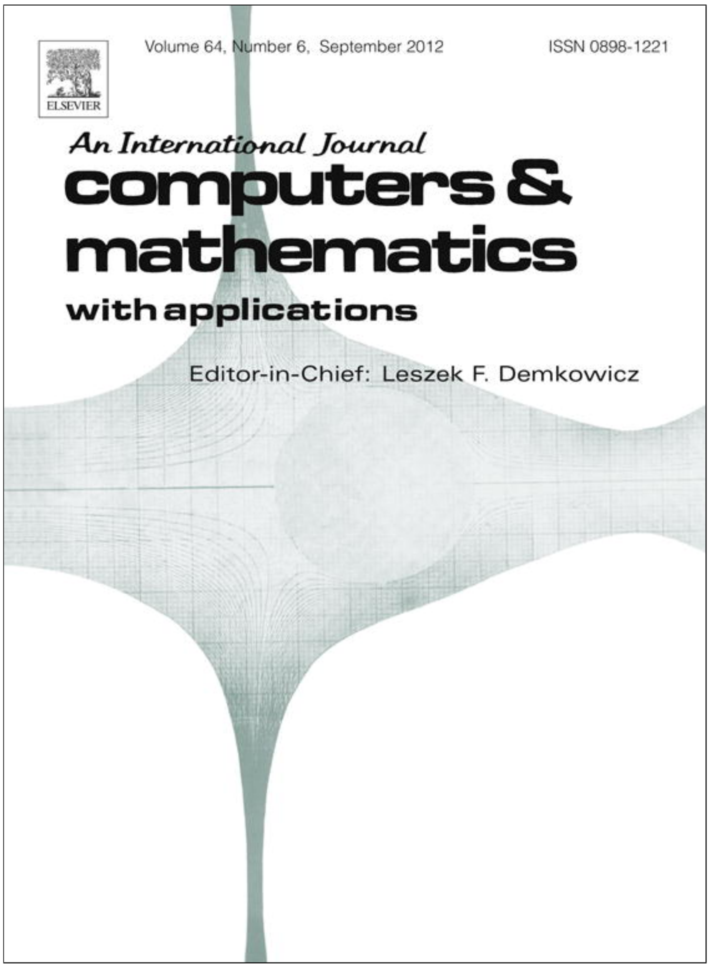
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A forecasting decision on the sales volume of printers in Taiwan: An exploitation of the Analytic Network Process

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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 four alternatives: strong decline, weak decline, weak growth, and strong at the bottom level. Considering each probability of the alternatives, this product's expected demand growth rate in the market was 0.14%.

Saaty [15] employed the tool of the ANP to predict the market shares of the three biggest hamburger companies: McDonald's, Burger King, and Wendy's. An eight-cluster network was constructed, including competition, marketing mix, customer groups, time horizon, indirect competitors, public health, traits, and contemporary issues, under a single control criterion of economic influence. In its time horizon cluster, the short and medium terms were measured to improve market share by connecting other elements to this cluster. The predicted market shares for these three companies were 62.9%, 23.9%, and 13.2%, respectively.

Blair et al. [16] utilized the AHP with feedback to produce a forecast of when the US economy would recover. The model was composed of three levels, i.e., primary factors, sub-factors, and alternative time periods, in which there were some interactions among the levels. Four alternatives were defined by the adjustment periods of months. After obtaining the priority of each period, the synthesis forecast of the recovery was 8.53932 months later. Along the same lines, Blair et al. [17] further forecast the resurgence of the US economy in 2010 via the AHP with a feedback from the bottom level to the top level. A similar three-level hierarchy was established in which the geopolitical context cluster was replaced by a global financial context cluster at the level of sub-factors. Four alternatives were designated by periods of months with a long span. The expected number of months until a turnaround in the economy was 19.589 months which was the third quarter of 2010 from the forecasting date of December 2008.

Niemira and Saaty [18] made use of the ANP to forecast the probability of a country's financial crisis in six months for the US. The imbalance–crisis turning point model was formulated by a network having five clusters: policy actions, exogenous shocks, domestic imbalances, sources of financial crisis, and financial crisis chance. The result showed that the 1990 bank crisis in the US went through much empirical analysis, hoping to provide another robust forecasting system. Yuksel [19] utilized the AHP to adjust Winter's multiplicative forecasts for hotel demand forecasting in Ankara, Turkey. A four-level hierarchy was created, incorporating goal, criteria, scenarios, and effects. Five alternatives or effects were designated — very negative effect, negative effect, not important effect, positive effect, and very positive effect — in which the "not important effect" obtained the highest probability.

Voulgaridou et al. [20] applied the ANP to forecast the sales of a new book in Greece. A four-cluster network was established, including characteristics, environment, marketing, and alternatives. Three alternatives were defined: low sales of less than 1000 copies, medium sales of between 1000 and 2000 copies, and high sales of up to 3000 copies. The most probable predicted outcome was "high sales". Zammori [21] then made use of the AHP and ANP for forecasting, first using the AHP to predict the 2008 US presidential election. A four-level hierarchy was constructed, including goal, criteria, sub-criteria, and alternatives. As a result, Senator Barack Obama was projected to be the winning candidate for president. The second case used the ANP to estimate the market share for the five largest companies in Italy's alpine ski industry. A network with five clusters connected by 10 outer dependencies was established based on a single control criterion — economic influence. The predicted market shares for the five competitors, namely Rossignol–Dynastar, Atomic, Fisher, Volkl, and Salomon, were 40.02%, 24.74%, 16.2%, 10.2%, and 8.84%, respectively. Furthermore, the compatibility index proposed by Saaty [7] assesses how close a priority vector, the forecast market share, is to the actual market share.

After reviewing the literature, we have listed these developments by the AHP and ANP for forecasting in Table 1 so that the whole picture can be illustrated. Based on these works, the primary applications of the AHP in the forecasting area by Dyer and Forman [10] were further expanded to seven forecasting-related applications of the AHP and ANP under the categories of implicit or explicit representation of time as shown in Table 2. Expert-opinion forecasting, adjustment of other forecasting methods and hybrid forecasting with other forecasting methods are classified as the first category. Evaluating forecasting methodology, combining forecasts, prediction of future events, and assessment of future performance are grouped in the second category. The table gives us insight for making forecasts/predictions by the tools of the AHP and ANP; the present study is attributed to expert-opinion forecasting.

