Specification Establishment of UV Wide-Format Inkjet Print Attributes and Industry Survey

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Keywords: UV wide-format inkjet, Quality print attribute, Digital printing,

Abstract

UV wide-format inkjet printing combined characteristics of digital printing which provided clients with diverse printing products on demand and UV printing which could be used in various substrates, and it was more eco-friendly than other printing inks. In addition, the wide-format printing could be used on building material and home decorations. Due to its wide range of applications, UV wide-format inkjet printing possessed great marketing value in the future. The objectives of the project are as follows: 1.Establishing general quality attributes for UV wide-format inkjet printing in Taiwan, and 2. Determine the market potential for UV Wide format inkjet printing in Taiwan among the printing industry and their procurement intentions. This research is conducted in two phases, with the first stage involving a quantitative experimental study, by printing samples, with three kinds of printing substrates (glass, acrylic and melamine plywood) using five brands' UV wide format inkjet printer, to establish a quantitative measurement techniques and attributes for better quality of printing. The second stage relies on research methods, we would invite experts of printing industry and scholarship, and interview them concerning reasons for different aspects of UV wide-format inkjet printing. The content of the interview would be closely examined in order to clarify the ideas generated by them. From the result of the experiment, the data of how UV wide-format inkjet printers from five different brands adapted to three different printing materials could be obtained. The qualities of various materials could also be observed, and thus a proper specification of UV printers could be established. Moreover, through expert surveys, the study could also provide investors with the future trend of UV wide-format printing in

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both Taiwan and international market, which could help them examine whether the firm meets their requirement.

1. Introduction

As technology continues to progress, printing processes are enjoying continuous innovation, with digital printing gradually replacing traditional printing methods. From the 2010 Production Value by Printing Process report (as shown in Table 1), we can ascertain that the growth rates for digital printing output between 2009-2013, were far higher than other traditional offset printing, and are expected to continue to grow. Moreover, by 2009, the Printing Industry Production Reports (as shown in Table 2) indicate the future market development of digital printing and inkjet printing is worthy of attention.

Categories by Eure Million	Web Offset	Sheetfed Offset	Flexo	Gravure	Screen	Digital	Other	Total
2009 Total	19,664	45,564	14,595	8,228	4,446	10,808	1,779	105,084
2009 Process Share%	18.71	43.36	13.89	7.83	4.23	10.29	1.69	100.00
2009-2013 Growth%	1.90	8.80	9.10	-8.50	-10.80	28.20	8.80	7.36
2013 Total	20,038	49,574	15,923	7,529	3,966	13,856	1,936	112,820
2013 Process Share%	17.76	43.94	14.11	6.67	3.52	12.28	1.72	100.00

Table 1. *2010 Production Value by Printing Process*

	Printing Shipments (% change from previous year)
Total printing	-2% to -3%
Ink-on-paper	-3% to -3.5%
Digital/toner	2% to 3%
Inkjet	2% to 3%
Beyond print	1% to 2%

Table 2. *2009 Printing Industry Production Reports*

With the rise of environmental awareness in recent years, the printing industry is also working hard towards achieving accrual of the double benefit of environmental protection and economic impacts from development of environmentally friendly ink ("eco-ink"). The Global eco-ink market size reached $5.8 billion in 2009, and is expected to reach $7.2 billion in 2014, with the fastest sector growth in UV ink. Among 2009-2014 UV inks should enjoy compound annual growth rates around 7%, with the market size expanding from 1.28 billion Euros to 2 billion Euros.

UV inks not only provide the environmental benefit of containing no volatile organic compounds (VOCs), but also possess the advantages of being fast curing, can be applied to all kinds of hard and soft substrates, have stable ink composition,

enjoy good print quality, and are richly colorful. With the use of digital inkjet printing presses, it is possible to expand product applications, to include large outdoor advertising, packaging, building materials, housing accessories and the 3C electronics industry. For many types of printed materials, such as wallpaper, tiles, doors, mirrors, glass, etc., these technologies allow an innovative product range from the traditional cultural uses of paper conversion to creative lifestyle expressions produced in small amounts, diversely, yielding customized high-value personalized products.

Although the international market forecasts positive growth for UV inkjet printing applications, most of the printing industry in Taiwan still has reservations about this emerging field. Since 2009 with the introduction of a number of UV wide-format inkjet machines on Taiwan beginning to have more significant growth, use of these new equipment and a wide range of printing media, printing personnel lacked sufficient experience in using the right equipment for the right media, bringing to the forefront the question of which equipment is most suited for which printing media. But the UV wide-format inkjet printing is still in the trial stages on Taiwan, so there has been a dearth of intensive studies yielding any expert advice available for referential use by industry or academia.

