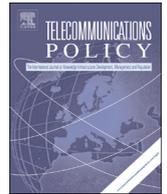


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Telecommunications Policy

URL: www.elsevier.com/locate/telpol

An integrated model for analyzing the development of the 4G telecommunications market in Taiwan

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ARTICLE INFO

Available online 16 September 2013

Keywords:

Conjoint analysis
Scenario analysis
Multigenerational diffusion model
LTE
WiMAX

ABSTRACT

Previous studies of development trends in the telecommunications industry have estimated market potential but have seldom integrated analyses of customer preferences and macro-environmental factors (political, economic, social, and technological analyses). In order to more accurately analyze 4G technological trends and market penetration and provide implications for businesses and policymakers, we use conjoint analysis to analyze customers' preferences for telecommunications technology and integrate the results with data from scenario analysis and the Delphi method to address possible scenarios for the development of 2G, 3G, Worldwide Interoperability for Microwave Access (WiMAX), and long-term evolution (LTE) in Taiwan. We then use the innovation diffusion model to forecast the sales volume for these four technologies in Taiwan over the next 10 years. Finally, we provide suggestions for policymaking and strategic actions for 4G stakeholders.

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1. Introduction

Telecommunications technologies have improved dramatically over the decades and have recently converged in terms of telecommunications services. Voice technology was the driver of second-generation (2G) mobile technology. Video and TV services are driving the third generation (3G). Worldwide Interoperability for Microwave Access (WiMAX) 802.16 m and long-term evolution (LTE)-Advanced were recognized as the foundation of fourth-generation (4G) technology by ITU at the end of 2009 (ITU, 2009). They are quite similar technologically but are supported by different groups. Currently, 2G and 3G have the most mobile subscribers in Taiwan, but operators are facing increasing competition from WiMAX. Moreover, LTE supported by traditional mobile operators will be available before 2012. The Taiwanese government provides significant support in the development of WiMAX, including launching six WiMAX licenses in 2010. Therefore, in the near future, 2G, 3G, WiMAX, and LTE will be competing in the market. The research question in this study is, what will the 4G technological trends and market penetration of these four technologies be in Taiwan?

In the telecommunications sector, Meade and Islam (1995) used data from 25 time series to compare the forecasted performances of 17 growth curve models, including the logistic, Gompertz, and Bass models, and found that the logistic and Gompertz models significantly outperformed the complex models. Botelho and Pinto (2004) used the exponential, Gompertz, and logistic models to analyze the pattern and rate of adoption of mobile telephones by the Portuguese population and found that the logistic model was the most accurate. Michalakelis, Varoutas, and Sphicopoulos (2008)

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analyzed the diffusion process in Greece and provided data on the correlation between diffusion speed and the number of competing operators as well as other socioeconomic and regulatory factors. [Chu, Wu, Kao, and Yen \(2009\)](#) used growth models to analyze accelerated diffusion and determinants of the diffusion rate. However, all of these studies focused on a single generation of technology and thus are inappropriate for forecasting and analyzing multigenerational replacements. To better understand and describe the replacement process, [Norton and Bass \(1987\)](#) developed a multigenerational diffusion model. This model has become a popular forecasting tool in the high-tech sector. In telecommunications industries, older generation technologies often coexist in the market with the latest generation, and more than one new product may enter the market at or around the same time. This can be modeled as a multigenerational innovation diffusion problem.