3. The ANP procedure for forecasting

The newly developed ANP possesses the ability to handle a complicated situation with flexibility and comprehension [18] and can manipulate tangible and intangible factors [14]. Therefore, while the prediction of printer sales volume is limited by many conditions, this research hopes to employ expert judgment to construct an ANP model to obtain the forecast value of the sales volume of printers in Taiwan. In the following, we will modify the ANP procedure for our forecasting and investigate some issues of using the model.

This study mainly refers to Niemira and Saaty [18] and Yuksel [19] in terms of the steps they propose for the calculation analyses of the ANP and AHP. Although Korpela and Tuominen [14] proposed three basic steps for demand forecasting by the AHP, a slight modification in [22] regarding the procedure of the ANP makes it clearer for forecasting by illustrating the following six steps.

Step 1: Clarify the goal of the forecasting problem and list some related clusters and their elements.

The first step of problem solving is problem formulation, which identifies the forecasting problem under the current circumstances. To obtain a better forecast to reach a goal, decision makers consider related factors under such circumstances. A helpful concept existing in the ANP is the control hierarchy. It assists decision makers in thinking about the spread of

Table 1
Forecasting applications of the AHP and ANP.

Authors (year of publication)	AHP/ANP	Level/network	Period of forecasting	Forecasting target	Note
Blair et al. (1987) [11]	AHP	4 levels	90 days	Foreign exchange rates of Japanese yen/US dollar	Five alternatives (outcome ranges)
Kim and Whang (1993) [12]	AHP	3 levels	40 years (by 8 periods, one for each 5 years)	Technological capabilities of South Korea's civil aircraft industry	Growth curve models combined with the AHP for forecasting
Ulengin and Ulengin (1994) [13]	AHP	5 levels	90 days	US dollar/DM exchange rate	The priorities of five alternatives (scenarios) are ranked
Korpela and Tuominen (1996) [14]	AHP	5 levels	1 year	Change rate in demand	Four alternatives for demand growth rates
Saaty (1999) [15]	ANP	8 clusters	n/a	Market shares of the three major hamburger companies in the US	Three alternatives (companies)
Blair et al. (2002) [16]	AHP	3 levels	24 months (max)	The time period of the US economic recovery in 2001	1. Four alternatives (within 3, 6, 12, and 24 months) 2. The AHP with feedback
Niemira and Saaty (2004) [18]	ANP	5 clusters	6 months	Probability of a financial crisis	Two alternatives using zero and one to represent no crisis and crisis, respectively
Yuksel (2007) [19]	AHP	4 levels	1 month	Adjustment of hotel demand forecasting	Five alternatives for the adjustment rates
Voulgaridou et al. (2009) [20]	ANP	4 clusters	3 months	New product (book) sales in Greece	Three alternatives
Blair et al. (2010) [17]	AHP	3 levels	36 months (max)	The time period of the US economic resurgence in 2010	1. Four alternatives (0–6, 6–12, 12–24, and 24–36 months). 2. The AHP with feedback from the bottom to the top
Zammori (2010) [21]	AHP ANP	4 levels 5 clusters	n/a n/a	US presidential election in 2008 Market share of ski equipment in Italy	Two alternatives (candidates) Five alternatives (companies)

Table 2
Forecasting-related applications of the AHP and ANP.

Category	Area	Real-world applications	Notes
Explicit representation of time	Expert-opinion forecasting	Forecast of the exchange rate of the US dollar/Deutsche Mark [13]	*This study
	Adjustment of other forecasting methods	Adjustment of Winter's multiplicative forecasts for hotel demand forecasting in Ankara, Turkey [19]	
	Hybrid forecasting with other forecasting methods	Forecast of the technological capabilities of South Korea's civil aircraft industry [12]	
Implicit representation of time	Evaluating forecasting methodology	Selection of a best sales forecast method [10]	
	Combining forecasts	Derivation of the weights for a composite forecast [10]	
	Prediction of future events	Prediction of a chess winner in 1978 [6]	
	Assessment of future performance	Prediction of the market shares of US hamburger companies [15]	

influence to all relevant factors that are essential for decision making. If the influencing relations are complicated, then some subcriteria associated with the hierarchy are suggested [22], and then some associated clusters and their elements can be listed. Literature survey and stakeholders' opinions are the input to the step.

Forecasting deals with future outcomes under uncertainty. The ANP or AHP has an ability to manage uncertainty starting with the influencing factors and looking forward toward the uncertain outcomes which is called a forward process compared to common analyses by a backward process [23]. Thus, the possible uncertain outcomes will be introduced at the alternative cluster, which is the generation of alternative paths to the future [24], in the forecasting problem.

Step 2: Take a questionnaire survey from experts to establish a preliminary network for forecasting.

A questionnaire survey from experts helps to separate the problem into several dimensions and establish an appropriate set of clusters and their elements. Hence, in the first questionnaire survey, experts are asked to revise the definition of each cluster resulting from this forecasting problem and the criteria belonging to these clusters. After collecting the experts' opinions, the components of the network are figured out. Note that the ranges of possible changes or target ranges of values in the alternative cluster are the key elements of forecasting.

Step 3: Perform expanded pair-wise comparisons and obtain relative priorities of clusters and their elements in the network.

Another questionnaire survey, by Saaty's 1–9 fundamental scale, is employed to collect expert judgment concerning what multiple of importance or dominance one element has over another element with respect to the criterion to which they are compared [22]. These opinions are realized by pair-wise comparisons so as to obtain their priorities. The survey illustrates the work as two parts: (i) make pair-wise comparisons on related clusters; and (ii) in order to deal with the interactions, including outer dependence among clusters and inner dependence among elements, make further pair-wise comparisons between the elements of any two clusters by experts so as to get priorities represented by the ratio scale. This will be zero when there is no influence or interaction, which is an extra questionnaire beyond the AHP. All reciprocal matrices should pass the consistency check, whose value is suggested to be less than the value of 0.1 [25]. That means that the consistency of the logic in the comparison is in an acceptable range; otherwise, the comparison in the matrix needs to be redone for a better judgment. Observe that the responses in the individual questionnaires are aggregated through a geometric mean as the decision of this group [26], at the respective position, so as to form the elements of the supermatrix in the next step.

Step 4: Construct a supermatrix and compute the limiting priorities.