Hence the UV wide-format inkjet printing industry's immediate needs for present and future research must address resolving "optimal combinations of UV wide format ink jet printers with different printing media" and "elucidating the status of UV wide format inkjet printing industry development in Taiwan". This research project focuses on developing printing quality characteristics related specifications for industry reference on Taiwan for UV wide-format inkjet printers and printing media combinations, enhancing currently invested manufacturers capabilities to produce better print quality performance, and their products concomitant industry competitiveness both at home and abroad; permitting research about the UV wide-format inkjet printing industry on Taiwan to provide a clearer direction for procurement and investment decisions.

1.1 Research purposes

The purpose of this study was to establish a reference set available for use on Taiwan for the printing industry to appreciate optimal print quality characteristics for various combinations of UV wide-format inkjet printers and printed media. Additionally, this study seeks to better understand our UV wide-format inkjet printing market trends on Taiwan, and industry procurement intention trends for UV wide-format inkjet printers, as well as the factors affecting such procurement decisions, through the following research purposes:

1. Explore different printing media and UV wide format inkjet printer combinations' print quality performance on Taiwan

2. Establish print quality performance specifications for UV wide format inkjet printer and different printing media combinations' on Taiwan

3. Better understand the UV wide-format inkjet printing market trends on Taiwan

4. Analyze the print industry in Taiwan for UV wide-format inkjet printers procurement intentions and the underlying factors affecting procurement decisions

1.2 Literature Review

1. Inkjet Printing

The most widely used digital printing Non - Impact Technology is inkjet printing. This Computer to print process relies on nozzle ink jet printing directly on the print media surface, which means that the ink-jet printing process does not need to proceed through the mediation of an image carrier.

2. Wide-format printing

There are very many wide-format printing systems, such as those for posters and large format signage often uses wide-format inkjet printers. 135cm production width is very common, although there are also systems for a printing width of 5 ~ 8m. The use of a suitable ink permits printing on a variety of materials, fabrics and plastic film. During system operations, the inkjet head scanning direction is perpendicular to the orientation of the paper. For large-format printing width you must also use a wide-format inkjet head. Each color for the ink-jet head must be arranged according to rows in the print direction, either contiguously or in both directions to the formation of the jet matrix (Kipphan, 2001, p 726).

3. UV printing

UV printing has tremendous potential for development and printing, with the most important reason in addition to environmental factors, being that the range of printability of media is very extensive. Moreover many of these newly printable materials pose challenges that traditional printing cannot overcome (Hu Shunhwa, 2004, pp. 1-2). UV drying ink can be widely used in a variety of printed materials, and provides high-quality printing performance on hard glass, wood, ceramic and metal materials. This ink can make production proceed more quickly, because it uses ultraviolet light polymerization with instant drying. It is true that the UV system is more expensive than other wide-format inkjet systems, and also cannot be fully used on some soft media (Robertson, 2008).

2. Method of Evaluation

2.1 Research Process

This study consists of both quantitative and qualitative research, we the first phase deploying qualitative document analysis, collection and integration across our entire region on Taiwan for combinations of different UV wide-format inkjet printing systems and UV ink combinations, followed by analysis of the development potential for various printed media for UV wide-format printing processes. During the second stage of this study we conducted quantitative experimental research, to explore three kinds of printed media (glass, acrylic, melamine board) for developmental potential in printing with UV wide-format inkjet printers across five different systems and ink combinations for their printing quality performance characteristics. The third stage of the study involved qualitative interviews with experts, and industry interviews on Northern and Southern Taiwan with five larger scale UV wide-format inkjet printing industry leaders and representatives, through in-depth interviews to understand how regional market trends on Taiwan for UV wide-format inkjet printing, industry willingness to invest and procurement factors. The three-stage research process can be summarized as developing a set of print quality specifications for use on Taiwan with various UV wide-format inkjet printers and ink combinations across three kinds of printed media (glass, acrylic, and melamine board), as well as analysis of UV wide-format inkjet printing industry trends on Taiwan through survey research methods to provide as references for the printing industry who are considering investing in the UV wide-format inkjet printing market, thereby enabling the printing industry both on Taiwan and in foreign markets to enjoy greater accuracy and optimize the highest efficiency of combinations of different models of UV wide-format inkjet printers. The study flow chart is shown in Figure 1.

2.2 Experimental Materials

This study used a quantitative True Experimental Designs, relying on qualitative literature analysis, to determine the three main factors of the UV wide-format inkjet printing quality were the printing system, nozzle type, and UV ink, with the prevalent printing system, nozzle type, and UV ink combinations on Taiwan, this study explored a total of five groups of printer and ink combinations. Through discussions with the UV wide-format inkjet printer industry participants, we selected three different print media (glass, acrylic, melamine board) with high development potential in a broad range of applications. In this study, a total of 15 experimental groupings, explore print quality characteristics through the dimensions of Solid Ink Density, Print Contrast, Dot Gain /TVI, and the Color Gamut. This study's experimental architecture is shown in Figure 2.

