graph transmission shall refer to the graph transmission between the start and the finish nodes, and is denoted by T_{sf}, also known as the transfer function.

The coefficient of each term in the graph transmission is the probability associated with the path(s) it represents, and the exponent of z is the duration associated with the path(s). The graph transmission can be derived using the standard operations for signal flow graphs, which are summarized in Appendix A. The impulse response of the graph transmission is then a function representing the probability distribution of the lead time of the process.

Each term of T_{sf} is of the form $\rho_{jk}z^k$ (branch or arc value), where k is the time associated with the path(s) represented by the term, and ρ_{jk} is the probability. The sum of all the terms $k\rho_{jk}$ is then represented the expected lead time from first node to the last node, and this sum in turn relates to T_{sf} by a simple derivative:

$$E(Time) = \Sigma k\rho_{jk} = \left.\frac{dT}{dz}\right|_{z=1}. \qquad (2)$$

Similar arguments lead to the variance of lead time:

$$Var(Time) = \left.\frac{d\left(z\dfrac{dT_{sf}}{dz}\right)}{dz}\right|_{z=1} - \left(\left.\frac{dT_{sf}}{dz}\right|_{z=1}\right)^2 \qquad (3)$$

4.3.3 Results of the Chinese Phone Repair Process

The repair process map can be converted into a signal process map shown in Figure 4.3. The upper case letters represent values (transmissions) of the arcs, while the lower case letters are the task performance times. The transfer function from *Installation Base* to *Bad Line Base*, T_{sf}, is given by:

$$T_{sf} = \frac{A(P + QBC + RBCDE + SBCDEFG + TBCDEFGHI)}{1 - (K + BCL + BCDEM + BCDEFGN + BCDEFGHIO)} \quad (4)$$

where A ~ T represent values of arc shown in Figure 4.3. The values of the arcs are defined in Table 4.3 (original data see Table 4.1).