Arrange all priority vectors, representing the impact of a given set of elements in a cluster on another element in the network, from the previous step to be the sub-columns of the corresponding column of an unweighted supermatrix, $\boldsymbol{W}$. Here, $\boldsymbol{W}$ is composed of k clusters, i.e., $\{C_1, C_2, \ldots, C_k\}$, and the linkages of these clusters $\boldsymbol{W}_{ij}$, where $C_k = \{e_{k1}, e_{k2}, \ldots, e_{kn}\}$, are the elements of the cluster k.

$$\boldsymbol{W} = \begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \cdots & C_k \\ e_{11}\ e_{12}\cdots e_{1n} & e_{21}\ e_{22}\cdots e_{2n} & \cdots & e_{k1}\ e_{k2}\cdots e_{kn}\end{array} \\ \begin{array}{cc} C_1 & \begin{array}{c} e_{11}\\ e_{12}\\ \vdots \\ e_{1n}\end{array} \\ C_2 & \begin{array}{c} e_{21}\\ e_{22}\\ \vdots\\ e_{2n}\end{array} \\ \vdots & \vdots \\ C_k & \begin{array}{c} e_{k1}\\ e_{k2}\\ \vdots\\ e_{kn}\end{array}\end{array} & \begin{bmatrix} W_{11} & W_{12} & \cdots & W_{1k} \\ W_{21} & W_{22} & \cdots & W_{2k} \\ \vdots & \vdots & & \vdots \\ W_{k1} & W_{k2} & \cdots & W_{kk}\end{bmatrix}\end{array} \tag{1}$$

where

$$\boldsymbol{W}_{ij} = \begin{bmatrix} W_{i_1j_1} & W_{i_1j_2} & \cdots & W_{i_1j_{nk}} \\ W_{i_2j1} & 1W_{i_2j_2} & \cdots & W_{i_2j_{nk}} \\ \vdots & \vdots & \cdots & \vdots \\ W_{i_{ni}j_1} & W_{i_{ni}j_2} & \cdots & W_{i_{ni}j_{nk}} \end{bmatrix}.$$

If there is no linkage between C_i and C_j, then $\boldsymbol{W}_{ij}$, where $i, j = 1, 2, \ldots, k$, equals zero. Each column of the unweighted supermatrix is then normalized and synthesized to account for the overall influence of the clusters by column, and this operation makes the column of the supermatrix stochastic, known as a weighted supermatrix $\boldsymbol{W}^a$. Afterwards, the limiting supermatrix $\boldsymbol{W}^n$ can be obtained with almost identical elements column-wise through the following operation:

$$\boldsymbol{W}^n = \lim_{a\to\infty} \boldsymbol{W}^a. \tag{2}$$

The derived weights are used to weight the elements of the corresponding column blocks of the weighted supermatrix. Two types of outcome are possible, and one can refer to Saaty [22] for obtaining limiting priorities by multiplying the weighted supermatrix by itself n times until the columns stabilize. The limiting priorities are the corresponding column values for each cluster and their elements.

Step 5: Process the forecasting outcome.

The limiting supermatrix provides the priority information for the elements of each individual cluster. Since the forecast is implicitly represented in the alternative cluster, we will focus on the cluster. As previously mentioned, each element in the cluster presents one possible range of an increasing or decreasing ratio or a physical value. While obtaining the respective priorities, acting as the role of probability, of all elements, we multiply each priority by its corresponding middle value of the range and then sum them together to obtain the forecast. The value of the forecast is the forecasting outcome.

Table 3
Historical data of the sales volume of registered printers in Taiwan by year.

Year	2002	2003	2004	2005	2006	2007	2008
Sales volume	1,047,957	1,138,440	1,091,705	1,083,829	981,984	838,822	820,161

Note: From RFMB, EPA, ROC Government.

Step 6: Execute sensitivity analysis of important parameters.

Sensitivity analysis is the study of how the optimal solution responds to changes in the input parameters or the elements in the network. It is a technique for systematically changing the input parameters of the elements to see whether the final selection is stable to changes in the inputs. Some important elements or clusters are chosen for analysis to see the possible change of the final outcome. One special interest is to see whether these changes alter the order of the final outcome by the ANP [7].

Now that the comprehensive steps have been illustrated, we demonstrate the procedure through a case study in Taiwan.

4. Case study

Throughout Taiwan's rapid economic development during the 1950s to 1990s, small- and medium-sized enterprises blossomed, helping to increase national income and the standard of living and creating the nation as "the Island of Silicon" in the global technology sector. Due to the high prevalence of personal computers, electronic printers have become essential computer peripherals for both individuals and firms. There are four main types of printer: laser, ink jet, dot matrix, and thermal, with thermal not included in the announcement list of the RFMB. Since the RFMB set the regulation on recycling waste printers starting from April 2001, it has been collecting funds from importers (as there are no domestic manufacturers now), and when they sell printers to customers, they also subsidize the recycling industries with a recycling and treatment fee on a yearly basis. Table 3 lists the sales volumes of registered printers from 2002 to 2008.

For forecasting, Blumberg [27] points out irregular demand, a short product life cycle, and a fast turnover rate as the characteristics of high-tech products. Wen [28] also addresses the issue that complicated usage and consumer behaviors make it hard to estimate the sales volume and the volume of electronic waste collected. Hence, our study tries to utilize the ANP to avoid the difficulties of traditional techniques.

The study was executed in the July of 2009. Since the forecasting needs reference data to measure the accuracy of the method, the volumes from years 2002–2007 were used as the training data, and the volume of 2008 was selected as the testing data. The detailed study is illustrated step by step as follows.

Steps 1 *and* 2:

Applying a forecast on a specific product demand, this research predicts the sales volume of printers in Taiwan. Korpela and Tuominen [14] deem that national economic development could cause product demand. Saaty [15] believes that economic factors are the main reasons affecting market share, and Yuksel [19] applied changes in the economy to work as a factor to adjust the time series to predict hotel demand. Both Korpela and Tuominen [14] and Saaty [15] consider the influences of competitive strategies and various types of consumer behavior to affect each predicted alternative or analytical objective when analyzing a specific market and demand. As mentioned above, an economy is a consequential element when forecasting quantity of demand and undergoing any relevant product market analysis. Therefore, economic influence is considered to be the only control hierarchy that builds a primary forecast model for analyzing the mutual influence of consumers, manufactures, and sales volume within a single network.