[Nam, Kim, and Lee \(2008\)](#) modified the Bass diffusion model by combining conjoint analysis and the Bass model that used the adjustment coefficient to reflect the relative relationships between technologies. This coefficient represents the impact that the relative preference for one service has on the diffusion of the other service. But they focused on the customer perspective only. [Tseng, Cheng, and Peng \(2009\)](#) combined scenario analysis, the Delphi method, and the technological substitution model to analyze the organic light-emitting diode TV market. [Tseng, Lin, and Yang \(2012\)](#) combined conjoint analysis, scenario analysis, the Delphi method, and the innovative diffusion model to analyze the development of light-emitting diode TV market. [Iimi \(2005\)](#) estimated demand for cellular phone services in Japan and found that the demand was quite price-elastic. The telecommunications industry is highly integrated with other disciplines, such as electronics, physics, and mechanics, and it also tends to be affected by market change (e.g., new services, customer demand, and new entrants into the field). Yet some studies have considered customer preferences for the development of mobile broadband without considering macro-environmental factors (political, economic, social, and technological analysis). Meanwhile, previous studies of development trends in the telecommunications industry have estimated market potential but have seldom integrated analyses of customer preferences and macro-environmental factors.

Therefore, to address these gaps in the research, we use conjoint analysis to analyze customers' preferences and then combine the results with scenario analysis. Furthermore, we rely on expert opinion to forecast possible scenarios for the development of the telecommunications industry and then use the innovation diffusion model to forecast the sales volume for 2G, 3G, WiMAX, and LTE in each scenario over the next 10 years. This paper is organized as follows. [Section 2](#) describes the telecommunications industry in Taiwan and reviews the literature on conjoint analysis, scenario analysis, and the diffusion model. [Section 3](#) describes the methodology for the study, and [Section 4](#) is the empirical analysis. [Section 5](#) presents the research results and discussion.

2. Literature review

2.1. The development of WiMAX and LTE

Digital mobile telecommunications networks were introduced in the early 1990s ([Gruber & Verboven, 2001](#)). Over the past few years, there has been increasing demand for accessing the Internet over mobile devices. To address this, the telecommunications industry has strived to define a new air interface for mobile communications to provide a framework for high-mobility services and increase the overall system capacity, reduce latency, and improve spectral efficiency and cell-edge performance (WiMAXForum, 2009). Two emerging technologies, the IEEE 802.16 WiMAX and the 3rd Generation Partnership Project (3GPP) LTE, aim to provide mobile voice, video, and data services by promoting low-cost deployment and service models through Internet-friendly architectures and protocols ([Shan, 2009](#); WiMAXForum, 2009). Both of these technologies are being considered as candidates for 4G mobile networks.

Whereas the LTE standard has moved the Global System for Mobile Communications (GSM) standards toward what are more traditionally thought of as computer networking standards, WiMAX has moved traditional computer networking toward what has traditionally been thought of as mobile telephony standards. The two standards have different backgrounds with different strengths and weaknesses ([Speece & Maclachlan, 1995](#)). A comparison of mobile phone technologies appears in [Table 1](#). North American carriers AT&T and Verizon and European carriers T-Mobile, Orange, and Vodafone all show support for LTE ([Shen, 2009b](#)). Meanwhile, according to International Data Corporation (IDC) forecasting performed at the end of 2010, LTE mobile phone shipments worldwide will reach a total of 129.1 million units in 2014 ([Llamas, 2011](#)). This represents a CAGR of 811.9% for 2010–2014 ([ITU, 2009](#)).

2.2. The development of telecommunications in Taiwan

Taiwan launched its first digital mobile phone in 1995 ([National Communications Commission, 2009](#)). Until the end of 1997, the government opened the telecommunications operation authority to private companies, including FarEasTone Telecommunications, Taiwan Mobile, and KG Telecom. In light of such competition, low prices were the norm, and the number of mobile subscriptions grew dramatically in the following years. Taiwan had mobile telephony subscriptions of 108% in 2002 and 111% in 2003, ranking it the first in the world ([Chu et al., 2009](#); [Tseng & Lo, 2011](#)).

In addition to three 2G mobile operators, two companies were awarded 3G licenses in 2002, as shown in [Table 2](#). In 2004, Asia Pacific Broadband Wireless adopted Code Division Multiple Access 2000 (CDMA2000) technology, beginning the first 3G service. Soon afterward, other operators adopted Wideband Code Division Multiple Access (WCDMA) technology, and 3G service was introduced to the market in 2005.

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