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Combining conjoint analysis, scenario analysis, the Delphi method, and the innovation diffusion model to analyze the development of innovative products in Taiwan's TV market

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ABSTRACT

In science and technology industries, innovative products are launched rapidly, making the lifecycle of new products ever shorter. Thus, it is important that companies understand consumers' needs and consider expert opinion when analyzing the development of a new technology. However, no studies have combined these two perspectives with regard to the development of a new product. Therefore, this research combined conjoint analysis, scenario analysis, and the Delphi method with the innovative diffusion model to analyze the development of Taiwan's TV market over the next 10 years. The results show that the outlook for demand for light-emitting diode (LED) TVs in Taiwan is very optimistic; sales of LED TVs will surpass sales of liquid crystal display TVs in 2015 in the optimistic scenario and in 2017 in the most likely scenario.

1. Introduction

When a new-generation product is introduced into the market, older ones, especially in high-tech industries, may either continue to exist or be replaced by the newer product. Therefore, the introduction of a new-generation product results in diffusion and substitution effects in the market. To better understand and describe this process, Fisher and Pry [1] developed the technological substitution model to analyze the penetration process of new-generation technology. However, this model does not address levels of scale for each generation, and market shares exhibit much more regularity than do absolute scales [2]. Marchetti and Nakicenovic [3] revised Fisher and Pry's [1] model to make it applicable to the analysis of more than two competitive technologies. Furthermore, Norton and Bass [2] proposed a multigenerational diffusion model that takes into account diffusion effects, substitution effects, and time-varying factors. Nevertheless, this model is limited by insufficient data for the latest generation product. Scenario analysis produces rich and complex portraits of possible future scenarios; however, it does not provide objective quantifiable forecasting results [4]. For that reason, some researchers have combined scenario analysis (to address an uncertain future) and quantitative methods to analyze the future development of new-generation technology. For example, Wang and Lan [5] combined scenario analysis and the technological substitution model to forecast new-generation technological development. Tseng et al. [6] combined scenario analysis, the Delphi method, and the technological substitution model to analyze the organic light-emitting diode (OLED) TV market. However, they did not consider consumers' heterogeneity. Jun and Park [7] were the first to propose a model that incorporates both diffusion and choice effects to capture simultaneously the diffusion and substitution processes for each successive generation of a durable technology; Jun et al. [8] and Kim et al. [9] revised this model. Lee et al. [10] proposed a two-stage model that uses consumer preferences to analyze the development of TV technology. They combined conjoint analysis (customer preference analysis) and Bass' diffusion model to estimate the market potential of large-screen TVs. However, they did not consider expert

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opinion and develop the future scenarios. In fact, TVs of many types exist and compete simultaneously, and thus consumer preference and expert opinion are very important in predicting the development of TV technologies. However, no studies have combined these two perspectives. Therefore, the present research question is how to consider consumer preference and expert opinion when analyzing the development of multigenerational technologies.

We considered both customer and expert viewpoints when analyzing the development of cathode ray tube (CRT), liquid crystal display (LCD), and light-emitting diode (LED) TV technology in Taiwan. That is, we performed conjoint analysis to analyze customers' preferences and then combined these results in the scenario analysis. Based on expert opinion, we address possible scenarios for the development of the LED TV. Furthermore, we elaborate specific scenarios and then use the innovation diffusion model to forecast sales volume of CRT, LCD, and LED TVs for each scenario over the next 10 years.

This paper is organized as follows. Section 2 describes conjoint analysis, scenario analysis, and the innovation diffusion model. Section 3 describes the methodology. Section 4 presents the empirical analysis. Section 5 discusses the results and presents conclusions.

2. Conjoint analysis, scenario analysis, and the innovative diffusion model

2.1. Conjoint analysis

Conjoint analysis is a technique for analyzing situations in which a decision maker has to consider options that vary simultaneously across two or more attributes [11]. Luce and Tukey [12] invented conjoint measurement, which was originally applied to the area of mathematical psychology. Green and Rao [13] adjusted Luce and Tukey's model, then introduced it into marketing research. Carmone et al.[14] changed the name from *conjoint measurement* to *conjoint analysis*. Thereafter, the technique was applied to many social science fields, including marketing, product management, and operation research.

In the 1980s, conjoint analysis and computer programming technologies such as adaptive conjoint analysis developed rapidly, resulting in the development of commercial conjoint analysis programs [15]. In the 1990s, an important commercial system, the Statistical Analysis System (SAS), was developed by Kuhfeld, Tobias, and Garratt [16]. Today, more than 30 years later, researchers continue to improve conjoint analysis by introducing more efficient design plans and reducing the complexity of conjoint questions. Yet no matter how it changes, the conjoint analysis process follows the six steps proposed by Green and Srinivasan [17] and shown in Table 1.

2.2. Scenario analysis

Since the 1960s, scenario analysis has been an important method for predicting future developments. It has been used in many areas, such as energy [18], hydrogen fueling systems [19], and biotechnology [20]. Some researchers have also adapted it for use in strategic management [21]. Because scenario analysis is a qualitative method, it fails to provide quantitative forecasts; rather, it provides rich and complex portraits of possible future scenarios [4]. Therefore, to improve the precision of their results, researchers may combine scenario analysis (to address an uncertain future) and other quantitative methods to analyze the future development of new-generation technology. Generally speaking, researchers collect the opinions of experts when conducting scenario analysis; however, experts' opinions often vary greatly. Therefore, some researchers combine scenario analysis and the Delphi method to generate future scenarios [22,23]. There are numerous approaches to conducting scenario analysis. Table 2 lists the procedures of six different studies used to create scenarios.

