Discrete Choice Analysis and Cost Modeling for Implementing Wireless Internet Services in Developing Countries: The Case of Thailand

by
Mr. Poondej Krairit

A Doctoral Dissertation

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy
in
Computer and Engineering Management
Assumption University

November 2005

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Ph.D. Program
Dissertation

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ABSTRACT

Wireless technologies have been adopted as a telecommunications technology infrastructure of choice in many developing countries because of its low implementation costs and a wide variety of applications available. This research attempts to examine the driving factors of wireless technologies from both the demand and supply sides in developing countries, using Thailand as a case study.

On the demand side, econometric method will be used as a well-proven approach to capture the dynamics and the complexity of the wireless technology demand at both corporate and individual levels. The demand analysis will provide a basis for understanding the importance of wireless network system elements and services.

On the supply side, technical cost models of wireless technologies will be constructed based on the demand and other technical data. The model will provide the framework for determining typical cost requirements of future wireless services and will be used to determine the market potential of each service from the providers' perspective. The expected outcome will show the possibility of future wireless services that suppliers might be interested in offering.

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TABLE OF CONTENTS

Chapter			Page
ABSTRACT			i
ACKNOWLEDGEMENTS			ii
LIST OF FIGURES			vii
LIST OF TABLES			viii
LIST OF ABBREVIATION			xi
LIST OF MATHEMATICAL NOTATIONS			xiii
I.	INTRODUCTION		1
	1.1	Problem Statement	4
	1.2	Objectives of the Study	5
	1.3	Scope of Study	6
	1.4	Outline of the Dissertation	6
II.	LITERATURE REVIEW		8
	2.1.	Overview of Economic Researches regarding IT Industries	9
	2.2	Literature Review on Economics of Wireless Network Technologies	11
	2.3	Literature review on Demand Factors regarding the Implementation of Wireless Networks	14
	2.4	Literature on Wireless Network Technologies	16
	2.5	Literature Review on Telecommunications Demand Analysis and Forecasting	18
		2.5.1 Literature on Demand for New Products and Trends using Demand Analysis	18
		2.5.2 Literature on Forecasting New Products and the Impact of Competition	20

Chapter		Page
	2.6. Literature Review on Research Tools and Methodologies	23
	2.6.1 Econometric	23
	2.6.2 Cost Modeling	27
	2.6.3 Cost-benefit Analysis	27
	2.7 Conclusion	30
III.	RESEARCH METHODOLOGY	31
	3.1 Industry related to Framework	31
	3.2 Research Questions	34
	3.3 Theories on Fundamental Factors	36
	3.4 Research Hypotheses	38
	3.5 Research Methodology	40
	3.6 Research Tools	43
	3.6.1. Research Tools for phase I: Econometric method	43
	3.6.2. Research tools for phase II: Cost Modeling	57
	3.6.3 Research tools for Phase II: Sensitivity Analysis	58
	3.7 Conclusion	60
IV.	SURVEY RESULTS AND EMPIRICAL DATA ANALYSIS	61
	4.1 Results of Expert Interviews	61
	4.2 Empirical Data Analysis	63
	4.2.1 Statistical Tests for Model Specifications regarding Non-User	67
	4.2.2 Current User Analysis	78
	4.2.3 Generalized Model- Statistical Tests for Model Specifications regarding All User	81
	4.3 Cost Modeling	88

Chapter Page

4.3.1 Overview of the Current Network Infrastructure 89

4.3.2. Potential of Low-speed Data Networks: Cost Modeling Scenarios of Cellular Networks 91

4.3.3. Potential of High-speed (Broadband) Data Networks: Cost Modeling of WiMax Network 96

4.4 Conclusion 101

V. FINAL RESULTS 102

5.1 Detailed Methodology: Sensitivity Analysis using Cost Modeling 102

5.2 Scenario Assumptions 104

5.3 Baseline Scenario 106

5.4 Sensitivity Analysis: Applying the Logic to Wireless Internet Market 107

5.5 Conclusion 112

VI. CONCLUSION 113

6.1 Conclusion 113

6.1.1 Comparison of Results between Literature Review, Expert Interview, and Research's Findings 116

6.12 Recommendations to Network Operators and Service Providers 120

6.1.3 Recommendations to Policy Maker 121

6.2 Further Studies 122

APPENDIX A Theories on Fundamental Factors 123

APPENDIX B Types of Multivariate Techniques 129

APPENDIX C Questionnaires for Research Study 133

APPENDIX D Overview of Cellular Technologies 152

APPENDIX E Overview of Wireless Broadband Network in Thailand 164

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Chapter Page

BIBLIOGRAPHY 169

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LIST OF FIGURES

Figure		Page
Figure 3.1.	The Procedure to formulate Research Hypotheses	38
Figure 3.2.	Research Hypotheses Framework	39
Figure 3.3.	Two Phases of Research Methodology	42
Figure 3.4.	Expected Outcome of the Research	59
Figure 4.1.	Graphical Results of the Cost Models	95
Figure 4.2.	Graphical Results of WiMax Cost Modeling	100
Figure 5.1.	Detailed Methodology – Sensitivity Analysis	103
Figure A.1.	Technology Acceptance Model for Wireless Internet via Mobile Devices	124
Figure A2.	Product Life Cycle	127
Figure D1.	EDGE Network Scheme	153
Figure E2.	3G Evolution Paths	156
Figure E3.	UMTS Logical Concepts	158
Figure E4.	IS-2000 CDMA	162

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LIST OF TABLES

Table		Page
Table 2.1.	Literature Review in Economics of Information Technologies	9
Table 2.2.	Literature Review in Economics of Wireless Network Technologies	12
Table 2.3.	Literature Review in Demand Factors of Wireless Network	14
Table 2.4.	Findings of the Literature Review in Industries that are implementing Wireless Network Technologies	16
Table 2.5.	Literature Review on Demand for New Product and Trends using Demand Analysis	19
Table 2.6.	Literature on Forecasting New Products and the Impact of Competition	20
Table 2.7.	Literature Review on Econometric in Telecommunication Industries	24
Table 2.8.	Literature Review on Cost Modeling and Cost-Benefit Analysis	29
Table 3.1.	Summary of Preliminary Factors	35
Table 3.2.	Theories on Fundamental Factors	37
Table 3.3.	Key Indicators used for developing Questionnaire	47
Table 4.1.	Summary of the Expert Interview	62
Table 4.2.	Characteristics of Data –Age	63
Table 4.3.	Characteristics of Data -Education Level	64
Table 4.4.	Characteristics of Data –Gender	64
Table 4.5.	Characteristics of Data -Income Distribution	65
Table 4.6.	Number of Devices carried by One Respondent	66
Table 4.7.	Number of Methods used for Internet Access	66
Table 4.8.	Model Summary (Non-users)	71
Table 4.9.	Hosmer and Lemeshow Test (Non-Users)	73

Table		Page
Table 4.10.	Results of Binary Logistic Regression (Non-Users)	74
Table 4.11.	Relationship between Probabilities of Independent Variable and Dependent Variable (Non-Users)	77
Table 4.12.	Model Summary (Complete model)	83
Table 4.13.	Hosmer and Lemeshow Test (Complete model)	84
Table 4.14.	Results of Logistic Regression (Complete model)	84
Table 4.15.	Relationship between Probabilities of Independent Variable and Dependent Variable (Complete model)	87
Table 4.16.	Cost Modeling of Cellular Networks	93
Table 4.17.	Major Capital Expenditure Components and Operating Expenditures	97
Table 4.18.	Capital Expense (CAPEX) per Base Station	98
Table 4.19.	Operating Expense of Wi-Max	99
Table 4.20.	Cost Modeling of WiMax	99
Table 5.1.	Baseline Scenario	106
Table 5.2.	Approximated Amount of Data by Application	108
Table 5.3.	Significant Variables related to Services and Applications and their Associated Coefficients (Non-Users)	109
Table 5.4.	Significant Variables related to Services and Applications and their Associated Coefficients (Complete model)	111
Table 6.1.	Recent Developments on Non-voice Applications and Services in Thailand	113
Table 6.2	Comparison between Literature Review, Expert opinions and our Findings	116
Table E1.	Characteristics of the 2G and 3G Networks	156

Table		Page
Table E2.	GSM Compliance for UMTS Targets	157
Table E3.	UMTS Network Elements	159
Table E4.	CDMA Network Elements	162
Table F1.	Advantages and Disadvantages of WiMax	167

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LIST OF ABBRIVIATION

Abbreviation	Elaboration
2G	Second Generation Wireless Telephone Technology
2.5G	2.5 Generation Wireless Telephone Technology
2.75G	2.75 Generation Wireless Telephone Technology
3G	Third Generation Wireless Telephone Technology
802.11/Wi-Fi	A Set of Wireless LAN Standards
802.16	Broadband Wireless Access Standards
CAT	Communication Authority of Thailand
CDMA	Code Division Multiple Access
FCC	Federal Communications Commission
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
IEEE	Institute of Electrical and Electronics Engineers
IMT-2000	Global Standard for Third Generation 3G Wireless Communications
ISP	Internet Service Provider
ITU	International Telecom Union
LANs	Local Area Networks
MMS	Multimedia Messaging Service
NTC	National Telecom Commission
PDAs	Personal Digital Assistants
PIM	Personal Information Manager
SMS	Short Message Service
TAM	Technology Acceptance Model
TDMA	Time Division Multiple Access

Abbreviation	Elaboration
UMTS	Universal Mobile Telecommunications System
W-CDMA	Wideband Code Division Multiple Access
WANs	Wide Area Networks
WAP	Wireless Application Protocol
Wi-Max	Worldwide Interoperability for Microwave Access
WLANs	Wireless Local Area Networks

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LIST OF MATHEMATICAL NOTATIONS

U1	Technology Complexity Variables
U2	Individual Differences Variables
U3	Facilitating Conditions Variables
U4	Social Influences Variables
U5	Wireless Trust Environment Variables
W	Cost Variables
X	Alternate Technology Variables
Y	Variables related to Mobile Technology Impacts on Business Practices
ε	Errors / Disturbance

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I. INTRODUCTION

Convergence of the wireless device with data computing abilities is resulting in portable mobile devices such as smart phones or Personal Digital Assistance. The wide adoption of such devices is showing a tendency that consumer's demands for high-speed data services on wireless networks are increasing. In order to satisfy the growing demand for mobile data services, wireless operators need to upgrade their systems or deploy new system that results in higher data rate and bandwidth.

In the U.S. and in Europe, many industries have also shown interests and demands in using wireless technologies as a complement to their existing communication networks. Common advantages of wireless technologies recognized by various industries can be classified as follows:

(1) Wide range of business applications

Generally, wireless technology has vertical and horizontal applications (David C. Yen, David C. Chou, 2000). Vertical applications refer to the use of wireless technologies in specific industries and application domains. Task structures and user profiles are particularly suited to the functionality and capability provided by wireless technologies. These technologies have been used in business such as the package shipping, trucking, public safety, and remote equipment monitoring.

Horizontal applications refer to the mass-market and domain-independent use of wireless technologies across industries. Three categories of horizontal wireless applications exist: personal information management (PIM), messaging and electronic mail, and information services and database accesses.

Wireless PIM applications extend its PIM functionality from office desktop computers. Examples of prevalent wireless PIM applications include memory aids and calendaring (such as to-do lists, address books, meeting planners, and note-taking), and form and document management (such as time reporting and billing, presentation aids, order entry, and expense reporting).

(2) Efficiency gains

Through compressing time and geographic distance, wireless technologies can greatly enhance the efficiency of operations and business processes, and also reduce product/service cycle time. Efficiency gains have been achieved by establishing direct communication links between remote workers[1] and information sources, bypassing information intermediaries.

(3) Organizational transformation toward mobility

Wireless technologies expedite the move toward the "virtual" office by alleviating time and geographic distance constraints. It allows employees to work at home, at customers' sites, or on the road. The potential benefits include enhanced worker productivity and satisfaction, and reduction in the expense of office real estate.

By providing connectivity between an organization and its remote field service workers, wireless technology can lead to the provision of better service with improved reliability and responsiveness.

---

[1] Workers who perform their work from home full-time, although they may occasionally go into a company office" (Richman, Noble, & Johnson, 2002, p. 9)

(4) Management issues

Business pursuing active management on organizational change and avoiding common pitfalls can lead to the success of implementing wireless technologies.

Wireless communications offer time and space compression and lead to major process changes. Successful implementation of wireless applications is contingent upon successful management of the organizational change.

The benefits of wireless technologies are far more recognized when implemented in a location where network infrastructure is not ready but strong demands from consumers exist. In addition to the network readiness factor, each industry has its own unique objective in adopting new technology. In general, three levels of adoption of technology can be identified: information access (Level 1), work collaboration (Level2), and core business transactions (Level 3) (Satish Nambisan and Yu-Ming Wang, 1999). At the lowest level, the technology is used as a tool for disseminating information about products, services, and organizational policies, and to channel feedback from such internal/external entities as employees and customers. At the next level, technology is used to facilitate real-time work collaboration and document flow between different entities within and without the organization. At the third and highest level, the technology is directly integrated with core business processes/transactions.

1.1 Problem Statement

Data is a growing component of communications worldwide, as a consequence of which, developing regions will eventually have to upgrade their infrastructure to accommodate data communications. In developing regions, deployment of wireless networks is viewed as the most economically solution for providing extensive coverage throughout the countries, as they are relatively inexpensive to install and maintain and are quickly deployable. Instead of focusing only on voice-centric service, the incorporation of data communications as an integral part of the growth policies should maximize the benefits of implementing wireless networks.

However, wireless networks for data communication are still not fully implemented in Thailand due to many issues regarding infrastructure, end-user devices, and spectrum to be used. These issues can be viewed as the relationship between demand and supply in telecommunication industry.

In Thailand, like everywhere else in the world, the main issue in deciding whether one should invest the technology or not is to justify the benefit and cost of introducing new technology based on the technological directions, demand, and regulatory issues.

There have been many research publications done related to network technologies and their economic impacts. These researches were conducted by looking at the overall impact of Information Technology toward the economic aspects and technical aspects (Johgseo, 2003, Rejendra, 2002, Krishman, 2002). The economic aspects can be divided into technology transition (Laguna, 2000, Nambisan, 2002) and measurement of its effects (Parsons, 2000, Mendelson, 2000). The technical aspects were focusing more on the standard compatibility and multiple-platform Integration.

However, as can be clearly seen from that none of the research has touched on the effects of the implementation of wireless technologies, especially integrated wireless network, in the business environment. In order to study the effects, researchers usually set a study parameter and develop a model around the parameter to identify its relationship with the environment (independent and dependent variables) (Greenstein, 1997, Farias, 2002). The popular parameters for studying the effect of new technology includes cost, price, and demand (Chen, 2000, Lee, 2000, Gasmi, 2001).

Demand, either of that of individual users or corporate, is considered to be an important parameter when one develops a framework for new technology introduction and implementation (Taylor, 2003, Loebbecke, 1997). If consumer demand cannot be correctly explained, it would be almost impossible to create an investment plan.

Therefore, based on the literature review in this report, it is necessary to study the demand of wireless technologies and analyzes the impacts of such demand on new technology implementation for businesses.

1.2 Objectives of the study

This dissertation attempts to identify the driving factors of wireless technologies and to extrapolate networking trends. For this purpose, Econometric method will be used as a well-proven approach to capture the dynamics and the complexity of the Wireless technology demand. They then will be translated into an equation to show the interdependence of the various assumptions and the results.

The proposed demand analysis provides a framework for understanding the dynamic interrelationships between system elements. Subsequently, we can then use demand and other technological constraints as inputs to the benefit and cost analysis in

order to create the frameworks demonstrated by cost modeling and predicts the directions of future networks that would be appropriate to business environments.

1.3 Scope of Study

The scenarios described in this paper are developed based on data of current network implementations. Some directions and limitations regarding contracts, policies are also applied to these scenarios. This study is limited to the case of Thailand and only hi-speed wireless networks are covered.

The first phase of the study consists of expert interview and empirical data analysis using econometric method. The empirical data analysis is relied based on survey results. The second phase of the study creates a framework and baseline scenario based on technical constraints and associated costs of implementation. The final results are derived from sensitivity analysis which varies input (demand) for each scenario.

1.4 Outline of the dissertation

This dissertation comprises of seven chapters.

Chapter 1 presents an introduction of the research and points out problem statement and scope of study.

Chapter 2 presents literature review on various areas of telecommunication researches including economic and technical aspects of wireless network technologies, demand analysis and forecasting, and related research tools.

Chapter 3 formulates research questions and hypotheses. The selection and evaluation of research method and associated research tools are demonstrated. The selected research tools including logistic regression method and cost modeling are also explained in this chapter.

Chapter 4 presents survey results and empirical data analysis of demand for wireless internet service. The results are presented in three parts; a model for non-user (consumer who is not subscribing to any wireless Internet services), an analysis of current users (consumers who is currently subscribing to one or more wireless Internet services), and a generalized model for most consumer, The cost models of cellular cost model and hi-speed wireless network are also presented in this chapter.

Chapter 6 and Chapter 7 present the final results and demonstrate how researchers incorporate results through the method of sensitivity analysis. Then, the validity of results is demonstrated to the comparison between research's findings, literature review, current and future implementation, and results of expert interview.

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II. LITERATURE REVIEW

More than 75 percent of worldwide cell phone users are currently accessing the Internet through their cell phone, but only one percent is using it consistently as part of their daily activities. The reasons are the concerns in security issues and low quality of mobile contents.

Although recent researches show increasing demands for wireless Internet access, various methods of Internet access could cause difference in benefits and usefulness that consumer perceive. These differences can also be seen among different countries especially among developing countries. This leads researchers to question whether factors driving the demand for wireless Internet are the same as those of wired Internet access.

With the objective of determining demand factors of wireless Internet and predicting the characteristics of future wireless data networks in developing countries, the literature review in this chapter covers the studies of market dynamics of IT industry and technological transitions for predicting market potential and viability of IT industry, especially wireless technologies.

This chapter begins with an overview of economics in IT industries. The next two sections summaries the trends of recent researches related to wireless technologies and its practical implementation. The chapter also includes literature review on telecommunications demand analysis and forecasting as well as related computational tools.

2.1. Overview of Economic researches regarding IT industries

The section describes the literature on economics of Information Technologies. The objective of this section is to review researches done in the economic aspects of information technologies, with particular interest in wireless technologies. The researches related to economic of Information Technology has been studied and classified into 5 areas (shown in Table 2.1) which cover technologies and their effects on productivity, impacts on market and consumer, and technology forecasting.

Table 2.1. Literature Review on Economics of Information Technologies

Topics	Major research papers	Authors
IT Market Dynamics	Market Dynamics of IT industry	Kim Namwoon, Jin K. Han and Rajendra K. Srivastava, 2002
Technology Transition, Technology Selection and Technology acceptance	Comparing existing technology to new technology Complementary product integration Calculating the time to implement prospective technology	Jongseo, Jeho, and Lee, 2003 Greg Shaffer , Z. John Zhang , Satish Nambisan ,2002 Krishnan, Bhattacharaya, 2002
Measuring Technological yield and productivity	Productivity growth and learning potentials of Thai industry Organizational Architecture and success in IT industry	Pramongkit, Shawyun, Sirinaovakul, 1999 Mandelson H., 2000

Table 2.1. Literature Review on Economics of Information Technologies

(Continued)

Topics	Major research papers	Authors
Measuring Technological yield and productivity	Measuring technological potential and technological yield of product	Iansiti M., 2000
IT and Productivity Measurement	IT and productivity IT and productivity growth at the firm and country level	Dewan S., Kraemer, 2000 Jason Dedrick, Viijay Gurbaxani, and Kenneth L. Kraemer, 2001
IT Technological Forecasting	Survivability model of communication networks Network expansion model related to demand for capacityTechnological forecasting	Y. Myung, H. Kim, D. Tcha, 2002 Laguna M., 2000

In order to conduct research related to the market dynamics of IT industry, as suggested by Kim, Chang and Shocker, the researcher needs to study in the form of technology selection, integration, and implementation simultaneously. Doing so, the researcher would be able to predict market potential and viability of IT industry, especially wireless technologies.

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2.2 Literature Review on Economics of wireless network technologies

The interproduct category and technological substitution effects had been studied in the form of technology selection (Kim, Han, Rajendra, 2002), integration (Nambisan, 2002), and implementation (Krishnan, Bhattacharaya, 2002). These studies demonstrate the linkage between firm growth and the characteristics of technology implementation (Jongseo, Jeho, and Lee, 2003).

Currently, there are many types of wireless network technologies. These technologies, which are classified according to technical aspects, standards, and applications, are competing among themselves and between wireline such as Blutetooth VS Wi-Fi, 802.11b VS 802.11g, 2.5G VS 3G. With unique advantages and disadvantages of each technology, compatibility and integration have to be clarified in order to make the right decision regarding technology selection forecasting.

In addition, the study of how to define firm growth and how to control it using technologies has become popular (Parsons, 2000). Also, the question of what kind of benefit would the firm gains when implementing a specific technology has been raised. Benefits from implementing technology are defined in several ways such as productivity (Pramongkit, Shawyun, Sirinaovakul, 1999), success (Mandelson, 2000), etc., depending on each research environment and situation. While the different techniques of benefit measurement have been developed, the cost of implementing a technology has also been studied by using cost modeling technique (Kitabi, Krairit, 1998).

Based on the aforementioned statements, this literature review section narrows the focus of the study to only the exploration of the previous researches regarding wireless technologies. This section also provides the overall picture of academic

researches related to wireless technology and the trends of interesting academic research in the future.

The literature review of the research related to wireless technologies is divided into four topics, which are technology selection, compatibility and integration, market growth, and application, and is summarized in Table 2.2.

Table 2.2. Literature Review on Economics of Wireless Network Technologies

Issues	Articles
Technology Selection	Which wireless Infrastructure? (Singh G., 2003) Virtualization, wireless, new hardware drive 2003 trends (Institute of Management & Administration, 2003) The Wi-Fi threat (Anderberg 2002) Could 2.5G networks pose a threat to 3G? (Tonbridge 2002) Charting the course of wireless markets (Browne 2001) Wireless LAN's future established as Big Tech and Telecom companies enter the market (Microwave Journal 2003)
Compatibility and Integration	M2M wireless solution simplifies integration (Control Engineering, 2002) Explore the future of backward-compatible WLANs (Microwaves& RF 2002) Solving the multiprocessor design problem for wireless LANs (Electronic Engineering Design 2002)
Market Research and market growth	Public WLAN market prospects remain strong in US and Europe (Microwave & RF 2003)

Table 2.2. Literature Review on Economics of Wireless Network Technologies (Continued)

Issues	Articles
	Mobile Commerce: Promises, challenges and research agenda (Siau, K., Lim, E., Shen, Z., 2001)
Application of wireless technologies	Bluetooth and Wi-Fi technologies will revolutionize automotive landscape (Microwaves & RF, 2002) New automotive wireless networks study (Dedham, 2002) The report of the Cellular Telecommunications & Internet Association (CITA) Wireless 2002 conference

Singh (2003) suggested that the applications, organizational structure, and security aspect should be considered in implementing network in order to generate highest return on investment. It is not technical constraints that would be primary driver of wireless technology implementation; the future wireless networking infrastructure is rather shaped by the growing demands of business. Thus, the trends of implementing future network would not be limited by just single technology. It would be a combination of several technologies that would be best to satisfy user demand.

2.3 Literature review on Demand Factors regarding the Implementation of Wireless Networks

User demand is considered to be an interesting aspect in conducting telecommunication research. Several researches had been conducted to demonstrate the factors of demand in order to implement the network infrastructure that can satisfy user and eventually bring benefits to firm or enterprise. (Altobelli, 1991; Loebbecke, 1995; Veldkamp, 1994) The summary table of demand factors is demonstrated in Table 2.3. These factors can be broadly categorized into factors that related to consumer perceptions, attitudes, knowledge and factors that related to technical constraints and availabilities.