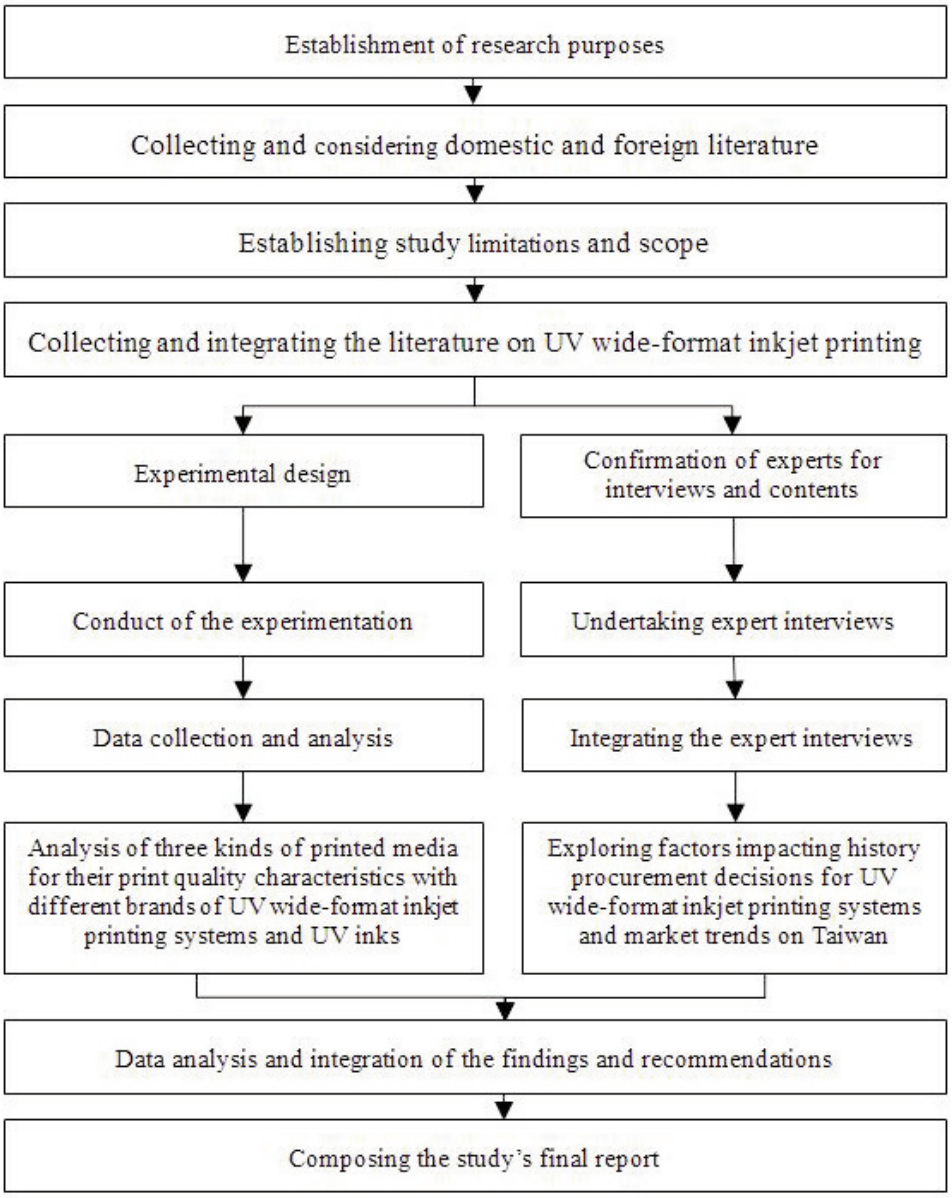


Figure 1. *Study Processes*

In this study, samples from five selected UV wide-format inkjet printing industry participants were studied. The electronic original files are as shown in Figure 3, with the printing process deployed according to the manufacturers' normal procedures. Manufacturers produced the same electronic original on three kinds of printed media (glass, acrylic, melamine board), with 30 copies for each, and a total of 450 samples. All 450 samples were collected for data measurement using the GretagMacbeth Eye-One Io reflection spectrophotometer.

15 experimental groupings -Independent variable (X)						
Five groups of printer and ink combinations				Surface Treating	print media	
	Inkjet	Pinter	ink			
1	Toshiba	FUJIFILM Acuity Advance HS HD3545	Fujifilm		1	glass
2	Toshiba	Mimaki JFX1631	Mimaki		2	acrylic
3	Konica-Minolta	GCC Stellar JET K100UV	Tongjou			
4	Konica-Minolta	ANDI COJET	Threeroyal		3	melamine board
5	Konica-Minolta	ANDI COJET	Sunjet			
Dependent variable (Y)						
Solid Ink Desity		Print Contrast		Dot Gain/TVI		Color Gamut