2.3. The innovative diffusion model

Norton and Bass [2] proposed the multigenerational diffusion model based on the simple diffusion model [24] and the technological substitution model [1]. They proposed that the development of every generation of a product involves not only diffusion

Table 1
Steps involved in the conjoint analysis.

Steps	Alternative methods	Our adoption method
1. Selection a preference model	Vector model, Ideal-point model, Part-worth model, Mixed model	part-worth function
2. Data collection method	Two-factor-at-a-time (trade-off analysis), Full-profile (concept evaluation)	Full-profile (concept evaluation)
3. Stimulus set construction for the full-profile method	Fractional factorial design, Random sampling from multi-variate distribution	orthogonal design
4. Stimulus presentation	Verbal description (multiple cue, stimulus card), Paragraph description, Pictorial or three-dimensional model representation	pictures and descriptions
5. Measurement scale for the dependent variable	Paired comparisons, Rank order, Rating scales, Constant-sum paired comparisons, Category assignment (Carroll, 1969)	Rating scales
6. Estimation method	MONANOVA, PREFMAP, LINMAP, Johnson's nonmetric tradeoff algorithm, Multiple regression, LOGIT, PROBIT	MONANOVA

Table 2
Procedure to create scenarios.

Process	Porter et al. (1987)	Martino (1993)	Schoemaker (1995)	SRI (1996)	Kosow & Gaßner (2008)
Decision focus	1. Identify topical dimensions 2. Identify intended users' interests and the appropriate style of information presentation 3. Identify time frame 4. Specify general society contextual assumptions and specific technology assumptions	1. Develop a framework for the scenario 2. Forecast the technology to be considered	1. Define the scope 2. Identify the major stakeholders	1. Identify the decision topic	1. Identification of the scenario field
Key decision factors, KDF	5. Set up the key dimensions		3. Identify key uncertainties	2. Confirm decision factors	2. Identify key factors
Driving force			4. Identify basic trend	3. Analyze drive power	
Uncertainty axes	6. Decide on the number of scenarios and their emphases		5. Construct initial scenario themes	4. Choose the uncertain framework	3. Analysis of key factors
Select and elaborate the scenarios	7. Build and present the scenarios	3. Plot the scenarios 4. Write the scenarios	6. Check for consistency and plausibility 7. Development learning scenarios	5. Write the scenarios	4. Scenario generation
Analyze strategies			8. Identify research needs 9. Develop quantitative models 10. Evolve toward decision scenarios	6. Analyze the decision meaning	5. Scenario transfer

effects and substitution effects but also time-varying factors. The present study involves three generation technologies; therefore, Norton and Bass'[2] model is expressed mathematically as follows:

$$S_1(t) = F(\tau_1)m_1(1-F(\tau_2)) \tag{1}$$

$$S_2(t) = F(\tau_2)[m_2 + F(t)m_1](1-F(\tau_3)) \tag{2}$$

$$S_3(t) = F(\tau_3)[m_3 + F(\tau_2)[m_2 + F(t)m_1]], \tag{3}$$

where τ_i is the time at which the ith generation is introduced, $S_i(t)$ refers to sales of the ith generation in time period t, $i = 1,2,3$ (1 = CRT TV, 2 = LCD TV, 3 = LED TV), $F = \left[1-e^{-(p_i+q_i)t}\right] / \left[1 + \frac{q_i}{p_i} e^{-(p_i+q_i)t}\right]$, m_1 is the market potential for the first generation, and m_2 and m_3 are the incremental market potentials uniquely served by the second and third generations.

3. Methodology

The analysis consisted of four stages (Fig. 1). They are summarized as follows.

Stage 1 Use conjoint analysis to identify consumer preferences.
The conjoint analysis process follows the six steps proposed by Green and Srinivasan [17] (Table 1). We adapted the method as follows.

- Step 1 Selection of a preference model: We selected a part-worth model.
- Step 2 Data collection: We used the full-profile approach to collect data, and each card described all of the product features.
- Step 3 Stimulus set construction for the full profile: After we set up the attributes and designed all of the combinations, if the number of combinations was too great, we used orthogonal design to reduce the number of conjoint cards.
- Step 4 Stimulus presentation: The questionnaire was completed in pictorial representation form. We conducted the stimulus survey base on the online survey platform. Subjects more easily recognized different types of TVs by their pictures and descriptions through the e-survey questionnaire.
- Step 5 Measurement of the dependent variable: All combinations were measured on a 7-point Likert scale from 1 to 7. The larger the number, the more desire to buy; the smaller the number, the less desire to buy.
- Step 6 Estimation: Because our dependent variable was measured on a 7-point ordinal Likert scale, we used MONANOVA to estimate parameters.

Stage 2 Combine industry information and the results of conjoint analysis to create scenarios.

- Step 1 Identify the research focus, including the research scope and the display technology.
- Step 2 Identify the key decision factors (KDFs) influencing the decision outcomes, such as market demand, production capacity, and government policy. Also, add customers' key preference factors that resulted from conjoint analysis to the KDFs.