According to expert judgment, the important issue affecting the sales volume of printers is economic factors that also affect consumers and firms at the same time. In other words, consumers and firms change their behavior due to economic conditions and different consumers' behavior not only causes firms to modify their competitive strategies but also directly affects the total sales volume of printers. Depending on the various types of consumer and sales achievement, firms will conduct different competitive strategies that in turn affect consumers' behavior. Thus, a four-cluster network is established as shown in Fig. 1: (1) consumers, (2) consumers' behavior, (3) marketing mix, and (4) forecasts or alternatives. Afterwards, the elements inside each cluster are further illustrated in the following.

(1) The cluster of consumer types.

Korpela and Tuominen [14] consider that customers and potential customers affect the level of product demand. Saaty [15] evaluated the market share of the US fast-food industry by way of different consumer types such as the white collar professional, the blue collar laborer, the student and the family. Through the correction of expert judgment, consumer types are classified into individuals and organizations, with the former referring to individuals like students or family while the latter include government, schools and universities, and profit or non-profit organizations.

(2) The cluster of consumers' behavior.

Korpela and Tuominen [14] indicate that customers' behavior is influenced by the growth of the entrepreneur, logistics demand, and product characteristics. Saaty [15] further indicates that consumers' attitude is altered with the issues or activities currently valued or influenced. With a literature review and expert judgment, consumers' behavior is set by three elements: users' habits, printer requirements, and purchasing power. Users' habits affect the usage of printers which

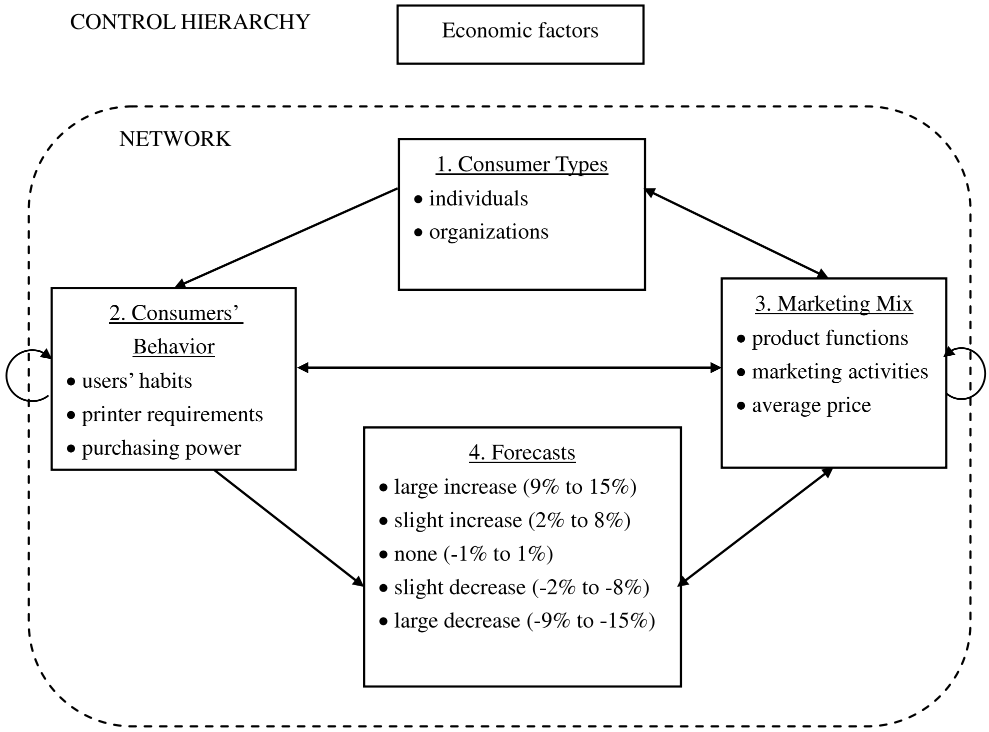

Fig. 1. The network of the sales volume forecasting of printers.

further influences the sales volume of printers. Printer requirements refer to the desire for buying printers and their special functions. Purchasing power measures whether consumers are capable of buying printers.

(3) The cluster of the marketing mix.

Korpela and Tuominen [14] state that different competitive strategies are considered in forecasting product demand. Saaty [15] regards it as the marketing strategies of major competitors and indirect competitors. Through expert judgment, there are three elements to be considered when evaluating firms' marketing mix: product functions, marketing activities, and average price. "Product functions" means the combination of useful functions, e.g., wireless network, all-in-one type, etc. "Marketing activities" refers to the activities that affect the sales volume, e.g., extended warranty, promotion, etc. "Average price" is the average price of the standard printers sold from a couple of well-known brands.

(4) The cluster of alternatives.

One major feature using the AHP and ANP for forecasting is to define future outcomes at the cluster of alternatives. Ulengin and Ulengin [13] divided the value of the foreign exchange rate into large increase, slight increase, none, slight decrease, and large decrease based upon the current data when forecasting. Yuksel [19] applied large increase, slight increase, none, slight decrease, and large decrease to cover plus or minus 50% of the changes. With the range of increasing and decreasing rates from Table 3's historical data and expert judgment, the study sets up the percentage of annual sales alteration, contracting to the sales volume of the previous year, for the forecasting made by five possible alternatives: large increase (9%–15%), slight increase (2%–8%), none (−1% to 1%), slight decrease (−2% to 8%), and large decrease (−9% to −15%). Here the interval of 6% is used except that the interval of 2% is selected for a better catch of the status of no change. Fig. 1 presents the network for forecasting the sales volume of printers, influencing the relations among the four clusters under the control hierarchy.

Through the literature review and expert judgment, the forecast model establishes the control hierarchy and the mutual influences among the four clusters and their elements of the network. Note that the questionnaires are given to seven experts, i.e., salespersons, sales managers, and sales engineers. For the ANP, there are two types of questionnaire design. The first type evaluates the influences among the four clusters while the second type assesses the elements of the four clusters and judges the mutual influences among the clusters in the network. To ensure that the experts understand the essence of the study, those experts who filled out the questionnaires were the same as the experts who were interviewed in confirming the model.

Step 3:

After the network configuration is fixed, pair-wise comparisons are conducted by another four experts, under the economic factor in order to acquire the intensity of the influences via Saaty's fundamental scale. Table 4 shows a combined reciprocal matrix of the cluster of customers' behavior under economic influence. Its priorities will be arranged in the corresponding column of the clusters' weight matrix listed in Table 5.