Figure 2. *Experimental Architecture*

Figure 3. *The electronic original files and GretagMacbeth Eye-One iO*

2.3 Expert Interviews

The study selected prospective industry interviewees among large scale UV wide-format inkjet printers and machine equipment dealers/representatives on northern, central and southern Taiwan, for a total of five industry experts and academics. Interviews explored UV wide-format inkjet printing industry participants' willingness to invest, procurement decision factors, market trends and other issues. After the first contact by the research team and provision of pre-interview materials (interview questions and expert Information Form) the interview time and place were confirmed, oral interviews conducted, with staff recording the interviews, followed by the research team compiling the interviews for analysis, and integrating a comprehensive analysis of the experts different perspectives. The expert interviews processes are shown in Figure 4:

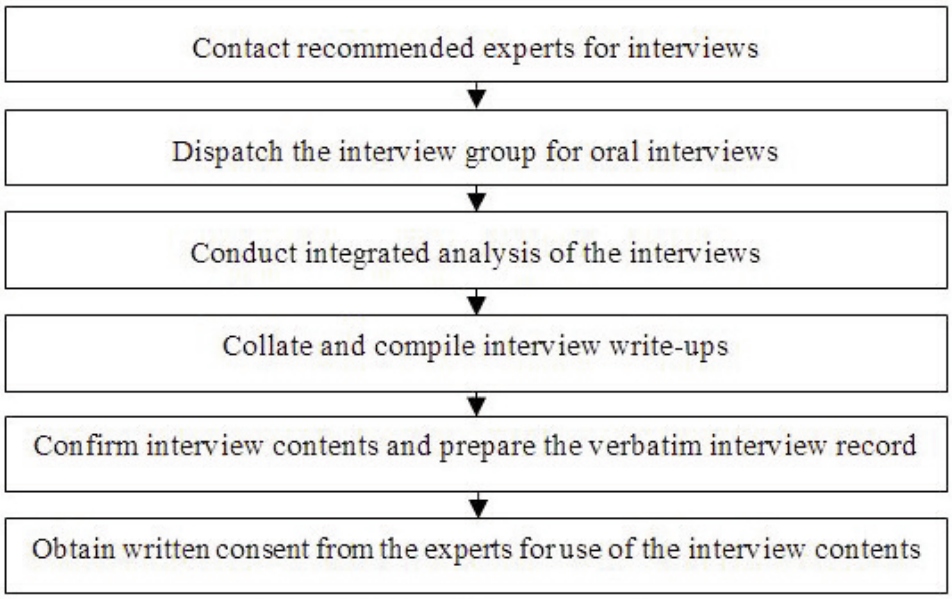


Figure 4. *In-depth interview processes*

3. Results & Conclusions

3.1 Analysis of experimental data and findings

1. Solid Ink Density

Solid Ink Density refers to the "highest concentration of ink pigment present on the printed media", and generally means, the richer the color among the CYMK, the greater the solid ink density ("Print Quality Assessment", 2001). From Table 3 one can see the Solid Ink Density for Acrylic, Glass, and Laminate are highest for K followed by C, then M, and Y. For Acrylic, Glass and Laminate, C, M, Y, and K, Solid Ink Density was highest for the Fuji printer ink combination.

Solid Ink Density	Acrylic				Glass				Laminate			
	K	C	M	Y	K	C	M	Y	K	C	M	Y
Fuji	4.795	5	2.263	1.7	4.649	4.165	2.263	1.37	3.565	3.872	2.358	1.182
Mimaki	2.038	1.673	1.703	0.753	2.232	1.841	1.878	0.935	2.208	1.73	1.856	0.813
GCC	1.933	1.144	1.208	0.777	2.131	1.337	1.397	0.977	1.975	1.242	1.351	0.814
ND-RO	1.384	0.944	1.228	0.9	1.578	1.032	1.394	1.066	1.547	0.944	1.428	0.937
ND-SUN	2.134	1.447	1.401	0.922	2.23	1.626	1.534	1.097	2.184	1.575	1.563	0.998
Mean	2.348	1.899	1.530	0.976	2.412	1.952	1.644	1.148	2.215	1.741	1.677	0.930

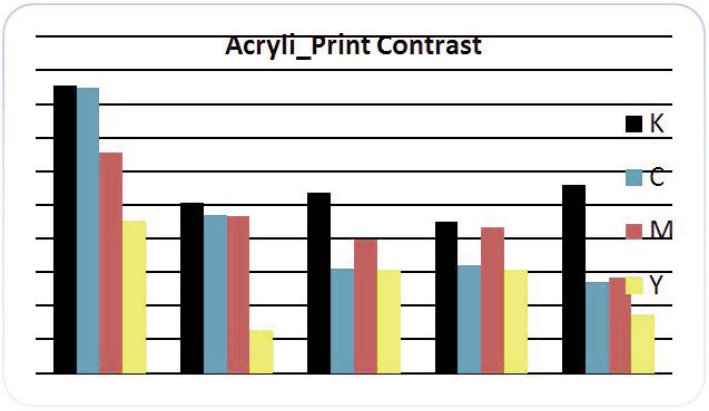
Table 3. *The Result of Solid Ink Density*