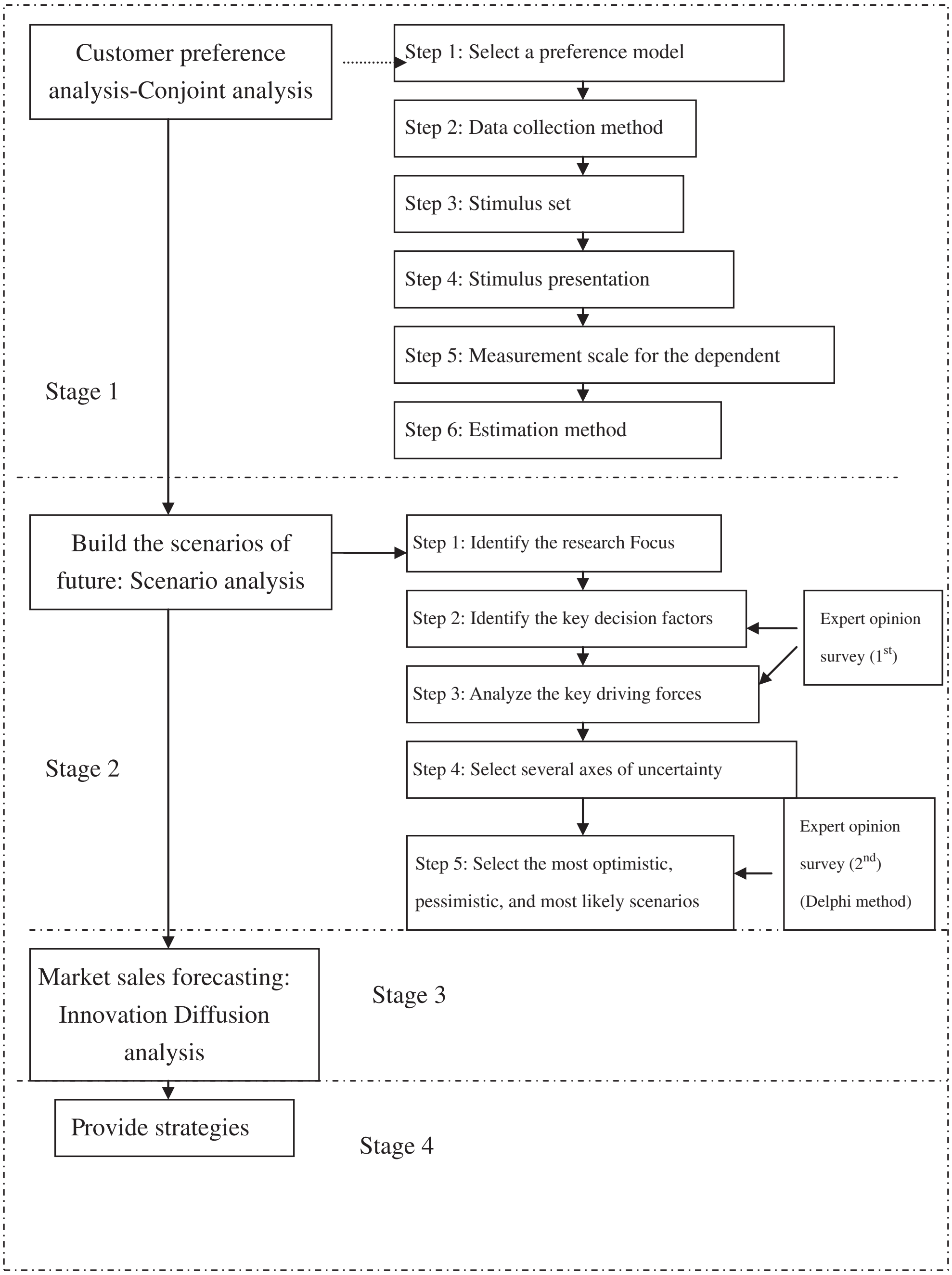

Fig. 1. Research process.

Step 3 Analyze the future status of the key driving forces of the technology's penetration into the market. This step included distributing a questionnaire to experts to evaluate the degree of uncertainty regarding each driving force and its impact on the KDFs. The *degree of uncertainty* is the degree of explicitness in the direction and breadth of change when environmental influences impact the driving force; it is used to construct the impact and uncertainty matrix of the drivers.

Step 4 Select several axes of uncertainty based on key external forces with high/medium uncertainty and high impacts on the future status of KDFs and the results of conjoint analysis (relative important factors). Analyze their extremes to provide structure to the scenarios and construct a framework within which to develop the main focus of the scenario. Driving forces with high impact and low uncertainty are typically treated as the main drivers of the scenario. Axes of uncertainty are coherent, plausible views of different ways in which the world might work.

Step 5 Use the Delphi method to select the most optimistic, most pessimistic, and most likely scenarios developed from the experts' opinions, and forecast the sales volume of different display technologies in each scenario. Prepare a statistical summary of the forecasts for each event consisting of the median and upper and lower quartile dates of each event, and use this to draw up a new questionnaire for the second round. Distribute this questionnaire to the experts, again soliciting forecasts for each event, which may be new or the same as previous forecasts.