Table 2.3. Literature Review on Demand Factors of Wireless Networks

Demand factors	Details	Authors
Cost	Minute Cost Monthly Cost	Eutelis, 1993; Romtech Systems Dynamics, 1989; Ross, 1992
Product Quality	Network Quality Service Quality Terminal Quality	Bacon, 1992
Information about the network	Advertising Word of mouth Publications	Peppers, D., Rogers, M, 1993; Kotler, 1997, Phillips, 1992
Impacts on private lifestyle	Private reachability Security needs Image	Halal, 1992

Table 2.3. Literature Review on Demand Factors of Wireless Networks (Continued)

Demand factors	Details	Authors
Mobile technology impacts on business practices	Work reorganization Business Process Redesign New business opportunities Effects to manage mobile network	Deloitte Touche Tohmatsu International, 1993 JagodaA., DE Villepin, 1993 Hiltz and Turoff, 1993
Alternate technologies	Fixed and mobile network integration Existing mobile technologies Future mobile technologies Fixed network stand alone quality	Altobelli, 1991; Loebbecke, 1995; Veldkamp, 1994
Availability of a network evaluation framework	Research Level Cost benefit investment level	Jussawalla M. and Braunstein H., 1990

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2.4 Literature Review on Wireless Network Technologies

A fundamental challenge facing Information Technology decision makers is identifying and implementing architectures, technologies, and processes that reduce the total cost of ownership (TCO) of corporate networks -- one way is the wireless LAN. The researcher believe that if companies understand the true costs and economic benefits of wireless LAN solutions they will generate quicker return on investments

Currently, the wireless LAN is not a replacement for the wired infrastructure, but it is a significant complement to what currently exists. Schools, manufacturing companies, hospitals, and offices purchase these wireless LAN systems for two predominant reasons: they are seeking an increase in user productivity and IT team productivity.

Wireless technologies have been implemented as a solution to many types of industry. These types of industry are categorized in Table 4 for further study of user demand. In the implementation phase of this research, the list of targeted industries will be adjusted for compatibility with Thailand's environment. In addition, their associated applications are also listed in Table 2.4.

Table 2.4. Literature Review on Applications in Wireless Industries

Usage Method	Industry	Example
Multimedia	Education	University/ College connectivity
Database	Healthcare (Point of care) E-Government	

Table 2.4. Literature Review on Applications in Wireless Industries (Continued)

Usage Method	Industry	Example
Inventory Management	Manufacturing	Production/ Distribution/ Maintenance/Shipping/Receiving
Mobility	Retail (Point of sale) Insurance	Sale force support
Finance and Commerce	Financial/Office-Automation	Banking, consulting

Examples of Applications for business purposes includes Wireless Remote access / Internet access, Commerce / Advertising / Marketing, Push-to-talk, voice calling and instant messaging, Video conferencing / streaming, E-mail with attachment capability, Personal Information Management (PIM), Customer Service and Support, Sales Force Automation, Online Information, Navigation, Translation.

Chris Neal (2003) mentioned that a lot of companies recognize the need for mobile access because they are getting a push internally. The most commonly used wireless applications are e-mail and calendar applications. The next step will be equipping the sales force, technical support and customer support representatives with a customer relationship application application. The industries such as retail (inventory management) and health care (patient records management) are primed for wireless applications.

Future trends of applications

Nearly one in four of business users rank push-to-talk voice calling and instant messaging as their top mobile needs. Video conferencing/streaming ranked next in

popularity, tied with e-mail with attachment capability. Internet access is the last in top five applications.

2.5 Literature Review on Telecommunications demand analysis and forecasting

The aim of this research is to provide leading research in the area of empirical telecommunications demand analysis and forecasting in the light of tremendous market and regulatory changes. This part of literature reviews demonstrates how traditional analytic techniques can be used to assess new telecommunications products and how new analytic techniques can be better address existing products. This part of literature reviews is divided into two subject areas: Demand for New Products and Trends in Demand Analysis, and Forecasting New Products and the Impact of Competition.

2.5.1 Literature on Demand for New Products and Trends using Demand Analysis

Today, telecommunication industry boundaries are rapidly changing, markets are increasingly competitive, and company-based data have become increasingly competitive, and company-based data have become increasingly fragmented and proprietary. These following researches are the major references derived from literature review and are able to provide background on overview of the current state of telecommunications demand analysis as well as a description of problems that have to be overcome. The literature review is summarized in Table 2.5.

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Table 2.5. Literature Review on Demand for New Product and Trends using Demand Analysis

Topics	Brief Description	Authors
An Econometric Study of the Demand for Access to the Internet	First attempt to estimate the price elasticity of demand for access to the Internet in household	Donald J. Kridel, Paul N. Rappoport, and Lester D. Taylor, 1997
Demand for and use of Additional Lines by Residential Customers	Calculation of the penetration rate for second line and classification of rates according to each target segment.	Carol A. Cassel, 1998
The Changing Market for Inland and International Calls	Demonstrating some of the key structural and demographic changes that have influenced demand pattern in the UK	David Cracknell, 1997
Demand Modeling at Bell Canada: A Retrospective	Demand models used by Bell Canada over a 15-year period to estimate price elasticities	Chis Dineen and Mohammed Abrar, 1998
Effects of Large Price Reductions on Toll and Carrier Access Demand in California	Test whether the increase in demand followed large reductions in toll and switched access prices	Timothy J. Tardiff, 1995

Table 2.5. Literature Review on Demand for New Product and Trends using Demand Analysis (Continued)

Topics	Brief Description	Authors
Semi-parametric estimates of Intra-LATA Demand Elastic ties	Find demand price elasticities for rating the re-balancing for the LECs after deregulation	Armando Ley, 1998

2.5.2 Literature Review on Forecasting New Products and the Impact of Competition

In telecommunications, as in other industries, the forecasting role is of prime importance to good planning and decision-making. Empirical forecasts are used as input to the engineers as they design and plan the network and revenue forecasts provide budgeting information to finance groups. Similarly, product managers and marketers forecast product revenues and costs to ensure profitability. Table 2.6 summarizes major publications from extensive literature review in the field of forecasting new products and the impact of competition.

Table 2.6. Literature on Forecasting New Products and the Impact of Competition

Topics	Brief Description	Authors
Forecasting New Telecommunication Services at a Pre-development Product Stage	New product forecasting during the product development phase	David G. Loomis

Table 2.6. Literature on Forecasting New Products and the Impact of Competition (Continued)

Topics	Brief Description	Authors
Analysis of Customer Expectations for the Introduction of New Telecommunications Services	Suggest the procedure to examine an individual's preferences regarding each distinct service attribute	Isabella Maria Palombini and Bartolomeo Sapio
Limits to Growth in Telecom Markets	Examine demand for telecommunications with respect to driving forces and limitations	Jan-Petter Saether
Forecasting Telephony Demand Against a Background of Major Structural Change	Upgrading traditional forecasting models to meet new environments	David Cracknell and Clive Mason
161 Days of Full Competition – Some Observations from the German Market	Examine the main elements of the regulatory regime along with the opportunities of new market entrants	Ernst-Olav Ruhle

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Table 2.6. Literature on Forecasting New Products and the Impact of Competition (Continued)

Topics	Brief Description	Authors
Competition in the Chinese Cellular Market: Promise and Problematic	A survey of the contemporary environment, internal and external, impinging on China Unicom as a new entrant to a formerly monopolized market	Xu Yan and Douglas C. Pitt

New issues have arisen in telecommunications which provide significant challenges to telecommunications forecasting. First, new products and product innovations have been introduced at a rapid pace. Many of these products are extensions of existing services but others are completely new services. In either case, new methods of forecasting must be applied to new products and services; forecasters can no longer rely on years of historical data as the basis for their forecasts.

Second, the telecommunications industry structure has changed dramatically. Many services that were formerly provided by a regulated monopoly are now open to competitive entry. This has led to price declines, increased advertising and product innovations, resulting in a transition from relatively stable demand based predominantly on factors controlled by the firm to a fluctuating demand influenced by many outside factors.

Third, the telecommunications marketplace is experiencing a shift in emphasis away from voice telephony towards data services and a shift from wireline to wireless communications for voice. No only has the use of the Internet increased holding times on analog access lines, but it also has stimulated demand for data offerings using

digital technology. While the wireline network has not experienced large declines, it is clear that much of the new growth in access and usage has moved to wireless providers.

These three issues – new products, competitive forces, and the shift to data and wireless services – provide tremendous challenges to telecommunications forecasting.

2.6. Literature Review on Research Tools and Methodologies

2.6.1 Econometric

Econometric modeling produces "qualitative economic statements that either explains the behavior of variables we have already seen or forecast behavior that we have not yet seen, or both" (Pindyck, Rubinfeld, 1998)

However, the term ""econometrics" when coupled with modeling tends to have an even more specialized meaning. It applies especially to the body of techniques utilized to estimate the parameter of economic systems.

The literature review regarding econometric method had been done with two purposes:

(1) To study the type of telecommunication industries that used econometric concept as a major tool in conducting the research.

(2) To decide which type of econometric model is appropriate for conducting telecommunication and IT research. The appropriation in this case refers to the analysis of the possibility and difficulty in creating several models for covering every significant factor in a research including the environmental factors.

Applications of econometric in telecommunication industries vary depending on which dependent variable the researcher wants to study. These dependent variables included cost, productivity, policy effects and demand.

Some of the past researches are:

Table 2.7. Literature Review on Econometric in Telecommunication Industries

Research Topic	Articles / Past Researches
Applications on Telecommunications	Productivity Convergence in the European Telecommunication Industry (Elisa Battistoni, 2004) Econometric Modeling of Telephone Cost-Output Relationships The determination of the United States Internet users' characteristics, dynamic preference change and rendering of the leading edge Internet users by an econometric study (Aydogan Dumrus, 2002) An empirical investigation of United States telecommunication policies (McKenzie, David J, 1997) Investment of Telecommunication Operators and Economic Growth- Evidence from Finland A Test of Natural Monopoly on Local Telecommunications Services Spatial analysis of telecommunication flows (Guldmann J, 2005) Making Sense of the Urban Spectrum: Valuation, Agglomeration and Location of Wireless Technologies (Sean P. Gorman and Angela McIntee, 2002)

Table 2.7. Literature Review on Econometric in Telecommunication Industries (Continued)

Research Topic	Articles / Past Researches
Telecommunications Industry	Estimating the Welfare Effects of Digital Infrastructure (Shane M. Greenstein and Pablo T. Spiller, 1996) Independent Regulation and Telecommunications Performance in Developing Countries (Audrey Baudrier, 2001) Is a POTS Dispensable? Substitution Effects between Mobile and Fixed Telephone in Korea (Sung, Kim, Lee, 2000) Econometric Cost Structure Estimates for Cellular Telephony in the United States (McKenzie, David J., Small, John P, 1997) A top-down financial model for the Australian (John Street and Glenn Gilmour, 2000)
Impacts of IT implementation	An Empirical Analysis of the Determinants of Information Systems Productivity and the Role of Outsourcing Policy (Malhotra, Y, 2005) Does National Culture Play a Role in IT Adoption? (Bagchi, Kallol, 2001) Effects of IT spending on growth and productivity in Chilean Economy: A Macroeconomic Perspective South Africa's international cost competitiveness and productivity: A sectoral analysis (Lawrence Edwards and Stephen S. Golub, 2002)

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Table 2.7. Literature Review on Econometric in Telecommunication Industries (Continued)

Research Topic	Articles / Past Researches
Impacts of IT implementation	Does money cause prices, or the other way around? (Masih R., 1998) Multi-country econometric evidence including error-correction modeling from South-east Asia (Masih A., 1999) Globalization, alliances and networking: A strategy for competitiveness and productivity (Prokopenko J., 2000) Policy Reform Economic Growth and the Digital Divide- an econometric analysis (David Wheeler & Susmita Dasgupta & Somik V. Lall., 2001) Entry, Standards and competition: firm strategies and the diffusion of mobile telephony (Koski H., Kretschmer T., 2001) Dynamic pricing for connection-oriented services in wireless networks (Viterbo E., Chiasserini C., 2001) Standardization versus Coverage in Wireless Telephone Networks (Neil Gandal, David Salant, Leonard Waverman, 2001) ERP Investment for IT use: Business Impact and Productivity Measures (Hitt, Lorin M., Wu, D.J. and Xiaoge Zhou,2002) Electricity Load and Price Forecasting (Smith M.)

2.6.2 Cost Modeling

The methodology of a forward-looking economic cost model is widely used to analyze business opportunities for new technologies and for new entrants. The U.S.' Federal Communications Commission (FCC) selected the use of forward-looking economic cost models as a basis for determining cost-based access charges, pricing for interconnection and unbundled network elements, and universal service support levels. Forward-looking economic costs are defined as "the cost that would be incurred if a new element or service were provided, or that could be avoided if an existing element or service were not provided, assuming that all input choices of the firms can be freely varied" (Atkinson et al., 1997).

Telecommunications Network Cost Model is principally used in two settings;

(1) Regulatory: Owner of telecommunications plant use TNCM to provide data in Universal Service Obligation and Unbundled Network Element hearings

(2) Strategic marketing, finance and engineering studies.

Cost-benefit analysis in telecom is commonly conducted through cost modeling technique in order to build a final output as a cost model based on investigation of the cost factors and scenarios (Wei, Frinke, Carter, and Ritter, 2001).

2.6.3 Cost-benefit Analysis

Theory and practice inform us that the adoption of new technologies is dictated by factors such as perceived costs and benefits, complexity, compatibility with existing systems, ease of use, and so forth. A favorable mix of these factors leads to high organizational intention to adopt. This framework can be applied to the adoption of many information technologies. Each potential adopter needs to create the knowledge to mesh the technology with its own unique business context (Attewell P, 1992).

Debra Harker and Jeanette Van Akkeren (2002) also suggested based on their research that the qualitative study related to mobile data technologies should focus upon technology use and associated benefits across different industry sectors, gauging levels of concern/comfort with technology.

Almost every company has their existing communication network. The network either basic telephone network or Local Area Network is needed to be substituted and upgraded from time to time to keep the company's efficiency at its best. As mentioned, the upgrade decision is usually based on costs and benefits of implementing new technology. This Benefits and costs are also analyzed based on several factors related to technology itself such as technology acceptance, user demand, and technical constraints.

This technique was developed in the first place as a decision maker's aid in investment choices and particularly in those concerning public investment expenditure. It is generally structured in five stages:

(1) Detail description of the programs of alternatives in question

(2) Selection if a reference solution; this can be a set of performance or desired effectiveness criteria.

(3) An inventory of social and economic groups which will be affected by the programs or by technological developments under investigation

(4) Assessment and comparison of costs and benefits

(5) Comparison of the respective merits of the alternative projects and establishment of criteria for final choice

Cost/benefit analysis is a way of setting out all data relevant to a given set of alternatives with the aim of maximizing the present value of all benefits less all costs, subject to specific constraints.

Some of the major papers utilizing the method of Cost Modeling and Cost-benefit analysis are demonstrated in Table 2.8.

Table 2.8. Literature Review on Cost Modeling and Cost-Benefit Analysis

Method	Major Papers	Authors
Cost Modeling	The Role of fixed Wireless Access Networks in the Deployment of Broadband Services and Competition in Local Telecommunication Markets	Kanchana, 2000
	Cost Benefit analysis for Network Intrusion Detection system	Wei, Frinke, Carter, and Ritter, 2001
	Cost modeling of telecommunication network: the cases of Kenya and Thailand	Kibati, Krairit, 1998
Cost-Benefit Analysis	Cost-Benefits analysis on Mobile Enterprise portals	Ericsson Consulting, 2002
	Seizing the opportunity for Corporate Wireless Data Applications	Infowave, 2003
	The ROI of Wireless LAN	Korostroff, 2003
	Wireless LANs Broadcast Their Benefits Over Cable	Davis, 1991
	Mobile and Wireless Communications Equipment Market	Alcatel, France Telecom, Nortel, 1997

2.7 Conclusion

This chapter presents literature reviews covered all the related areas regarding technology forecasting, consumer demand, and telecommunications. The literature review starts by looking at the big picture of IT industry and narrowing down to telecommunication industry especially, wireless and mobile Internet market. From this point, the reviews related to the economic aspects of the industry, especially consumer demand forecasting, and the technical aspects are covered as well as the associated research tools used by these researches.

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III. RESEARCH METHODOLOGY

This chapter gives a theoretical background to trends, fundamental drivers, factors, and economic theories, which were used to formulate a common ground and frame of reference before developing the research methodology.

This chapter describes industry trends together with a listing of the drivers underlying each trend. These trends and their associated drivers or factors are summarized into the form of research questions and research hypotheses. The process of solving these questions is proposed by identifying research methodology, underlying statistical tools, and expected outcomes of the research.

3.1 Industry Related to Framework

The diversity of the past researches related to telecommunication industry has provided a big picture of what industry has been and how it is growing. By focusing on wireless technologies and consumer, common knowledge can be concurred from the literature review and listed below:

Development will be more users driven: Up to now it can be argued that vendors and technology have driven development within the communication industry. Today there are signs this is changing and that future development within wireless telecommunications will be more user driven (Lindgren, Jedbratt, and Svensson 2001). It is, however, not clear how strong this trend is and what user segments will be the most important factors.

User Mobility will increase: For obvious reasons, user mobility is an important aspect for use of wireless services and development of wireless technology. Studies of lifestyle and other related areas indicate that user mobility will increase (IVA 2000).

The service and application market will grow: Today, the service and application market still emphasizes on voice and simple messaging. More advanced services such

as web surfing, payments, etc. are still only account for a small fraction of the market. But the future market should be much larger than today, consisting of more complex and differentiated services as well as the basic ones.

User security, integrity, and privacy will become more important: For fixed Internet, the topics regarding user security, integrity, and privacy, are still considered to be an ongoing issues that needed to be addressed. The difficulties and complexity are even greater in wireless Internet, both in technical aspects ad user perceptions.

Real or perceived health problems due to radiation will become more important: The fact that many people worry about health effects, whether real or perceived, makes this issue a very real problem that needs to be handled by the wireless industry (SNRV 2002).

Spectrum will become an increasingly scarce resource: Spectrum is a resource of great importance for wireless industrial development. Wireless consumer communications has been given less than one-tenth of all usable spectrums between 500 MHz and 5GHz. If governments allocate abundant spectrum to the wireless industry, growth will be much faster and prices for the consumer will be lower. If governments are slow to release new spectrum, growth will be slowed. Spectrum can be released either to the operators or to unlicensed bands for free use. Unlicensed spectrum will undermine the market power of the operators and create amore dynamic, but anarchistic and less controllable marketplace. Another way to reduce the problem is to develop technology, enabling a more efficient use of the existing system.

The developing countries will continue their positive development: IDC (www.idc.com) expects Thailand telecom market to show most relative growth over the period with an overall 5-year compound annual growth rate of 12.9% followed by India and the Philippines with CAGRs of 7.3% and 9.1% respectively. Mature markets

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like Hong Kong, Korea, Singapore and Taiwan on the other hand are expected to show slightly negative CAGRs - especially Korea with a 3.8% decline (IDC 2005).

The Wireless Industry will grow: Thailand's mobile terminal market, which is worth THB 46 Billion in 2004, is estimated to hit THB 53.4 Billion by 2008. The sales to end-users for smart phones and wireless PDAs is expected to grow at compounded annual growth rates of 56.1% and 29.5% for the period 2004-2008. The market opportunity for Thailand is well-aligned with increasing telephony penetration. Thailand has 22.6 million telephone subscribers in 2003, representing telephony penetration of 36.5% *(source: International Telecommunications Union)*. And, it is expected Thailand's telephony penetration to rise to 47% by 2006 (Gartner Dataquest - Ann Liang and Nick Ingelbrecht 2004).

Market Concentration in the wireless industry will change and the fight for market dominance in the wireless industry will intensify: Several factors are pointing towards increased concentration with a few market leaders wielding great market power, but other factors are pointing towards a fragmented marketplace where the market leaders have little market power. It is possible that the industry is facing a consolidation phase, with fewer but bigger actors. The merging of telecommunication, data communication, and media into an at least partly integrated industry will have an important impact on the existing telecommunications companies. It is not clear which industry will emerge as the long-term winner. Operators might lose market power to new wireless ISPs or through media companies owning content being integrated with wireless service.

Managing the complexity of a heterogeneous wireless world will become increasingly important problems: There are many technical constraints that might have a negative impact on the development of the wireless industry. The problems of

integrating various wireless systems, achieving seamless services from a user's viewpoint, are still unsolved especially in developing countries where there are so many adopted standards available.

3G will be implemented: It is clear that 3G will be implemented, but the question is at what speed and to what extent. In some countries, 3G is deployed later than scheduled and many networks are canceled or merged with other networks, leading to a problem of unifying telecommunication infrastructures and services.

Business sectors will play an important role regarding the adoption of wireless technologies: In times of economic slowdown, investments in new technology are often one of the first items eliminated, yet cancellation of technology implementation can cripple a company's ability to rapidly respond to changing needs of staying competitive. An organization's ability to deploy future wireless network can hinge on its ability to deploy its solution successfully.

3.2 Research Questions

Underlying these trends used as a research framework, are a number of fundamental factors. These fundamental factors are a compilation of common wisdom from a number of areas, such as technology, socioeconomics, politics, business, the telecom industry, and user values. These fundamental drivers can be categorized in four main areas (Karlson, Bria, Lind, Lonnqvist, Norlin 2003) and shown in Table 3.1.

Table 3.1. Summary of Preliminary Factors

Technology	Socioeconomic and political	Business and industry	Users, values, attitudes
Hardware will be improved significantly	Globalization will increase	Industries mature over time	Value change at the pace of generations
Capacity in air will increase	Increasing amount of information and choices	Companies strive towards monopoly	Different user groups have different values and needs
Standardization will increase	Air Bandwidth is affected by political decisions	Attractive markets attract new entrants	Individualism will increase
Large and complex systems become increasingly difficult to control centrally		Wireless infrastructure costs will fall slower than electronics costs	Need for mobility and communication will increase
Internet development and associated application will be improved significantly		Value of network increases with number of nodes	Increased technology adoption in everyday life
		Value of information and knowledge will increase	Environmental and health concerns will increase
			Explosion in social group formation in very large networks

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According to table 3.1, the research questions can be broadly stated as follows:

(1) What are the factors associated with technology that will affect the successful implementation of future wireless networks in developing countries?

(2) What are the factors associated with socioeconomic and political that will affect the successful implementation of future wireless networks in developing countries?

(3) What are the factors associated with business and industry that will affect the successful implementation of future wireless networks in developing countries?

(4) What are the factors associated with users, values, and attitudes that will affect the successful implementation of future wireless networks in developing countries?

3.3 Theories on Fundamental Factors

To assure that these trends and fundamental factors should be the focusing point of the research, the related theories are also studied. First the technology acceptance model and the technology adoption cycle has been considered since it involves directly in the study related to consumer demand and technology implementation. Then, theories such S-curve, Product life cycle, etc, which related specifically to products and services are also examined. The results are summarized in table 3.2 and suggest what issues are needed to be aware of and used as references for comparison with the final outcomes of the research.

Table 3.2 . Theories on Fundamental Factors

Theories Supporting Fundamental Factors	**Effects to research framework**
The Technology Acceptance Model and the Technology Adoption Cycle	Examine *attention and willingness to adopt* of user in chasm stage of the Technology Adoption Cycle
Microprocessor and Other Growth Paths	Examine the effects of capacity-in-air and device performance regarding processing power, battery capacity.
Falling Prices and the Experience Curve	Examine the effects of accumulated production volume to price.
Network and Software Effect	Rapid expansion in terms of network value, could affect other area such as software, and should be taken into account when conducting research.
The S-curve and the Product Lifecycle	It can be concluded that *technical, network and supply issues, and marketing and demand areas*, predominate at different stages of the cycle.