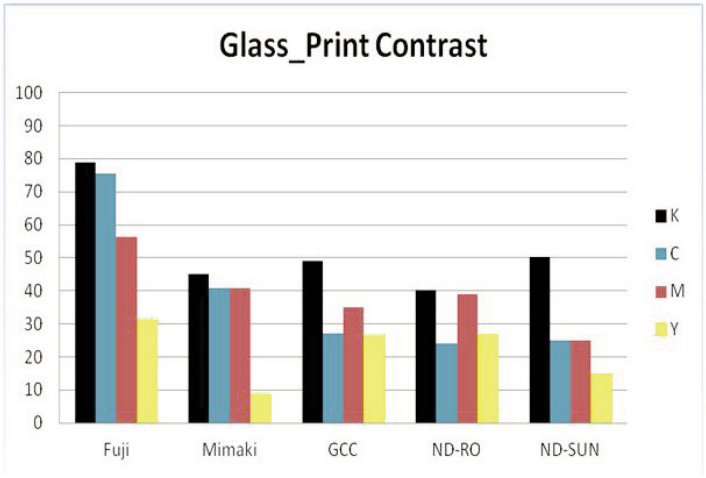
2. Print contrast

The print contrast value is calculated from the Solid Ink Density and 75% density, for a value which shows the degree of contrast between the Solid Ink Density and three-quarters tone thereof, in other words, the print contrast serves as a critical indicator in the printing process, in general permitting a more rich, dark tone that can be rendered as a result of the higher print contrast reflected by the tone darkness. From Table 4 it can be seen that for Acrylic, glass and Laminate, the highest print contrast were obtained with the Fuji printer ink combination for C, M, Y, and K. The CMYK printing contrast findings for Acrylic, Glass and Laminate are shown in order in Figure 5.

Print contrast	Acrylic				Glass				Laminate			
	K	C	M	Y	K	C	M	Y	K	C	M	Y
Fuji	85.55	84.66	65.49	44.88	78.81	75.68	56.30	31.46	79.61	79.00	63.23	36.89
Mimaki	50.64	47.10	46.74	12.62	45.12	40.90	40.68	8.88	44.88	40.52	40.14	9.47
GCC	53.75	31.03	39.65	30.89	48.94	27.15	34.93	26.41	48.81	26.49	37.68	29.24
ND-RO	44.94	31.99	43.24	30.89	40.18	24.13	39.02	26.83	40.98	29.56	43.70	31.91
ND-SUN	55.95	27.09	28.41	17.14	50.13	25.09	25.10	14.95	48.86	26.03	24.50	14.93
Mean	57.76	44.83	45.39	29.25	53.11	40.62	40.60	26.12	52.34	39.25	41.79	26.54

Table 4. *CMYK Print contrast*





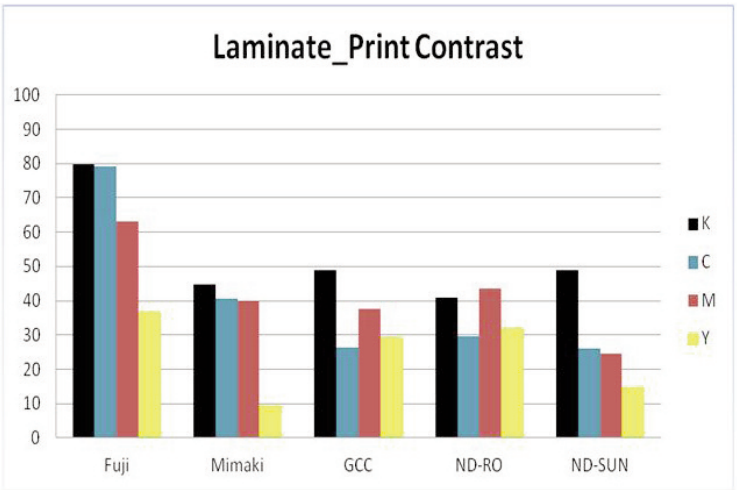


Figure 5. *Acrylic, Glass and Laminate are shown in order*

3. Tone Value Increase Ratio, TVIR / Dot Gain

In this study, tone was usually divided into 11 values at 10%, 20%, 25%, 30%, 40%, 50%, 60%, 70%, 75%, 80%, and 90% tone. The more stable the TVIR value, or more constant, represents a more ideal print TVIR. Ordinary paper printed materials TVIR curves are shown in Figure 6. From Figure 7, Figure 8 and Figure 9 can be found the TVIR for Acrylic, Glass and Laminate, across C, M, Y, and K, with the brightest (10%) tone producing the greatest increase, while the darkest (90%) showed tone amplification gradually slowing downward in a curve, quite distinct from the performance of plain paper printing for tone amplification. For the Acrylic, Glass and Laminate TVIR across the C, M, Y, and K, the percentage of the overall TVIR tone amplification were largest for Y, followed in order by C, K and M.