Figure 4.3: Existing Process

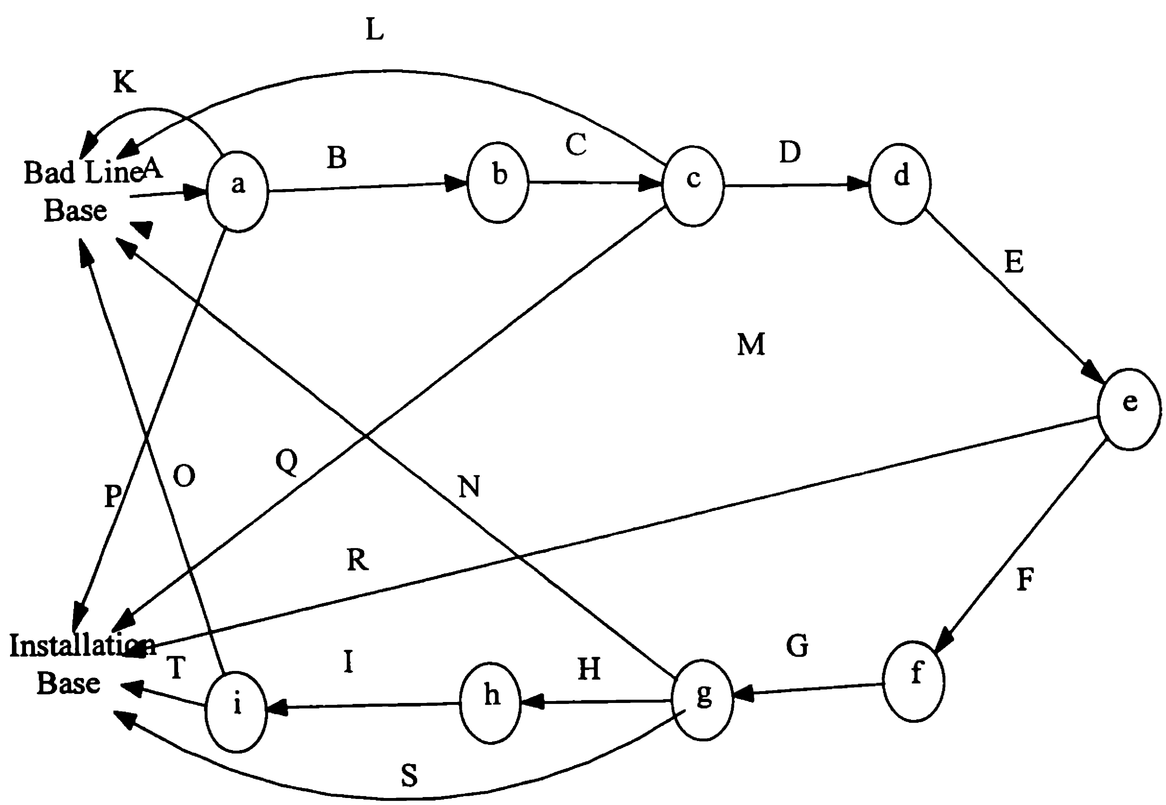


Table 4.3

Node to Next Node	Note to First Node (Iteration)	Node to Finish Node
$A = z^a = z^{0.5}$	$K = z^a \rho_{2a} = 0.9z^{0.5}$	$P = \rho_{3a} = 0.0$
$B = z^b \rho_{1a} = 0.1z^3$	$L = z^a \rho_{2c} = 0.7z0.5$	$Q = \rho_{3c} = 0.1$
$C = z^c = z^1$	$M = z^a \rho_{2e} = 0.2z^{0.5}$	$R = \rho_{3e} = 0.4$
$D = z^d \rho_{1c} = 0.2z^6$	$N = z^a \rho_{2g} = 0.1z^{0.5}$	$S = \rho_{3g} = 0.0$
$E = z^e = z^6$	$O = z^a \rho_{2i} = 0.5z^{0.5}$	$T = \rho_{3i} = 0.5$
$F = z^f \rho_{1e} = 0.4z^6$		
$G = z^g = z^1$		
$H = z^h \rho_{1g} = 0.9z^6$		
$I = z^i = z^6$		

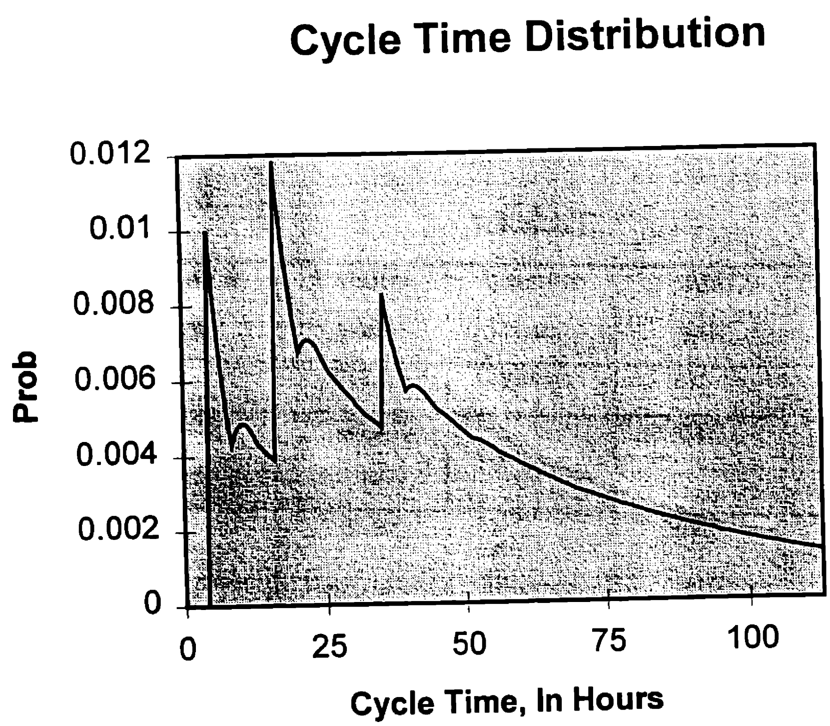
4.3.4 Results for Existing Process

Combination of data in Table 4.3 and equations (2) and (3) yields the results for the existing process.

$$E(Time) = 60 Hours,$$
$$Var(Time) = 50 Hours$$

The distribution of repair cycle time and their associated probability can also be found by performing an polynomial expansion on T_{sf}. The results are shown in Figure 4.4.

Figure 4.4



The possibility of repairing a telephone line within certain time t_0, P_t, can be easily obtained by integrating the above chart to point t_0. That is,

$$P_t\big|_{t=t_0} = \int_0^{t_0} pf(t)dt. \tag{5}$$

Some of the calculated points from equation (5) are shown in Table 4.4. **This is probably the most important result of this analysis.** From a telephone customer's point of view, all one cares is how long it takes to fix a phone problem. According to the results in Table 4.4, there is almost impossible for a phone problem to get fixed within 4 hours after it is reported; there is 26% likelihood that the phone problem gets fixed within 1 day (24 hours); only after 7 days (168 hours) can the user be reasonably sure that the reported problem is resolved (96%).

The above results, compared to the requirements from China MPT on B city's telephone company, has a big performance gap. According to China MPT, all CO and station faults (approximately 65% of all faults in B city) are to be repaired within 24 hours, and 100% of phone calls to be repaired within 72 hours (3 days).

Table 4.4

Time to Repair	**Within 4 hours**	**Within 1 day**	**Within 2 days**	**Within 3 days**	**Within 7 days**	**Over 1 week**
Probability	0	0.258	0.538	0.712	0.958	0.042
Required by China MPT		0.65		1.00		
Performance Gap		0.39		0.29		

4.3.5 Sensitivity Analysis

The results of the existing repair process is far from desirable: long average repair time and high uncertainty (large standard deviation). It is therefore imperative to analyze the dependency of the expected cycle time and variance on the probabilities of iteration and the task time. The purpose of this analysis is to discover where the major improvements can be made - changing the parameters which cycle time and variance depend on heavily.

If L is lead time and k is a parameter on which depends, the sensitivity of L to change in k, denoted S_k^L is given by

$$S1 = S_k^L(ExpTime) = \frac{\Delta E(L) / E(L)}{\Delta k / k}, and \qquad (6)$$
$$S2 = S_k^L(DevTime) = \frac{\Delta Dev(L) / Dev(L)}{\Delta k / k}$$

Calculation of the sensitivity of the expected lead time to changes in task times yields the lead time sensitivity matrix in Table 4.5.