3.4 Research Hypotheses

The procedure to formulate research hypotheses can be illustrated as follows:

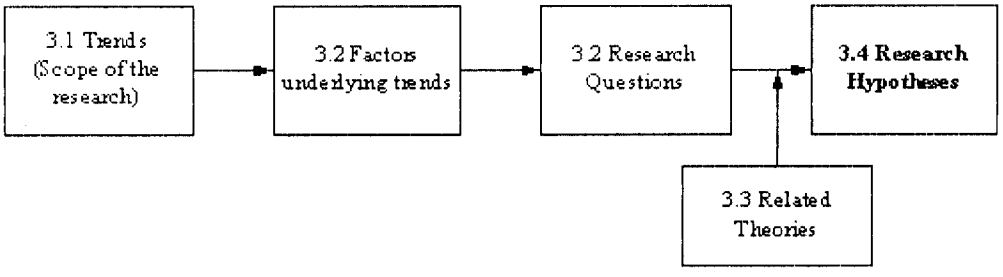

Figure 3.1 The Procedure to Formulate Research Hypotheses

The trends, used as dimensions to define the research space, are a number of fundamental factors. Some of these factors are better supported empirically and theoretically than others.

Since our research focuses more on empirical analysis, the factors that form research questions, are reselected and regrouped based on the ability to be statistically measured and their related theories (Figure 3.2).

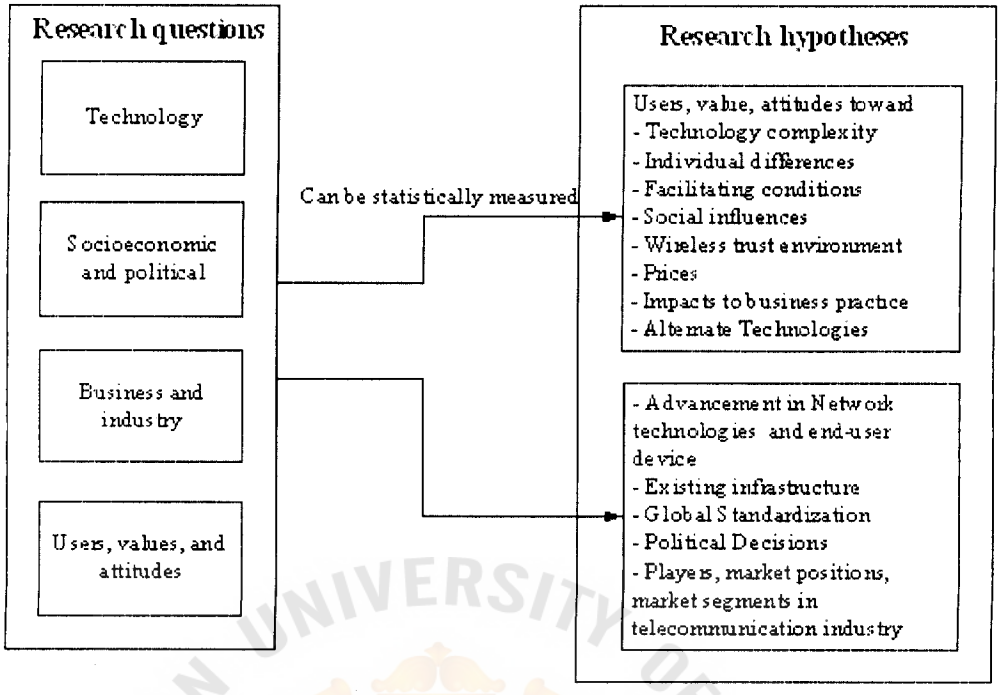

Figure 3.2. Research Hypotheses Framework

User's value and attitude toward certain technology can be statistically measured through survey. However, the affects caused by factors including costs, technology complexity, current network implementation, global standards can be studied through appropriate theoretical models. Thus, the hypotheses are then developed based on these preliminary factors

(1) Hypothesis 1: Technology Complexity will have a negative effect on demand for wireless access

(2) Hypothesis 2: Individual Differences will have a positive effect on demand for wireless access

(3) Hypothesis 3: Facilitating Conditions will have a positive effect on demand for wireless access

(4) Hypothesis 4: Social Influences will have a positive effect on demand for wireless access

(5) Hypothesis 5: Wireless Trust Environment will have a positive effect on demand for wireless access

(6) Hypothesis 6: Price will have a negative effect on demand for wireless access

(7) Hypothesis 7: Impacts on business practices will have a positive effect on demand for wireless access

(8) Hypothesis 8: Alternative technologies will have a negative effect on demand for wireless access

(9) Hypothesis 9: The rest of the preliminary factors including *Technical Advancement, Existing infrastructure, Global standardization, Political decisions and Situation of telecommunication market* are also considered to influence wireless Internet service. Although it cannot be statistically studied, the associated research method will be discussed later on in this chapter.

3.5 Research Methodology

Based on the literature review and the aforementioned reasons which are specific to this research, it is quite clear that it would be best to study all hypothesized factors in a form of demand-supply relationship. Demand in the field of telecommunication consists of several factors including preferable prices, ease of use, etc., while the supply side include available technologies and services, cost and other intangible limitations of operators and providers, etc.

As the first step in the first phase of the research framework, preliminary factors involving demand and supply of wireless technologies found from the literature are

divided into two categories. The first category consists of preliminary factors related to consumer perceptions and demands which can be measured statistically by creating a measurable scale for each factor. These constructed scales will be tested and verified by reliability analysis. The questionnaire will then be designed based on the literature review and purified measures as the result of the first phase of the research. After that, the questionnaire survey will be launched on at least 400 randomly-sampled respondents in the Bangkok Metropolitan area. The statistical results analyzed from the questionnaire will then be used to form an econometric model for demands for hi-speed wireless technologies.

The second category of preliminary factors consists of factors related to the supply of wireless technologies and applications (e.g. service providers, operators). These factors are used in the second phase of the research to develop a cost model of different wireless technologies that can possibly accommodate consumer demands found in the first phase.

In summary, this study will be conducted in two phases. The analysis of demands for special access services, wireless telecommunication services, is developed in phase I. After that, the analysis of the supply of hi-speed wireless networks will be conducted using cost models in Phase II.

In the final step, the researcher attempts to combine the results from Phase I and II together in order to present the linkage between demand and supply of hi-speed wireless networks. This uses the general baseline scenario of the cost model to represent the supply side and then vary the demand on network and application, which are the inputs from Phase I, using the sensitivity analysis technique. Thus, the final recommendations will be based on the linkage found between demands and cost modeling which will present possible outcomes of future implementation of network

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infrastructure. The findings of this research will be unique and original in this field because it will present the technical findings that also accounts for non-technical components of consumer demands.

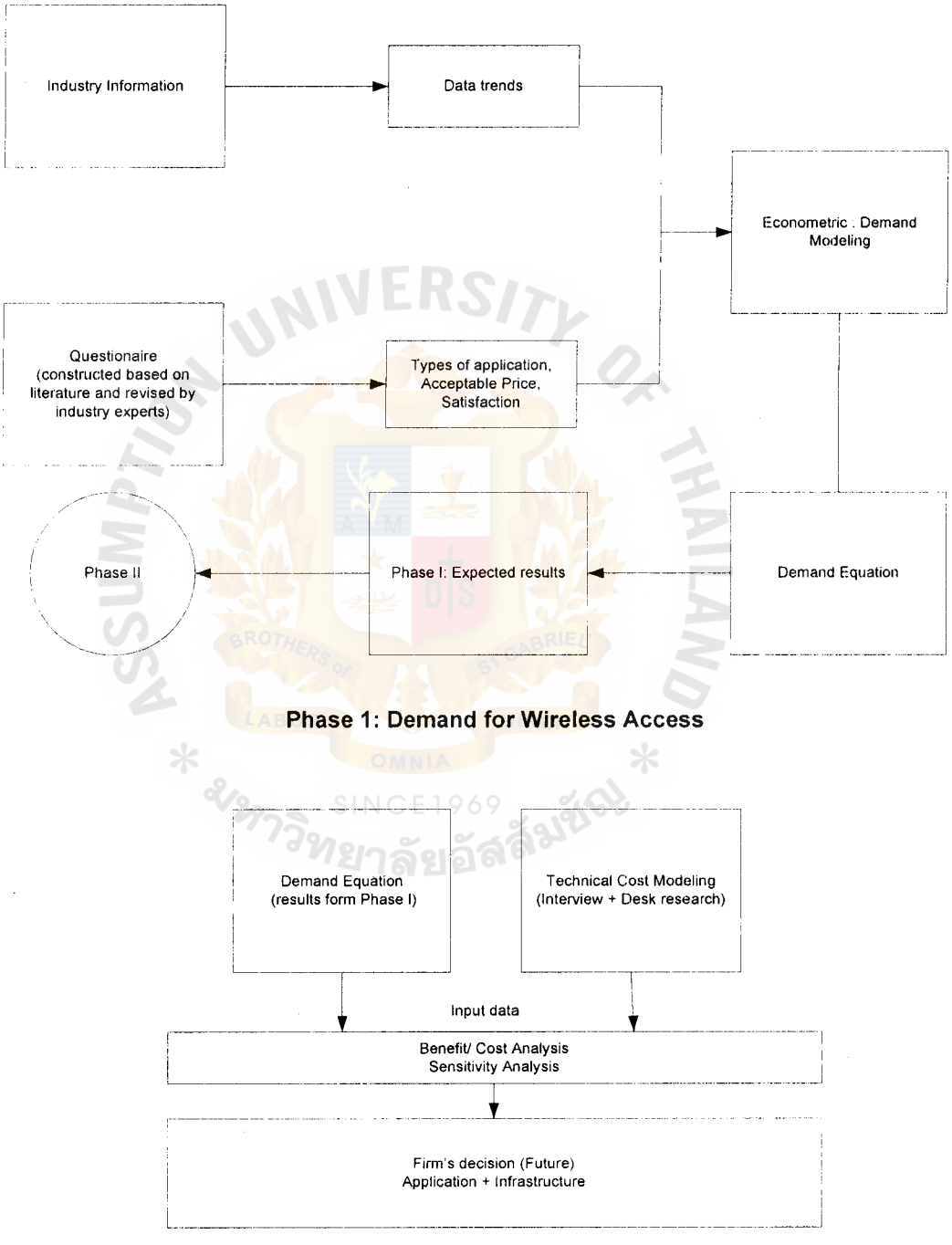

Figure 3.3. Two Phases of Research Methodology

3.6 Research Tools

Research tools described in this section will be described according to phases of the research.

3.6.1. Econometric method

The term "Econometrics" used in this paper refers to 'economic measurement'. It is a combination of mathematical economics, statistics, economic statistics and economic theory. The main purpose of econometrics is to estimate demand relationships. Once this relationship has been specified it can be used as a tool for estimating future demand by including forecast values for the determining variables. The major modeling is as follows:

(1) Step 1: Specifying the hypothesized model

  (1.1) State economic theory of hypothesis of interest

  (1.2) Specify a mathematical model of the theory

  (1.3) Specify an econometric model of the theory

(2) Step 2: Obtain data

(3) Step 3: Estimate the econometric model

(4) Step 4: Verify the estimated model using diagnostic tests

  (4.1) If the results are unsatisfactory, revise or reformulate the model, gather additional or new data if necessary, and then reestimate econometric model.

  (4.2) If the results are satisfactory, proceed to steps 5.

(5) Step 5: Use the verified model to

  (5.1) Test hypotheses of interest (Hypothesis testing)

    (5.1.1) If rejected, formulate a new hypothesis

(5.1.2) If the hypothesis falls to be rejected, test the hypothesis again

(5.2) Hypothesis testing generally involves testing predictions concerning the magnitude or signs of model coefficients

(5.3) Perform forecasts or predictions

(5.4) Perform policy analysis or simulation

(6) Step 6: Report and interpret the results

There are 3 general classes of models that can be constructed for purposes of econometric analysis. They are Time-series model (Examine the past behavior of a time series in order to infer something about its future behavior), single-equation regression models (The variable under study is explained by a single function (linear or nonlinear) of a number of explanatory variables), and multi-equation models (The variable to be studied may be a function of several explanatory variables, which are related to each other as well as to the variable under study through a set of equations).

This research focuses on the relationships between consumer demand and services will be focused and use consumer demand as a variable under the study. Therefore, the single-equation regression method has been selected to be used in the first phase of the research.

Details of Step 1: Specifying a preliminary model

In this section, the model will be continued developing based on forecasting objectives and hypothesized demand factors found from the literature review.

Hypothesized demand function: Statement of logistic regression model

A preliminary logistic regression model can be stated in the form

Demand = f (U1, U2, U3, U4, U5, W, X, Y, ε)

Definitions and Notations

(1) U1 = Technology Complexity variables

(2) U2 = Individual Differences variables

(3) U3 = Facilitating Conditions variables

(4) U4 = Social Influences variables

(5) U5 = Wireless Trust Environment variables

(6) W = cost variables

(7) X = alternate technology variables

(8) Y = variables related to mobile technology impacts on business practices

(9) Error: observed data points do not fall exactly along a linear relationship

The demand function will be revised over time as more data are derived from the survey. Dependent variable, in this case, demand, is on the left-hand side of a regression equation and to be determined by the independent variable(s). Independent variables appear on the right-hand side of a regression equation

In this model, there exist latent explanatory variables that are important factors of the choice. The latent variables are used to capture attitudes, perceptions, and knowledge of respondents. However, these latent variables cannot incorporate directly into choice model. The associating "indicators" of the latent variables are then used to demonstrate responses to attitudinal and perceptual survey questions.

Most of the indicators using in this questionnaire are created using five-point Likert scale anchored by stating 1 as "Not important at all" and 5 as "Very Important".

The indicators of independent variables

According to research hypotheses, there are eight preliminary factors in the hypothesized demand equation. Five of them are derived from Technology Acceptance Model for wireless Internet via mobile devices (TAM for wireless Internet). User acceptance in this model is examined by attitude toward use and intention to use rather than actual use.

The reason behind this is that, at this early stage of wireless telecommunications, most consumer has no experience regarding wireless telecommunication services. The current attitudes, expectations and values of wireless internet services are built upon current wired Internet services and limited version of wireless Internet services. Thus, instead of focusing only on experienced consumers, the inclusion of consumer who has no experience with wireless Internet services would help providing more accurate result with the data from potential wireless user in the future.

The three others preliminary factors are costs (W), Mobile technology impacts on business practices (Y) and Alternate technologies (X). These factors consist of several underlying variables that can be used to form a list of element for developing questionnaire shown in Table 3.3.

Table 3.3. Key Indicators used for Developing Questionnaire

Hypothesized factor	Indicators
Technology Complexity	Efficiency of data transfer System functionality Interface design Mobile capacity
Individual Differences	Past experience of using similar technologies Personal innovativeness Age Gender Income
Facilitating Conditions	Resource factors (such as time and money needed) Technology factors regarding compatibility issues that may constrain usage Policies, regulations, and legal environment Standardization
Social Influences	Subjective norm (other people's opinion, superior influence, and peer influence) Image
Wireless Trust Environment	Security (protocols, encryption methods, etc) Privacy (collection of personal information, etc)

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Table 3.3. Key Indicators used for Developing Questionnaire (Continued)

Hypothesized factor	Indicators
Cost	Minute Cost Monthly Cost
Mobile technology impacts on business practices	Work reorganization Business Process Redesign New business opportunities Effects to manage mobile network
Alternate technologies	Fixed and mobile network integration Existing mobile technologies Future mobile technologies Fixed network stand alone quality

In this research, several factors are observed as the results of individuals' choices between two numbers of alternatives. Each preliminary factor consists of several underlying variables. For example, the factor regarding technology complexity includes network speed, network stability, ease of use, memory and storage, etc. These variables are verified by industry experts for determining if they are able to capture all the aspects related to consumer demands. The survey questionnaire is also developed based on these verified variables.

The indicators of dependent variables

Demand, defines as the willingness and ability of the people within a market area to purchase particular amounts of a good or service at a variety of alternative prices during a specified time period (Paul M. Johnson 1998). Thus, two sets of alternatives are used to capture demand of respondents (willingness of consumer to subscribe for

wireless internet services: will use / will not use, currently not using/ currently using). Since, our dependent variable has 2 possible values which is 0 or 1 (Dichotomous). Binary Logistic regression is used as a methodology for obtaining the value of coefficients.

In Chapter 4, the logistic regression model is successfully extracted from the set of hypothesized variables.

However, to make the model more practical and concrete, the possible bias and strict assumption of logistic regression are continued to be studied in this chapter.

Modeling the response probability

In general, this research is interested in the behavior regarding decision of a large number of individuals or organizations expressed in terms of aggregate quantities (the demand for a service). However, this aggregate behavior is the result of individual decisions.

Making a choice is a collection of procedures that defines the following elements; a decision maker, alternatives, attributes of alternatives, and decision rule. One class of decision rules assumes commensurability of attributes. This defines a single objective function expressing the attraction of alternative in terms of its attributes (factors and variables). This index of attractiveness is also known as "Utility". In other words, utility is a measure that the decision maker attempts to maximize through his or her choice (Ben-Akiva, R. Lerman 1985).

However, one can argue that human behavior consists of inconsistent and nontransitive preferences. Thus, a probabilistic choice behavior was introduced to better explain the human behavioral inconsistencies. A probabilistic choice behavior can be divided into two approaches: **Constant Utility and Random Utility**. The random utility approach, formalized by Manski (1977), accounts human behavioral

inconsistencies and is more in line with consumer theory. The observed inconsistencies in choice behavior are taken to be a result of observational deficiencies on the part of the analyst. The individual is always assumed to select the alternative with the highest utility. However, the utilities are not known to the analyst with certainty and are therefore treated by the analyst as random variables.

From this perspective the choice probability of alternative i is equal to the probability that the utility of alternative i, Uin is greater than or equal to the utilities of all other alternatives in the choice set. This can be written as follows:

P(i, Cn) = Pr [Uin> Ujn, all j ∈ Cn] : *the probability of any alternative i being selected by person n from Choice set Cn* (Note that we assume that no ties occur).

The basic for this distributional assumption is a logical argument about the underlying sources of the randomness of the utilities. Manski (1973) identified four distinct sources of randomness as: unobserved attributes, unobserved taste variations, measurement errors and imperfect information, instrumental (or proxy) variables. Thus, the equation can be rewritten to include unobservable components as follows:

P(I, Cn) = Pr [Vin + εin > Vjn + εjn, all j ∈ Cn]; j refers to alternative j, ε refers to disturbance

Binary Choice Model

In this research, this basic idea is pursued further by considering the special case where Cn contains exactly two alternatives. Such situations lead to what are termed binary choice models. In order to model the response probability, ε[2] must be assumed. Disturbance (ε) can be assumed in one of these three methods; uniformly distributed,

---

[2] Specification of the Disturbance (ε): The unknown measurement error is introduced into the utility function with two objectives. It is intended to capture the random error which might occurred from imperfect relationship between dependent and independent variables. It is also used to demonstrate a possible error of inappropriate variables in the model.

normal distribution, and logistically distributed. However, only the assumption that ε is logistically distributed would be able to provide a result in a closed form and express the choice probability as an integral. When binary choice model is constructed with the assumption that ε is logistically distributed, the model is also known as binary logit.

Details of Step 2: Types of input data

(1) Cross-sectional: Individual observations measured at a given point in time

(2) Time-series: Observations measured at different points in time

(3) Pooled: Mix of cross-sectional and time-series observations

(4) Longitudinal (or panel): A cross-section of observations is followed through time

In our research, the input data of phase I would be cross-sectional data, which individual observations regarding demand for wireless access measured at a given point in time.

Targeted industries

The recent proliferation of access points, or hot spots, enabling wireless broadband Internet connections via Wi-Fi (802.11) technology has created a surge in demand for Wi-Fi service. Yet enterprises, which typically drive the acceptance of cutting-edge technologies, thus far have expressed lukewarm interest in wireless local area networks (WLANs).

Enterprise use of WLANs falls into two categories, says IDC analyst Abner Germanow:

(1) Internal deployment, such as at hospitals, corporate campuses and hospitality businesses, including hotels and airports; and

(2) Mobile Internet access by large businesses that use Wi-Fi to enable their field workers to dial into a connection service

However, in the case of developing countries where wireless Internet services is still not fully implemented, the general consumer who has no experience with wireless Internet services are also considered in addition to these two categories. The objectives behind this are to be able to compare the model between current wireless Internet consumer and non-consumers and eventually able to construct the most generalized model.

The first phase of research will be initially conducting based on the data from targeted industries. These targeted industries are assumed for the purpose of gathering preliminary data. The data will be input to the hypothesized equation and the equation will be revised according to real world data.

Details of Step 3: Estimating the econometric model (binary logit model)

Discriminant analysis and logistic regression are the appropriate statistical techniques when the dependent variable is categorical (nominal or nonmetric) and the independent variables are metric. Discriminant analysis involves deriving a variate, the combination of the two (or more) independent variables that will discriminate best between a priori defined groups.

Logistic regression, also known as logit analysis, is limited in its basic form to two groups. Logistic regression can be used to predict a dependent variable on the basis of independents and to determine the percent of variance in the dependent variables explained by the independents; to rank the relative importance of independents; to assess interaction effects; and to understand the impact of covariate control variables.

Logistic regression applies maximum likelihood estimation after transforming the dependent into a logit variable (the natural log of the odds of the dependent occurring or not). In this way, logistic regression estimates the probability of a certain event occurring.

Assumption of Logistic Regression

Logistic regression is popular in part because it enables the researcher to overcome many of the restrictive assumptions of OLS regression (G. David Garson, 2001):

(1) Logistic regression does not assume a linear relationship between the dependents and the independents. It may handle nonlinear effects even when exponential and polynomial terms are not explicitly added as additional independents because the logit link function on the left-hand side of the logistic regression equation is non-linear. However, it is also possible and permitted to add explicit interaction and power terms as variables on the right-hand side of the logistic equation, as in OLS regression.

(2) The dependent variable need not be normally distributed (but does assume its distribution is within the range of the exponential family of distributions, such as normal, Poisson, binomial, gamma).

(3) The dependent variable need not be homoscedastic for each level of the independents; that is, there is no homogeneity of variance assumption.

(4) Normally distributed error terms are not assumed.

(5) Logistic regression does not require that the independents be interval.

(6) Logistic regression does not require that the independents be unbounded.

However, other assumptions still apply:

(1) Meaningful coding: Logistic coefficients will be difficult to interpret if not coded meaningfully. The convention for binomial logistic regression is to code the dependent class of greatest interest as 1 and the other class as 0, and to code its expected correlates also as +1 to assure positive correlation. For multinomial logistic regression, the class of greatest interest should be the last class. Logistic regression is predicting the log odds of being in the class of greatest interest.

(2) Inclusion of all relevant variables in the regression model: If relevant variables are omitted, the common variance they share with included variables may be wrongly attributed to those variables, or the error term may be inflated.

(3) Exclusion of all irrelevant variables: If causally irrelevant variables are included in the model, the common variance they share with included variables may be wrongly attributed to the irrelevant variables. The more the correlation of the irrelevant variable(s) with other independents, the greater the standard errors of the regression coefficients for these independents.

(4) Error terms are assumed to be independent (independent sampling): Violations of this assumption can have serious effects. Violations will occur, for instance, in correlated samples and repeated measures designs, such as before-after or matched-pairs studies, cluster sampling, or time-series data. That is, subjects cannot provide multiple observations at different time points. In some cases, special methods (SPSS NOMREG, for

instance) are available to adapt logistic models to handle non-independent data.

(5) Low error in the explanatory variables: Ideally assumes low measurement error and no missing cases. See here for further discussion of measurement error in GLM models.

(6) No multicollinearity: To the extent that one independent is a linear function of another independent, the problem of multicollinearity will occur in logistic regression, as it does in OLS regression. As the independents increase in correlation with each other, the standard errors of the logit (effect) coefficients will become inflated. Multicollinearity does not change the estimates of the coefficients, only their reliability. High standard errors flag possible multicollinearity. Multicollinearity and its handling is discussed more extensively in the StatNotes section on multiple regression.

