



# The prioritization and verification of IT emerging technologies using an analytic hierarchy process and cluster analysis

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## ABSTRACT

This study proposes a quantitative technology forecasting method for prioritizing investments using analytic hierarchy process (AHP) analysis and a verification process to evaluate the prioritization using factor analysis and cluster analysis of the factor scores.

To verify the prioritization process of emerging technologies, this study completed two surveys of experts. Cluster analysis of the factor scores based on the second survey is used to verify the results of prioritization using AHP analysis based on the first survey. The results suggest high hit ratios between the prioritization using AHP analysis and the cluster analysis of factor scores. This confirms that the AHP method is significantly reliable as a method for selecting promising electronic device technologies. As the emerging technology market is more changeable than ever before, the study's prioritization and verification process provides a relevantly robust solution.

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## 1. Introduction

For the past few decades, as technologies have been becoming more important to ensuring that a country stay competitive in the world market, many countries have been investing financial and human resources in emerging technologies. This is especially true for technology forecasting. Forecasting involves a complex process with multi-interdisciplinary and interactive characteristics. The electronic device technologies are a basis of the information technology (IT) industry, which has recently experienced a rapid growth, and one of the most decisive driving forces of this progress has been the emergence

of diverse IT-based technologies and various kinds of convergence among them. From a national point of view, investing in competitive technologies can clearly create more national value. This means that national businesses should heavily invest in emerging technologies. Due to limited financial and human resources, however, even a wealthy country cannot afford to invest its resources in all profitable technologies. Therefore, a cautious appraisal and prioritization (selection) of competitive technologies should be conducted before investments are concentrated in cautiously selected technologies.

There is no dominant efficient formal method for prioritizing competitive technologies since there is a lack of verification processes for the technologies funded by the government. As for effective technology forecasting or selecting, quite a few researchers have been using various methods, such as clustering analysis [2], the Delphi method [3,4], the analysis hierarchy process (AHP) [1,5], and patent data analysis [6]. In particular, the Delphi technique is a method of eliciting and refining group judgments and as a forecasting method relying on historical data is also one of the most popular tools [7]. Technology is predicted on the

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criterion of the life cycle variables observed by experts. However, the Delphi technique can only rely on the latest data if there are not enough growth curves in the technology life cycle or historical data. In particular, the Delphi technique is based on multiparty analyses of opinion gaps among Delphi participants depending on the job or expertise and resolutions toward consensus.

To overcome these limits of the Delphi technique, the AHP was created by Saaty [8] and it is widely used in the research fields of technology selection [9–11]. The fuzzy Delphi method together with AHP was adopted to support decision making in the context of the e-marketplace [12] and managerial talent assessment [13]. The AHP, one of the multi-criteria decision making (MCDM) processes, can be easily applied when qualitative and quantitative data are mixed. As forecasting results are typically influenced by the forecasting method used, it is important to determine the forecasting method that is most appropriate to a given situation.

While previous studies aimed to find promising future technologies [14,15] using clustering analysis [2] and AHP [1,5], studies on selecting emerging technologies based on economy, technology, and policy factors using a systematic prioritization and verification method are rare. A system of technology prioritization and verification using a combined approach with different methods to identify and plan core emerging technologies is not yet well established. This study intends to fill the void. We develop a quantitative technology forecasting scheme for prioritizing IT emerging technologies and a verification process to evaluate the prioritization of these technologies. This study focuses only on the field of electronic device technology in order to enhance the immediate and practical applicability of the study.

To verify the process of prioritizing emerging technologies, we developed two surveys of experts. First, we examined the questionnaire data collected from experts to prioritize emerging technologies using AHP analysis. Second, we used the questionnaire data collected from another group of experts to produce another prioritization using clustering analysis of factor scores. The main factors affecting technology forecasting are identified and the results of AHP analysis are verified. To establish the verification of the prioritization of various technologies, the latent factors of the technologies are extracted through factor analysis, and the technologies are then scored and ranked using the factor scores. A cluster analysis of the scores is conducted, and the classification of cluster analysis is compared with the prioritization of the AHP analysis to verify the result of prioritization and examine whether the importance of the technology is different between AHP and cluster analysis of the factor scores. Discussions and implications are included in this paper.

## 2. Theoretical background

### 2.1. Emerging technology prioritization and verification

The development of electronic device technology is essential for the sustainable growth of the IT industry. It also has an enormous influence on overall national competitiveness as well as on the strategies, tactics, and operational decisions of various organizations. Applying marketing principles to commercializing technology has particularly been a vital issue in a

highly competitive global market place [16]. The rapid growth of investments in the high-technology industry has emphasized that intensive consideration of the investment risks and payoffs should be included in the decision-making process. Therefore, prioritizing and selecting the appropriate R&D investments can be regarded as a key factor in sustaining national growth viability and prosperity. In addition, there has been much assertion that the technology forecasting method needs to become more effective, efficient and result-oriented [17].

Emerging technology forecasting can be simply defined as an attempt to predict the future characteristics of useful electronic devices. Technology verification verifies the technology forecasting results. The concept of verification indicates whether the results concur with the original plan. Specifically, the verification of technology forecasting is the process of determining the performance and the quality of forecasting. The performance and quality are used as input for the administrative, scientific and economic decision-making. Many researchers have been investigating the verification process of the forecast technologies. However it is difficult to create a reasonable verification and evaluation of forecast technologies, which must be done in a coherent fashion such that the administrative, scientific and economic needs are met. This study develops a verification process that considers a number of basic factors based on a factor analysis of the results of technology prioritization obtained through AHP analysis.

### 2.2. Analytic hierarchy process (AHP)

AHP is designed to solve complex multi-criteria decision problems. It is a flexible and powerful tool for handling both qualitative and quantitative problems. The AHP approach has been adopted in many applications including project selection and business performance evaluation. Durán and Aguilo [18] showed an analytic hierarchical process (AHP) based on a fuzzy number multi-attribute method for evaluating and justifying an advanced manufacturing system. Cebeci [19] applied the AHP method to select a suitable ERP system for the textile industry. The fuzzy analytic hierarchy process, a fuzzy extension of the multi-criteria decision-making technique AHP, compared these ERP system solutions. Chen and Wang [20] discovered the critical operational factors of the information service industry in developing a market for using the AHP method and provided a referential framework for operations in the information service industry. They investigated how the choice of a typical commercial application software product company influenced its investment project for the strategy of entering the target market using the AHP.

The AHP is composed of four steps: First, state the problem and broaden the objectives of the problem or consider all the factors, objectives and outcomes. Second, identify the criteria that influence the behavior. Then, structure the problem in a hierarchy of different devices constituting goal, criteria, sub-criteria and alternatives. Third, compare each element in the corresponding devices and calibrate them on a numerical scale. This requires  $n(n - 1)/2$  comparisons, where  $n$  is the number of elements with the considerations that diagonal elements are equal or '1' and the other elements are simply the reciprocals of the earlier comparisons. Fourth, perform calculations to find the maximum eigenvalue, consistency index (CI), consistency ratio (CR), and normalized values for each criterion/alternative. To

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