Table 4.5 Sensitivity to Task Time

Station	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Sen. of Cycle Time	0.39	0.23	0.08	0.09	0.09	0.04	0.01	0.03	0.03
Sen. of Var.	0.42	0.22	0.07	0.08	0.08	0.05	0.01	0.04	0.04

Similarly, the sensitivity of the expected lead time to change in iteration probabilities (ρ_{2k}) is shown in Table 4.6. The sum of probabilities on branches emanating from a node is constrained to 1.0, which assures pure sequential iteration.

Table 4.6 Sensitivity to Iteration Probability

Station	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
Sen. of Cycle Time	3.86	####	0.85	####	0.03	####	0.01	####	0.17
Sen. of Var.	4.14	####	1.13	####	0.05	####	0.02	####	0.28

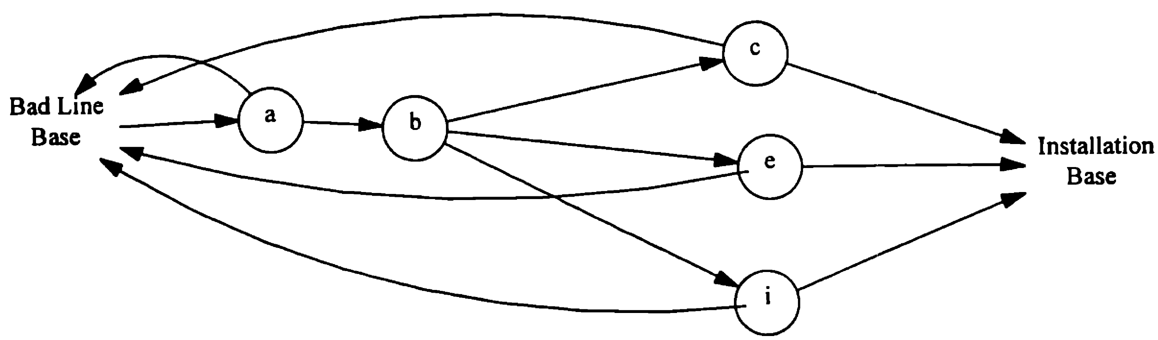
It is obvious that from Table 4.5 and Table 4.6 that both the expected value and variance of cycle time are more sensitive to the front stations of the process. A decrease of task time in station a, for example, creates a bigger drop in total system cycle time and variance than a same percentage decrease of task time in station c. The conclusion is that the quality of performance is critical in early stages of the process.

4.4 Process Improvements

The major process improvements come from two aspects. First is to improve the quality and accuracy of task performing in early stations. Second is to change the sequential process into a parallel one, such eliminating the need for buffers.

A new process, using automatic testing equipment, is proposed in Figure 4.5. A automatic testing terminal would be installed in reception station; the main process would become a parallel process because dispatchers, now co-located in reception area, knows exactly to which repair group the troubled ticket should be dispatched. Most of the buffers, along with some stations, would be eliminated in this process.

Figure 4.5: Improved Process



Task performance time at each station is assumed to stay the same. The probabilities from station *a* to *c* (CO repair), *e* (Station Repair), and *i* (Cable Repair) are 5%, 60%, and 35%, respectively. These probabilities come from existing data on the likelihood of fault occurring at each of those locations (Table 2.1). There would still be small iterations (5%) from *c*, *e*, and *i* back to *i*, indicating a 95% testing accuracy of the automatic testing equipment.

The expected value of cycle time in this case is 14.5 hours, and standard deviation is 6.0 hours. Once pass through cycle time is 4.5 hours with probability of 0.00475 when fault is a CO fault, and is 9.5 hours with a probability of 0.09025 when faults are station or cable faults.

Similar to the calculation performed on the existing process, different points of cycle time and their correspondent probabilities are shown in Table 4.6.

Table 4.6

Time to Repair	**Within 4 hours**	**Within 1 day**	**Within 2 days**	**Within 3 days**	**Within 7 days**	**Over 1 week**
Probability	0	0.929	0.998	1.000	1.000	0.000
Required by China MPT		0.65		1.000		
Performance Gap		(-0.28)		0.00		

Compared with results from the existing process, this presents a big improvements both in average cycle time and in predictability of the system. Most of the phone problems would get fixed during the first day of reporting; eventually no phone problems will go beyond 3 days without getting fixed. The change from a sequential process into a parallel one eliminates not only work stations, but also buffers, which consumes much of the process time; the installation of a automatic testing system in early stages of the process enables the enhancement of accuracy in the first stations and therefore reduces iterations.

4.5 Conclusions and Applications

The results from the existing process are largely due to the inherent inefficiency of the existing system. The expected repair time is 2.5 days; the standard deviation is more than 2 days; the percentage of trouble tickets resolved within a 24 hour window is only 26%. A comparison of the computed results with actual repair record is difficult to make, largely due to the lack of record keeping system in the Chinese Telephone Company where this study was conducted. A general survey of 10 random sampled telephone users in China yielded an average repair time of 4 days, more than the computed results. (Only 10 telephone users were surveyed due to time and resources limitation).