(7) Large samples: Also, unlike OLS regression, logistic regression uses maximum likelihood estimation (MLE) rather than ordinary least squares (OLS) to derive parameters. MLE relies on large-sample asymptotic normality which means that reliability of estimates decline when there are few cases for each observed combination of independent variables. That is, in small samples one may get high standard errors. In the extreme, if there are too few cases in relation to the number of variables, it may be impossible to converge on a solution. Very high parameter estimates (logistic coefficients) may signal inadequate sample size. As a rule of thumb, Peduzzi et al. (1996) recommend a minimum of 10 observations per parameter in the model.

(8) Sampling adequacy: Goodness of fit measures like model chi-square assume that for cells formed by the categorical independents, all cell frequencies are >=1 and no more than 20% of cells are < 5. Researchers should run crosstabs to assure this requirement is met. Sometimes one can compensate for small samples by combining categories of categorical independents or by deleting independents altogether.

Expected outcome of Phase I research

In the first phase, the research focuses on the study of the dependence of one variable on one or more other variables (regression analysis). The outcome variable (the dependent variable) is the demand of user toward wireless access for business purpose.

We use econometrics as an application of statistics to economic models to test hypotheses. The hypotheses which are formed by the relationship between dependence (demand) and independence variable will be tested to demonstrate the significant of independence variables and estimate the magnitude of quantitative relationships.

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3.6.2. Research tools: Cost Modeling Method

When enterprise considers investing in an upgrade of the existing network infrastructure environment, one way to ensure that the funds of the enterprise are properly spent, a total Economic Impact analysis of the costs, benefits, flexibility and risk of deploying a wireless integrated network for firm level is needed. In other word, Cost analysis provides a way to develop "quantitative" support for decision making.

In assessing alternative technological options through cost analysis, all positive effects are considered as benefits and all negative effects are considered as costs. The necessary steps to be followed in assessing technological options are:

(1) Listing of available alternative technologies

(2) Identification of all cost components both tangible and intangible

(3) Reduction of all costs to total monetary equivalent

(4) Selection of appropriate alternatives on the basis of objectives and constraints

An engineering-economic model was developed to estimate the cost of implementing a network to provide data services. Following the forward-looking economic cost methodology, the model assumes a "Greenfield" deployment where all construction takes place in an area where there is no pre-existing telecommunications infrastructure, which is usually the case for implementing wireless technologies.

Preliminary variables relating to Cost Modeling of wireless telecommunication network

Impact to the cost of the current wireless initiative is seen in a variety of different areas. Costs are divided between peripheral hardware, server, and device software, increased labor costs to install and manage the devices, as well as monthly wireless costs.

Generally, Cost can be categorized as

(1) Device Hardware

(2) Software

(2.1) Application development expenses

(1) Other Costs

(3.1) Monthly expenses

(3.2) Management expenses

(3.3) Outsourcing

(3.4) Downtime

(3.5) Related management and support costs

(3.6) Network infrastructure planning

(3.7) Training

(3.8) Troubleshooting and repair

(3.9) Hardware management

3.6.3 Sensitivity Analysis

Sensitivity analysis involves adjusting model input values to determine the impact on the cost estimate from varying the project factors. You attempt to identify factors with a high uncertainty and a high impact. These aspects can be quantified to help calculate the range of your estimates. (Madachy, 2003)

In the sensitivity analysis method, cost modeling is used to estimate the cost consequence of alternative situations. Detailed Methodology and its application to the research are mentioned in Chapter Five.

Expected Outcome of Phase II research

The sensitivity analysis will rely partly on the cost modeling of wireless service providers. The cost models will be used to determine the market potential of each service from the providers' perspective. It will indicate the typical or minimum requirements of implementing a wireless access service. Therefore, the expected outcome yields the possibility of future wireless services that suppliers might be interested in offering.

Enterprises will benefit from the outcome of this cost model by applying cost model to a specific industry or firm and see if the planned services should be provided in the future. The long-term planning of network implementation will be more realistic and consistent resulted from the ability to justify network investment and network upgrading trends.

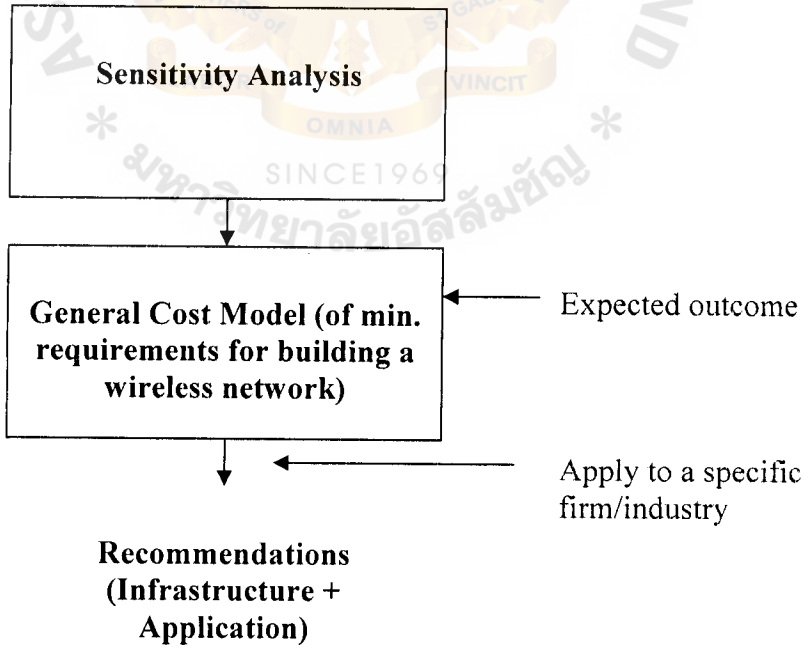

Figure 3.4 Expected Outcome of the Research

3.7 Conclusion

This chapter approaches the problem statement by identifying research problems and research hypotheses based on literature review and related theories.

This chapter also explains the procedure of method selection. The limitations and constraints associated to each method are explained. The selected method and tool, econometric and logistic regression, is then developed and customized toward research assumptions for the purpose of model testing in the next phase of the research.

The assumptions related to cost modeling are mentioned and used as a baseline which will be adjusted according to the experts' opinions before final model development.

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IV. SURVEY RESULTS AND EMPIRICAL DATA ANALYSIS

This chapter presents the results regarding significance fundamental drivers and factors found from the study of consumer demands for wireless Internet service.

The results can be separated into the results of expert interview and empirical data analysis. The empirical data analysis is further divided into three parts including non-user analysis, user analysis, and combination model. The demand model is then derived in the form of network specification that should be able to satisfy consumer's expectations. The current implementation, technical constraints and limitations are also studied in order to identify associated benefits and costs from the service provider's aspect.

4.1 Results of Expert Interviews

The preliminary questionnaire and hypothesized model are handed to experts on telecommunications of five for accuracy of factors and associated scales. These experts are selected based on different aspects of industry they are responsible to, and includes the representatives from National Science and Technology Development Agency, DTAC Corporation, TRUE Corporation, SETTRADE Corporation (software developer for Thailand's stock market) and engineering faculty of Krasetsart university.

The results from the interview consist of the significant factors in each expert's telecommunication field and what kind of benefits they would expect from this research. The researcher divides all factors into low-end and high-end according to the locations that these experts conduct their researches. Low-end refers to factors found in rural areas of Thailand. And High-end refers to factors found in urban areas of Thailand.

Table 4.1 Summary of the Expert Interview

Tier	Factors
Low-end	Affordability, Income level, Willingness to pay
High-end	Quality of service Business model changing (Convergence of Telecom service provider + Information service/Content provider + Carrier provider) Regulator (Operator level, Country level, International level) Most of the factors are already included in the model For financial services – Price and expenses are not important issues – Consumer may feel uncomfortable to use services without human interaction
Specific to Thailand	Promotions, Add-on values that related to consumer lifestyle The readiness of Backbone infrastructure Economic development stage of the country Consumer attitude, advertisement

New Potential customers for Wireless Internet Service are expected to be Corporate (MNC, Multi-location operation, Transportation), Service business (Hotel, Hospital, Airport, Coffee shop), Institution/University/Campus, Government.

With the current limitations of networks and devices, issues regarding reliability and user interface are founded to be insignificance for both low and high-end consumers. However, the important issue is the compatibility of device that is capable to use new services.

The development trends regarding services and applications for most demanded consumers (e.g. financial sector) are speed, responsiveness when requesting for data, and streaming data applications.

4.2 Empirical data analysis

Characteristics of data

In this survey, the target sample size was 540 users. The characteristics of data regarding age, educational level, gender, and income distribution are presented in Table 4.1, 4.2, 4.3 and 4.4 accordingly. The majority of respondents belong to the age group of 21-30, graduate education and average income of 5000-10000 THB per month.

Table 4.2 Characteristics of Data -Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 20	58	10.7	10.8	10.8
	21-30	387	71.7	72.2	83.0
	31-40	72	13.3	13.4	96.5
	41-50	11	2.0	2.1	98.5
	51-60	8	1.5	1.5	100.0
	Total	536	99.3	100.0	
Missing	System	4	.7		
Total		540	100.0		

Table 4.3 Characteristics of Data -Education Level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Elementary school	18	3.3	3.4	3.4
	Junior high school	4	.7	.8	4.1
	Senior high school	65	12.0	12.2	16.4
	Diploma	17	3.1	3.2	19.5
	Bachelor Degree	388	71.9	72.9	92.5
	Master Degree	37	6.9	7.0	99.4
	Doctorate Degree	3	.6	.6	100.0
	Total	532	98.5	100.0	
Missing	System	8	1.5		
	Total	540	100.0		

Table 4.4 Characteristics of Data -Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	232	43.0	45.0	45.0
	Female	283	52.4	55.0	100.0
	Total	515	95.4	100.0	
Missing	System	25	4.6		
Total		540	100.0		

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Table 4.5 Characteristics of Data -Income Distribution

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 5,000 Baht	103	19.1	19.4	19.4
	5,000-10,000 Baht	282	52.2	53.0	72.4
	10,001-25,000 Baht	89	16.5	16.7	89.1
	25,001-50,000 Baht	42	7.8	7.9	97.0
	50,001-75,000 Baht	13	2.4	2.4	99.4
	More than 75,000 Baht	3	.6	.6	100.0
	Total	532	98.5	100.0	
Missing	System	8	1.5		
	Total	540	100.0		

Numbers of devices carried per respondent and current methods used for Internet access are presented in table 4.6 and table 4.7. The majority of respondent tends to carry one device. Almost half of the respondents have only one method of Internet access.

Table 4.6 Number of Devices carried by One Respondent

	Frequency	Percent
Carry 1 device	380	70.3
Carry 2 devices	121	22.4
Carry 3 devices or more	25	4.63
No device	14	2.6
Total	540	100

*The choices of devices include no device, cell phone, Personal Digital Assistance (PDA), Smart Phone / PocketPC Phone Edition, and Computer Notebook.

Table 4.7 Number of Methods used for Internet Access

	Frequency	Percent
1 method of connection	263	48.7
2 methods of connection	185	34.2
3 or more methods of connection	63	11.6
No Internet connection	29	5.4
Total	540	100

*The choices include no connection, dial-up, wireless via cellular network, wireless via Hotspot, wired broadband, or Internet access provided by organization.

Analytical Techniques

First, the reliability analysis technique was used to test the reliability of the hypothesized variables by examining the correlations between each item from the questionnaire. Some items may be deleted from the scale to improve overall reliability.

Second, the factor analysis technique was used for summarization and data reduction by selecting a subset of variables from a larger set (based on which original variables have the highest correlations with principle factors) and reducing a large number of variables to a smaller number of factors for modeling purposes.

Since this paper focuses on a problem that involves a categorical dependent variable (with two classifications) and several metric independent variables, the third technique, Logistic regression was used to predict a dependent variable on the basis of independents and to determine the percent of variance in the dependent variables explained by the independents; and to rank the relative importance of independents; to assess interaction effects; and to understand the impact of covariate control variables.

4.2.1. Statistical Tests for Model Specifications regarding Non-User

The sample size for non-user analysis is equal to 427 respondents. The data was collected randomly with one condition that the respondent must not be using any kind of wireless data services.

Test 1: Reliability of Measurement

Reliability is estimated from high correlation among the variables comprising the scale. Cronbach's alpha is the most common form of reliability coefficient. By convention, alpha should be 0.70 or higher to retain an item in a scale. However, this cut-off value can be adjusted to 0.60 or 0.80 depending on type of research (G. David Garson 2001).

Cronbach's alpha can be interpreted in two ways

(1) The percent of variance the observed scale would explain in the hypothetical true scale composed of all possible items.

(2) The correlation of the observed scale with all possible other scales measuring the same thing and using the same number of item

The variables related to demographic data, hardware, software, and network pass the test with high reliability results. However, the variables related to sociology and business practices are not be able to pass this test.

Test 2: Confirmatory Factor Analysis

Confirmatory factor analysis seeks to determine if the number of factors and the loadings of measured (indicator) variables on them conform to hypotheses.

Before proceed with factor analysis, the following tests are performed:

(1) **KMO and Barlett's Test:** sampling adequacy measured by KMO statistics predict if data are likely to factor well, based on correlation and partial correlation. KMO varies from 0 to 1.0 and KMO overall should be 0.60 or higher to proceed with factor analysis (G. David Garson 2001).

According to the results, Kaiser-Meyer-Olkin Measure of Sampling Adequacy yields the value of 0.807 which is higher than cutoff value, indicating enough sampling adequacy.

(2) **Barlett's test of sphericity:** Barlett's test of sphericity tests whether the independent variables have relationship between each others. The significant value must be less than .05 to indicate that these variables relate to each others. So, that they can continue be analyzed by technique of factor analysis.

Approx. Chi-square = 3099.012

df = 561

Sig. = .000

The test yields the significant value of .000 which is less than 0.5. Thus, these variables can be examined using factor analysis.

(3) Communalities

Communality is the squared multiple correlation for the variable using the factors as predictors. The communality measures the percent of variance in a given variable explained by all the factors jointly and may be interpreted as the reliability of the indicator.

When an indicator variable has a low communality, the factor model is not working well for that indicator and possibly it should be removed from the model. So, the value of communality is constrained to be more than 0.5 (G. David Garson, 2001). If a variable has communality value less than 0.5, it cannot be clearly categorized as one factor.

All variables except "Level of Education" have the value of communality more than 0.5 and are able to pass the test.

There are different methods of extracting the factors from a set of data. The most common methods are Principal components analysis (PCA) and Principle factor analysis (PFA). PFA seeks the least number of factors which can account for the common variance of a set of variables, whereas the more common PCA seeks the set of factors which can account for all the common and unique (specific plus error) variance in a set of variables. Since PCA can maximize the chance of capturing all of the significance variables, it is chosen as an extraction method.

To make the output more understandable and facilitate the interpretation of factors, the ration method of Equamax, which combined concepts of Varimax[3] and Quartimax[4], is used for categorizing factors based on related value of factor loading.

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[3] Variamax rotation seeks to maximize the variance of the squared loading of a factor on all the variables.

[4] Quartimax rotation seeks to minimize the number of factors needed to explain each variable.

The variables are then categorized into factors based on the value of factor loading and shown as follows:

Rotated Component Matrix

(1) Network

(2) Hardware, Ease of Network Installation

(3) Software

(4) Financial Services

(5) Web Surfing, Entertainment, E-mail, Display resolution

(6) Cost of End-User Device, Cost of Wireless Internet Connection Fee

(7) Income, Age, Educational Level

(8) Address

(9) Payment Method, Decision to subscribe for a wireless Internet service in the next few years

Component 1, which covers all variables related to "Network", can be best used to define the underlying structure in data that are subjected to demands for wireless Internet service. Characteristics of Hardware are reflected in second factor. Software and applications are ranked next to the characteristics of Hardware. However, software and applications related to financial services such as E-commerce, Stock trading are ranked separately in third factor.

The fifth factor consists of "web surfing", "entertainment", "E-mail", "Display Resolution". This is reasonable as web surfing and entertainment applications are normally required to use large display resolution. "E-mail" is also considered to be in this group as it would require large bandwidth and is still not a critical application as in U.S. or other developed countries.

The demographic variables are all grouped into seventh factor. This is because, in Thailand, amount of income, age, and level of education usually increase or decrease in the same direction.

Test 3: Logistic Regression

The regression model was constructed based on the purpose of demonstrating how the independent variables influence demand for subscribing wireless data services of respondents. The maximum likelihood estimation (MLE)[5] is utilized in this test in order to demonstrate how likely it is (the odds) that the observed values of the dependent may be predicted from the observed values of independents.

The significance tests of the proposed model are performed first to justify if it is appropriate to use this method. The Model Summary and the results of Hosmer and Lameshow tests are shown in Table 4.8 and 4.9 accordingly.

Table 4.8 Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	178.043	.149	.263

[5] **Maximum likelihood estimation** is the method used to calculate the logit coefficients. This contrasts to the use of ordinary least squares (OLS) estimation of coefficients in regression. OLS seeks to minimize the sum of squared distances of the data points to the regression line. MLE seeks to maximize the log likelihood, LL, which reflects how likely it is (the odds) that the observed values of the dependent may be predicted from the observed values of the independents.

Measure strength of association: Goodness of fit and Coefficients of Determination Pseudo R^2 (Nagelkerke R^2)

Instead of making a statement about the "percent of variance explained," the variance of a dichotomous or categorical dependent variable depends on the frequency distribution of that variable. Thus, R^2-like measures for dichotomous variable are not goodness-of-fit tests but rather attempt to measure strength of association. The most-reported of the R-squared estimates is based on the likelihood and known as Cox and Snell's R-square[6] and Nagelkerke's R-Square[7]. According to the result in table 4.8, 26.3 % of variance can be explained by logistic model.

Loglikelihood test for Validity of Hypotheses / model: Hosmer-Lemeshow Test (based on Deviance Chi-square[8] Significance Test)

Hosmer and Lemeshow's Goodness of Fit[9] Test tests the null hypothesis that the data were generated by the model fitted by the researcher. The test divides subjects into deciles based on predicted probabilities, then computes a chi-square from

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6 **Cox and Snell's R-Square** is an attempt to imitate the interpretation of multiple R-Square based on the likelihood, but its maximu can be (and usually is) less than 1.0, making it difficult to interpret.

7 **Nagelkerke's R-Square** is a further modification of the Cox and Snell coefficient to assure that it can vary from 0 to 1. That is, Nagelkerke's R^2 divides Cox and Snell's R^2 by its maximum in order to achieve a measure that ranges from 0 to 1.

8 **Deviance chi-square**: Because -2LL has approximately a chi-square distribution, -2LL can be used for assessing the significance of logistic regression, analogous to the use of the sum of squared errors in OLS regression. The -2LL statistic is the "scaled deviance" statistic for logistic regression and is also called "deviation chi-square," Dm, or L-square. It is called the "goodness of fit" test in SPSS, but some researchers call it the "badness of fit" test because deviance reflects error associated with the model even after the independents are included in the model. It thus has to do with the significance of the unexplained variance in the dependent.

9 **Goodness of fit**: A statistical test in which the validity of one hypothesis is tested without specification of an alternative hypothesis is called a goodness-of-fit test. *The general procedure consists in defining a test statistic, which is some function of the data measuring the distance between the hypothesis and the data (in fact, the badness-of-fit), and then calculating the probability of obtaining data which have a still larger value of this test statistic than the value observed, assuming the hypothesis is true.*

observed and expected frequencies. Then a probability (p) value, shown by Significance value, is computed from the chi-square distribution with 8 degrees of freedom to test the fit of the logistic model.

Table 4.9 Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	11.181	8	.192

According to the results in Table 4.10, the value is 0.192 indicates that the logistic model is a good fit. That is, if the Hosmer and Lameshow Goodness-of-Fit test statistic is .05 or less, we reject the null hypothesis that there is no difference between the observed and predicted values of the dependent; if it is greater, we fail to reject the null hypothesis that there is no difference, implying that the model's estimates fit the data at an acceptable level.

The results of logistic regression are presented in table 4.10.

Table 4.10 Results of Binary Logistic Regression

	B	S.E.	Wald	df	Sig.	Exp(B)
Display size	.450	.306	2.156	1	.142	1.568
Display resolution	-.295	.346	.727	1	.394	.744
Ease of Use	.455	.365	1.553	1	.213	1.577
Mobility	.264	.315	.706	1	.401	1.302
Durability	-.564	.349	2.609	1	.106	.569
Battery life	-.199	.314	.403	1	.526	.819
Memory/Storage	.673	.395	2.898	1	.089	1.960
Ease of Installation	-.525	.335	2.465	1	.116	.591
E-mail	.196	.264	.555	1	.456	1.217
Entertainment	.175	.287	.372	1	.542	1.191
Web Surfing	-.659	.345	3.649	1	.056	.517
Financial Services	-.561	.300	3.497	1	.061	.571
E-commerce	.560	.315	3.157	1	.076	1.750
Stock trading/info.	.133	.258	.264	1	.607	1.142
GPS, navigation	.073	.290	.064	1	.800	1.076
Travel info.	.035	.323	.012	1	.914	1.035
E-government	.288	.272	1.121	1	.290	1.333

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Table 4.10 Results of Binary Logistic Regression (Continued)

	B	S.E.	Wald	df	Sig.	Exp(B)
Education	-.140	.259	.293	1	.589	.869
Working	.025	.282	.008	1	.931	1.025
Emergency	-.126	.243	.269	1	.604	.881
Network Stability	-.265	.382	.481	1	.488	.767
Network Security	.205	.348	.349	1	.555	1.228
Network Speed	-.101	.459	.048	1	.826	.904
Always on	.152	.339	.199	1	.655	1.164
Ease of Use (software)	.310	.378	.673	1	.412	1.364
Cost of Hardware	.625	.325	3.694	1	.055	1.869
Internet connection fee	-.497	.354	1.965	1	.161	.609
Payment Method	.461	.266	3.003	1	.083	1.585
Age	.611	.437	1.951	1	.163	1.841
Gender	.677	.448	2.282	1	.131	1.968
Income Level	.120	.302	.159	1	.690	1.128
Address	.009	.103	.007	1	.934	1.009
Constant	-3.410	2.521	1.830	1	.176	.033

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The Wald statistic[10] and the corresponding significance level test the significance of each of the independents in the model.

At 90% confidence level, the model is shown as following:

Log [Probability of subscribing to wireless Internet services] =
[Probability of not subscribing to wireless Internet services]

0.673 (memory/storage) – 0.659 (web surfing) – 0.561 (financial services) + 0.56 (e-commerce) + 0.625 (Cost of end-user device) + 0.461 (payment method) -4.602

The Direction of Influence

The implications from this analysis demonstrate that memory and storage have a positive influence to the demand as can be seen from the growing mobile applications and mobile phone capabilities regarding multimedia usage such as Photography, MP3 player, and Video player.

While small transactions are preferred to do over wireless networks, larger transactions (represented by "Financial services"), which is usually required middle person such as bankers, is likely to do more on wired networks or networks that support higher level of security. This implication can also be used to describe a variable such as "web surfing" as it is more comfortable to do on desktop or notebook PC.

Cost of end-user device is also considered as a significant factor since wireless Internet services are usually supported and easier to use on high-end device such as pocket pc phone edition, smart phone, etc. The pricing of these high-end devices could increase their value to consumer perceptions and can also be a barrier to adopt these devices as well.

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[10] Computationally, the Wald test is a "Z" test using the logistic coefficient for a given independent variable, divided by its standard error (S.E).

The Magnitude of the Effect

As the direction of influence can be seen using the value of coefficient B, odds ratio[11] (demonstrated by Exp(B)) indicates magnitude of the effect.