Table 4
The combined reciprocal matrix of the cluster of customers' behavior with three clusters under economic influence.

	Consumer behavior	Marketing mix	Forecasts (alternatives)	Weight
Consumer behavior	1.0000	2.1147	1.4953	0.4669
Marketing mix	0.4729	1.0000	0.7071	0.2208
Forecasts (alternatives)	0.6687	1.4142	1.0000	0.3123

Note: There is no influence from this cluster to the customer types.

Table 5
The weights (priorities) of four clusters under economic influence.

	Consumer types	Consumers' behavior	Marketing mix	Forecasts (alternatives)
Consumer types	0	0	0.1164	0
Consumers' behavior	0.7122	0.4669	0.3014	0
Marketing mix	0.2878	0.2208	0.3319	1
Forecasts (alternatives)	0	0.3123	0.2503	0

Note: The values in each column present the priorities of mutual influences between two corresponding clusters.

Table 6
Unweighted supermatrix.

		1. Customer Types		2. Consumers' Behavior			3. Marketing Mix			4. Forecasts				
		1-1 individuals	1-2 organizations	2-1 users' habit	2-2 printer require-ments	2-3 purchasing power	3-1 product functions	3-2 marketing activities	3-3 average price	4-1 large increase	4-2 slight increase	4-3 none	4-4 slight decrease	4-5 large decrease
1. Customer Types	1-1 individuals	0.00000	0.00000	0.00000	0.00000	0.00000	0.09370	0.09759	0.08216	0.00000	0.00000	0.00000	0.00000	0.00000
	1-2 organizations	0.00000	0.00000	0.00000	0.00000	0.00000	0.02224	0.01835	0.03378	0.00000	0.00000	0.00000	0.00000	0.00000
2. Consumers' Behavior	2-1 users' habit	0.10753	0.15379	0.15727	0.12235	0.13244	0.09570	0.18003	0.11615	0.00000	0.00000	0.00000	0.00000	0.00000
	2-2 printer requirements	0.11936	0.45981	0.08285	0.17675	0.11099	0.21034	0.12601	0.18989	0.00000	0.00000	0.00000	0.00000	0.00000
	2-3 purchasing power	0.48531	0.09860	0.22682	0.16784	0.22350	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
3. Marketing Mix	3-1 product functions	0.06833	0.16461	0.11306	0.06644	0.02565	0.05507	0.08131	0.07658	0.30411	0.14998	0.16859	0.16547	0.13709
	3-2 marketing activities	0.03861	0.03875	0.03401	0.05568	0.03237	0.07007	0.11128	0.09691	0.24268	0.45947	0.36790	0.39706	0.46057
	3-3 average price	0.18086	0.08444	0.07374	0.09868	0.16278	0.20508	0.13762	0.15673	0.45321	0.39055	0.46352	0.43747	0.40234
4. Forecasts	4-1 large increase	0.00000	0.00000	0.04499	0.03964	0.04979	0.04057	0.06668	0.08896	0.00000	0.00000	0.00000	0.00000	0.00000
	4-2 slight increase	0.00000	0.00000	0.04451	0.03551	0.03019	0.05902	0.06959	0.06447	0.00000	0.00000	0.00000	0.00000	0.00000
	4-3 none	0.00000	0.00000	0.02835	0.03323	0.02365	0.03525	0.02834	0.02260	0.00000	0.00000	0.00000	0.00000	0.00000
	4-4 slight decrease	0.00000	0.00000	0.08167	0.08171	0.05605	0.05575	0.03101	0.02801	0.00000	0.00000	0.00000	0.00000	0.00000
	4-5 large decrease	0.00000	0.00000	0.11274	0.12216	0.15259	0.05722	0.05219	0.04376	0.00000	0.00000	0.00000	0.00000	0.00000
		1	1	1	1	1	1	1	1	1	1	1	1	1

All pair-wise comparisons are then executed for the priorities among clusters and their elements with inside and outside dependence relations. All priorities of the corresponding elements and clusters will be arranged in a supermatrix in the next step.

Note that the consistency index (C.I.) of each matrix is less than 0.1; otherwise, the comparison needs to be redone for a better judgment. The analyst brings a laptop PC with a predetermined Excel worksheet to check the consistency after each matrix is finished to shorten the time-consuming process. In addition, the geometric mean of four individuals' evaluations, at the corresponding element in each matrix, is aggregated together as the group's evaluation.

Step 4:

The priorities of the corresponding elements and clusters will be arranged in a 13 × 13 supermatrix or unweighted supermatrix as presented in Table 6. Each element of the unweighted supermatrix will then multiply the corresponding cluster's weight, in Table 5, and this operation makes the column of the supermatrix stochastic, or known as a weighted supermatrix $\boldsymbol{W}^a$. Afterwards, a limiting supermatrix $\boldsymbol{W}^n$, i.e., 14th power of the weighted matrix, can be obtained following Eq. (2) as shown in Table 7 with almost identical elements column-wise.

Step 5:

The priority information for the elements of each cluster is shown in the limiting supermatrix. The importance of the elements is based on these priorities. The most important cluster is the fourth one, forecasts, in which five intervals describing the rates of change are considered.

This study considers the value of each priority weight as the probability of each corresponding interval, which is the percentage change in annual sales volume forecast for printers. However, the middle values of the percentage changes are considered for further calculation, and the combined value is −0.957% of the change, corresponding to the sales volume of printers for 2007. After a back test is executed, the forecasted sales volume for 2008 is 830,797 in Table 8, and the percentage

Table 7
Limiting supermatrix.

		1. Customer Types		2. Consumers' Behavior			3. Marketing Mix			4. Forecasts				
		1-1 individuals	1-2 organizations	2-1 users' habit	2-2 printer require-ments	2-3 general customers	3-1 organiza-tions	3-2 users' habit	3-3 printer require-ments	4-1 general customers	4-2 organiza-tions	4-3 users' habit	4-4 printer require-ments	4-5 general customers
1. Customer Types	1-1 individuals	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890	0.03890
	1-2 organizations	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142	0.01142
2. Con-sumers' Behavior	2-1 users' habit	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472	0.10472
	2-2 printer requirements	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390	0.12390
	2-3 purchase power	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312	0.08312
3. Marketing Mix	3-1 product functions	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651	0.09651
	3-2 marketing activities	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708	0.13708
	3-3 average price	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880	0.19880
4. Forecasts	4-1 large increase	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472	0.04472
	4-2 slight increase	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994	0.03994
	4-3 none	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094	0.02094
	4-4 slight decrease	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872	0.03872
	4-5 large decrease	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123	0.06123
		1	1	1	1	1	1	1	1	1	1	1	1	1

Table 8
Detailed forecasting information of alternatives via the ANP.