Stage 3 Use the innovation diffusion model to forecast the sales volume for each scenario. Based on historical data and forecast data for CRT, LCD, and LED TVs, we used Norton and Bass'[2] multigenerational diffusion model to estimate the sales volume in Taiwan of each technology for the three scenarios.

Stage 4 Analyze each scenario and provide strategies and recommendations with respect to the focus or decision defined in stage 2. This stage concludes the analysis.

4. Empirical results and analysis

4.1. Overview of TV display technologies

Before 2000, CRT TVs were regarded as the mainstream, followed by black-and-white TVs, color TVs, and flat-screen CRT TVs. However, with the demand for sleeker and lighter TVs, and with the rise in environmental consciousness, flat panel display TVs are going to replace CRT TVs [25]. LCD TVs are sleek, lightweight, and energy efficient and produce high-resolution images. LCD TVs made up 46.7% of the market share worldwide in 2007, making them the dominant new-generation technology. However, a market-wide overinvestment led to a surplus, and thus all LCD panel companies decreased their selling price [6]. They are gradually replacing CRT TVs, and the market share of LCD TVs in Taiwan was 89% in 2009. TV technology has continued to develop, and one of the latest technologies is OLED. The advantages of OLED TVs are their lower cost and larger viewing angle and the fact that they emit their own light and respond quickly. In addition, OLED can be combined with a flexible plastic substrate that uses electric polymer film to generate a flexible active matrix display [26]. Currently companies are looking for ways to keep costs down and increase product lifetimes. OLED technology has threatened the LCD market, but it is still in its infancy and has not yet been introduced in Taiwan.

Recently, with the focus on global environmental protection and energy saving, LED has become a shining star in the TV industry. Samsung introduced the LED TV in Taiwan in June 2009. Since then, many other firms, including Sony, LG, and Sharp, have promoted their own LED TVs [27]. The display technology for LED and LCD TVs is the same; the only difference is the backlight module. The backlight for the LCD TV is taken from a built-in cold cathode fluorescent lamp, whereas the LED TV uses an LED as a backlight module. LED display technology has many advantages over traditional light sources in terms of energy savings, a longer lifetime, improved robustness, and environmental protection [27]. However, LED TVs are relatively expensive and require more precise current and heat management than traditional light sources. According to the Digitimes, the penetration rate of the LED TV was 20% in 2010 [28]. Table 3 shows the comparison of the display technology.

4.2. Trends in Taiwan's TV market

We combined conjoint analysis, scenario analysis, and the innovative diffusion model to analyze trends in Taiwan's TV market over the next 10 years. Our presentation of the results here follows the outline set forth in Section 3.

4.2.1. Consumer preference analysis

Stage 1 Use conjoint analysis to identify consumer preferences.

Conjoint analysis is used to analyze consumer preferences. Table 4 shows attributes (and their values for conjoint analysis) noted as important considerations for consumers purchasing a TV: price, screen size, resolution, and Internet access. These attributes were identified from previous research [25,29,30] and expert opinion. After setting the values for each attribute, we asked five experts (working for industry research institute and TV manufacturers) to confirm the classification, thus making it more reliable. The spreads were combined in a full factorial design. The conjoint design consisted of five attributes: 4 TV levels, 3 price levels, 3 size levels, 2 resolution levels, and 2 Internet access levels. This yielded 144 alternatives ($4\times3\times3\times2\times2=144$). We used orthogonal design to reduce the number of alternatives to 25 by using the conjoint analysis module of SPSS 8.0. We further reduced the number of alternatives to11 by deleting unreasonable combinations (e.g., “CRT TV, price more than NT$ 35,000, 20–23 in., 1920×1080, and Internet”; this product does not exist, as the price and resolution are too high).

Data were collected from December 2009 to January 2010 over the Internet. There were 419 participants and 403 (96%) valid responses; 4% of surveys were rejected due to missing data and some duplication. The descriptive statistics of the respondents are presented in Table 5. A total of 39.7% of the respondents were female and 60.3% were male; most were 21–25 years old, were undergraduate students, and had monthly incomes of less than NT$ 10,000.

We asked the respondents about their current TV. According to the frequency distribution in Table 6, 39.95% own an LCD TV and 37.47% own a CRT TV. A few people own an LED TV (9.43%). We also asked respondents whether they want a new TV and, if so, which type of new TV they prefer. According to Table 6, 75.07% want to buy a new TV, especially, 97.35% of the CRT TV owners want to buy a new TV, and 49.66% (73) CRT TV owners who prefer an LED TV. Moreover, 52.80% of LCD TV owners want to switch out their LCD TV. Of these, 68.24% prefer an LED TV, 30.59% prefer an OLED TV, and 1.18% prefer a plasma display panel TV. The results reveal that the LED TV is the most popular.

Table 3
Comparison of the display technology.