The calculated sample mean is about 2.4 standard deviation below the sampled result, if assuming that 2 days is the true deviation (the standard deviation of the sample mean is $\sqrt{\sigma^2 / 10} = 0.63day$). The possible underestimation by calculation can come from many sources. One of these may come from deterministic task time and probability assumptions. Another may be the fact that the study was conducted in one of the best managed telephone district in B City.

Sensitivity analysis reveals much insight into the existing repair process. Because of dependency of expected cycle time and its variance on early stations (a,b,c), effort should be spent in improving the task performing quality of these stations such as eliminating unnecessary iteration. Much of the unnecessary iteration comes from the lack of knowledge about the fault situation: the fault type and fault location. This lack of knowledge often results in iteration - a repair group spends hours only to find out that the fault should be dispatched to another group in the first place.

Another main cause of this inefficiency is buffer time. In the one pass situation, buffer time counts 60% of the total activity time. In such a highly sequential process, buffers are difficult to avoid: there is a buffer any time one group interacts with another. These buffers, coupled with many iterations in the system, are responsible for the long cycle time and large uncertainty. Another possibility for improvement is to build a system with smaller buffers, buffers where trouble tickets spend time less in queue. The less queuing time will also translate into less total cycle time. This will occur when task times and hence congestion is reduced.

CHAPTER 5: CONCLUSIONS

5.1 The Framework

The author believes that it is imperative for US companies, large or small, to study the Chinese market in a thorough, cohesive, and quantitative manner, and to position themselves strategically before committing to the Chinese market. Rushing into the market without a good understanding is a major source of frustrations and failures. This framework is therefore proposed and is served as a tool to facilitate companys' strategic decision making. Although this framework is a useful tool for a company to study the Chinese market, it is only of many possible tools. The focus of this thesis is not on the framework itself; the focus is on the process - a structured process which includes asking questions, collecting data to answer questions, discovering strength and weaknesses, and finding out ways to sustain strength and to improve weaknesses.

The basic assumption of this framework is that a company should compete in a market where the market attractiveness is high and the company itself is strong in the market. The framework consists a series of questions a company needs to answer before it commits its resources and investments to China. The first question "is the market attractive?" represents business potential for the company in China as compared with that in other markets. The second question "are we strong in the market?" allows the company to examine its ability to compete effectively in the Chinese market. In the process of answering the second question, a company normally discovers how strong (weak) it is in the Chinese market, and why it is strong (weak) in the Chinese market. Next step is to take corrective actions to improve its weaknesses. This iterative process of answering questions, discovering strength (weaknesses), and improving weaknesses continuous until the company is ready to enter the Chinese market.

The framework was applied to a 6 month project conducted in the Chinese telecommunications industry. This project was funded by a US company - Teradyne Inc. of Boston, Massachusetts, and conducted jointly by the Leaders for Manufacturing

Program at MIT and Teradyne. The industry segment where the study was conducted is the Automatic Line Testing (ATE) sector in the telephone market. The framework proposed here is in its final form; in actuality, the concepts and structures evolved in the course of the project. The thesis not only describes the analytical results from using the framework, but more importantly, documents the actions and strategies taken during the project to demonstrate the continuous effort to identify opportunities, tackle weaknesses, and refine the framework.

5.2 Results of the Project

5.2.1 Market Attractiveness and Business Strength

The Chinese market is an attractive market. Compared with other markets under study, the Chinese market is attractive mostly because of its size and growth potential. However, the study also reveals that Teradyne needs to be aware of the fact that the Chinese telephone companies have little market pressure to improve their services due to their monopolistic status, and that the increasing decentralization in the Chinese telephone market has made Teradyne's marketing and engineering effort difficult.

The second conclusion is that Teradyne is in a weak position compared with its competitors. One of the major weaknesses stems from the fact that Teradyne does not currently have an installation base in China, and therefore has little knowledge about the current telephone repair process in China. The understanding of repair process plays an central role due to the nature of the line testing equipment market. ATE is a system product: it is highly customized and sold on the bases of process improvements. The ability to design a good system directly links to a manufacturer's knowledge on customer's telephone repair process.

5.2.2 Improving Weakness: Process Analysis

Recognizing the importance of process understanding, the project group cooperated with the telephone company in B city in a process study where the author conducted a 3-week field study to collect data and analyze the telephone process in B city.

The current repair process in China is a highly inefficient process. The sources of this inefficiencies come from both high level of iteration and process queuing. A quantitative analysis, based on the data collected and on a signal flow graph model, was then conducted to verify the findings.

Based on the qualitative observation and quantitative analysis, a new process was proposed to B city's telephone company, where this analysis was done. The new process would utilize automatic testing equipment in the repair process, thus reducing the need of unwanted iteration. The new process would also change the current highly sequential process into a parallel process, thus eliminating the need of buffering between repair stations.

5.2.3 Current Discussions with B City

The actions undertook by Teradyne to specifically address their weaknesses have been so far well received by the Chinese customers, especially those in B city. The project group conducted a presentation to B city's engineers and management personnel. There was generally agreement among the audience that the iteration and buffers of the process constituted the main problems of the system, and that a parallel process should be used to replace the current sequential process. The detailed quantitative results from the signal flow process are yet to be communicated to the B city people.