Elements of Forecasts	Convergent values	Normalized values	Central values (%)	Expected values (%)
Large increase	0.04450	0.21719	12.00	2.606
Slight increase	0.03962	0.19338	5.00	0.967
None	0.02086	0.10183	0.00	0.000
Slight decrease	0.03868	0.18876	−5.00	−0.944
Large decrease	0.06123	0.29884	−12.00	−3.586
	0.20490	1.00000		−0.957

Table 9
Sensitivity analysis with respect to the change in the priority of the customers' behavior.

Percentage of change	−40%	−30%	−20%	−10%	0%	10%	20%	30%	40%
Weight of the customers' behavior	0.4273	0.4985	0.5698	0.6410	0.7122	0.7834	0.8546	0.9259	0.9971
Expected growth rate	−0.831%	−0.863%	−0.895%	−0.926%	−0.957%	−0.989%	−1.016%	−1.045%	−1.073%

Table 10
Sensitivity analysis with respect to the change in the priority of the marketing mix.

Percentage of change	−40%	−30%	−20%	−10%	0%	10%	20%	30%	40%
Weight of the customers' behavior	0.1981	0.2312	0.2642	0.2972	0.3302	0.3632	0.3963	0.4293	0.4623
Expected growth rate	−0.962%	−0.960%	−0.959%	−0.958%	−0.957%	−0.956%	−0.954%	−0.953%	−0.952%

error is −1.297% of actual sales volume for that year in Taiwan. Note that the percentage error (%) is defined as (Actual−Forecast)/Actual in this study to eliminate the scaling effect.

Step 6:

Sensitivity analysis helps us know whether any important priority or weight in the network or clusters will affect the final outcome. Here, the priority of customers' behavior to customer type, with the greatest value in the network having a value of 0.7122, is chosen for the analysis. We change the range of its priorities from −40% to +40%, i.e., within the interval of [0.4273, 0.8546], based on its original value of 0.7122, and the forecast expected growth rate (%) for the sales volume in 2007 is changed from −0.831% to −1.073%, respectively. This means that the forecasting results are slightly sensitive to the corresponding priority. Please see Table 9 for details.

The priority of the market mix itself, with a value of 0.3302, is next examined. We change the range of its priorities from −40% to +40%, i.e., within the interval of [0.1981, 0.4623], based on its original value of 0.3302, and the combined forecasts are altered from −0.962% to −0.952%, respectively, corresponding to the sales volume for 2007. This means that the results are insensitive to the corresponding priority. Please see Table 10 for details. Both results show that the model is almost insensitive to a change in the priorities of cluster weights.

Table 11
Comparison of the forecasting errors of some common techniques.

Forecasting technique	Forecast of sales volume of printers for 2008	Actual value	Percentage error (%)	Note
Moving average	910,403	820,161.	−11.003	$n = 2$
Exponential smoothing	854,168		−4.146	$\alpha = 0.9$
Quadratic trend	646,699		21.150	
Cubic trend	665,629		18.842	
Non-linear trend	876,998		−6.930	*Transformation of logarithm function
ANP	830,797		−1.297	

Note: Percentage error (%) = (Actual–Forecast)/Actual.

5. Comparisons of statistical approaches

After the ANP model for forecasting is made, some traditional naïve statistical approaches are compared by the same historical data in Table 3 so that the advantages and disadvantages of these approaches can be illustrated. The common techniques of moving average, exponential smoothing, and trend functions are examined [29].

A moving average forecast utilizes a number of the most recent actual data values in generating a forecast. Since the number of available data by year is just a few, we can execute a moving average with the numbers of period n less than the number of data points given. Here, the values of n for 2, 3, and 4 are considered for ease of operation, and their mean absolute deviations (MADs) are 83,151, 115,077, and 171,833, respectively. Thus, the number of periods, $n = 2$, is selected for the purpose of our comparison, and the forecast of sales volume for 2008 is 910,403 with a percentage error of −11.003%.

Exponential smoothing is another weighting average technique based on the previous forecast plus a percentage of the difference between that forecast and the actual value of the series at that point. The key factor is the smoothing constant α, which represents a percentage of the forecast error. Values of α of 0.1–0.9 with a difference of 0.1 are taken into consideration, and their MADs are 89,054, 87,411, 84,535, 82,141, 80,599, 81,127, 80,950, 80,273, and 79,257, respectively. Therefore, the value of smoothing factor $\alpha = 0.9$ is chosen for our comparison, and the forecast for the sales volume for 2008 is 854,168 with a percentage error of −4.146%.

Since the linear trend model by Wen [3] is inadequate for our purpose, quadratic and cubic trend models are developed to examine their forecasting accuracy. The quadratic and cubic trend equations for the forecast of period t are illustrated as follows.

$$F_t = 951\,304 + 130\,071t - 24\,798t^2 \tag{3}$$

$$F_t = 932\,399 + 153\,852.3t - 32\,674.6t^2 + 750.2t^3 \tag{4}$$

where t is the specific number of time periods from $t = 0$. Their forecasts of the sales volume for 2008 are 646,699 and 665,628, respectively, and the percentage errors are 21.150% and 18.842%, respectively.

In addition to the abovementioned five common techniques, a non-linear trend model is also investigated. Since the first differences of the nearest parts of the series in Table 3 are decreasing greatly, a logarithm function is chosen for the investigation. The non-linear trend equation is

$$F_t = \exp(13.99702 - 0.04468t). \tag{5}$$

The forecast of the sales volume for 2008 is 876,998 with a percentage error of −6.930%.

The forecasts and their percentage errors from the demonstrated techniques are illustrated in Table 11. We can see that the proposed ANP approach indeed has an edge with a minimal percentage error, i.e., −1.297%, over the five statistical approaches through the use of back testing in our case study.