The ratio of odds ratios of the independents is the ratio of relative importance of the independent variables in terms of effect on the dependent variable's odds. For the dichotomous case, a unit increase in the independent variable is associated with a log B of the dependent variable (the natural log of the probability that the dependent = 1 divided by the probability that the dependent = 0).

For example, according to the results in Table 4.10, for a one-level of importance increase regarding memory and storage, a consumer was 1.568 times (56.8 % increase) more likely to subscribe to wireless Internet access. The implications of all the significant variables are summarized in table 4.11.

Table 4.11. Relationship between Probability of Independent Variable and Dependent Variable

Variable	Relationship between probability of independent variable and dependent variable
Memory/Storage	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future
Web Surfing	Probability decreases, less chance of respondent to subscribe to wireless Internet services in the future
Financial Services	Probability decreases, less chance of respondent to subscribe to wireless Internet services in the future

[11] ***Odds*** is the ratio of the probability something is true divided by the probability that it is not.

Table 4.11. Relationship between Probability of Independent Variable and Dependent Variable (Continued)

Variable	Relationship between probability of independent variable and dependent variable
E-commerce	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future
Cost of Device	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future
Payment Method	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future

4.2.2. Current User Analysis

The sample size for user analysis is equal to 113 respondents. The data was collected randomly with one condition that the respondent must be using any kind of wireless data services.

Test 1: Reliability Test

Using the same cutoff value of Cronbach's alpha in Part I, all variables related to demographic data, hardware, software, and network pass the test with high reliability results. However, the variables related to sociology and business practices are not be able to pass this test.

Test 2: Confirmatory Factor Analysis

Before proceed with factor analysis, the following tests are performed:

(1) KMO and Barlett's Test

According to the results, Kaiser-Meyer-Olkin Measure of Sampling Adequacy yields the value of 0.697 which is higher than cutoff value, indicating enough sampling adequacy.

(2) Barlett's test of sphericity

The test results are shown as follows:

Approx. Chi-square = 1324.027

df = 528

Sig. = .000

The test yields the significant value of .000 which is less than 0.5. Thus, these variables can be examined using factor analysis.

(3) Communalities

By using to the cutoff value of 0.5, all variables except "Network Stability" have the value of communality more than 0.5 and are able to pass the test.

The Principal Component Analysis method is used as an extraction method. To make the output more understandable and facilitate the interpretation of factors, the ration method of Varimax is used for categorizing factors based on related value of factor loading. The variables are then categorized into factors based on the value of factor loading and shown as follows:

Rotated Component Matrix

(1) Software and Financial services

(2) Hardware

(3) Network (group 1) ‘

(4) Demographic group 1: Age and Income

(5) Web Surfing and Entertainment

(6) Network (group 2): Network Security

(7) Educational level and E-mail

(8) Address, Cost of End-user device

(9) Payment Method

Software and applications are the most important factor to be considered. This is because the current user normally has a specific need before considering buying a device. This need would be difference for each user and would be able to overcome the disadvantages such as high cost, low speed of network, as we can see from the selected critical applications such as financial services, stock trading and stock information.

The supported hardware and network factors to the applications are categorized in second and third factor accordingly. However, "Network Security" became so important that it can be considered alone as sixth factor.

The importance of affordability can be seen in forth factor which consists of age and income variables.

The other applications that required large bandwidth are included in fifth factor. This may be because the current network infrastructure is still not able to cope with these application requirements.

Address and Cost of End-user device are put into the same category as the more expensive and advance device, the more coverage area and types of connections you can get from one device.

The other interesting point from these results is the seventh factor which might be interpreted as the usage of e-mail has some kind of relationship with level of education.

4.2.3. Generalized Model- Statistical Tests for Model Specifications regarding All User

To make the model more concrete, we added our data with the response from current wireless Internet users. The sample size for analysis is equal to 540 respondents. The data was collected randomly without any condition.

Test 1: Reliability Test

Using the same cutoff value of Cronbach's alpha, all variables related to demographic data, hardware, software, and network pass the test with high reliability results. However, the variables related to sociology and business practices are not be able to pass this test.

Test 2: Factor Analysis

Before proceed with factor analysis, the following tests are performed:

(1) KMO and Barlett's Test

According to the results, Kaiser-Meyer-Olkin Measure of Sampling Adequacy yields the value of 0.834 which is higher than cutoff value, indicating enough sampling adequacy.

(2) Barlett's test of sphericity

The test results are shown as follows:

Approx. Chi-square = 4021.410

df = 528

Sig. = .000

The test yields the significant value of .000 which is less than 0.5. Thus, these variables can be examined using factor analysis.

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(3) Communalities

By using to the cutoff value of 0.5, all variables except "Level of Education" have the value of communality more than 0.5 and are able to pass the test.

The Principal Component Analysis method is used as an extraction method. The technique of Equamax, which combined concepts of Varimax and Quartimax, is used for categorizing factors based on related value of factor loading. The results are demonstrated as following:

Rotated Component Matrix

(1) Software

(2) Network

(3) Financial Services

(4) Hardware 1: Durability, Battery Life, Memory/Storage, Ease of Installation

(5) Hardware 2: Display size and resolution, Ease of Use, Mobility

(6) Demographic: Income, Age, Educational Level

(7) Entertainment and Web Surfing

(8) Cost of end-user device, Cost of Internet Connection Fee

(9) Payment method

Overall, software is still considered as the most important factor. This means that consumers are looking at the software, services, and application which can be supported by a device and networks with objectives of usage and certain level of expectations in their minds. Network operators and service providers can take this knowledge to provide more innovative and customized application in order to attract more customers.

The other software and applications that required large bandwidth and are not fully supported by current network infrastructure can be viewed as an additional benefits to consumers.

Cost and pricing strategy for both end-user device and connection fee must be planned together in order to increase consumers' willingness to pay and subscribe for fulfilling needs in using their expected applications.

Test 3: Logistic Regression

The regression model was constructed based on the purpose of demonstrating how the independent variables influence demand for both current users and non-users.

The significance tests of the proposed model are performed first to justify if it is appropriate to use this method. The model summary and the results of Hosmer-Lemeshow test are demonstrated in table 4.12 and 4.13 accordingly.

Table 4.12. Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	199.803	.146	.274

Measure strength of association: Goodness of fit and Coefficients of Determination Pseudo R^2 (Nagelkerke R^2)

R^2-like measures for dichotomous variable are not goodness-of-fit tests but rather attempt to measure strength of association. According to the result in table 4.12, 27.4 % of variance can be explained by logistic model.

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Loglikelihood test for Validity of Hypotheses / model: Hosmer-Lemeshow Test

Table 4.13 demonstrates the results of Hosmer and Lemeshow test. Using the same cutoff value as in Part I, the results yield the value of 0.535 which means that the model fails to reject the null hypothesis that there is no difference, implying that the model's estimates fit the data at an acceptable level.

Table 4.13. Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	7.014	8	.535

The results of logistic regression are presented in table 4.14.

Table 4.14. Results of Logistic Regression - Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)
Display Size	.499	.283	3.104	1	.078	1.647
Display Resolution	-.085	.336	.064	1	.800	.918
Ease of use	.326	.348	.874	1	.350	1.385
Durability	-.281	.294	.912	1	.340	.755
Ease of installation	-.380	.302	1.584	1	.208	.684
E-mail	.135	.259	.271	1	.602	1.144

Table 4.14. Results of Logistic Regression - Variables in the Equation (Continued)

	B	S.E.	Wald	df	Sig.	Exp(B)
Entertainment	.223	.272	.671	1	.413	1.250
Web Surfing	-.545	.319	2.910	1	.088	.580
Financial Services	-.532	.282	3.559	1	.059	.587
E-Commerce	.479	.296	2.615	1	.106	1.615
Stock info. And trading	.246	.246	1.005	1	.316	1.279
Navigation system, GPS	.068	.262	.068	1	.795	1.071
Travel info.	-.077	.294	.068	1	.795	.926
E-government services	.152	.252	.364	1	.546	1.164
Educational services	-.380	.236	2.593	1	.107	.684
Work, business purposes	.206	.250	.676	1	.411	1.229
Network Stability	-.049	.343	.020	1	.886	.952
Network Security	.180	.318	.321	1	.571	1.197
Network Speed	.199	.428	.216	1	.642	1.220
Always online	.171	.325	.278	1	.598	1.187
Ease of using software and application	.334	.349	.911	1	.340	1.396

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Table 4.14. Results of Logistic Regression - Variables in the Equation (Continued)

	B	S.E.	Wald	df	Sig.	Exp(B)
Cost of device	.576	.315	3.345	1	.067	1.779
Internet connection fee	-.436	.336	1.681	1	.195	.647
Payment Method	.474	.246	3.699	1	.054	1.606
Age	.740	.395	3.503	1	.061	2.095
Gender	.504	.416	1.467	1	.226	1.656
Income level	-.141	.263	.288	1	.592	.869
Constant	-4.587	2.378	3.720	1	.054	.010

The Wald statistic and the corresponding significance level test the significance of each of the independents in the model.

At 90% confidence level, the model is shown as following:

Log [Probability of subscribing to wireless Internet services] =
[Probability of not subscribing to wireless Internet services]

0.499 (Display size) – 0.545 (Web Surfing) – 0.532 (Financial Services) + 0.479 (E-commerce) – 0.38 (Educational services) + 0.576 (Cost of device) + 0.474 (Payment Method) + 0.740 (age) – 4.587

The Direction of Influence

The same factors found in the model of non-user are found this model as well. These factors include web surfing, financial services, E-commerce, cost of device, and payment method. However, the factors such as age, educational services, and display size are also added to the model.

Display size has a positive influence to demand as consumers tend to prefer larger screen and higher resolution for multimedia capabilities. This can also attract developers to create their mobile versions of popular software.

Applications related Educational services (for registration, Distance learning) has negative influences to consumer demands as these fields still suffer from current controversies in Thailand (issue of standard in distance learning that is still not well established and widely accepted).

The Magnitude of the Effect

As the direction of influence can be seen using the value of coefficient B, odds ratio (demonstrated by Exp(B)) indicates magnitude of the effect.

For example, according to the results in Table 4.14, for a one-level of importance increase regarding display size, a consumer was 1.647 times (64.7 % increase) more likely to subscribe to wireless Internet access. The implications of all the significant variables are summarized in table 4.15.

Table 4.15. Relationship between Probability of Independent Variable and Dependent Variable

Variable	Relationship between probability of independent variable and dependent variable
Display size	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future
Age	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future
Educational services	Probability decreases, less chance of respondent to subscribe to wireless Internet services in the future

Table 4.15. Relationship between Probability of Independent Variable and Dependent Variable (Continued)

Variable	Relationship between probability of independent variable and dependent variable
Web Surfing	Probability decreases, less chance of respondent to subscribe to wireless Internet services in the future
Financial services	Probability decreases, less chance of respondent to subscribe to wireless Internet services in the future
E-commerce	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future
Cost of device	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future
Payment method	Probability increases, greater chance of respondent to subscribe to wireless Internet services in the future

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4.3 Cost Modeling

This section presents the results of technical cost modeling based on current implementations in Thailand, technical limitations, and international standards.

This section is further divided into two sections including the cost models of cellular networks and potential hi-speed network based on Wi-Max technology accordingly.

4.3.1 Overview of the Current Network Infrastructure

GSM-based Network

Two GSM operators in Thailand, AIS and DTAC selected solution from Nokia in order to upgrade their existing GSM network to be EDGE-capable network. The Nokia's solution includes transceiver units such as Nokia UltraSite base stations, base station controller upgrades, and a mobile switching center.

However, AIS selected Ericsson for providing EDGE upgrade in Bangkok metropolitan area. The Ericsson solution requires no change in core network as same as Nokia and includes Base Transceiver Stations (BTS) such as RBS 2206 or upgraded RBS 2000 and software for flow controlling.

Enhancing a GPRS network is accomplished through evolution with EDGE within the existing spectrum and by deploying WCDMA in the new frequency band. EDGE can be seen as a foundation toward one seamless GSM and WCDMA network with a combined core network and different access methods that are transparent to the end user.

CDMA-based Network

In Thailand, Hutchison Wireless MultiMedia Holdings, Ltd. and The Communications Authority of Thailand (CAT) has selected Motorola Global Telecom Solutions Sector (GTSS) to implement the Network Enabling Services Platform.

Motorola's CDMA 2000 1x solution utilizes a distributed IP-RAN (Radio Access Network) architecture that integrates packet-based network elements to support packet-based services independently of the voice traffic. This approach supports both bursty services, such as data, and continuous services such as voice effortlessly on the same network.

Even though, ITU's 3G concept, known as IMT-2000, included several other accepted technologies for 3G systems. However, the referenced WCDMA + GSM combination will be the most widely used. The simple reason for this is the fact that among the 2G mobile cellular networks, GSM is by far the most widely used technology. All of the significant 3G proposals for IMT-2000 are those that successfully protect the investments in their 2G legacy networks in a 3G world. The 3GPP work strives to protect the GSM investments and bring the markets into 3G. The present-day operators will not want to invest in new networks if they cannot recycle their existing GSM networks. Most big network manufacturers and operators are actively supporting this approach. So, for these operators, this 3G solution is a good deal because they can continue to use their upgraded GSM networks.

However, GSM operators also have an option to enhance their systems with EDGE and possibly WLAN hot-spot coverage, which are relatively inexpensive when compared to 3G investments.

Note that the easy accommodation of GSM for the UMTS requirements may also be a problem for new UMTS operators because the existing GSM (non-UMTS) operators can provide almost the same services without the extra UMTS investments. The competition will be hard for the new UTMS operators in the early phases, and it is especially hard for the new UMTS operators, which do not have an existing 2G network. It is very expensive for them to build out wide-area-coverage 3G networks

while they don't have any income from existing networks. Furthermore, in many countries the operating licenses are very expensive. The combined cost burden from the licensing fees, interest, and network construction can push a new green-filed operator into a very unfavorable position.

The solution could be that Telecommunications authorities may ease the situation by forcing the current 2G network operators to lease their networks to new 3G operators so that they can provide wider coverage for their customers from the beginning. This method was used in many countries.

This leads us to provide the scenarios for Cost Modeling as follows:

4.3.2. Potential of Low-speed data networks: Cost Modeling Scenarios of Cellular Networks

The models developed for 3G networks including GSM-EDGE, GSM-WCDMA, and CDMA have been compared to each other to yield insights into their relative costs to the hypothetical Thailand operator.

Four scenarios have been developed to explore these customizations. They represent a more realistic migration path toward mobile data networks by combining the models in different configurations.

Scenario 1: Installing an all-new GSM-EDGE network

This scenario describes an operator implementing a new cellular network by utilizing 2.75G technology.

Scenario 2: Upgrading the existing GSM-EDGE network to WCDMA network

This scenario describes a GSM operator beginning to offer data services based on 3G technology by upgrading their existing GSM-EDGE system. It is interesting to note that the cost of upgrading from GSM-GPRS network to GSM-EDGE is less than

upgrading from GSM-EDGE to GSM-WCDMA since EDGE only needed minor changes in transceiver stations.

Scenario 3: Installing an all-new CDMA 2000 1x EV-DO network

This scenario describes an operator beginning to offer 3G data services based on CDMA 2000 1x EV-DO technology. Compared with further investment solely in EDGE or WCDMA, CDMA technology is more cost-efficient for new mobile operators when considered the data rate achieved.

Scenario 4: Installing an all-new WCDMA network

This final scenario represents an operator approaching the wireless market as a new competitor. This operator would be able to build a purely WCDMA network without existing GSM infrastructure.

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Analysis and Comparison of the results

Results and its graphical representation of cost modeling for potential low speed wireless network are demonstrated in Table 4.16 and figure 4.1 accordingly.

Table 4.16. Cost Modeling of Cellular Networks

Scenarios	2005	2006	2007	2008	2009
GSM-EDGE					
GSM-EDGE capital costs*	6,334.54	5,701.09	5,130.98	4,617.88	4,156.09
GSM-EDGE Operating Costs*	2.37	2.48	2.61	2.74	2.87
Total Cost of installing new GSM-EDGE	6,336.91	5,703.57	5,133.58	4,620.62	4,158.97
Upgrading Capital Cost [EDGE to WCDMA]	38,007.24	34,206.52	30,785.86	27,707.28	24,936.55
Total cost of installing WCDMA through existing EDGE infrastructure	44,344.15	39,910.09	35,919.45	32,327.90	29,095.52

*Cost per subscriber; All costs are in Thai Baht (1US$ = 40 Thai Baht).

Table 4.16. Cost Modeling of Cellular Networks (Continued)

Scenarios	2005	2006	2007	2008	2009
WCDMA					
New WCDMA capital costs	76,014.48	68,413.03	61,571.73	55,414.56	49,873.10
Operating Costs	2.37	2.48	2.61	2.74	2.87
Total cost of installing new WCDMA	76,016.85	68,415.52	61,574.34	55,417.29	49,875.98
CDMA 2000 EV-DO					
CDMA Capital costs	6,581.63	5,923.47	5,331.12	4,798.01	4,318.21
CDMA Operating Costs 1xRTT cdma2000	1.57	1.65	1.73	1.82	1.91
Total Cost of installing new CDMA 2000 EV-DO	6,583.20	5,925.12	5,332.85	4,799.83	4,320.12

*Cost per subscriber; All costs are in Thai Baht (1US$ = 40 Thai Baht).

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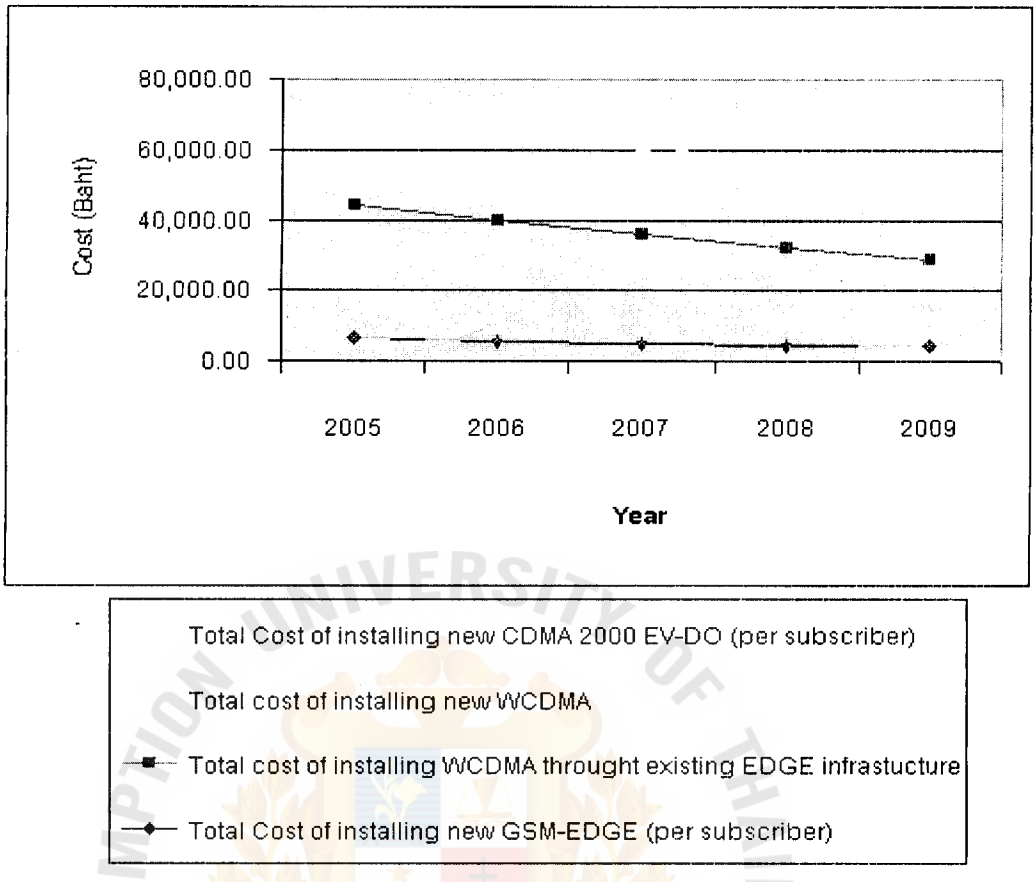

Figure 4.1. Graphical Results of the Cost Models

Current operators face many options in upgrading their infrastructure in order to support data services. The cost model demonstrates that upgrading the GSM- GPRS network to EDGE and WCDMA-capable network would be appropriate to existing GSM operators as it costs less than deploying new WCDMA network or changing their underlying technology to CDMA 2000 1X- based network. The new entrant can consider the CDMA 2000 1X EV-DO network as it provides low cost of installation and still support high data rate for the third generation data services.

4.3.3. Potential of High-speed (Broadband) data networks: Cost Modeling of WiMax Network

Broadband wireless provides one of many physical layer options for the operator of a public service network. Furthermore, the different wireless networking technologies themselves exhibit widely varying capabilities for fulfilling the needs and expectations of various customers and enterprise. The singular strength of wireless broadband access technologies is the degree to which they lend themselves to pervasive deployments. Wireless increasingly be characterized by their impermanence and flexibility, and as such they will be complementary to be expensive albeit extremely fast fiber-optic linkages.

Assumptions and Scenario for WiMax in Thailand

The cost modeling of High-Speed data networks is modeled according to the 802.16a, revision d standard (WiMax) since its major rollout is anticipated in 2005 (after WiMAX conformance testing). While Wi-Fi is ubiquitous in laptops, it cannot go much beyond 100-300 feet. WiMax is designed for longer range, perhaps 31 miles in a fixed network (or 1-3 miles in a mobile (802.16e) configuration) and still allows users connectivity without a direct line of sight to a base station.

Unlike cellular solutions like EV-DO, WiMax can use inexpensive base stations, unlike WiFi access points, and may use an Ethernet (IP) backbone rather than a proprietary cellular backend. It can use licensed (2.6 & 3.5GHz) and unlicensed (2.4 & 5 GHz) bands.

In this paper, the cost of implementation is mostly based on the cost of physical infrastructure. This paper does not cover factors such as selection of network topology, frequency reuse, and cell planning since these issues can be varies according

to each service provider. Assuming Greenfield Network, the major capital expenditure components and operating expenditures can be clarified in Table 4.17.

Table 4.17. Major Capital Expenditure Components and Operating Expenditures

Major Capital Expenditure Components	Operating Expenditures
CPE investments	Roof/tower lease
Installation and commissioning CPE	Base station and O&M
Radio/Network planning	CPE O&M
Base station investment	Network O&M
Roof/tower site acquisition cost	NOC O&M
IP switching/routing network	Leased line rental
Backhaul	Office expenses
Network management and NOC	Advertising/ subscriber acquisition
Customer care and billing	Facilities

The technology also provides shared data rates up to 70 Mbit/s, which, according to WiMAX proponents, is enough bandwidth to simultaneously support more than 60 business users with T1-type connectivity. The capital expense per base station is shown in Table 4.18.

Table 4.18. Capital Expense (CAPEX) per Base Station

Description	Scenario	Comments
Wi-Max Equiment	$35K per Base station for 4 sector/ Channel configuration	+$7K per channel for additional channels/sectors
Other Base station Equipment	$15K	Covers any necessary cabinets, network interface cards, etc.
Backhaul Link	$400 for installation satellite link (CS/Loxinfo's satellite-based service, iPSTAR)	Allows for at least one multiple hop in rural area
Core & Edge Equipment	$100K	Router on ATM , Switch, NMS, etc.
Spectrum License	n/a	
Base station Acquisition & Civil Works	$50K Average per BS	Includes indoor and outdoor site preparation, indoor to outdoor cabling, etc.

ADSL, fiber optics and satellite are Backhaul links that are available in Thailand. In this model, satellite is a preferable choice since its footprint almost covers all of the metropolitan and rural areas and there is no Line-Of-Sight (LOS) problem.

Regarding the spectrum license, the issue of spectrum availability is still under the consideration of the National Telecommunication Commission. The operating expense is shown in Table 4.19.