Another presentation, aiming at resolving another of Teradyne's weaknesses - high perceived price, was done to the same group of people in B city. This presentation focused on the technical features of Teradyne product, and on how they differ from those of competitors. The purpose was to differentiate Teradyne in terms of product features, and shifted the customer's focus away from the pricing issue.

Whether Teradyne will be successful in B city and in China, however, remains to be seen. So far, Teradyne has successfully differentiated itself in B city from its competitors because of its process knowledge and orientation, and because it has communicated effectively to B city about its product features.

5.3 Discussion

This thesis advocates conducting careful, thorough, cohesive, and quantitative studies on the Chinese market before committing to the market. The focus of this thesis is not the actual mechanics of the framework, instead is the structured process which includes asking questions, collecting data to answer questions, discovering strength and weaknesses, and finding out ways to sustain strength and improve weaknesses. Teradyne project is the first project where this methodology was applied to the study of the Chinese market.

This framework was developed and applied to analyze the Chinese market. Yet the approach and the concepts are applicable in analyzing other markets. When a company is considering entering a market, especially one which the company is not familiar with, the company should analyzes the attractiveness of the market, its ability to compete effectively in the market, its weaknesses in the market, and its ability to improve on the weaknesses.

Although Teradyne has learned a great deal in this project about the Chinese market, there are several possible weaknesses in applying this methodology. First, the Tavassoli's model strives to quantify a company's knowledge about a particular market, and about its strength and weaknesses. Yet the quantitative rating is somewhat subjective. A good rating requires good business understanding and judgment.

A second possible weakness is potential of over analyzing. For example, the complexity of the Chinese market forced the project group to narrow down to six criteria for market attractiveness (Table 3.3) and five for business strength (Table 3.3). In addition, the initial approach taken towards improving Teradyne's weaknesses attempted to cover all weaknesses, and the complex nature of this task quickly narrowed the focus on the most significant one - the lack of process knowledge. This experience reinforces the need for balancing structured detailed approach with focusing on major improvements areas.

Finally, the benefits of this learning is difficult to quantify in the context of this project. This is because of the short time frame of this project, 6 to 7 months, compared with the typical purchase cycle in the Chinese ATE market, 3 to 4 years (Figure 3.4).

This thesis also shows how a particular type of probability model, signal flow diagram, can be applied to the analysis of the telephone repair service operation. First the existing process in China is described and analyzed, using process mapping techniques and a mathematical model, Markov chain[13]. Then a new process is proposed and same analysis is applied. The would-be benefits, reduction in repair cycle time and repair variation, from the proposed model are presented. The focus of this chapter is not the mathematical model; instead, the quantitative results from the model and how these results would help the telephone company in increasing efficiency in its telephone repair process.

[13] Hillier, Frederick; Lieberman, Gerald. "Introduction to Operations Research." Holden-Day, Inc., 1967. Chapter 13.

APPENDIX A: INTRODUCTION TO SIGNAL FLOW GRAPH

This appendix provides an introduction to the manipulation of signal flow graphs (adopted from Eppinger et al).

A.1 Rules and Definitions of Signal Flow Graphs

Signal flow graphs follow four rules:

1. Signals travel along branches only in the direction of the arrows.
2. A signal traveling along any branch is multiplied by the transmission of that branch.
3. The value of any node variable is the sum of all signals entering the node.
4. The value of any node variable is transmitted on all branches leaving that node.

A path is a continuous succession of branches, traversed in the indicated branch directions. The path transmission is defined as the product of branch transmissions along the path. A loop is a simple closed path, along which no node is encountered more than once per cycle. The loop transmission is defined as the product of the branch transmissions in the loop.

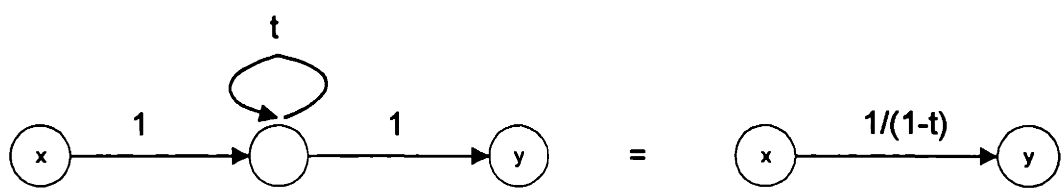
The transmission T of a flow graph is defined as the signal appearing at some designated dependent node per unit of signal originating at a specified source node. Specifically, T_{jk} is defined as the signal appearing at node k per unit of external signal injected at node j. There are a number of ways of computing transmissions.

A.2 Basic Operations on Signal Flow Graphs

Solution of signal flow graphs requires knowledge of certain of their topological properties. The basic operations of addition, multiplication, distribution, and factoring can be used to reduce the number of branches and nodes in the system. At first glance, it might appear that by successive application of such transformations a graph could be reduced to a single branch connecting any two given nodes.

