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Technology forecasting for wireless communication

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Abstract

Wireless communications technologies have undergone rapid changes over the last 30 years from analog approaches to digital-based systems. These technologies have improved on many fronts including bandwidth, range, and power requirements. Development of new telecommunications technologies is critical. It requires many years of efforts. In order to be competitive, it is critical to establish a roadmap of future technologies. This paper presents a framework to characterize, assess and forecast the wireless communication technologies. A DEA-based methodology was used for predicting the state-of-the-art in future wireless communications technologies.

Keywords: Technology forecasting; Data envelopment analysis; Wireless communication

1. Literature review

There are many techniques that can be used to develop technology forecasts. Linstone (1999) provides an overview of methods evolving over time. Other researchers including Ayres (1999), Martino (1999) and Porter (1999) also provide comprehensive treatments of many approaches. Technology forecasting can be done both qualitatively as well as quantitatively. Linstone (2003) and du Preez and Pistorius (2003) provide examples of qualitative approaches such as multiple perspectives and threat/opportunity analysis which help to dissect problems so that further analysis can be done with quantitative models. Fildes (2006) provides an excellent review of forecasting research and outlets for publications. De Gooijer and Hyndman (2006) add to this research by focusing on time series forecasting. Meade and Islam (2006) provide a similar in-depth analysis for innovation diffusion.

The Technology Futures Analysis Methods Working Group (Porter et al., 2004) provides a good review of integrating multiple methods and evolving new methods for technology forecasting. Methods used frequently include scenarios (Sager, 2003; Silberglitt et al., 2003; Winebrake and Creswick, 2003), Delphi (Rowe and Wright, 1999), Growth Curves (Modis, 1999; Devezas et al., 2005), Analogies (Barley, 1998) and Innovation Diffusion Forecasting (Ilonen et al., 2006). Emerging methods include use of DEA (Anderson et al., 2002; Inman et al., 2006), Evolutionary Theory (Bowonder et al., 1999), Technology Roadmaps (Phaal et al., 2004), Patent Analysis (Kayal, 1999), Bibliometric Analysis (Watts and Porter, 1997; Daim et al., 2006), and Back Propagation Network (Wang and Shih-Chien, 2006). Kumar et al. (2002) indicate the necessity of combining the forecasting model with the perceived future industry dynamics. He emphasizes that the quantitative forecasting methods such as time series and econometric modeling have become less accurate and cannot be relied upon because the industry no longer has the stable historical relationship that these models rely on. The literature suggests that including forecasts from different statistical methods generally improves accuracy when significant trends are involved. Useful information can be obtained using several sources of forecasts, adjusting for biases. Yoo and Moon (2006) suggest that instead of trying to choose the best single method, one should combine the results from different methods, which would help in reducing errors arising from faulty assumptions, biases, or mistakes in the data.

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The new product development literature is relevant because the efforts to create these new technologies are relatively similar to product development and it will provide technology platforms upon which other products will be developed. There is an extensive literature on new product development but for the sake of providing a context and linkage to this literature, we will provide a discussion of a few select papers. The importance and usefulness of this work can be demonstrated in a survey by G.M. Scott of technology management practitioners concerning new product development (Scott, 1999). Scott ranked the 24 most significant management of technology problems in new product development. The top six problems identified by practitioners were

(1) Strategic planning for technology products
(2) Technology core competencies
(3) Creating a conducive culture
(4) New product project selection
(5) Cycle time reduction
(6) Technology trends and paradigm shifts

This paper has a clear link to four of these six most important new product development problems (1, 4–6) faced by practitioners.

First, Moore's Law has been an important part of the long-term strategic plan of microprocessor companies as evidenced by the billions of dollars spent on manufacturing facilities for each new generation of microprocessors and the roadmaps of Sematech. Similarly, this approach can be used to develop estimates of future performance from past performance trends to assist in longer range product planning.

The connection between this work and the problem of *new product project selection* is clear in the domain of these types of rapidly evolving products. Using estimates of technical progress, a project can be evaluated against how it performs relative to this future level of performance. The estimate of rates of product performance change can be used to provide a clearer product performance goal early in the development stage.

As noted by Gupta and Wilemon (1990), problems with product definition were the leading cause of delayed projects. Improvements in this area will help in *cycle time reduction*.

The work in this paper is particularly well suited to examining *technology trends and paradigm shifts*. The annual technology change directly estimates measure trends. Also, it may be possible to recognize the impact of disruptive technologies such as the digital light processor technology of Texas Instruments on the computer display projector market by seeing sudden changes in the efficiency frontier or rate of change. In this way, a disruptive technology may initially appear to occupy a small niche, but as this new technology is refined, it becomes standard practice and occupies a larger portion of the frontier. This study attempts to estimate future demand for wireless technologies and evaluate the service. To this end, Technology Forecasting using Data Envelopment Analysis (TFDEA) method will be used in addition to other supplemental methods. In the last few years, the mobile industry has been planning on the launch of communication technologies beyond third generation (3G).

Nunno (2003) claims that the demand for more robust mobile networks will increase even after deployment of 3G. Some characteristics of the next generation of mobile service are expected to be a greater global compatibility, a greater bandwidth and robust securities for emergent mobile-commerce applications (Nunno, 2003). Rappaport (2001) indicates in his book that the most important future process for the wireless communication will be its standardization. Table 1 provides a list of literature, the technology forecasting methods used and the results for the forecasting of future wireless technologies.

2. Methodology

One of the key methods used in this report is Data Envelopment Analysis (DEA). The approach of DEA has been used in comparing telecommunication systems and countries frequently; for example, see Majumdar and Chang (1996), Sueyoshi (1998), Cooper et al. (2001), Lien and Peng (2001), and Uri (2001). In contrast, this work uses a recently developed extension of DEA called TFDEA to predict future state-of-the-art technologies. This is the first time TFDEA has been applied to wireless communication systems. TFDEA was created in 2001 as an alternative quantitative approach for technology forecasting. It has been applied to a number of industries to lend insight to managerially relevant issues. In the case of enterprise database systems (Anderson et al., 2001), it was able to empirically identify the potentially disruptive technology of open source software upon the traditional database software industry. Another application showed how Moore's Law could be extended to multiple dimensions in the case of microprocessors (Anderson et al., 2002). The latter paper, by Inman, Anderson, and Harmon, formalizes the linkage to the technology forecasting literature by rigorously comparing TFDEA to a previously published influential paper (Martino, 1993; Anderson et al., 2002) and model for technology forecasting. The TFDEA approach was found to provide both a managerially and statistically significant improvement over the previously published technology forecasting results.

TFDEA uses the concept of state-of-the-art (SOA) in conjunction with DEA to determine historical levels of technology and determine trends in order to assess future technological characteristics. SOA is determined through analysis of products that implement a particular technology at a given point in time. The SOA is defined (Sahal, 1976) as "the state of best implemented technology as reflected by the physical and performance characteristics actually achieved during the time period in question." TFDEA improves on previous SOA approaches by