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A forecasting decision on the sales volume of printers in Taiwan: An exploitation of the Analytic Network Process

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ABSTRACT

This study applies the Analytic Network Process (ANP) to forecast the sales volume of printers in Taiwan for adjusting the recycling and treatment fee as an incentive for recycling industries. When historical data are lacking and when a broad spectrum of social impact is involved, the ANP, with the capacity to manage dependence and feedback among the factors, can serve as a tool to forecast outcomes by using expert judgment. The priorities derived from numerical judgment are similar to probabilities. They are obtained from the limit supermatrix of the ANP that represents forecasts for the next period. The result of back testing has shown that the ANP's percentage error is small compared with those of some naïve statistical techniques. Sensitivity analysis is also made to ensure robustness of the model. Finally, the characteristic strengths of the Analytic Hierarchy Process (AHP) and ANP in forecasting are discussed to simplify their use in future applications.

1. Introduction

Global warming and environmental deterioration have drastically forced people to make compensatory decisions for survival on our Earth as well as prompting them to be concerned about sustainable and green issues for humans. In 1971 the Environmental Protection Administration (EPA) of the Republic of China (ROC) in Taiwan initialized some actions on waste clean-up and resource recycling by establishing regulations to force people to recycle waste. To consider environmental costs, the Recycling Fund Management Board (RFMB) of the EPA was established in 1998. The RFMB collects funds from manufacturers and importers when they sell goods (33 categories announced so far) to customers and subsidizes recycling industries with a recycling and treatment fee as an incentive to increase the recycling rate of waste goods, containers, and packages [1].

Electronic waste (e-waste) is the major target in environmental policy making, because it contains many hazardous materials that are not easily disposed of and decay over a long period of time. Such waste requires industries to specialize in dissolving and cleaning to prevent environmental pollution, particularly for end-of-pipe recycling [2]. In 2001 the RFMB set forth a regulation on recycling used printers due to the fact that waste printers make up a large part of the e-waste from consumers. To balance the input and output of funds, sales volume and volume of waste printers collected are the two major factors for setting up a fee, and both rely heavily on forecasting for the next year so that the fee can be predetermined on a yearly basis. However, the amount of printers for selling and recycling is difficult to estimate due to the state of the economy and customer behavior at the time of the forecast, along with the availability of sparse historical data.

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The RFMB has estimated the sales volume for the purpose of fund allocation in the past. Wen [3] employed three techniques to evaluate sales volume and volume of waste collected for announced recyclable items: trend functions with quadratic and cubic forms, a simple moving average, and a modified moving average from the growth rates of the nearest two periods. Liu [4] made use of a simple moving average and trend techniques for estimating the volume of waste cars in Taiwan, but the forecasting results were not good enough due to the complexity of the economic factors. The current work still relies heavily upon expert judgment. Thus, a reliable technique is in demand, because it has a significant impact on decision making with regard to environmental policy.

Forecasting is an analytical technique used to assist managers to develop a business plan or to proceed with decision-making with uncertainties, and a forecast of the sales volume is closely related to a business' competitive strategy [5]. Traditional forecasting approaches have been found difficult to use in predicting the sales volume and the amount of waste because of the inadequacy of historical data, the extensiveness of the social dimension, and because of unforeseeable factors. To conduct a forecast, this study therefore applies the Analytic Network Process (ANP), which is a generalization of the Analytic Hierarchy Process (AHP) that deals with dependence and feedback among the factors, combines qualitative and quantitative analyses through expert judgment, and relies on the constraining attributes mentioned above. Moreover, the AHP and AHP can be used to forecast general events whose actual outcomes have not yet been observed, e.g., predicting a chess winner [6] or market share in the hamburger industry [7]. We concentrate the forecasting on a time basis and apply the ANP to forecast printer sales volume for the next period based on the data from the RFMB since 2002. It is hoped that this study can be used as another choice for solving the current problem.

The paper is organized as follows. After the introduction, a literature review on forecasting using the AHP and ANP is provided in Section 2. Forecasting-related applications of AHP and ANP are also collected for ease of understanding. Then, the detailed procedure of the ANP model for forecasting is proposed in Section 3. A case study is then illustrated in Section 4, and sensitivity analyses are performed to ensure that the model is robust. In Section 5 some common statistical techniques are applied to the same problem for comparison. The essence of utilizing AHP/ANP for forecasting is discussed in Section 6. In the final part, some concluding remarks are made for ease of future applications.

2. Literature review

AHP and ANP are two related techniques in the discipline of multi-criteria decision making (MCDM) that are general for the purpose of ranking (prioritizing), selecting, and sorting when a complex decision is made. However, MCDM techniques for forecasting are implicitly represented in which their alternatives will be the possible forecasts. Vargas [8] first implied that the AHP for forecasting is done through judgment based on experience, feeling and subjective information, or possibly using quantitative data. The technique tries to develop alternative futures and paths in which the most feasible desired future from the present state of the system is attained. At the same time, he emphasized that the important characteristics of the AHP are the abilities for measuring intangibles and for making tradeoffs among intangibles and between the controllable and uncontrollable factors. These advantages have made the AHP, and later on the ANP, one option for forecasting over other MCDM techniques.

Wolfe [9] pointed out that the AHP prioritizes the alternatives in a multiple-alternative scenario based upon the inputs of decision makers and both quantitative and judgmental factors are considered. The output from the process is composed of probabilistic weighting for each alternative defined in the hierarchy. He first deemed the values of the AHP in a forecast adjustment and the determination of how much the factors influence the forecasts. Dyer and Forman [10] indicated three forecasting-related applications of AHP: (i) expert-opinion forecasting—as a forecasting technique; (ii) combining forecasts—combining the results of several forecasting tools; and (iii) evaluating forecasting methodology—selecting the most appropriate forecasting tools. Therefore, the potential of the AHP and the ANP can be developed for many applications in forecasting, but the first part is the major interest in most applications.

The application of the AHP for forecasting dates back to the late 1970s, when a chess winner was predicted using technical and behavioral factors [6]. However, the process was very similar to the purpose of selecting in MCDM, and not a time basis. Later, Blair et al. [11] forecast the exchange rates of the Japanese yen to the US dollar by the AHP. A four-level hierarchy, including five outcomes ranged at the bottom level, was established for forecasting the exchange rates for the next 90 days, and the actual rate was within the "no change" range. Kim and Whang [12] utilized growth curve models and the AHP to forecast the technological capabilities of South Korea's civil aircraft industry, in which the aircraft industry technology was decomposed into a three-level hierarchical structure and two types of indices were established for measuring industrial capability. The capability was evaluated for every 5-year period. They concluded that South Korea will reach the self-development stage by 2010. Nevertheless, the AHP did not play a major role in their forecasting.

Ulengin and Ulengin [13] used the AHP to forecast the exchange rate of US dollar/Deutsche Mark. A five-level hierarchy was constructed, and five alternatives, i.e., sharp decline, moderate decline, no change, moderate increase, and sharp increase, presented the priorities of the outcome ranges that could be ranked for forecasts of 90 days. The result of the first-period evaluation showed that the "no change" range had the highest probability of occurring and the "moderate increase" had the second priority. Korpela and Tuominen [14] dealt with demand forecasting for inventory via the AHP. They defined a five-level hierarchy that considered goal, actors and environmental factors, factors, scenarios, and demand growth rates, respectively. The possible change rates in demand compared to the sales estimates for the present year were illustrated by