A.3 Solution by Node Absorption

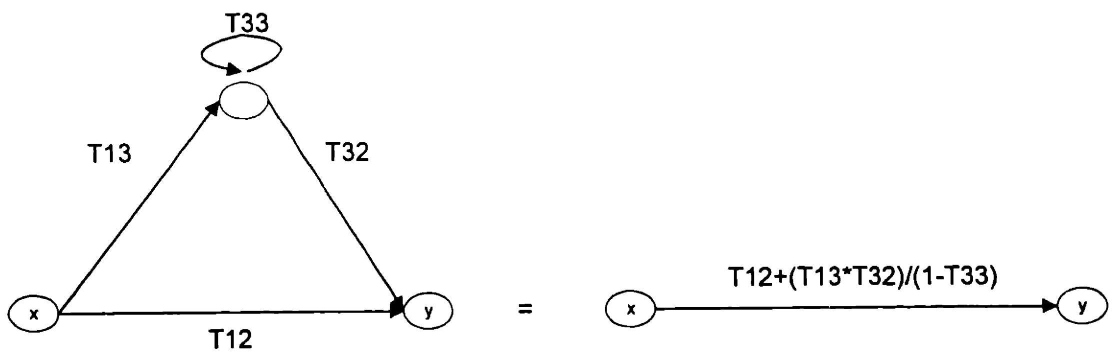
The effect of a self loop at some node on the transmission through that node is analyzed in Figure A1.



$$TransferFunction = 1 + t + t^2 + t^3 + \ldots = \frac{1}{1-t}$$

The node signal at the first node is x and the signal returning around the self loop is xt. Since the node signal is the algebraic sum of the signals entering that node, the external signal arriving from the left must equal $y(1-t)$. Hence, the effect of a self loop t is to divide an external signal by the factor $(1-t)$ as the signal passes through the node. This holds for all t.

Node absorption corresponds to the elimination of a variable by substitution in the associated algebraic equations. With the aid of the basic transformations and the self loop replacement, any node in a graph can be absorbed and the equivalent expressions for the transmission between two other nodes calculated. Although the branch is no longer shown, its effect is included in the new branch transmission values, as shown in Figure A2.



To compute the overall graph transmission, all the intermediate nodes are absorbed in turn, yielding the transmission between the start and finish nodes. Reduction of graphs is computationally intensive and manual solution of graphs of even moderate size can be difficult.

A.4 Transmission of a Flow Graph

Before defining the transmitting of a flow graph, the following definitions are in order.

1. path A path is a continuous succession of branches, traversed in the indicated branch directions, along which no node is encountered more than once.

2. path transmission: The path transmission is defined as the product of branch transmission along the path.

3. loop: A loop is a simple closed path, along which no node is encountered more than once per cycle.

4. loop transmission: The loop transmission is defined as the product of the branch transmission in the loop.

The transmission T of a flow graph is defined as the signal appearing at some designated dependent node per unit of signal originating at some specified source node. Specifically,

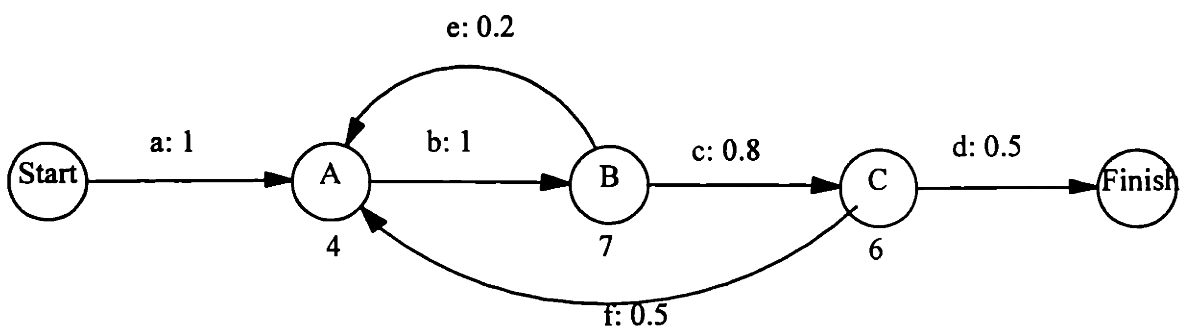
T_{jk} is defined as the signal appearing at node k per unit of external signal injected at node j. There are a number of ways of computing the graph transmission.

A.5 Solution by Node Elimination

First, the two nodes between which the transmission is to be computed are identified. Then all the remaining nodes are absorbed in turn, yielding the required transmission between the designated nodes. Reduction of the graphs is computationally intensive and solving graphs of even moderate sizes is computationally expensive.

A.6 Consistency between Signal Flow Graph and Markov Chain

The consistency between signal flow graph and Markov chain is checked by calculating the expected cycle time using both of these methods.



A task starts from station A, where the task duration is 4 minutes. The task will be passed onto B station, where it spends 7 minutes. After B station, the task has 20% chance of iterating back to A, and 80% chance of going to C, whose task performance time is 6 minutes. After C station, there is 50% chance the task is finished, and 50% chance the task will iterate back to A again. The expected task time is calculated using both the Markov Chain approach and the Signal Flow Graph approach in the following.