To avoid any possible misunderstanding from one observation, the forecasts of the sales volume for 2009 are also executed, in which the actual sales volume was 675,403. The percentage errors from the quadratic and cubic trend models are 40.065% and 32.463%, respectively, compared to the percentage error of −18.985% by the ANP. The results show that the ANP has an edge over the other two approaches in our case.

6. How to Use the ANP for forecasting

According to Korpela and Tuominen [14], the five drawbacks of traditional forecasting methods are: (i) a need for explanatory variables to be mostly expressed in quantitative terms, (ii) not considering the development of new relationships among variables and possible changes in trends, (iii) an assumption of the dimension on which the prediction takes place is autonomous, (iv) the forecasts are based on past data, and (v) being both deterministic and structurally stable, leading to errors in forecasting. The AHP is an expert judgment approach [11] and can avoid such drawbacks. Moreover, the AHP provides a systematic procedure to deal with quantifiable and intangible criteria, which is different from traditional judgmental forecasts, such as a consumer survey or the Delphi technique. It converts judgment, experience, and expertise into quantitative data through pairwise comparisons. The ANP is a generalization of the AHP and can handle dependence and feedback among elements/factors and clusters. Although the AHP and ANP have been applied to many areas, we will concentrate on three key arguments so that their utilization in forecasting is clear.

6.1. AHP or ANP

Saaty [22] mentions that the ANP is a general framework of the AHP to deal with decisions of dependence and feedback. The ANP is usually more accurate and supplies better results than the AHP. However, a hierarchy switching to a network in order to capture more influences of dependence and feedback will significantly increase the complexity of the model [21]. If there is a mid-sized network, e.g., 15 clusters with 50 elements, the work in determining the factors and their influence relations and making pairwise comparisons among them would cause decision makers and questionnaire respondents to suffer greatly. This phenomenon indeed restricts the applications of the ANP.

There are two options that might relieve the burden of manipulation by the ANP. One option is to keep the basic structure of the hierarchy — the AHP — and consider dependence and feedback among the levels and their elements. In such an arrangement, the supermatrix is the core of the calculation, e.g., the forecast of US economic recovery [16]. The other option tries to separate a single network into multiple networks such as benefits, opportunities, costs, or risks [22]. Since different aspects are shared by the multiple networks, the load of the ANP manipulation is lessened. The choice of the AHP or ANP will be a tradeoff between operational complexity and modeling adequacy.

6.2. Possible uses of the AHP/ANP for forecasting-related applications

Two main categories of forecasting-related application are illustrated in Table 2. There are four areas, i.e., evaluating forecasting methodology, combining forecasts, prediction of future events, and assessment of future performance, in the second category. The essence of these areas is based on the priorities obtained from the AHP and ANP such that the priorities or weights of alternatives can be determined. From this viewpoint, the AHP and ANP here are much like the roles of MCDM for ranking and selecting. However, the advantages of the AHP and ANP over other MCDM methods are in dealing with quantifiable and intangible criteria in which expert judgment is easily imbedded. Of course, handling dependence and feedback among factors is another contribution of the ANP.

The first category, including three areas of expert-opinion forecasting, adjustment of other forecasting methods, and hybrid forecasting with other forecasting methods, is the major role of the AHP and ANP for forecasting. The first area is most important for making a forecast by collecting expert opinions. However, the second and the third are used for assisting other methods in making a forecast.

6.3. How to define the alternatives for direct forecasting

One crucial piece of work in direct forecasting done by the AHP and ANP is to determine alternatives. The alternatives are usually defined related to the forecasting targets. For instance, four alternative time periods are interpreted as 0–6 months, 6–12 months, 12–24 months, and 24–36 months for forecasting the resurgence of the US economy [17]. In the other example five alternatives are designated by degree of change (and range) as sharp decline (¥119.99 and below), moderate decline (¥119.99–134.11), no change (¥134.11–148.23), moderate increase (¥148.23–162.35), and sharp increase (¥162.35 and above) in forecasting foreign exchange rates of the Japanese yen/US dollar [17]. Another example of four alternatives of demand growth rates is depicted as strong decline (−5% to −10%), weak decline (0% to −5%), weak growth (0%–5%), and strong growth (5%–10%) for covering the possible change rates in demand for a product compared to the sales estimate for the present year [14]. Later, the priorities of alternative can be derived from a pairwise comparison of the AHP and ANP. In general, forecasts can be obtained by multiplying each priority by the midpoint of its corresponding time interval or spread range and then adding up the results. Note that the midpoint of an interval is easily taken if the interval has a sharp boundary.

To make a better forecast, there are four key issues for developing alternatives. The first one is about designing the alternatives. It is better that the alternatives are homogenous. Although many mixed indices, e.g., tax rates, government spending, issuance of bonds, and issuance of money, can be considered simultaneously [30], a homogenous group of alternatives will be easy for comparison by the experts. The second issue involves setting the range or time span of the alternatives. Historical data, political and economical situations, and expert judgment are suitable inputs for arranging alternatives. For example, the growth rates of the historical data are used in our case to develop the ranges of alternatives. The third issue is associated with how many alternatives. To avoid any difficulty of complicated judgment, a number of alternatives less than seven is suggested [25]. The last issue concerns the range or time span of each alternative. Although different intervals are possible, near equal space intervals are recommended for ease of manipulation. In addition, the midpoint of each range or time span is the basis for accurate forecasting in a numerical sense. Although there are many topics in using the ANP for forecasting, the above discussion can provide a straightforward direction for future applications.

7. Concluding remarks

When historical data are lacking and when a broad spectrum of social impact is involved, the ANP, with the ability to handle dependence and feedback among factors, is a valuable technique for forecasting the next period via expert judgment. This study exploits the ANP as a forecasting tool to predict the sales volume of printers in Taiwan. Through a back test, the percentage error of the result from the proposed model is −1.297%, which is minimal compared to the errors from five naïve statistical techniques. In addition, the results of sensitive analysis show that the model is almost insensitive to a change in the priorities, within plus or minus 40% of the original values, of the cluster weights.

After a comprehensive review, the applications of the AHP and ANP for forecasting are given in a table in which the numbers of levels or clusters, the period of forecasting, the forecasting targets, and the alternatives are displayed. The forecasting-related applications of the AHP and ANP are then classified as seven areas under two categories of explicit or implicit representation of time. The two tables clarify possible applications for the reader.