	CRT TV	LCD TV	OLED TV	LED TV
Introduced time	1928 	1998 	2007 	2009 
Advantage	Relatively inexpensive, the best picture, wide viewing angle higher contrast ration Longevity	Thin, low power consumption, less radiation production, higher contrast, larger range of sizes, higher resolution, no danger of burn-in, bright, small flat screens, accepts digital singles an increased image brightness, Longevity	Good image quality, higher contrast, emit own light, broader color gamut, larger viewing angle, fast motion and rapid eye movement more life-like, low power consumption, simple production procedure	Lower energy consumption, longer lifespan, improved robustness, faster switching, higher contrast ratio, high purity and broader color gamut, environmental protection
Disadvantage	Bulky, heavy, limited screen size (bellow 40 in.), lower resolution, usually not PC-compatible	Did not have a fast refreshing rate, poor color saturation, higher price of larger screen, relatively narrow viewing angle, have a difficulty going fully black Doesn't track motion well, some pixel failure rates can be as high (or higher) than 10%	Limited life span of material, immature fabrication, high cost, low color purity	High cost, relatively expensive and require more precise current and heat management
Typical size	27 and 30 in.	37 to 73 in.	Start at 11 in.	40 to 55 in.
Price range	$450 to $600	$1300 to $5200	$1600	$1219 to $4200
Longevity	The longest	50,000 hrs	Above 10,000 hrs	Above 50,000 hrs

We further analyzed the differences between men and women. Women pay more attention to resolution than size and prefer a TV between 32 and 40 in., whereas men prefer a TV larger than 42 in. Moreover, 34% of participants prefer 3D technology, 22.33% prefer a TV with Blu-ray player, and 20.10% like to use their TV to surf the Internet.

The results of the conjoint analysis reveal that consumers consider TV type first (degree of importance = 61.506%) when purchasing a new TV set (Table 4). They prefer LED TVs, LCD TVs, OLED TVs, and CRT TVs, in that order. Then they consider price, size, and resolution, looking specifically for low price, large size, and high resolution. Internet access is the least important variable (degree of importance = 3.518%).

4.2.2. Scenario analysis

Stage 2 Combine industry information and the results of conjoint analysis to create scenarios.

Step 1 Identify a focus or decision.

We focused on possible scenarios for development of the LED TV in Taiwan over the next 10 years. We also forecasted the sales volume of CRT, LCD, and LED TVs for each scenario.

Steps 2–4 Identify the KDFs influencing the decision outcomes, analyze the main drivers of the scenario, and develop the scenarios.

Three axes of uncertainty, consumer demand and preference, breakthroughs in TV technology and function, and government policies and manufacturer strategies, were adapted from Tseng and Chang [6] and applied to

Table 4
Importance of attributes.

Attributes	Features	Part-worth value	Range of part-worth value (relative importance)
TV type	CRT TV	−1.956	61.506%
	LCD TV	0.625	
	OLED TV	0.518	
	LED TV	0.814	
Price (in NT dollars)	Below NT15,000	0.261	15.337%
	NT15,001–35,000	0.169	
	More than NT35,001	−0.430	
Size (in in.)	20"–23"	−0.297	10.443%
	32"–40"	0.123	
	Above 42"	0.174	
Resolution	1366*768	−0.207	9.196%
	1920*1080	0.207	
Internet access	Yes	0.079	3.518%
	No	−0.079	

Table 5
Descriptive statistics of the respondents.

	Items	Frequency	Percentage
Gender	Male	243	60.3%
	Female	160	39.7%
Age	Under 20 years	42	10.42%
	21–30 years	281	69.73%
	31–40 years	46	11.41%
	41–50 years	27	4.70%
Education	Above 65 years	7	1.74%
	Below college	19	4.71%
	College/undergraduate	246	61.04%
	Graduate and above	138	34.24%
Occupation	Student	195	48.39%
	Service industry	75	18.61%
	Professional	46	11.41%
	Public servant	31	7.69%
	Self-employment	13	3.23%
	Others	43	10.68%
Income (NT dollars)	Less than 10,000	168	41.69%
	10,001–20,000	46	11.41%
	20,001–30,000	51	12.66%
	30,001–40,000	49	12.16%
	40,001–50,000	35	8.68%
	50,001 and above	54	13.38%

($n=403$; CRT TV = 151, 37.47%; LCD TV = 161, 39.95%; PDP TV = 53, 13.15%; OLED TV = 0; LED TV = 38, 9.43%).

the global TV market. Because Tseng and Chang did not consider consumer preferences or recent TV development in Taiwan, we modified these axes by incorporating the results of our conjoint analysis. Moreover, we focused on the LED TV market rather than the OLED TV market.

"High image quality demand," "acceptable price range for consumers," "consumers' preferences for TV size," "economic growth rate," and "acceptance of new TV functions, i.e., 3D" were grouped into the axis of consumer demand and preference. "Maturity of 3D display technologies," "technological development of raw material from upstream sectors," and "manufacturing process of new display technologies" were identified as breakthroughs in TV technology and function. The two extremes of this axis were "fast development" and "slow development." "Country's attitudes toward environmental protection," "technology development of brand name companies," "strategy alliances of companies," and "development a next-generation production line" were grouped into government policies and manufacturer strategies. The two extremes were "consistent" and "inconsistent." Each axis had two outcomes, translating into a total of eight ($2^3=8$) possible scenarios. Experts were requested to stand for LED TV development, selecting from the eight scenarios the most optimistic, most pessimistic, and most likely scenarios, and then to forecast the sales volume of CRT, LCD, and LED TVs in 2010, 2015, and 2020 for each of the three scenarios they chose. Table 7 lists the basic scenarios that might exist over the next 10 years.

Table 6
The situation of TVs.