Table 4.19. Operating Expense of Wi-Max

Description	Scenario
Network Operations	10% of gross revenue in year 1 dropping to 7% in year 5
Equipment Maintenance	5% of CAPEX for Base Station Equipment
Backhaul link	approximately $175 per month

Analysis and Comparison of the results

The total cost of installing Wi-Max is shown in Table 4.20 and its graphical representation is presented in Figure 4.2.

Table 4.20. Cost Modeling of WiMax

	2005	2006	2007	2008	2009
WiMax Capital Expenses	133600	120240	108216	97394.4	87654.96
WiMax Operating Expenses	14000	14700	15435	16206.75	17017.09
Total Cost of Installing WiMax	147600	134940	123651	113601.2	104672

*Cost per business users with T1-speed connectivity

*Cost per subscriber; All costs are in Thai Baht (1US$ = 40 Thai Baht).

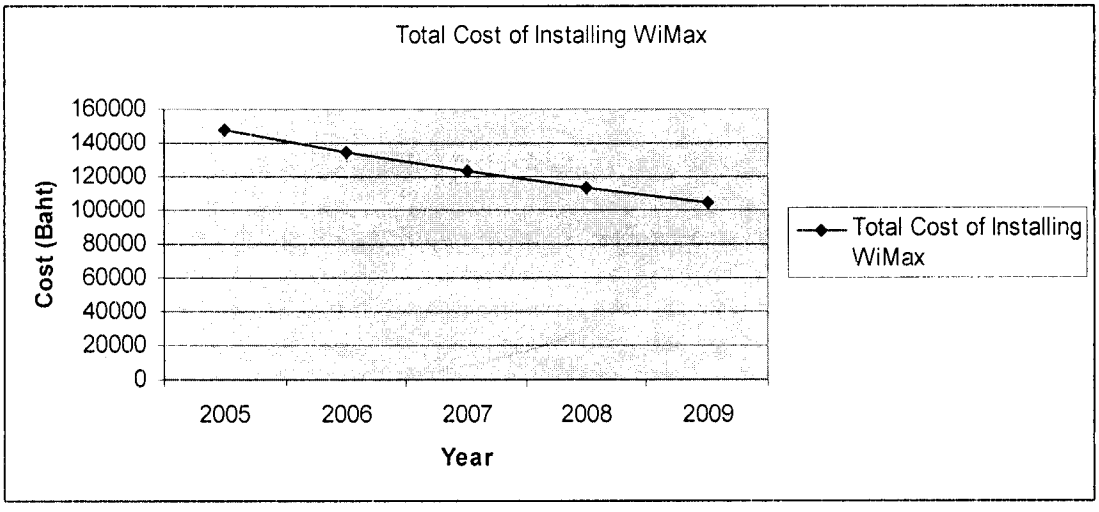

Figure 4.2. Graphical Results of WiMax Cost Modeling

The cost of installing Wi-Max networks is significantly higher than networks utilizing cellular technologies. However, WiMax can handle more applications including Voice Over IP (VoIP), HotSpot Backhaul, etc.

In developing countries, due to lack of suitable access alternatives and high demand, one can expect higher market penetrations and quicker adoption rates than in developed countries. Also, the availability of portable devices based on IEEE 802.16 in the near future will provide additional business opportunities for the WiMax operator.

Discussion of Cost Models

The results of the economic modeling demonstrate the relationship between the wireless technologies and their cost of installation. With the existing GSM network, current operators are likely to choose to upgrade their network to be EDGE and then, WCDMA capable network as this method costs less than switching technology to CDMA or deploying new network for WCDMA.

However, the new entrant for data service competition is likely to choose CDMA as it provides adequate data rate for 3G and minimal total cost of installation.

Deploying new WCDMA network is still a choice for new entrants who want to position themselves as a leading data service provider.

While 2.75G and 3G cellular networks are able to deliver acceptable data speed to subscribers, alternate technologies such as WiMax can be viewed as a supplementary service to wireless Internet access. By combining two technologies together, high-speed data networks can be created for business or enterprises that consider speed, connectivity, and coverage areas as their critical issues.

The results of the cost modeling demonstrate the possibility is creating data networks comprising several technologies. Operators can choose among these technologies in order to provide integrated network that would benefit the most to themselves and their subscribers.

4.4 Conclusion

The results of expert interview and the empirical results are demonstrated in this chapter. The empirical results are divided into three sections; a model for non-user (consumer who is not subscribing to any wireless Internet services), an analysis of current users (consumers who is currently subscribing to one or more wireless Internet services), and a generalized model for most consumer.

The cost models for low-speed data network are constructed based on the nature of cellular technologies. These cost models are modeled toward the third generation of cellular network, which is the common milestone for many developing countries. The cost models for high-speed data network are constructed based on the structure of Wi-Max technology since its standard is widely accepted and thus makes it the best candidate for high-speed data network that is not based on cellular technologies.

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V. FINAL RESULTS

In Chapter 4, the consumers' point of view is examined and explained in the form of an econometric model. The model derived from the survey represents the future demand for hi-speed mobile networks and users' expectation in terms of applications, network conditions and payment preference.

As presented earlier in the research methodology chapter, Chapter 5 was then followed to offer the viewpoints of service and network providers as suppliers of the networks. The economical effects and related technical issues are presented using the cost modeling techniques.

In this chapter, an attempt will be made to combine the results from both the demand and the supply sides of the future hi-speed mobile networks. The aim of this chapter is to explain possible business models and usage scenarios of the hi-speed mobile industry in the future.

5.1 Detailed methodology: Sensitivity analysis using cost modeling

The results of demand analysis are customized according to each scenario. The scenarios are constructed based on current implementation (market position and network infrastructure). The cost models are used to provide available alternatives and demonstrate associated consumer benefits and costs of service provider. This would eventually help to pinpoint the balance between demand and supply.

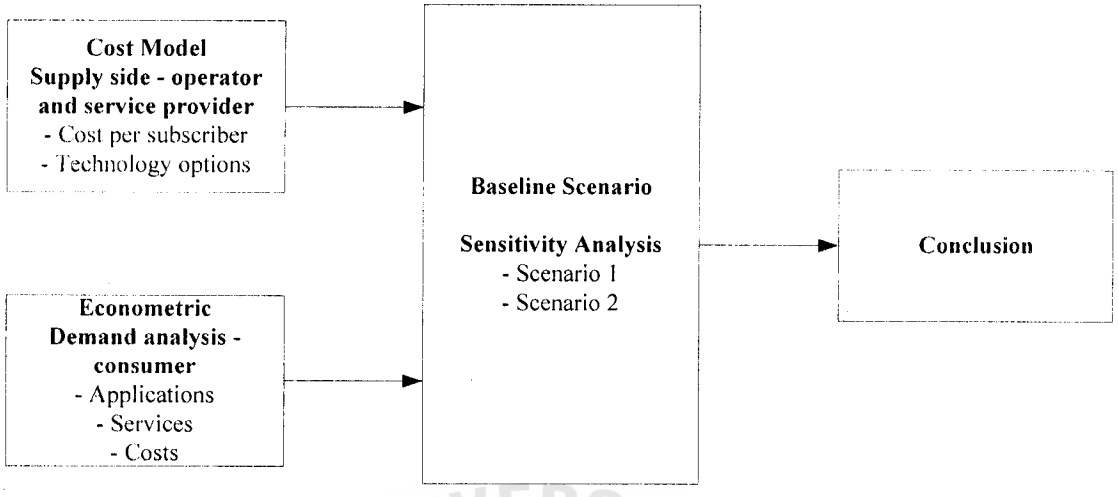

Figure 5.1. Detailed Methodology – Sensitivity Analysis using Cost Modeling

Our findings yield the results of cost models and demand analysis. To be best described and interpreted these results, the method of sensitivity analysis is applied to this final phase of the research.

Sensitivity Analysis is a procedure to determine the sensitivity of the outcomes of an alternative to changes in its parameters (as opposed to changes in the environment; see contingency analysis, a fortiori analysis). If a small change in a parameter results in relatively large changes in the outcomes, the outcomes are said to be sensitive to that parameter. This may mean that the parameter has to be determined very accurately or that the alternative has to be redesigned for low sensitivity.

Sensitivity analysis is used to ascertain how a given model output depends upon the input parameters. This is an important method for checking the quality of a given model, as well as a powerful tool for checking the robustness and reliability of its analysis.

In this chapter, sensitivity analysis is divided into two scenarios based on current market situations in Thailand and the theory of technology life cycle. The amount of data transfer based on demand analysis is varied in order to project the effects in network infrastructure.

5.2 Scenario Assumptions

Usage and applications in cost modeling

Considering the sensitivity analysis which capacity of these two technologies are varied, capacity is then measured in "calls per cell per MHz" for the comparison purpose (Walter Tuttlebee 2002).

Given the knowledge of number of subscribers, number of base stations and cell coverage area, the researcher can calculate the approximated number of call per cell per MHz. In order to verify the results, technical constraints of each technology are used for comparison. These numbers are calculated by assuming that data rate per connection is equal to 25 kbps (current GSM bandwidth per user).

GSM Network Capacity

For all types of second generation cellular networks, which are digital, more than one person can carry on a conversation on the same frequency without causing interference. However, the difference can be seen at the underlying technologies. CDMA-based network lets everyone transmit at the same time using various techniques of signal modulation. TDMA-based network lets one person using the channel for short bursts of period at any given moment. To be able to compete with CDMA, TDMA continues to improve the channel allocation by utilizing the concept of frequency hopping which allows the transmission to jump from one channel (Radio Frequency) to another at fairly short interval.

The following assumptions are added in order to make the calculation possible: All base stations are able to be assigned at any available GSM frequency / carrier, Cluster size for GSM-based network is equal to seven (Valeri P. Ipatov 2005)

So, based on our assumption and technical constraints, there are approximately 2 connections per cell per carrier for GSM- based network compared with the technical limitation which has maximum 3 connections per cell per carrier.

CDMA Network Capacity

CDMA utilizes the special type of digital modulation called spread spectrum. This form of modulation takes the user's stream of bits and splatters them across a very wide channel in a pseudo-random fashion. Thus, CDMA could let everyone transmit at the same time on the same frequency. CDMA generally uses nine of 1.25 MHz carriers per cell.

The current number of 980 users per cell yields the result of 108 connections per cell per carrier for CDMA-based network compared with the technical limitation (the assumption of data rate equal to 25 kbps) of 45 connections per cell per MHz. However, considering that current number of CDMA subscribers in Thailand is still very few and confined within some areas such as metropolitan area, there is no need for CDMA operator to invest regarding base stations to reach maximum capacity right now. In addition, the contract between concession operator and government also stated the certain number of subscribers to be reach for every certain period of time (for the concession period of ten years).

5.3 Baseline scenario

A baseline scenario is used to present the current situation of the networks and consumer usage. It will be used as a tool to provide a baseline for the sensitivity analysis. The baseline scenario for the Internet mobile networks is as follow.

Table 5.1. Baseline Scenario

	Technology	Speed	Narrow/ Broadband	Cell Coverage	Subscriber per cell	Total Cost per subscriber (Baht)
EDGE	2.75G	180 Kbps	Narrowband	1-35 km	1530 (current, average number)	6336.91
WCDMA	3G	2 Mbps	Broadband			44344.15
CDMA 2000	3G	614.2 kbps	Broadband	1 – 10 km	980 (current, average number)	6583.20
WiMax	802.16	70 Mbps	Broadband	Less than 450 m at 2.6 GHz	60 T1-users	76016.85

This baseline scenario is based on the theory of product lifecycle which has always been applied to many research in telecommunication filed including the growth of mobile handset sales over the past 20 years, the rise and fall of telex, and fax. The product lifecycle theory comprises of four stages, which are introduction, growth, maturity and decline.

Looking at the four stages, one can conclude that *technical, network and supply issues, and marketing and demand areas*, predominate at different stages of the cycle.

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In stage 1, the predominant issues for operators concern technology and reach (supply) rather than the market or customers (demand). Stage 2 is all about building a mass-market position and requires different skills from the passive approach to marketing and demand stimulation that operators used in stage 1. Hence, marketing becomes the focus as operators stimulate demand for their products.

At the mature stage (stage 3), demand has slowed and so retention is more important than acquisition. In a mature market, competition is fierce and margins are low, so it is imperative that an operator has low unit costs. Consequently, demand and supply issues have equal weight. At stage 4, the challenge for operators is to reduce costs to maintain profitability. Thus there is an equal focus on the supply and demand sides of the equation.

5.4 Sensitivity Analysis: applying the logic to Wireless Internet Market

Currently, the wireless Internet market is still considered to be in stage 1 of product life cycle, where the growth will continue by the major push of technical advancement. Operators and providers need to change the model in the same way the mobile telephone industry did in the late 1980s. By inventing a low-cost entry price point in pre-pay or pay-as-you-go services, along with subsidized handsets, they transformed take-up of mobile phones.

Thus, the scenarios have been constructed based on demand analysis in order to cope up with the changes from the aspects of operators and providers.

If one assumes that the current applications and usage traffic are to remain the same in the future, GSM technology still has some room left before congestion will happen.

At present, CDMA operators still have not yet provided enough base stations according to the concession with the government. However, this will certainly

changed in the near future as the operators will have to complete their responsibilities and put in the complete networks.

After both technologies are in place, one can expect to see fiercer competition and more variety services. Possible scenarios and results could be the followings.

Scenario 1: crossing the chasm- increasing traffic with new customers

A critical phase or the chasm between stage 1 and stage 2 (from the last early adopters to mainstream acceptance of the product), is vital to long-term value creation and market dominance.

The company should focus on a solution for a problem built around the needs of a niche market. This total solution is called a "whole product," an imperative for penetrating the pragmatic buyers, and can be defined as "the minimum set of products and services necessary to ensure that the target customer will achieve his or her compelling reason to buy." The whole product created for a niche market represents the potential of successful entry into the mainstream market.

Table 5.2. Approximated Amount of Data by Application (Jackson 1998)

Application	Approximated amount of data
SMS/E-mail	30 kb
Web browsing	40 kb
Web interaction	100 kb
Voice over IP	167 kb
Audio	325 kb
Video	500 kb

The current approximation of bandwidth used per cell is 50 kbps for GSM. As the traffic grows based on demand analysis, the services including web surfing financial services, e-commerce could increase the traffic volume up to another 240 kb per person based on the approximated amount of data shown in Table. This can be added up to maximum 530 kbps per cell (= 100 + 100 + 40 = 240 kb).

However, due to limited bandwidth of EDGE network which can only support data rate of 180 kbps, all of the services and applications cannot be implemented at the same time. Thus, there are two alternatives for network operators and service providers. The first alternative is to make the most out of an existing network by setting a priority for each service and application to be implemented.

With the objective of attracting more customers during the first phase of network implementation by implementing selected services and applications, a principle of service selection can be derived based on the results of demand analysis.

Table 5.3. Significant Variables Related to Services and Applications and their Associated Coefficients

Variable	Coefficient
Web Surfing	– 0.659
Financial Services	– 0.561
E-commerce	0.56

All of these services and applications shown in table are significance to consumers. However, only E-commerce has a positive influence to consumer demand. While, the other two applications have negative influence to consumer demand, Web

surfing application has higher magnitude in term of influential when compared to financial services.

Thus, E-commerce application and service should be the first to be implemented to consumer. The consequence of this implementation will make overall bandwidth usage increased up to 150 kbps which can still be supported by EDGE network. Financial services and Web surfing application should be considered as second and third candidate accordingly.

The second alternative is to upgrade existing EDGE infrastructure to WCDMA in order to have enough bandwidth for every applications. One may consider this to be either a separate alternative or an extension after EDGE capacity has ran out after implementing selected services or applications in the alternative 1.

As for CDMA, the current approximation of bandwidth used per cell is 108 kbps. When considering the same results of demand analysis, CDMA-based network is still capable to support all of these three applications and services at the same time. Again, the same priority of implementation should be applied as well.

Scenario 2: Mainstream Acceptance- traffic is increased with same expected growth in scenario 1

As consumers feel more familiar with the technology after subscribing to wireless Internet service for a certain period of time, their behaviors and demands related to the technology will change. These changes regarding perceptions, knowledge, and attitudes toward certain wireless Internet services are modeled in Chapter 4 and will be applied to this scenario.

Table 5.4. Significant Variables Related to Services and Applications and their Associated Coefficients

Variable	Coefficient
Educational services	-0.38
Web Surfing	-0.545
Financial services	-0.532
E-commerce	0.479

Most of the significant variables related to services and applications used in this scenario are the same as in scenario 1. The difference is that the factor "Educational services" is added to the model. However, considering negative influence but with less magnitude than Web Surfing and Financial services, Educational services should be a better candidate than the other two factors.

So, once wireless Internet services have been accepted by mainstream consumers, it is likely that bandwidth will be increase up to 630 kb. This number is based on the assumption that Educational services will be more interactive and complicated than current plan of some operators which provide education services through MMS and SMS application.

Considering larger amount of data rate required for running all significant services and applications, GSM-based operator will have to upgrade their network infrastructure to WCDMA. CDMA-based operator will also have to upgrade their CDMA 2000 to at least CDMA 2000 1x EV-DO as well.

In sum, GSM-based operator does not have to immediately invest for a WCDMA network and could extend the lifecycle of current infrastructure through the period of scenario 1 using EDGE technology. Although, investment in EDGE technology costs

less than WCDMA, operator and service providers are required to invest in the applications expected by consumers such as E-commerce. These applications must be customized to be used in low data rate environment; in the case that operator decides to go through scenario 1 with EDGE technology.

An alternative is also available to an operator who could not invest for a WCDMA network. One can consider providing hi-speed data services through WiMax network, which, judging from the cost model is possible to coexist with cellular network.

This is in contrast with CDMA-based operator who can go through the period of scenario 1 without considering to upgrade their network infrastructure. However, the operator should focus on number of base stations and area coverage in order to catch up with GSM-operators.

5.5 Conclusion

This chapter demonstrates the limitations of each technology by varying consumer demands of the baseline scenario. Consumer demands are derived based on the empirical results in Chapter 4 and restated as two phases between transition periods of technology life cycle.

With the objective of maximize the capabilities of network and its technological lifetime as much as possible, the final results are explained by identifying the type of applications and services that are demanded by most consumers. However, the available alternatives are also pointed out for service providers.

VI. CONCLUSION

The research conclusion is presented in this chapter. The chapter begins with the current directions of application and service developments in Thailand related to wireless internet services. Researchers' findings, literature review, and results of expert interview are then compared in order to provide a recommendation and conclusion on how the directions of development can be changed and adjusted to achieve more benefits for both consumers and service providers.

6.1. Conclusion

The current and future developments related to wireless Internet services shown in table 6.1 are examined and categorized according to type of mobile operator.

Table 6.1. Recent Developments on Non-voice Applications and Services in Thailand

Type of Operators	Recent and future Non-voice Applications and Services	Technical Requirements
GSM Operators (AIS, True Orange, DTAC)	Educational services	SMS
	Free content Websites (e.g. AIS's nowLIFE Portal)	WAP-GPRS
	M-Pay	Can be implemented for both 2G and 3G network with added on wireless chip
	Contactless Card / 2D Barcode	Can be implemented for both 2G and 3G network with added on hardware

Table 6.1. Recent Developments on Non-voice Applications and Services in Thailand (Continued)

Type of Operators	Recent and future Non-voice Applications and Services	Technical Requirements
GSM Operators (AIS, True Orange, DTAC)	Better quality of Real-time TV and movies (through How-Come IP Ltd.)	GPRS
	Personal Advertisement for online selling	MMS
	Push-Email (Blackberry compatibility)	GPRS
	IP Telephony	GPRS or EDGE depends on an operator
	Wireless Data Services	EDGE
CDMA Operator (Hutch)	Navigation System	BREW Platform (153 kbps)
	Wireless Broadband Data Services	BREW Platform (153 kbps)
	International Data Roaming Services (between Japan and Thailand)	BREW Platform (153 kbps)
	PhotoMail 3D Stamp	BREW Platform (153 kbps)
	Food Ordering via voice instead of dialing phone number	BREW Platform (153 kbps)

One can see from the list of recent developments of each operator regarding applications and services that they are trying to maximize current potential of their network with these coming innovative services and applications.

For GSM Operators, even the demanding real-time data services are still relied on GPRS network instead of EDGE network. This provides CDMA operator to have a slightly advantage on offering data services with higher speed and thus focuses more on target customers who are corporate and business users.

With the effects of deregulation, the competition of non-voice services will be more intense as operators are moving toward the same trends of applications such as streaming or real-time data services. For example, various types of navigation systems are offered by both GSM and CDMA operators. The differences between these two types of operators are speed and area coverage. Most of the GSM operators set lowest requirement for using navigation system to be GPRS compared to BREW platform of CDMA operator. However, GSM operators still have more coverage area than CDMA operator.

As operators are competing to gain leadership by implementing applications and services with respect to consumer demands as well as balancing their assets and investment, the comparison of the results between researchers' findings, literature review, and the results of expert interview along with the recommendation based on cost models are demonstrated in the next section.

6.1.1. Comparison of Results between Literature Review, Expert interview, and Research's Findings

The literature review, the results of expert interview, and empirical data analysis are compared and demonstrated in table 6.2.

Table 6.2. Comparison between Literature Review, Expert opinions and our Findings

	Literature Review	Findings	
		Expert Interviews	Survey
Services and Applications	**Current deployments** Web / WAP access Data services via SMS and MMS Wireless broadband data services Navigation System / GPS **Current developments** Educational services E-commerce: M-Pay , M-Cash and contactless card Real-time Entertainment Voice over IP / IP Telephony	Streaming / Real-time data services in high-end applications Contents that related to lifestyle and attitude of consumers	Web Surfing Financial Services E-commerce Education

Table 6.2.. Comparison between Literature Review, Expert Opinions and our Findings (Continued)

	Literature Review	Findings	
		Expert Interviews	Survey
Network	GSM operators: Limited area coverage of EDGE network , still no major plan for WCDMA For CDMA Operator: CDMA 2000 (Brew platform), plan for upgrading to CDMA 2000 1x EV-DO network	Quality of services (speed and reliability) are already well implemented: Seamless handover between GPRS and Wi-Fi Costs that depends on affordability, income level, and willingness to pay	Payment Method
End-user Device	Hybrid device such as Smart Phone and Pocket PC phone edition Capable of supporting higher data rate Multifunction (Camera, media player) Larger built-in memory	Technical Compatibility User Interface is already well implemented Costs that depends on affordability, income level, and willingness to pay	Cost of end-user device Memory / Storage Display size Ease of use

According to Table 6.2, most of the significant factors found in our study, especially related to applications and services can also be seen from current deployments and developments. However, the influences of these factors to consumer demands found in the study are not all the same as real-world implementation.

Web Surfing

Today, consumers can access website using their mobile devices via different types of mobile network. The study demonstrated that "web surfing" has negative influence to demand as it does not give consumer the same perception as surfing on desktop or notebook personal computer. This leads to the real-world situation where operators and service providers need to develop their own WAP sites for adjusting the contents, resolution, and context to be appropriate for mobile devices. These WAP sites are then customized according to lifestyle of consumer as suggested in the results of expert interview. The example is the AIS's nowLIFE portal which divides the WAP portal into seven types of teenage lifestyles.

Data services: Streaming and Real-time Data

The current deployments also include wireless broadband data services, IP telephony, and navigation services. These are not found to be significant in our study since they are still very limited in small groups of consumers who use and customize such services for business purposes. This can be supported by the information that operators are only provided these services in limited areas such as in the metropolitan area, not country-wide coverage.

Financial Services and E-commerce

The factors related to finance such as "financial services" and "E-commerce" have different direction of influence to consumer demands. As mentioned earlier, "E-commerce" has positive influence to consumer demand and the term E-commerce

using in this paper, is limited to small transactions only. The same implications of "E-commerce" from the aspects of operators and service providers are reflected by the developing applications and services such as M-Pay, M-Cash, 2D barcode, and contactless card jointly introduced by AIS and NTT Docomo. "Financial services" which defined to have larger transaction, is found to be negatively influenced to consumer demand in our study. This can also be supported by the fact that many operators in corporation with banks chose to implement only the basic services such as account information and status checking.