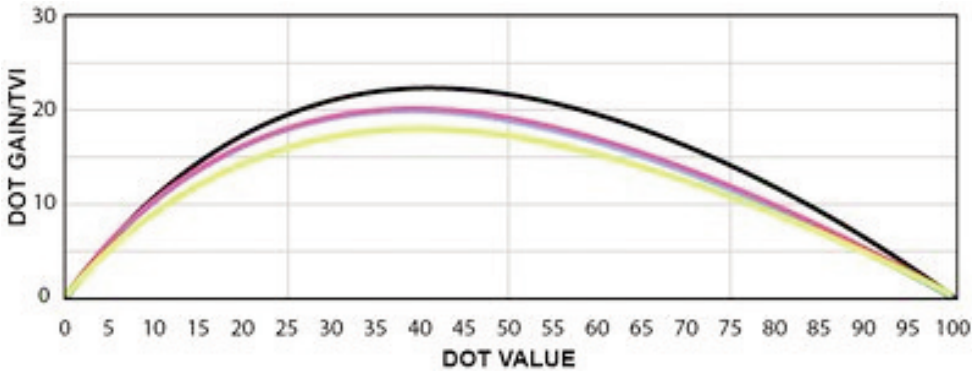
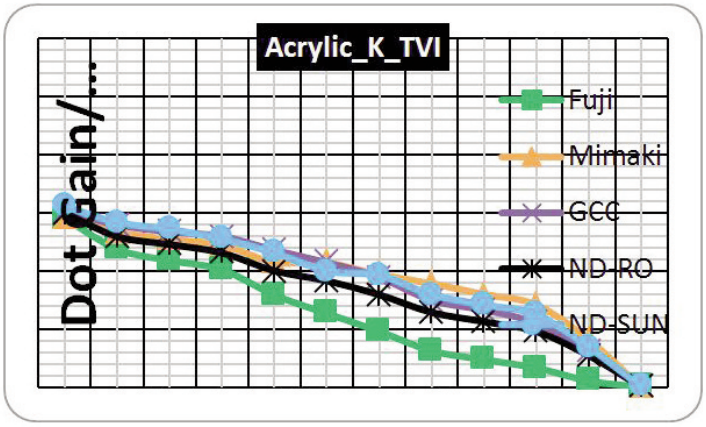
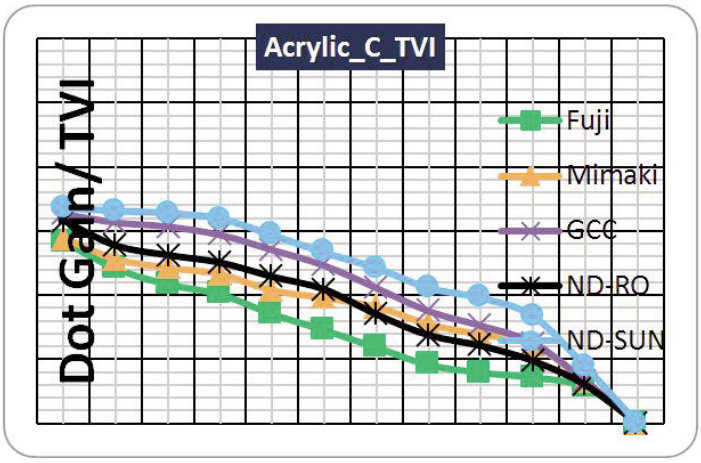