Original TV	The number of people wants to change (%)	TV type	Number	Percentage
CRT TV ($n=151$)	147 (97.35%)	PDP TV	4	2.72%
		LCD TV	42	28.57%
		OLED TV	28	19.05%
		LED TV	73	49.66%
PDP TV ($n=53$)	42 (79.25%)	CRT TV	1	2.38%
		LCD TV	6	14.29%
		OLED TV	8	19.05%
		LED TV	27	64.29%
LCD TV ($n=161$)	85 (52.80%)	PDP TV	1	1.18%
		OLED TV	26	30.59%
		LED TV	58	68.24%
Total ($n=365$)	274 (75.07%)	CRT TV	1	0.36%
		PDP TV	5	1.82%
		LCD TV	48	17.52%
		OLED TV	62	22.63%
		LED TV	158	57.66%

Table 7
Background of experts.

Range of service	Display manufacturer	TV manufacturer	Technology related	TV industry analyst	
Number of people	2	4	2	3	
Characters of work	Industry analysis	Tech innovation	Product planning	Marketing	
Number of people (Note 1)	3	3	2	5	
Type of work	Director	Analyst	Manager	Vice manager	Team leader
Number of people	2	2	4	1	2
Years of work experience	4–5	6–9	10–12	13–16	17–up
Number of people	2	3	2	1	3

Note 1: Because multiple options were permitted, the sum of the total number of people is more than 11.

Step 5 Use the Delphi method to select the most optimistic, most pessimistic, and most likely scenarios developed from the experts' opinions, and forecast the sales volume of different display technologies in each scenario. We used the Delphi method to collect the opinions of experts in Taiwan with an average of 11.7 years of work experience in relevant TV industries (see Table 7 for details). The Delphi questionnaire was administered in two rounds in February and March 2010. We asked 11 experts in the TV industry to select the most optimistic, most pessimistic, and most likely scenarios. Initially, their opinions were not consistent; therefore, we prepared a statistical summary of the median and upper and lower quartile dates of each event and sent them to the 11 experts again to elicit forecasts for each event.

The results of the second round are shown in Table 8, 10 experts thought that Scenario 1 (high consumer demand and preference, rapid breakthroughs in TV technology and function, and consistency between government policies and manufacturer strategies) was the most optimistic scenario for the development of LED TV; we named this the "stable growth" scenario. Nine experts thought that Scenario 8 (low consumer demand and preference, slow breakthroughs in TV technology and function, and inconsistency between government policies and manufacturer strategies) was the most pessimistic scenario; we named this the "low saturation" scenario. Seven experts thought that Scenario 3 (high consumer demand and preference, slow breakthroughs in TV technology and function, and inconsistency between government policies and manufacturer strategies) was the most likely scenario; we named this the "bureaucracy" scenario.

4.2.3. Penetration in the TV market

Stage 3 Use the innovation diffusion model to forecast the sales volume for each scenario.

Historical sales volume data for CRT, LCD, and LED TVs from 1999 to 2009 were applied to the Norton and Bass model. We also collected data from reports of the Industrial Research Institute in Taiwan (Market Intelligence & Consulting Institute (MIC), Industrial Economics & Knowledge Center (IEK)) and estimates for three points in the future (2010, 2015, and 2020) from the 11 experts in the TV industry regarding the most optimistic, most pessimistic, and most likely scenarios for the development of LED TV. Results for the three scenarios are as follows.

(1) Most optimistic scenario: stable growth

The most optimistic scenario for the development of LED TV in Taiwan is marked by high consumer demand and preference, rapid breakthroughs in TV technology and function, and consistency between government policies and manufacturer strategies. Economic growth will remain strong, which will encourage consumers to spend more on TVs and expand their range of acceptable prices. Not just first-time purchases of TVs but also upgrades will increase. Therefore, the sales volume of LED TVs will increase noticeably.

Moreover, strong economic growth will also give TV manufacturers more access to capital. Firms can increase investment in research and development (R&D), expand production lines, train staff, and so on. Newer TVs are better than traditional TVs and thinner, with larger screens, higher resolution, and a lower production cost; they are even better for the environment. We could see display panels everywhere—both indoors and outdoors. Therefore, a strong demand will increase the sales volume of TVs and indirectly decrease costs for manufacturers.

In the market, major companies will have more opportunities to cooperate with other suppliers or form alliances

Table 8
Scenario logic of development of the LED TV market.

Scenario no.	The most optimistic scenario	The most pessimistic scenario	The most likely scenario	Consumer demand and preference	Breakthrough in TV technology and function	Government policies and manufacturer strategies
1	10		1	High	Fast	Consistent
2			1	Low	Fast	Consistent
3	1		7	High	Fast	Inconsistent
4				Low	Fast	Inconsistent
5		1	2	High	Slow	Consistent
6				Low	Slow	Consistent
7		1		High	Slow	Inconsistent
8		9		Low	Slow	Inconsistent

with dealers in related fields to create a new market and marketing strategies, increase competition among same-trade contenders, and reduce the costs of product planning and marketing. Furthermore, some companies will gradually shut down older product lines to concentrate on making newer products; this strategy will entice consumers to buy and limit the choices they have to make. On the technology and strategy side, panel makers and major TV manufacturers will form alliances with each other. They will cooperate on R&D, technology transfer, or joint investment in next-generation product lines in order to enhance competition and dominate the market.