A.6.1 Markovian Approach

Assuming r_a, r_b, and r_c are the total expected time to finish before task starts at *A, B,* and *C.* In Markov Chain, the relationship among these three parameters can be represented by the following equations.

$$
\begin{aligned}
r_a &= r_b + 4 \\
r_b &= 0.2r_a + 0.8r_c + 7 \\
r_c &= 0.5r_a + 6
\end{aligned}
$$

Solving for r_a for the above equations yields $r_a = 39.5\,\text{min}$.

A.6.2 Signal Flow Diagram

Using the signal flow approach, the transfer function from start to finish has to be worked out first. The values of *A, B, C, D* relate to the arc values *a, b, c, d, e,* and *f* by the following equations.

$$
\begin{aligned}
A &= a(Start) + eB + fC \\
B &= bA \\
C &= cB \\
Finish &= dC
\end{aligned}
$$

Eliminate A, B, C, D from the above equation yields

$$
TransferFunction = \frac{abcd}{1 - eb - fcb}.
$$

The arc values are defined by the task performance time and probability.

$$a = z^4$$
$$b = z^7$$
$$c = 0.8z^6$$
$$d = 0.5$$
$$e = 0.2z^4$$
$$f = 0.5z^4$$

Applying equation (2) in Chapter 4, the expected time is

$$E(time) = \left.\frac{dT}{dz}\right|_{z=1} = 39.5\,\text{min}$$

The result is the same from that obtained by using Markovian approach.

A.7 The Geometric Transform (*z*-Transformation)

Consider a discrete function which can be take on any real value, positive or negative, at any non-negative integer, $n = 0, 1, 2, \ldots$. It is also convenient to define the function to take on the value zero at all negative integers. The geometric transform of such a function is found by multiplying it termwise with a geometric sequence in the transform variable and summing. Using the transform variable z and denote the transform of a function $f(n)$, $n = 0, 1, 2, \ldots$, by $T[f(n)]$. The geometric transform is then defined by

$$T[f(n)] = f(0) + f(1)z + f(2)z^2 + f(3)z^3 + \ldots = \sum_{n=0}^{\infty} f(n)z^n$$

APPENDIX B: FACETS ON THE CHINESE CULTURE

Since its "open-door" policy in 1978, the Chinese economy has grown to become the third largest in the world, and has become one which can no longer be ignored by any multinational companies. From consumer product to telecommunications, the Chinese market offers vast potential for foreign companies and investors. Indeed, legions of foreign investors have been penetrating the Chinese market, all with the purpose of having a share of China's vast market.

Except for rare occasions, foreign business people, especially those from the West, are frustrated with the Chinese business system - the enormous complexity and huge uncertainty. The intent of this appendix is to identify some common issues facing foreign business people, and to trace their roots back to the Chinese culture. Many examples are drawn from the 6 month research project in the Chinese telecommunications industry. The focus here is to bring out awareness of these problems and their sources, and this awareness is an important threshold in understanding the Chinese people and their actions.

B.1 Overview

In China, connections (*Guang Xi*) is an important first step in business dealings. In fact, the word *Guang Xi* encompasses rich and meaningful connotations which its literal translation is not able to capture. *Guang Xi* involves trust: having *Guang Xi* with somebody means having mutual trust. It means obligation: obligation in helping each other when needed; obligation to offer favor just to maintain the relationship, and, often times, obligation to share either personal feelings or wealth. The other side of obligation is rights: the ability to ask for favor when needed.

Chinese culture is a non-confrontational culture. The nature of the Chinese society, authoritarian and hierarchical, helps to preserve this culture because decisions can be made without much second opinions and therefore with little confrontations. The non-confrontational nature of Chinese people is displayed when dealing with other people. Chinese strive for "saving face", both for themselves and for the groups they are dealing with. Inherent in it is the rarity of open criticism, the acceptance of inequality for protection, and the subsuming of individual into groups. Anyone who breaks this balance of "saving face" is viewed by others as the betray of the loyalty, trust, and harmony, which often causes extremely distributive reactions.

B.2 Chinese Culture in Business Dealings

B.2.1 Importance of Guang Xi

Guang Xi starts by knowing, and knowing usually comes by in a form of referral or of acquaintance. Chinese people think that relationship takes time to build, and do not normally trust strangers at the first sight. The success of Hongkongese and Taiwanese in today's Chinese economy has verify the importance of knowing: many have relatives in China or had built relationship there before the taken over by the communist party in 1949.

The central element of *Guang Xi* is trust. Contrary to the Western system, the Chinese do not deal at arm's length, they maintain close relationships on personal level even in the business world. The reciprocity of obligations and rights and the intimacy of relationships determine that parties in the *Guang Xi* relationship have to place high trust on each other. Trust is the base on which Chinese enter relationship with each other; it is also the base on which Chinese firms enter business relations with each other.

Trust is earned. Cultivating trust requires effort; effort is appreciated in China as sincerity and commitment to *Guang Xi*. The 8 to 5 work schedule is often the warm up part of a typical Chinese business working day; discussions are continued a the dinner table and often into the rooms of Karaoke until midnight. A successful businessman in China is the one who has stamina to do this day in and day out.

B.2.2 Complex Business System

The Chinese system is a very bureaucratic system. It takes a long time for any thing to get approval. It is difficult to forecast the government policy because many agencies within the government have their own policies and interpret the policies of other agencies differently. The authority in central government or different layers of local government has wide latitude in implementing his/her preferences, which often results in nepotism and in selective targeting. Most importantly, the Chinese business activities and political system are intertwined, the personal power of bureaucrats often interferes with businesses.