Figure 6. *Ordinary paper printed materials TVIR curves*


Acrylic_K_TVI
Dot Gain/...
Fuji
Mimaki
GCC
ND-RO
ND-SUN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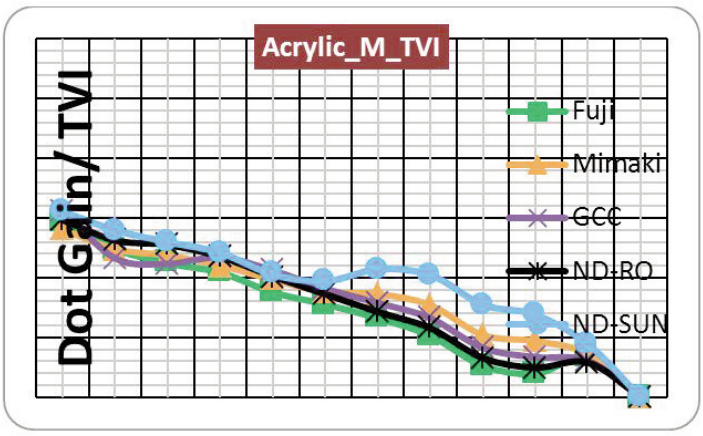
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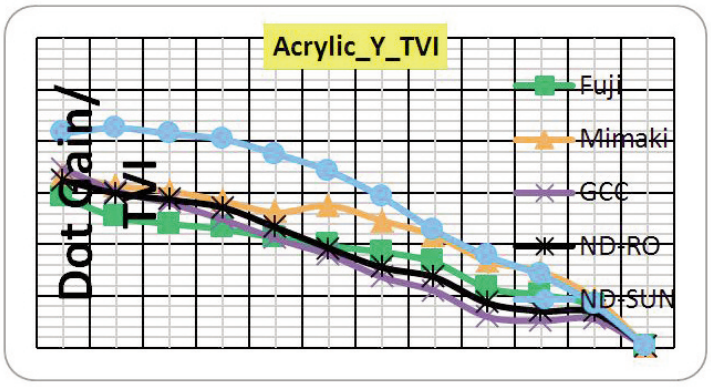
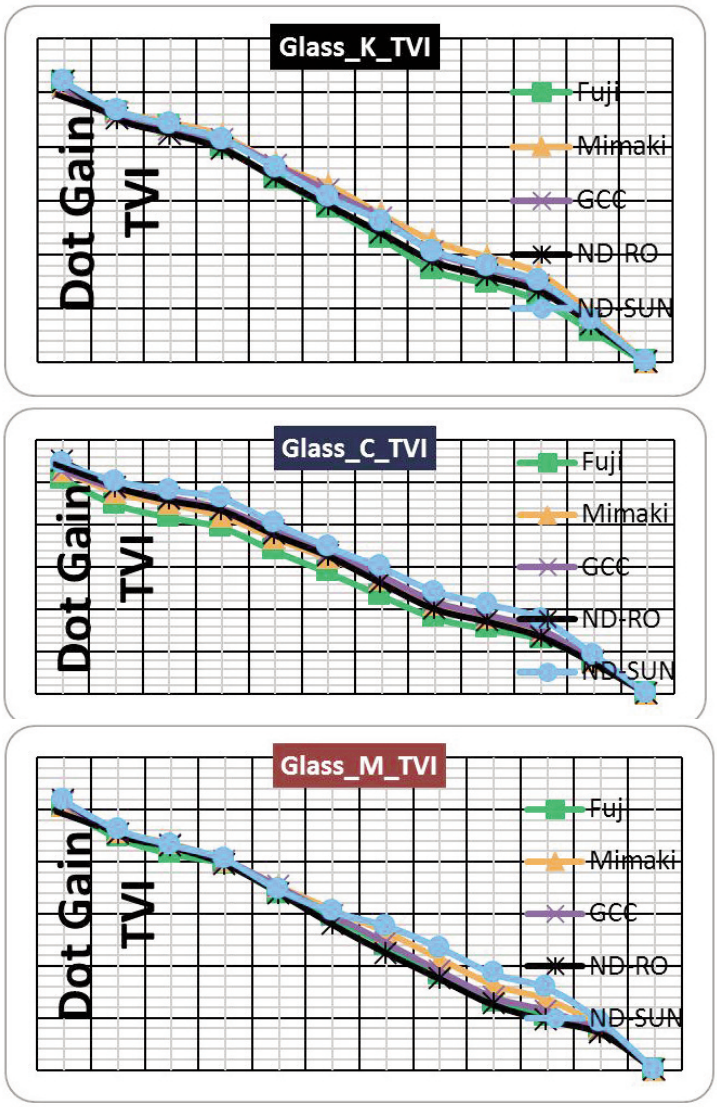