The parameters in this model of three equations were estimated using the nonlinear least squares procedure SYSLIN in SAS. All parameters in each model were significant ($p<0.001$; Table 9). They also had the expected signs and magnitudes; p was quite small relative to q, indicating that innovation is important only in the early stage. The R^2 values for the fit were very high for all three generations, with the lowest value exceeding 0.98. The forecasting results shown in Fig. 2 shows that the predictions are similar to the actual data. According to Fig. 2, sales volume of LCD TVs will peak in 2009, accounting for 898404 units, then decrease with the appearance of LED TVs. Sales of LED TVs will grow quickly and will surpass that of LCD TVs reaching 576,562 units in 2015, reaching 858,560 units in 2020.

(2) Most pessimistic scenario: low saturation

The most pessimistic scenario for the development of LED TV in Taiwan is marked by low consumer demand and preference, slow breakthroughs in TV technology and function, and inconsistency between government policies and manufacturer strategies. Under this scenario, the overall TV industry will face a bottleneck in technology development, and thus manufacturers will fail to make breakthroughs. Major companies will not have the chance to cooperate with other suppliers; they will develop independently and hesitate in research and development. New display technologies will mature slowly and companies will be unable to mass produce, which will result in poor economic efficiency.

The economy will still be showing signs of a recession, firms will not be willing to invest more capital in R&D, and consumers will narrow their range of acceptable prices for TVs. Developments in TV technology will be limited, but this will be of no consequence for consumers. Demand for large screens and high resolution will decrease, and consumers' range of acceptable prices will remain small. Finally, market supply will exceed consumer demand, so laggard firms will pull out of the industry, leaving the remaining firms with more opportunities when the TV market rebounds.

All parameters in each model were significant ($p<0.001$; Table 9). The R^2 values for the fit were remarkably high for all three generations, with the lowest value exceeding 0.98, and Fig. 3 shows that the predictions were similar to the actual data. In this scenario, the LED TV will develop slowly. Sales of LCD TVs will peak in 2010, accounting for 887972 units. LCD TVs will remain the mainstay of Taiwan's TV market. Sales of LED TVs will grow slowly, and in 2020 the sales volume will only reach 361784 units.

(3) Most likely scenario: bureaucracy

The most likely scenario for the development of LED TV in Taiwan is marked by high consumer demand and preference, rapid breakthroughs in TV technology and function, and inconsistency between government policies and manufacturer strategies. Under this scenario, government policies and manufacturer strategies will not be in line, which will make TV firms unwilling to invest in R&D, expand production lines, or increase production costs. For example, if the government emphasizes environmental protection, then manufacturers must consider more factors when designing TVs. TVs must then be subjected to more tests, which will increase costs and decrease profits. This will also indirectly affect consumers. Despite strong economic growth, consumers will be reluctant to buy the latest TVs because of their higher prices.

If the government persists in enacting policies that are not in line with the strategies of TV firms, the economic recession may grow more and more serious. If the government can forgo these policies, the TV industry will grow gradually and steadily, benefiting not only the government but also TV firms and consumers.

Table 9
Summary of estimation results of three scenarios.

	Stable growth		Low saturation		Bureaucracy scenario	
parameters	estimate	*t*-value	estimate	*t*-value	estimate	*t*-value
q_1	1.400	–	1.400	–	1.400	–
p_1	0.500	–	0.500	–	0.600	–
q_2	0.847	16.88**	0.861	21.64**	0.827	22.08**
p_2	0.005	4.15**	0.005	5.31**	0.005	5.58**
q_3	0.050	–	0.0001	–	0.010	
p_3	0.010	23.56**	0.003	10.57**	0.011	41.69**
m_1	918803.300	74.00**	937670.000	106.47**	929964.5.000	105.27**
m_2	50000.000	–	510.000	–	15000.000	–
m_3	92075.000	–	15000.000	–	75000.000	–
S_1 adjusted R^2		0.988		0.992		0.992
S_2 adjusted R^2		0.995		0.997		0.997
S_3 adjusted R^2		0.975		0.874		0.992

Note: **p-value<0.01—constraint value (e.g., q1<1.4).

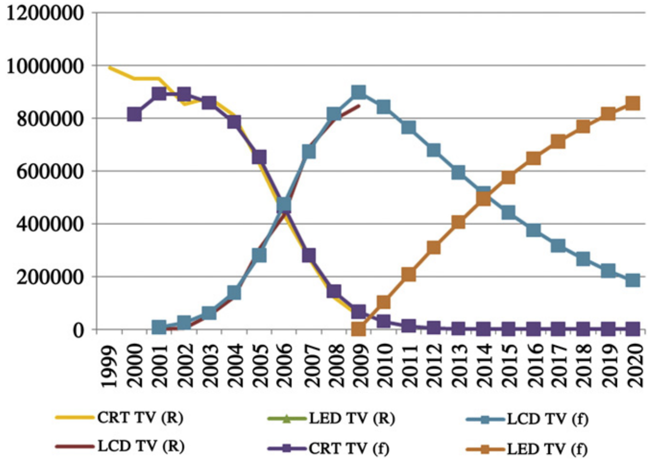

Fig. 2. Sales volume forecasts for display technology—stable growth scenario.