Education and Training

In our study, Educational services are found to be negatively influenced to consumer demand. Although, this factor is significance, it is likely to be delayed until supported technologies are ready and other higher potential services are already implemented. For Educational services, operators are beginning to explore the opportunities by starting to provide basic services via low-speed applications such as SMS and MMS.

Personal Entertainment

In contrast to the findings, the factor "Entertainment" is on the operators' list of developing services and applications, but it is not found to be significant in the study.

In an attempt to clarify the factor "Entertainment", our findings also found that memory storage and display size are positively influenced to consumer demand. Thus, it might suggest that current consumers are likely to prefer offline services or services that let consumer downloads a specific content per time and keep it on a mobile device. This can be seen from current usage pattern of mobile device as digital camera, Video, and MP3 Player. Entertainment services that relied on network such as

streaming Video and TV are not significant to consumer as they are not fully implemented and thus have not demonstrated the potential and capability to consumer.

6.1.2 Recommendations to Network Operators and Service Providers

Network Operators and service providers should be aware of quality of services as suggested in the results of expert interview. Although the study found no significant problem related to network factors, we must keep in mind that most of consumers hasn't have any experience with demanding applications and services such as streaming data services. Many current services and applications are still relied on SMS, MMS which required low data transfer rate. The problem may arise and be recognized by consumers when implementing the services via a network that has limited speed and capacity.

For network operators and service providers, even though, they can extend the life cycle of network by developing appropriate services and applications, the underlying network infrastructure will eventually be upgraded after reach its full potential. Once considering upgrading option, they can plan according to network standards, suppliers' information, etc. However, this paper suggests to plan according to cost models which combines aspects of potential of alternate technologies, technical constraints, and financial aspects together.

Even though there are many new standards being adopted in Thailand, Most of the consumers in Thailand do not question the capabilities of the next generation device and the network. They are ready to switch and try out these new technologies as long as service providers come up with understandable pricing strategy for both devices and connection fee.

This can be seen on the results that more than half of the respondents (333 respondents out of total 407 respondents), who are not using the wireless Internet

access, are planning to use the service within the next two years. The respondents are likely to adopt with new technology if they are offered familiar Internet applications, but with more functionalities, not by offering different kinds of services.

In addition to this, the more innovative way of web browsing from mobile device, more security and the new range of applications such as E-commerce or online shopping could help consumer make their decision / justification easier.

While 2.75G and 3G cellular networks are able to deliver acceptable data speed to subscribers, alternate technologies such as WiMax can be viewed as an additional supplementary service to wireless Internet access. By combining two technologies together, high-speed data networks can be created for business or enterprises that consider speed, connectivity, and coverage areas as their critical issues.

The results of the cost modeling demonstrate the possibility is creating data networks comprising several technologies. Operators can choose among these technologies in order to provide integrated network that would benefit the most to themselves and their subscribers.

Thus, the right combination of technical and applications can lead to successful implementation of wireless Internet services in developing countries. It may be able to change user perceptions on wireless Internet services, and eventually bring more benefits to business sectors.

6.1.3 Recommendations to policy makers

They should aim at protecting customer benefits and follow new technologies closely because each technology has its own policy implications. By implementing inappropriate technologies, operators could jeopardize public interests by inhibiting new innovations or slowing down the adoption of new applications and development.

6.2 Further Studies

In the end, it is important to note that this study is conducted based on the Thai case study. It would be useful to see if the model proposed in this study could be applied to other developing countries. In that regard, after studies on other countries are done, it would be beneficial to compile and compare the results in a comparative study on this topic.

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APPENDIX A

THEORIES ON FUNDAMENTAL FACTORS

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I. Technology Acceptance Model

In the last two decades, a number of studies have provided some theoretical frameworks for research in the acceptance of information technology and information system (IT/IS) (i.e. Ajzen 1985, 1991; Davis, 1989; Mathieson, 1991, Moore, 1987; Taylor and Todd, 1995). Among them, the technology acceptance model (TAM) is believed most robust, parsimonious, and influential in explaining IT/IS adoption behavior (Davis, 1989; Igbaria, 1995, Mathieson, 1991).

Even though, the Technology Acceptance Model (TAM) has received fairly extensive attention from previous research, TAM is continuing to be improved by applying its concept to a specific type of technology such as wireless and mobile technologies. June Lu, Chun-Sheng Yu, Changliu and James E. Yao (2003) introduced a TAM for wireless Internet via mobile devices (WIMD). The proposed model tries to explain the factors influencing user acceptance of Wireless Internet via mobile devices. By revising the technology acceptance model to represent some unique features of the wireless system under study, TAM for wireless Internet proposes that constructs such as individual differences, technology complexity, facilitating conditions, social influences, and wireless trust environment determine user-perceived usefulness, and ease of using WIMD. These, in turn, determine user attention and willingness to adopt WIMD.

These factors of TAM for WIMD play an important role in determining the components of user demand for wireless access describing in the methodology chapter.

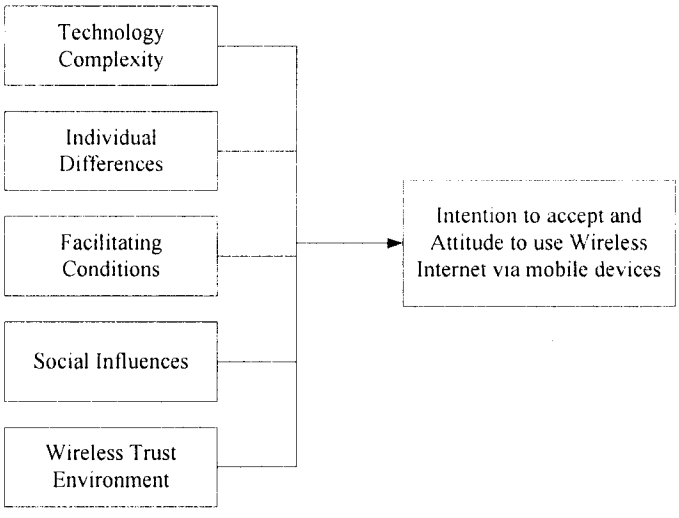

Figure A.1. Technology Acceptance Model for Wireless Internet via Mobile Devices (Lu, Yu, Liu, Yao, 2003)

II. The Technology Adoption Life Cycle

In addition to *Technology Acceptance Model,* the technology adoption life cycle also provides us where to focus when conducting research related to consumer, both business and general consumers. The technology adoption life cycle can be visualized as a bell curve segmented by certain characteristics that must exist for the products to transition throughout each stage of the cycle. The bell curve consists of several phases: Innovators, Early Adopters, Bowling Alley, Tornado, and Main Street.

The critical path: the Chasm

The Chasm represents a critical phase from the last early adopters to mainstream acceptance of the product. As Steve Jobs of Apple says on the cover of the book, "The Chasm is where many high-tech fortunes have been lost. The Tornado is where many have been made." Crossing the Chasm is vital to long-term value creation and market dominance.

To cross the Chasm, Moore (Moore, "Inside the tornado") suggests that the

company focus on a "beachhead" or a total solution for a problem built around the needs of a niche market. Moore calls this total solution a "whole product," an imperative for penetrating the pragmatic buyers. Moore defines the whole product as "the minimum set of products and services necessary to ensure that the target customer will achieve his or her compelling reason to buy." The whole product created for a niche market represents the potential of successful entry into the mainstream market, an area called the Bowling Alley.

III. Microprocessor and Other Growth Paths

In the wireless Industry we assume that Moore's law will be valid until 2015 and the growth paths in the same range for memory storage capacity and fiber capacity will also hold until 2015. The exponential growth in performance has been valid over a number of technology generations, and from 1940 computing power has grown steadily by 55% (Nordhaus 2001), closely matching the 59% performance growth of silicon processors stated as Moore's law. Battery capacity is also growing but much slower than Moore's law. Capacity in air (defined as spectral efficiency/ covered area) is another much slower but still exponential growth path.

IV. Falling Prices and the Experience Curve

When new technologies reach the market, economies of scale will cause prices to fall as production volumes increase. This trend of falling prices is called the learning curve or the experience curve and was developed by the founder of the Boston Consulting Group in the 1960s. It has been empirically shown that for each doubling of accumulated production volume, prices will fall 25-35%. The experience curve has been shown to hold for such diverse products as photovoltaic solar cells, B17 bombers during World War II, and AT&T long-distance voice tariffs over a 50-year period. (Grubler 1998; Mishina 1999)

V. Network and Software Effect (Metcalfe's Law)

Metcalfe's law can be described as the situation when a successful new technology gets a larger user base, network effects will give additional benefits for extra user. In other words, total network value rises by the square of the number of terminals.

Metcalfe's law can also be applied in software. Network effects also rise from a large installed base, which will enforce the market leadership when the dominant software gets a large base of software developers (Shapiro and Varian 1998).

These network effects are very important in the early market when several technologies are competing with each other. When one technology gets a lead by a large market share, this advantage is often enough to tip the balance and enforce market leadership. This transition is enforcing one dominant design, and once that is in place, the technology is ready for the mass market. In the software industry, this transition has been called crossing the chasm and the ensuring explosion in sales and market size is called the tornado (Moore 1991, 1995).

VI. Network Effect (Reed's Law)

Metcalfe's law may be a valid model for one-to-one communication, where you can call or fax another subscriber on the network. The network effects of Metcalfe's law are impressive but the really large effects will be found when looking at the number of groups that can be formed among the network members. Reed's law (Reed 1999) states that in a given network of size N, the number of nontrivial groups that can be formed grows exponentially.

Networks that support communicating groups, Reed calls them group-forming networks (GFNs). The web and email are GFNs but the traditional telephone network is not a GFN. When N becomes large, the term 2^N will grow much faster than the

term N^2 in Metcalfe's law. This is an indication of the potentially very large impact on social life and community building when the global network grows very large.

VII. The S-curve and the Product Lifecycle

Is the product lifecycle relevant to the telecoms industry? The short answer is yes. The product lifecycle is not unknown in telecommunications - the growth of mobile handset sales over the past 20 years perfectly fits the pattern of stages 1 to 3. The rise and fall of telex, and probably fax, fits all four stages.

The reason the product lifecycle concept is so important lies in the curve. The growth rate of demand in stage 2 is significantly higher than in stage 1. For this to happen in practice, something has to happen to prompt this accelerated demand.

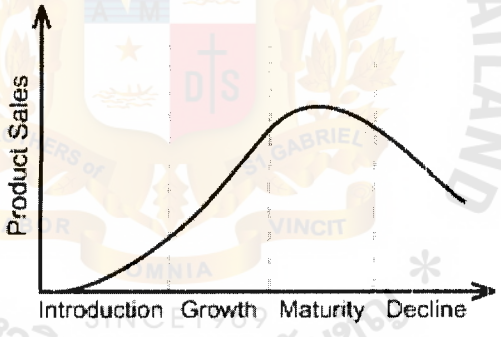

Figure A2. Product Life Cycle

Looking at the four stages, we conclude that *technical, network and supply issues, and marketing and demand areas*, predominate at different stages of the cycle.

In stage 1, the predominant issues for operators concern technology and reach (supply) rather than the market or customers (demand). Stage 2 is all about building a mass-market position and requires different skills from the passive approach to marketing and demand stimulation that operators used in stage 1. Hence, marketing becomes the focus as operators stimulate demand for their products.

At the mature stage (stage 3), demand has slowed and so retention is more important than acquisition. In a mature market, competition is fierce and margins are low, so it is imperative that an operator has low unit costs. Consequently, demand and supply issues have equal weight. At stage 4, the challenge for operators is to reduce costs to maintain profitability. Thus there is an equal focus on the supply and demand sides of the equation.

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APPENDIX B

MULTIVARIATE TECHNIQUES

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Types of Multivariate Techniques

The major tool, planning to be used for estimating the econometric model, can be broadly described as multivariate analysis. This refers to all statistical methods that simultaneously analyze multiple measurements on each individual or object under investigation. Any simultaneous analysis of more than two variables can be loosely considered multivariate analysis. In addition, the single dependent variable found in analysis of variance is extended to include multiple dependent variables in multivariate analysis of variance. The well-established techniques are including:

(1) Multiple Discriminant Analysis

(2) Structural Equation Modeling

(3) Linear Probability Models

(4) Multivariate Analysis of Variance and Covariance

(5) Conjoint Analysis

(6) Canonical Correlation

(7) Cluster Analysis

(8) Multidimensional Scaling

(9) Correspondence Analysis

(10) Multiple Regression

Selection of Estimation Technique

Regression analysis is any statistical method where the mean of one or more random variables is predicted conditioned on other (measured) random variables. The most basic and commonly used method is linear regression analysis in which basically assumed linear relationship between dependent variables and a set of independent variables. This section will begin with the discussion of the potential of using this

foundation method as our regression technique, which will lead to more appropriate technique described later in this section.

Erick Biorn (2004) described the inconvenient of using linear regression model with the dichotomous dependent variable as follows:

(1) The choice of values for binary dependent variable is arbitrary. This would, however, have changed the coefficients of independent variables, which means that the coefficients of independent variables get no clear interpretation.

(2) If we draw a scatter of points exhibiting the value of dependent variable, the linear regression would be zero or one, the independent variables varying continuously. It does not seem very meaningful, or attractive, to draw a straight line, or a plane, through this scatter of points in order to minimize a squared distance, as in classical regression analysis.

(3) In linear regression model, the disturbance for each independent variable is limited to follow a normal distribution. However, the error term of a discrete variable follows the binomial distribution instead of the normal distribution, thus invalidating all statistical testing based on the assumption of the normal distribution.

(4) Using the definition of an expectation in a discrete probability distribution, this implies that the disturbance variance is a function of both independent variable and its associated coefficient. This means that the disturbance is heteroskedastic, but its variance only depends on the slope of linear line, as in classical regression analysis.

(5) We know that any probability should belong to the interval (0, 1), but there is no guarantee that the RHS of probability of independent variable should be within these two bounds. However, logistic regression uses an assumed relationship between the independent and dependent variables that resembles an S-shaped curve. The linear models of regression cannot accommodate such a relationship, as it is inherently nonlinear. Moreover, such situations cannot be studied with ordinary regression, because doing so would violate several assumptions.

(6) The left-hand-side variable is, by nature, different from the RHS (Right-hand-side) variables. By linear regression model with binary dependent variable, we attempt to put something discrete equal to something continuous.

In attempting to choose a more appropriate technique for a problem that involves a categorical dependent variable and several metric independent variables, discriminant analysis and logistic regression are examined and compared for the case of two classifications of dependent variable.

Comparison between logistic regression and discriminant analysis (Hair, Anderson, Tatham, Black 1998)

(1) Discriminant analysis relies on strictly meeting the assumptions of multivariate normality and equal variance-covariance matrices across groups – assumptions that are not met in many situations. Logistic regression does not face these strict assumptions and is much more robust when these assumptions are not met, making its application appropriate in many more situations.

(2) Even if the assumptions are met, many researchers prefer logistic regression because it is similar to regression. Both have straightforward statistical tests, the ability to incorporate nonlinear effects, and a wide range of diagnostics.

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APPENDIX C

QUESTIONNAIRE FOR RESEARCH STUDY

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Questionnaire A

(for users who do NOT access the Internet through wireless connection)

Screening Questions

1. Age

□ Less than 20 □ 21-30 □ 31-40

□ 41-50 □ 51-60 □ More than 60

2. Gender

□ Male □ Female

3. Education

□ Elementary school □ Junior High school □ Senior High school

□ Diploma □ Bachelor degree □ Master degree

□ Doctoral degree

4. Occupation (Please specify).....

5. Income per month

□ Less than 5,000 Baht □ 5,001- 10,000 □ 10,001-25,000

□ 25,001-50,000 □ 50,001-75,000 □ More than 75,000

6. Location

□ Bangkok or metropolitan area

□ Other, please specify.....

7. Do you currently own or use the following device (Please check all that apply)

□ None (End of survey)

□ Computer Notebook

□ Cell phone □ Personal Digital Assistance (PDA)

□ Combined Devices (All-in-one device)

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Note: All-in-one device refers to a device that has both PDA and phone functionalities such as Smartphone or PocketPC phone edition.

8. How do you access the Internet? (Please check all that apply)

□ no access at all

□ dial-up from home □ ADSLfrom home

□ at the office □ Internet café

□ wireless connection

□ others, please specify.....

9. Methods for procuring systems (How did you get your device?)

	Own Purchase	Provided by org/company
Cell Phone		
PDA		
All-in-one device		
Computer Notebook		

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Part I – Device

1. If you can select any mobile device to have access to wireless the Internet, please specify the importance of the following features of that device.

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5
Display Size					
Display resolution					
Ease of use of User Interface					
Portability (Size &Weight)					
Durability					
Battery life duration					
Memory					

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Part 2

1. If you have a wireless access to the Internet, please specify the importance of the following services to you

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5
E-mail					
Entertainment (Game, music)					
Surf the web					
Financial transactions fee payments, etc.)					
Shopping					
Stock trading					
Locate destinations, GPS					
E-government					
Education / Training					
Teleworking					

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Part 3- Network

1. If you have a wireless access to the Internet, please specify the importance of the following wireless network characteristics.

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5
Reliability (not get disconnected often)					
Security of your information					
Speed					

2. What type of payment system do you prefer to use for wireless access to the Internet

□ prepaid

□ Pay as you go

□ Signed Contract

□ provided by company

3. According the current price of Wireless Internet Services **(Please see attached information, page 4)**, are you planning to use Wireless Internet Services in the future (in the next 2 years) ?

□ Yes

□ No

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Part 4: Alternate technologies

1. Importance of attributes by wireless Internet access

Please specify the importance of the following items

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5
Mobility					
Always online					
Cost					
Installation of the Internet service					

Part 5: Others

Social Influences: Changed behavior, Social and Cultural Concerns

1. In any of these situations, do you find your wireless device useful? (Please check all that apply)

□ Business and communications

□Travel information

□ Location technology

□ Access to corporate information

□ Wireless entertainment

□Emergency information

□ Other (Please list).....

2. Some users were concerned about the following issues regarding social and cultures. Do you find yourself having the same concerns? (Please check all that apply)

□ Stress in using new and unfamiliar technology

□ Distraction

□ Self-Consciousness

□ Body language and lack of eye contact

□ Health and Safety Concerns

□ Radiation

□ Heat dissipation

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Current Pricing structure of Wireless Internet Services

Average Cost of Wireless Internet Access at Hotspot

Hours	Price (Baht)
1	150 -180
5	600
20	1500

Average Cost of GPRS Access through Cellular Network

1. DTAC: 0.1 Baht per 1 Kilobyte

Current Promotions:

WAP User: no monthly fee, 0.1 Baht per 1 Kilobyte

PDA: 100 Baht per month

Free data transfer of 2 MB, 0.05 Baht per 1 Kilobyte (suitable for WAP or PDA users)

Notebook: 500 Baht per month

Free data transfer of 15 MB, 0.05 Baht per 1 Kilobyte (suitable for PDA or computer notebook users)

Web Surfer: 1500 Baht per month

Free data transfer of 50 MB, 0.05 Baht per 1 Kilobyte (suitable for computer notebook users)

2. AIS GPRS: 1 Baht per minute

Current Promotions

	Timing 1 (6 pm. - 11.59 pm.)	Timing 2 (12.00 pm. - 05.59 am.)	Cost (Baht)	Cost per minute
Package 4 hr.	2	2	30	0.13
Package 10 hr.	5	5	50	0.08
Package 60 hr.	30	30	200	0.06
Package 120 hr.	60	60	350	0.05
Package 200 hr.	100	100	500	0.04
Package 400 hr.	250	150	900	0.03

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Questionnaire B

(for users who access the Internet through wireless connection)

Screening Questions

1. Age

□ Less than 20 □ 21-30 □ 31-40

□ 41-50 □ 51-60 □ More than 60

2. Gender

□ Male □ Female

3. Education

□ Elementary school □ Junior High school □ Senior High school

□ Diploma □ Bachelor degree □ Master degree

□ Doctoral degree

4. Occupation (Please specify).....

5. Income per month

□ Less than 5,000 Baht □ 5,001- 10,000 □ 10,001-25,000

□ 25,001-50,000 □ 50,001-75,000 □ More than 75,000

6. Location

□ Bangkok or metropolitan area

□ Other, please specify.....

7. Do you currently own or use the following device (Please check all that apply)

□ None (End of survey)

□ Computer Notebook

□ Cell phone □ Personal Digital Assistance (PDA)

□ Combined Devices (All-in-one device)

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Note: All-in-one device refers to a device that has both PDA and phone functionalities such as Smartphone or PocketPC phone edition.

8. How do you access the Internet? (Please check all that apply)

□ no access at all

□ dial-up from home □ ADSLfrom home

□ at the office □ Internet café

□ wireless connection

□ others, please specify.....

9. Methods for procuring systems (How did you get the device?)

	Own Purchase	Provided by org/company
Cell Phone		
PDA		
All-in-one		
Computer Notebook		

10. Which of the following devices are used to access Internet through wireless connection?

	Used to access Internet through wireless connection	
	Yes	No
Cell Phone		
PDA		
All-in-one		
Computer Notebook (wireless connection)		

11. What are the major purposes of accessing the Internet via the device?

	Personal purposes	Business-related purposes
Cell Phone		
PDA		
All-in-one		
Computer notebook (access through wireless connection only)		

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Part I – Device

1. What kind of method are you using to input data?

□Manual

□Large volume (Keyboard)

□Small volume (Keypad, Touch screen, Handwriting recognition)

□Automated data capture (Barcode system, etc)

2. Frequency of access

□ Real time□ once a day □ twice a day

□ three times a day □ more than 3 times/day but not real time

3. Please specify the importance of the following features of that device.

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5
Display Size					
Display resolution					
Ease of use of User Interface					
Portability (Size &Weight)					
Durability					
Battery life duration					
Memory					

Part 2

2. Please specify the importance of the following services to you (even though you are not currently using)

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5	Currently using?
E-mail						
Entertainment (Game, music)						
Surf the web						
Financial transactions fee payments, etc.)						
Shopping						
Stock trading						
Locate destinations, GPS						
E-government						
Education / Training						
Teleworking						

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Part 3- Network

Characteristics of the network

1. What is the Coverage/Range of your network?

□ Close Proximity □ within an office □ Within a Building

□ Campus, Office Complex, Airport □ Regional

□National- Urban □ National- Full Coverage □ International

2. Please specify the importance of the following wireless network characteristics.

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5
Reliability (not get disconnected often)					
Security of your information					
Speed					

3. What type of payment system do you prefer to use for wireless access to the Internet

□ prepaid

□ Pay as you go

□ Signed Contract

□ provided by company

Part 4: Alternate technologies

1. Importance of attributes by wireless Internet access

Please specify the importance of the following items

(1 = Not at all important, 2= Not important, 3 = Neutral, 4 = Somewhat important, 5 = Very important)

	1	2	3	4	5
Mobility					
Always online					
Cost					
Installation of the Internet service					
Ease of use of software					

Part 5: Others

Social Influences: Changed behavior, Social and Cultural Concerns

1. In any of these situations, do you find your wireless device useful?

□ Business and communications

□Travel information

□ Location technology

□ Access to corporate information

□ Wireless entertainment

□Emergency information

□ Other (Please list).....

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2. Some users were concerned about the following issues regarding social and cultures. Do you find yourself having the same concerns?

- □ Stress in using new and unfamiliar technology
- □ Distraction
- □ Self-Consciousness
- □ Body language and lack of eye contact
- □ Health and Safety Concerns
  - □ Radiation
  - □ Heat dissipation

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Note: if you are not using wireless devices to access the Internet for business related purposes please skip part 6.