The complexity of the system, while a nightmare to many, is advantageous to those who understand and operate well in the system. Besides the traditional differentiators such as product price, functionality, convenience, and reliability, culture familiarity is one of the most important, if not the most important, reasons why some companies are more successful than others. The successes of Hong Kong business people such as Gordon Wu, in China are closely linked with their relationship with the Chinese government and their understanding of the Chinese system. The recent success of United Technologies and Alcatel of Belgium are examples of utilizing partnerships to familiarize themselves with the Chinese system.

B.2.3 "Hard to Read" Business People

To foreigners, Chinese business people are difficult to read, especially at the negotiation table. "Yes" sometimes means "No" or "Maybe." "Maybe" sometimes means "No." Chinese rarely say no, even when they are set to terminate the relationship. When conflicts or potential conflicts arise, Chinese defer to their authority, who often mumble things like "let's research and research and get back to you." Often times, "research and research" turns out to be a "politically correct" way of saying no.

In fact, the Chinese response is rarely intended to be unequivocal. The strive for harmony and to save face, both for themselves and for their counterparts, is the reason for the ambiguity in their business language. The ambiguity in language leaves the Chinese room for uncertainty. If they ever need to change, Chinese business people can do so without embarrassing themselves or their counterparts. Another reason for this business ambiguity boils down to trust issue again. In doing so, Chinese business people buy time for themselves to further observe and evaluate their counterparts - as a saying in China goes, "time is the only evaluation of friendship."

B.2.4 Distributive (Confrontational) Negotiation Styles

Contrary to popular notions in the West, Chinese people often times display highly distributive negotiation style. One common observation is that people are very price sensitive and keep on trying to drive the price down, yet at the mean time demands the best product. Another complaint from Western business people is that the Chinese, especially those representing government enterprises or agencies, always seem to worry they are getting ripped off by their Western counterparts. Also, many Western companies, especially technology companies, are frustrated by their Chinese counterparts (customers and/or joint venture partners) in negotiations. Rarely was the agreed path followed: there are all ways new questions and new specifications popping up at any given point of time.

As mentioned earlier in this chapter, Chinese culture emphases harmony and peace, and Chinese people enjoy non-confrontational environment. Another way to say this is that Chinese people are not customed to deal with situations where there are conflicts or potential conflicts, especially at high profile and visible places like negotiation table. When the balance of harmony and peace turns into intensity of negotiation, many Chinese business people find themselves out of their typical comfort zone. They deal with this discomfort in several ways. One is falling into silence or saying ambiguous things, becoming "hard to read." Another is deferring the issue to others or people in power, becoming "let's research and research." As they perceive that their counterparts turn up pressure on them, the Chinese business people can suddenly turn into highly distributive styles. In a way, they are effectively taking over the authoritative role, all in an effort to bring the party back to its original harmonic and peaceful state.

B.2.5 Technology, Functionality, and Price

Price sensitivity issue is one of the most discussed yet least understood issue in the business world in China. Many Western business people complain that the Chinese often want the highest technology, best quality, and cheapest price at the same time, in other words, ask for impossible. What frustrates the Westerners most is the impression that the Chinese want to make all the money without having anybody else making any money. And they are not afraid to leverage the enormous market potential and, often times, their market power to achieve their goals. Detailed discussion on this subject is a complex project by itself and beyond the scope of this thesis; yet some of the general observations are shared in the following paragraphs.

The most obvious and most often thought of reason for price sensitivity is the lack of financial resources in China. This reason is often misleading, and even when it is true, this reason, by itself alone, often explains a very small faction of the true story.

There are at least several other reasons, which can be as important but far less appreciated, underlying the issue of price sensitivity. One is the lack of technical sophistication of the Chinese compared with Western customers. Said in another way, they do not have the same level of appreciation on the product - its technology, functionality, reliability, etc., and therefore, they tend to focus on more concrete aspect of the product offering, the price. The possible solution is to educate the Chinese customers to bring out their awareness of the special aspects of the product. Technical seminars, trade shows, and marketing campaign, when targeted at the right people, can be very effective.

Another possible reason is the Westerner's lack of understanding of the special requirements pertaining the Chinese market. Even when the customers understand the intricacies of the product well, they would not appreciate it if the product is not designed to specifically address the Chinese needs. The product may worth a lot in the Western countries, but in the eyes of Chinese customers, that has little relevance. The result is a price war. A detailed study of the Chinese market's requirements, and a critical review internally within the company on its ability to support the change of requirements, is an essential first step when considering entering the Chinese market.

The third possible reason is that the market power gives many Chinese enterprises and agencies exposure to more than one supplier and therefore great negotiation power. However, it is important for potential Chinese market entrant to remember that in the Chinese market, just like in any other markets, there are other dimensions, more than just price, upon which one can differentiate oneself. The quality of product, the service, and, most importantly, the level of relationships all matter a great deal, although few of the above factors are expressed as explicitly as the price. The quality of Motorola product and the Motorola brand name, not its low price, makes its a successful leader in telecommunications industry.

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