All parameters in each model were significant ($p<0.001$; Table 9). The R^2 values for the fit were remarkably high for all three generations, with the lowest value exceeding 0.98, and Fig. 4 shows that the predictions were similar to the actual data. Sales volume of LCD TVs will peak in 2009, accounting for 847,725 units. Sales of LED TVs will surpass that of LCD TVs reaching 522,780 units in 2017, sales of LCD TVs is anticipated to reach 339,337 units in 2020, and sales of LED TVs will reach 657,187 units in 2020.

5. Conclusions

Despite the importance of consumer preference and expert opinion to analyses of the development of multigenerational technologies, little existing research has integrated these two perspectives. Therefore, we proposed a four-stage method that combines conjoint analysis, scenario analysis, the Delphi method, and the innovative diffusion model and used it to forecast the development of three main display technologies (CRT, LCD, and LED) in the Taiwanese market. We found that when buying a new TV, consumers consider TV type first. They prefer LED TVs, LCD TVs, OLED TVs, and CRT TVs, in that order. Then they consider price, size, and resolution. Internet access is the least important function.

We developed scenarios of LED TV sales in Taiwan over the next 10 years with three axes of uncertainty: consumer demand and preference, breakthroughs in TV technology and function, and government policies and manufacturer strategies. We then forecasted the development of LED display technology under three scenarios: the most optimistic (stable growth), the most pessimistic (low saturation), and the most likely (bureaucracy).

According to the multigenerational diffusion model, high consumer demand and rapid breakthroughs in display technology will enable the LED TV to surpass the LCD TV over the next 10 years, even if government policies are not in line with manufacturer's strategies. If government policies and manufacturer's strategies are in line, the LED TV will develop even more rapidly. In the most optimistic (stable growth) scenario, sales of LED TVs will grow quickly and will surpass that of LCD TVs in 2015, reaching 858,560 units in 2020. In the most pessimistic (low saturation) scenario, sales of LCD TVs will peak in 2009. Sales of LED TVs will grow slowly,

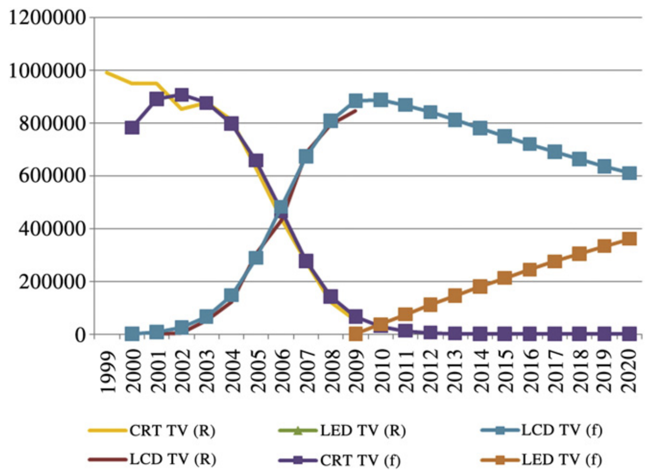

Fig. 3. Sales volume forecasts for display technology—low saturation scenario.

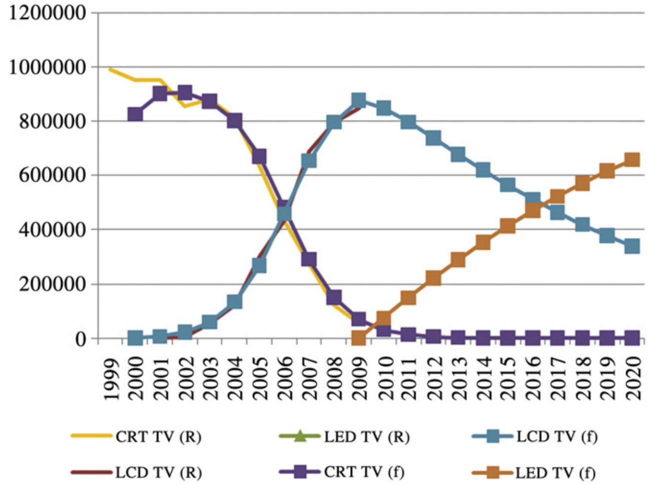

Fig. 4. Sales volume forecasts for display technology—bureaucracy scenario.

and in 2020 the sales volume will only reach 361,784 units. In the most likely (bureaucracy) scenario, sales of LCD TVs will peak in 2010. Sales of LED TVs will surpass that of LCD TVs in 2017, reaching 657,186 units in 2020.

The following limitations of the present research could be addressed in future studies.

(1) Many types of growth models can be used to forecast the development of the latest technology or product. The present study adopted Norton and Bass' innovative diffusion model to predict the sales volume of TVs with different display technologies. Future researchers may consider adopting other forecasting models, such as the technological substitution model, to compare market share among display technologies.
(2) 3D is another type of display (e.g., 3D LED TV, 3D LCD TV, 3D plasma display panel TV). Thus, whether 3D technology will affect the sales of LED TVs is an important issue that future researchers may take into consideration.
(3) Because LED TV is the newest display technology, there are limited statistical data on LED TV sales. Therefore, we used estimates from experts to forecast the future development of this new display technology. Future researchers could forecast after 1 or 2 years and add another new technology, OLED TV, to obtain more data, which may make the results more reliable and valid.

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