Part 6: Business-related section (Organization network)

1. Availability of resources and services at your organization (Please check all that apply)

What resources and services are currently available on your organizational network?	What are the organization resources or services you are looking for to be available on Wireless network?
☐Database ☐staff directory (HRM) ☐Technical learning materials/ IT training/tutorials ☐Financial resources ☐News/ Press releases/media services ☐Journals & reference resources ☐event schedule / calendar ☐IT support resources ☐E-commerce (fee payments, etc.)	☐Database ☐staff directory (HRM) ☐Technical learning materials/ IT training/tutorials ☐Financial resources ☐News/ Press releases/media services ☐Journals & reference resources ☐event schedule / calendar ☐IT support resources ☐E-commerce (fee payments, etc.)

2. What is the primary medium for your organization backbone/network?

☐Fiber ☐Gigabit Ethernet ☐Std. Ethernet/Coax

☐Twisted Pair ☐Other:_____ ☐none

Business Practices

3. Do you agree that wireless Internet access can improve efficiency in business processes?

□ Functionality □ Quality □ Speed

□ Teamwork □ customer relationship □outsourcing

□ Flatten management levels □ Supply Chain Management

□ Communication

4. Do you agree that Internet access can increase Competitive advantages?

□ No □ Somewhat agree □ Agree

5. Do you agree that wireless Internet access can bring new business opportunities?

□ No □ Somewhat agree □ Agree

Training and Development

6. Appropriate time period for training and development before you can start using wireless Internet

□ Within 2 weeks □ 1 months □ 3 months or more

□ None (no training needed)

7. What kind of a source of Training would you prefer?

□ Self-learning

□ On-site vendor-supplied seminars

□ Internally developed seminars specifically for your organization

APPENDIX D

OVERVIEW OF CELLULAR TECHNOLOGIES

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Overview of Cellular Technologies in Thailand

There are four main standards for 2G systems: Global System for Mobile (GSM) communications and its derivatives; digital AMPS (D-AMPS); code-division multiple access (CDMA) IS-95; and personal digital cellular (PDC). GSM and CDMA are by far the most successful and widely used 2G system. As AMPS is fading away and PDC is somewhat limited to be used within Japan. We begin by describing GSM technology and its current implementation, followed by CDMA technology.

2.5 and 2.75 GSM System

Generation 2.5 is a designation that broadly includes all advanced upgrades for the 2G networks. Generally, a 2.5 GSM system includes at least one of the following technologies: high-speed circuit-switched data (HSCSD), General Packet Radio Services (GPRS), and Enhanced Data Rates for Global Evolution (EDGE). Thai's GSM operators follow the same trends by becoming 2.5 G with the introduction of GPRS and EDGE.

The biggest problem with plain GSM is its low air interface data rates. There were several attempts to solve this problem. The first attempt utilized concept of HSCSD. This means that instead of one time slot, a mobile station can use several time slots for a data connection. The next solution is GPRS. With this technology, the data rates can be pushed up to 115 kbps (theoretical data rate). GPRS is especially suitable for non-real-time applications, such as e-mail and Web surfing. For those operators that will also operate 3G networks in the future, a GPRS system is an important step toward 3G system, as 3GPP core networks (3GPP is an organization that develops specifications for a 3G system based on the UTRA radio interface and on the enhanced GSM core network) are based on combined GSM and GPRS networks.

GSM-GPRS

The third 2.5G improvement to GSM is EDGE. The idea behind EDGE is a new modulation scheme called eight-phase shift keying (8PSK). It increases the data rates of standard GSM by up to threefold. EDGE is an attractive upgrade for GSM networks, as it only requires a software upgrade to base stations if there is no compatibility issue with RF amplifiers. If EDGE is used with GPRS, then the combination is known as enhanced GPRS (EGPRS). The maximum data rate of EGPRS using eight time slots is 384 Kbps (theoretical data rate).

GSM-EDGE

EDGE is an economical method to increase the data rates on an existing GSM network. EDGE introduces a new modulation technique and new channel coding that can be used to transmit both packet switched and circuit-switched voice and data services. Thus, EDGE is only an add-on to GPRS. By adding the new modulation and coding to GPRS-GSM network and by making adjustments to the radio link protocols, EGPRS offers significantly higher throughput and capacity.

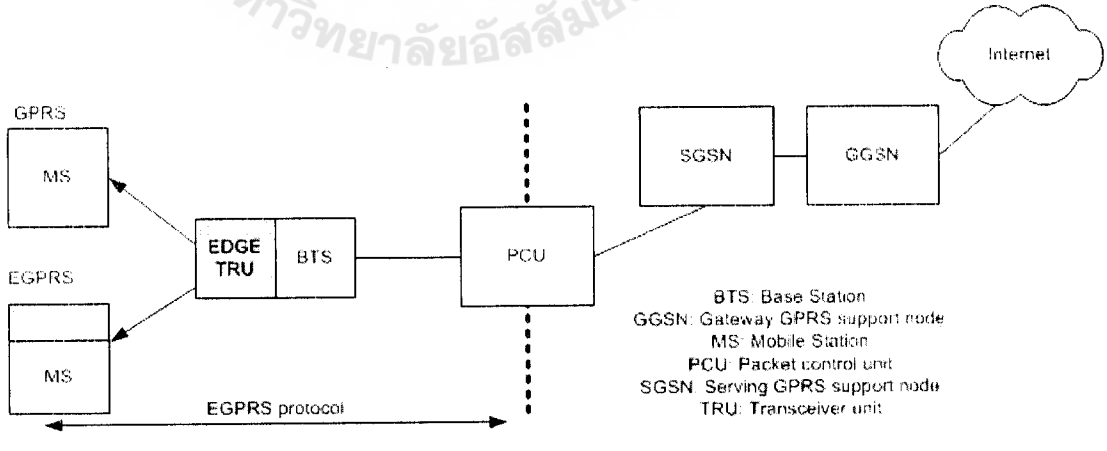

Figure D1. EDGE Network Scheme

Due to the minor differences between GPRS and EGPRS, the impact of EGPRS on the existing GSM/GPRS network is limited to the base station system. The base station is affected by the new transceiver unit capable of handling EDGE modulation as well as new software that enables the new protocol for packets over the radio interface in both the base station and base station controller. The core network does not require any adaptations. Due to this simple upgrade, a network capable of EDGE can be deployed with limited investments and within a short time frame. The components that are needed to be upgraded for EDGE capability is shown in Figure D1.

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Proposals for 3G standard

There have been several competing proposals for a global 3G standard. This research uses the following proposals, which are IMT-2000[12] compatible, released by International Telecommunication Union (ITU) in November 1999 as references.

- IMT Direct Spread (IMT-DS, also known as UTRA FDD)
- IMT Multicarrier (IMT-MC, also known as CDMA 2000)
- IMT Time Code (IMT-TC, also known as UTRA-TDD/ TD-SCDMA "narrowband TDD")
- IMT Single Carrier (IMT-SC, also known as UWC-136)
- IMT Frequency Time (IMT-FT, also known as DECT)

By judging from the proposals, progress of implementation, and current market situation, even though there are several IMT-2000 compatible systems, it seems that only two of them will survive in the end. WCDMA (IMT-DS), or UTRAN is the most important one, and CDMA 2000 (IMT-MC) will also gain a substantial but secondary market share. There will not be any IMT-SC systems (UWC-136) as the UWCC made a decision to join the WCDMA camp. For IMT-TC, TDD mode of WCDMA is still questionable as most operators start their 3G deployments with FDD mode equipment.

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[12] **International Mobile Telecommunications-2000 (IMT-2000)** is the global standard for third generation (3G) wireless communications, defined by a set of interdependent ITU Recommendations. IMT-2000 provides a framework for worldwide wireless access by linking the diverse systems of terrestrial and/or satellite based networks. It will exploit the potential synergy between digital mobile telecommunications technologies and systems for fixed and mobile wireless access systems.

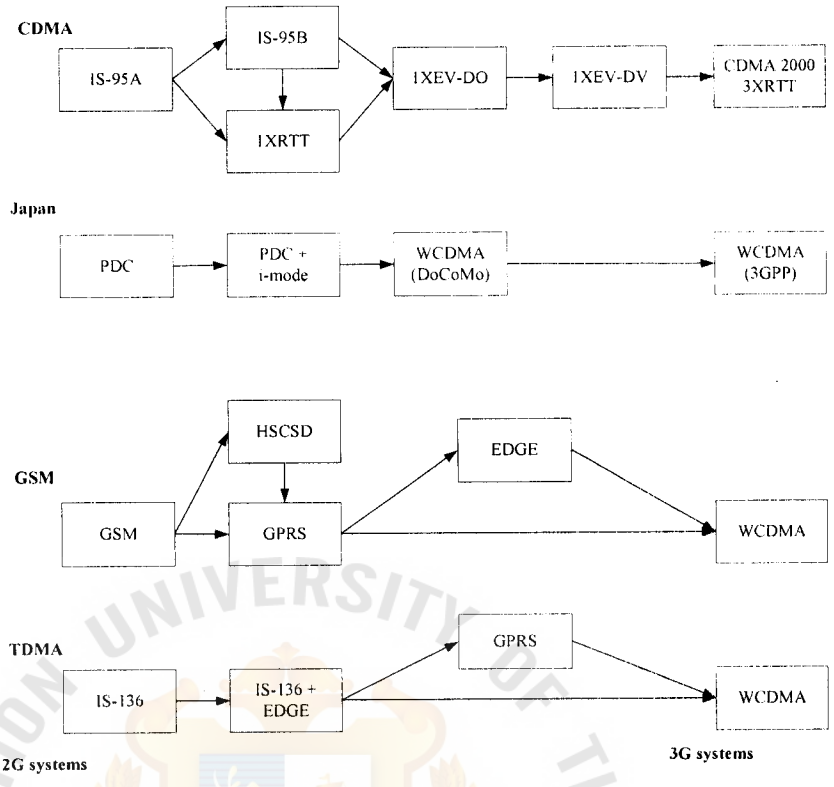

Figure E2. 3G Evolution Paths

Table E1. Characteristics of the 2G and 3G Networks

	GSM (GPRS)	GSM (EDGE)	WCDMA	CDMA 2000 1x (high speed)
Data speed (ideal)	115 kbps	Burst speed 180 kbps	2 Mbps	614.2 bps
Data speed (avg)	40 kbps	100-130 kbps		153 kbps (BREW platform)
Technology	TDMA	TDMA	TDMA	CDMA

3G: UMTS

Comparison of GSM and UMTS: A view from current GSM operators

Table E2 shows how well the future GSM 2.5 G network will comply with the UMTS[13] requirements.

Table E2. GSM Compliance for UMTS Targets

UMTS Target	GSM Compliance
Small affordable hand portables	Yes
Deep penetration	Yes; already in some markets
Anywhere, anytime (indoor, office)	Yes (picocells, GSM office)
Anywhere, satellite mobile interworking	Yes
Hot spot capacity	Yes (cell hierarchies)
Wireline voice quality	Yes (EFR codec)
Global roaming	Yes (SIM, MAP)
IN services	Yes (CAMEL)
Multimedia, entertainment, nonvoice	Yes (TCP/IP transparency, GPRS, HSCSD)
Flexibility to mix different bearer types (non-real-time and real-time)	No
High bit rate services (200 kbps)	No

[13] Universal Mobile Telecommunication System (UMTS): standardization for the next-generation mobile telecommunications network developed by **European Telecommunications Standards Institute** (ETSI)**'s technical committee Special Mobile Group** (SMG)

As we can see from the table, a GSM network with all the add-ons very closely mimics a UMTS network. The only difference is *the more flexible and capable UMTS air interface*, which can handle different bearer types at the same time. Real-time services are confined to dedicated connections whereas non-real-time low-bandwidth services can quite easily use shared communication channels, which can more easily be changed dynamically.

Network Structure: Where to upgrade

Because this paper focuses more on demand and cost modeling of wireless network implementation, not the technical aspect of it, figure E3 depicts the UMTS architecture at the very highest level.

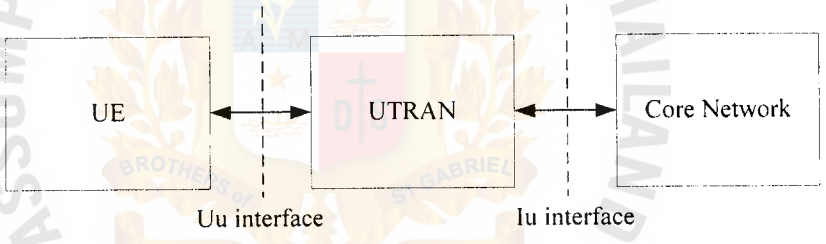

Figure E3. UMTS Logical Concepts

The IMT-2000 network is divided into two logical concepts, the core network (CN) and the generic radio access network (GRAN). Between the GRAN and the core network we find the *Iu interface*[14], and between the GRAN and the UE we see the *Uu interface*[15] (radio interface).

[14] Radio Network Controller (RNC) to GSM phase 2+ Core Network Interface

[15] User Equipment(UE) to Node B (UTRA, the UMTS W-CDMA air. interface)

The idea behind this arrangement is that the GRAN will be capable of connecting, perhaps simultaneously, to several different CNs, such as GSM, B-ISDN + IN, or a packet –data network. 3GPP has also specified a new dedicated UMTS radio access network (RAN) called the UMTS Terrestrial RAN (UTRAN). An important requirement for the GRAN implementations is that they conform to the Iu interface specifications.

Note that, in GSM terms, the GRAN contains the base station subsystem, that is, the base transceivers station (BTS) and the base station controller (BSC). In the 3GPP specifications, the generic GRAN concept is translated into a concrete UTRAN network in which the BTS has the name "Node B". The new name for the BSC is the "radio network controller (RNC)".

Table E3 describes the UMTS network elements generally be implemented.

Table E3. UMTS Network Elements

Core Network	- Mobile Switching Center - Visitor Location Register - Home Location Register - Equipment Identity Register - Authentication Center - Gateway MSC - Serving GPRS Support Node - Gateway GPRS Support Node
UMTS Terrestrial Radio Access Network	- Radio Network Controller - UMTS base station transceiver
GSM Radio Network	- Base Station Controller - Base Transceiver Station - Small Base Transceiver Stations

We can see that a GSM+GPRS combination provides a very good foundation for the UMTS core network building process. The biggest operator investment will clearly be building out the radio access network (UTRAN). Some of the latest GSM base stations are, however, said to be upgradeable to UTRAN standards.

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3G: IS-2000 CDMA

As a successor of IS-95 CDMA standard and cdmaOne, IS-2000 CDMA standard (also referred to as CDMA 1X), was developed and eventually approved by ITU as one of the standards for the 3rd generation mobile communications.

Standard evolution exploited the flexibility afforded by CDMA in multiplexing multiple channels, which has allowed the adoption of revolutionary concepts without disrupting backward compatibility. Among them, the concept of fast forward link data rate adaptation with fast scheduling and hybrid ARQ was first introduced in IS-856. This leaded to a CDMA system optimized for data only transmission that achieves very high forward link data rates and bandwidth efficiency. Similar concepts have been recently adopted in IS-2000-C (also referred to as CDMA 1X EVDV), which allows for both circuit switched voice and high speed forward link data applications.

CDMA Network Structure

A high-level representation of the cdma2000 network reference model is depicted in Figure E4. It comprises of three major parts: the core network (CN), the radio access network (RAN) and the mobile station (MS). The core network is further decomposed in two parts, one interfacing to external networks such as the Public Switched Telephone Network (PSTN) and the other interfacing to the Internet Protocol (IP) network or Internet. The interfaces toward the PSTN and the IP network are called the analog interface (Ai) and the packet interface (Pi) respectively.

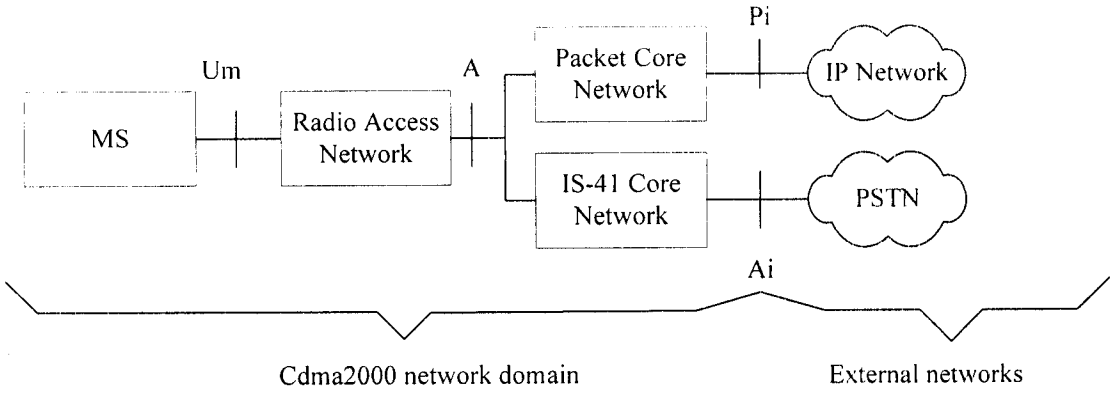

Figure E4. IS-2000 CDMA

Table E4. CDMA Network Elements

Mobile Station	Major Components
Radio Access Network	- Base Transceiver Station - Base Station Controller - Packet Control Function
IS-41 Core Network	- Mobile Switching Center - Home Location Register - Visitor Location Register - Authentication Center - Message Center - Short Message Entity

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Bandwidth Calculation

Since radio spectrum is a limited resource shared by all users, a method must be devised to divide up the bandwidth among as many users as possible. The method chosen by GSM is a combination of Time and Frequency Division Multiple Access (TDMA/FDMA). The FDMA part involves the division by frequency of the (maximum) 25MHz bandwidth into 124 carrier frequencies spaced 200 kHz apart. One or more carrier frequencies are assigned to each base station.

GSM provides 8 slots in a channel 200 kHz wide. Therefore GSM consumes 25 kHz per user. By assuming a cluster size (number of cell in one cluster) of seven, one can calculate the number of three calls per cell.

The current maximum number of calls per base station is 1530.A cell can be assigned with several carriers. By assuming that a cell can be assigned to support all possible carriers (124 carriers) and cluster size of seven, there are approximately two calls per cell per carrier. Thus, the capacity of GSM network in Thailand reaches approximately 66.67 % of maximum capacity.

Computing this figure for CDMA with the same logic required that certain assumptions are made. One cell can be assigned to support nine carriers per cell. Thus, bandwidth of 1.25 MHz is divided into maximum 45 calls (considering the same 25 kHz per user with GSM).

The current maximum number of calls per base station is 980. So, there are 86.4 calls per cell per MHz compared to the theoretical number of 45 calls per cell per MHz. Therefore, the capacity of each cell of CMDA network in Thailand is consumed more than theoretical capacity. But the network is still functional due to the fact that the number of current subscribers is very low.

APPENDIX E

OVERVIEW OF WIRELESS BROADBAND TECHNOLOGIES

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Overview of Broadband Network in Thailand: Architecting the Broadband Network to Fit the Business Model

Broadband wireless provides one of many physical layer options for the operator of a public service network. Furthermore, the different wireless networking technologies themselves exhibit widely varying capabilities for fulfilling the needs and expectations of various customers and enterprise. More than previous wireless standards, 802.16 addresses a multitude of needs on the part of the users of broadband access services, but it is not invariably the best solution for delivering broadband services in every market.

Broadband fixed wireless: The Competitive Context

In metropolitan space, wireless broadband competes with the following:

- T1 and E1 data services over legacy copper where aggregations of ordinary twisted pairs from the physical medium of propagation.
- Data services based on Synchronous Optical Network (SONET) and Synchronous Digital Hierarchy (SDH), running over fiber linkages.
- Frame relay services running over fiber or T1/E1.
- Ethernet data services running over active fiber-optic linkages.
- Ethernet data services running over passive optical networks (PONs).
- IP data services over active fiber
- Asynchronous Transfer Mode (ATM) services over active fiber.
- ATM over passive fiber.
- Wavelength services over active fiber.
- Ethernet services over hybrid fiber coax.
- Digital subscriber line (DSL); most existing DSL networks contain components based on ATM and Internet Protocol (IP) as well as Ethernet.

• Powerline carrier where AC transmission lines carry packet data.

• Broadband satellite

• Free-air or free-space optics where laser beams transmit information over an airlink, dispensing with fiber.

• 2.5 G generation and 3G mobile data services

• Integrated Services Digital Network (ISDN), a nearby obsolete type of medium-speed data services utilizing double pairs of ordinary copper phone lines to transmit data.

• Storage-area networks represent a special case; most user specialized data protocols of which Fibre Channel, which runs over optical fiber, is the most popular.

Of these rivals, several are currently entirely inconsequential. Broadband as opposed to medium-speed satellite services scarcely exists as yet, and powerline carrier services and PONs are scarce as well. Pure IP and Ethernet metro services over fiber are growing in acceptance, but they are not well established, and ISDN has almost disappeared in the U.S., though it lingers abroad. Finally, free-space optics have achieved very little market penetration and do not appear to be poised for rapid growth. Other services mentioned previously- such as wavelength, 3G mobile, direct ATM services over active fiber, and metro Ethernet over active fiber -- have some presence in the market but are spottily available and limited in their penetration this far.

In this context, broadband wireless does not look nearly as bad as detractors would have it. If one looks across the whole array of competing access technologies, broadband wireless has achieved more success than most. Still, it faces formidable competitors among the more established technologies, and there are T1/E1 (including fractional and multiple T1/E1), frame relay, DSL, and cable data.

Among the incumbent technologies, cable data and DSL are the leading technologies for residential services, and business-class DSL, T1/E1, and frame relay are the dominant service offering for small- and-medium-sized businesses. The largest enterprises that require large data transfers tend to prefer higher-speed optical services using both packet and circuit protocols.

Market Position of Wireless Broadband regarding high-speed data services

So where does all this leave wireless broadband?

The singular strength of wireless broadband access technologies is the degree to which they lend themselves to pervasive deployments. Wireless increasingly be characterized by their impermanence and flexibility, and as such they will be complementary to be expensive albeit extremely fast fiber-optic linkages.

However, focuses on the present, current wireless broadband networks are not and cannot be completely pervasive. In terms of current price and capabilities, wireless broadband is competitive with T1, DSL, and cable. The following table F1 describes how wireless speed and capacity compare with those of the major wireline competitors.

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Table F1. Advantages and Disadvantages of WiMax

Advantages	Disadvantages
- Wireless networks are shared resources networks which make it easier for capacity allocation. - Wireless networks can cope much better with catastrophic events. The network can easily redirect signals to reach the subscribers in case of strong interference or the problem of an individual base station.	- Difficulty in reaching all potential customers o Limited footprint of the wireless network: Base station equipment is expensive, and leased locations for installing equipments can represent heavy recurring costs. o Base station must be equipped with adaptive array antenna. - Issues of availability and reliability of wireless networks - Issues of thoughput and total network capacity of wireless networks - Quality of service in wireless networks is improving but still is not as good as in wireline networks.

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Strategic Planning of WiMax Implementation in General

The common implementation can be described as following

1. Setting up Physical Infrastructure

- Central Office and Main Base Station Facilities

- Additional Base stations

- Obtaining Roof Rights, Right of Way, and Access to Appropriate Buildings at Acceptable Cost

- Backhaul

2. Determining Basic Network Architecture

3. Performing Site Surveys and Determining Link Budgets

- Determining Line of Sight and Computing Fresnel Zones

- RF Analysis

- Analyzing the Data Stream

- Establishing the Link Budget

4. Examining the Equipment Selection Process

- Generalities

- Service-related specifics

5. Integrating Wireless with Wireline Infrastructure

6. Assembling the Management and Technical Teams

7. Estimating Operating and Capital Budgets

8. Examining Return on Investment for Wireless Broadband Networks

9. Putting Strategic Planning in Perspective

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