The last part discusses how to use the ANP for forecasting. There are three topics, including the selection of the AHP or ANP, the possible uses of the AHP and ANP for forecasting-related applications, and how to define the alternatives for direct forecasting. These observations provide a straightforward direction for ease of future applications in forecasting.

Although there are many criteria for judging the adequacy of the usage of various forecasting techniques [31], for simplicity this study chooses the percentage error as the index for measuring the accuracy of techniques. In addition, this work concentrates on how to use the ANP or AHP for forecasting through a case study, and some criticisms of the AHP, e.g., Belton and Goodwin [32], are left out. The issues of choosing a suitable measure for errors and of dealing with the criticisms of the AHP or ANP are left for a future study.

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References

[1] RFMB, The history of RFMB, Environmental Protection Agency, Republic China of China. http://recycle.epa.gov.tw/Recycle/index2.aspx (last retrieved: 10.01.11) (in Chinese).
[2] IEEE, IEEE Standard for Environmental Assessment of Personal Computer Products, Including Laptop Personal Computers, Desktop Personal Computers, and Personal Computer Monitors, New York: IEEE Computer Society, 2006.
[3] L.-C. Wen, A study on the definition of waste recycling items and the factors impacting fee settings, Taipei: Environmental Protection Administration, Executive Yuan, ROC Government, 2005 (in Chinese).
[4] C.-C. Liu, An investigation and planning of the recycling system for waste vehicles in Taiwan, Taipei: Environmental Protection Administration, Executive Yuan, ROC Government, 2008 (in Chinese).
[5] A.A. Ghobbar, C.H. Friend, Evaluation of forecasting methods for intermittent parts demand in the field of aviation: a predictive model, Computers and Operations Research 30 (14) (2003) 2097–2114.
[6] T.L. Saaty, L.G. Vargas, The Logic of Priorities: Applications in Business, Energy, Health, and Transportation, Kluwer-Nijhoff, Boston, 1982.
[7] T.L. Saaty, Decision Making with Dependence and Feedback: The Analytic Network Process, RWS Publications, Pittsburgh, 1996.
[8] L.G. Vargas, Prediction and the analytic hierarchy process, Mathematics and Computers in Simulation 25 (2) (1983) 156–167.
[9] C. Wolf, How to adjust forecasts with the analytic hierarchy process, Journal of Business Forecasting 7 (1) (1988) 13–17.
[10] R.F. Dyer, E.H. Forman, Analytic Approach to Marketing Decision, Prentice-Hall, Englewood Cliffs, NJ, 1991.
[11] A.R. Blair, R. Nachtmann, J.E. Olson, T.L. Saaty, Forecasting the exchange rates: an expert judgment approach, Socio-Economic Planning Sciences 21 (6) (1987) 363–369.
[12] S.B. Kim, K.S. Whang, Forecasting the capabilities of Korean civil aircraft industry, Omega 21 (1) (1993) 91–98.
[13] F. Ulengin, B. Ulengin, Forecasting foreign exchange rates: a comparative evaluation of AHP, Omega 22 (5) (1994) 505–519.
[14] J. Korpela, M. Tuominen, Inventory forecasting with a multiple criteria decision tool, International Journal of Production Economics 45 (1–3) (1996) 159–168.
[15] T.L. Saaty, Fundamentals of the analytic network process, in: Proceedings of the International Symposium on the Analytic Hierarchy Process, ISAHP 1999, Kobe, Japan, August 12–14, 1999.
[16] A.R. Blair, R. Nachtmann, T.L. Saaty, R. Whitaker, Forecasting the resurgence of the US economy in 2001: an expert judgment approach, Socio-Economic Planning Sciences 36 (2) (2002) 77–91.
[17] A.R. Blair, R. Nachtmann, T.L. Saaty, R. Whitaker, Forecasting the resurgence of the US economy in 2010: an expert judgment approach, Socio-Economic Planning Sciences 44 (3) (2010) 114–121.
[18] M.P. Niemira, T.L. Saaty, An analytic network process model for financial-crisis forecasting, International Journal of Forecasting 20 (4) (2004) 573–587.
[19] S. Yuksel, An integrated forecasting approach to hotel demand, Mathematical and Computer Modelling 46 (7–8) (2007) 1063–1070.
[20] D. Voulgaridou, K. Kirytopoulos, V. Leopoulos, An analytic network process approach for sales forecasting, Operational Research: An International 9 (1) (2009) 35–53.
[21] F. Zammori, The analytic hierarchy and network processes: applications to the US presidential election and to the market share of ski equipment in Italy, Applied Soft Computing 10 (4) (2010) 1001–1012.
[22] T.L. Saaty, Theory and Applications of the Analytic Network Process: Decision Making with Benefits, Opportunities, Cost, and Risks, RWS Publications, Pittsburgh, 2005.
[23] E.H. Forman, Facts and fictions about the analytic hierarchy process, Mathematical and Computer Modelling 17 (4–5) (1993) 19–26.
[24] T.L. Saaty, L.G. Vargas, Prediction, Projection and Forecasting: Applications of the Analytic Hierarchy Process in Economics, Finance, Politics, Games and Sports, Kluwer, Boston, 1991.
[25] T.L. Saaty, The Analytic Hierarchy Process, McGraw Hill, New York, 1980.
[26] T.L. Saaty, Group decision making and the AHP, in: B.L. Golden, E.A. Wasil, P.T. Harker (Eds.), The Analytic Hierarchy Process: Applications and Studies, Springer-Verlag, New York, 1989.
[27] D.F. Blumberg, Introduction to Management of Reverse Logistic and Closed Loop Supply Chain Process, CRC Press, Boca Raton, 2004.
[28] L.-C. Wen, An investigation on fee committee member's meeting operation and review of recycling-and-treatment fee structure, Taipei: Environmental Protection Administration, Executive Yuan, ROC Government, 2008 (in Chinese).
[29] W.J. Stevenson, Operations Management, tenth ed., McGraw-Hill, New York, 2009.
[30] T.L. Saaty, A new macroeconomic forecasting and policy evaluation method using the analytic hierarchy process, Mathematical Modelling 9 (3–5) (1987) 219–231.
[31] M. Lawrence, M. O'Connor, B. Edmundson, A field study of sales forecasting accuracy and processes, European Journal of Operational Research 122 (1) (2000) 151–160.
[32] V. Belton, P. Goodwin, Remarks on the application of the analytic network process to judgmental forecasting, International Journal of Forecasting 12 (1) (1996) 155–161.