Figure 7. *Tone Value Increase Ratio for Acrylic*



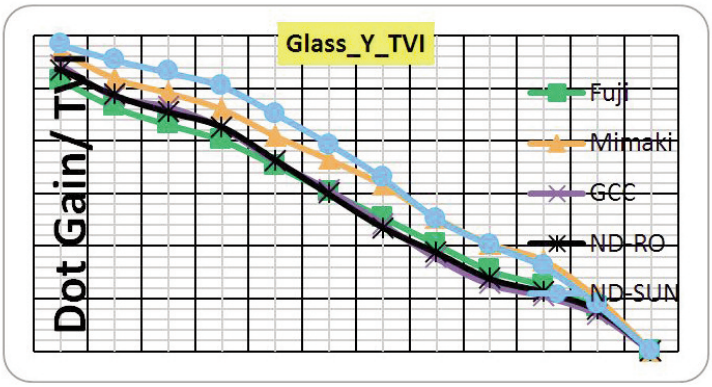
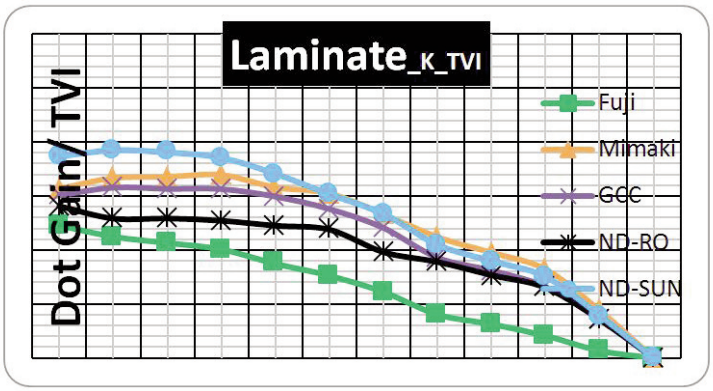
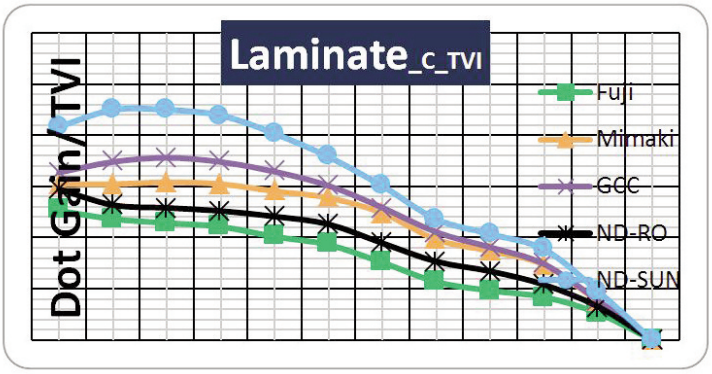


Figure 8. *Tone Value Increase Ratio for glass*





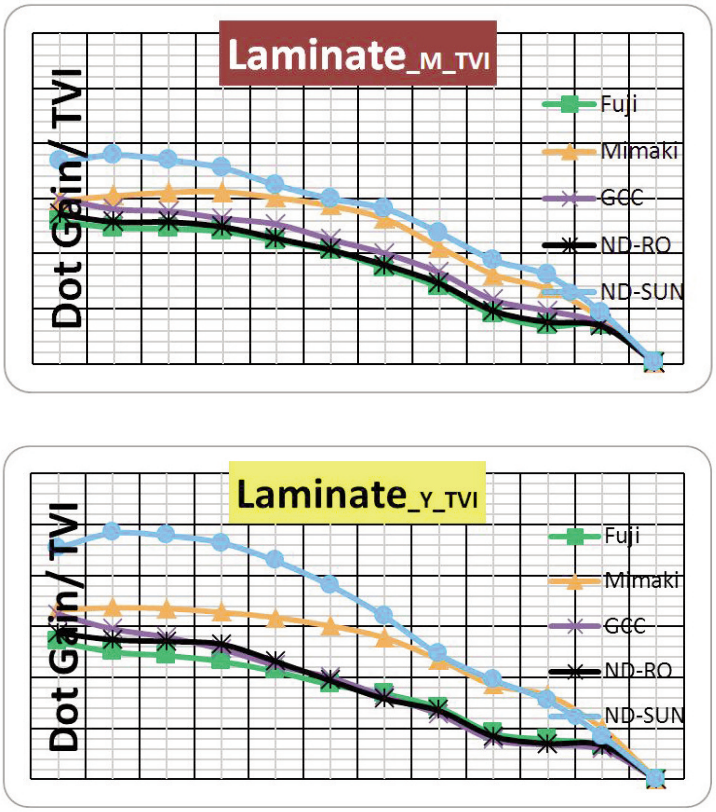
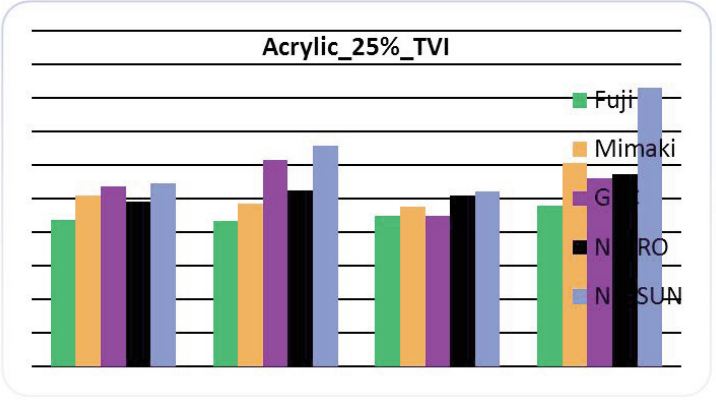


Figure 9. *Tone Value Increase Ratio for Laminate*

As Figure 10 shows, for the Acrylic, C, M, Y, and K, at 25%, provided the largest TVIR increase with the ND-sumjet printer ink combination, with the lowest from the Fuji combination. For the Acrylic, K, at 75%, the Mimaki printer ink combination provided the largest TVIR, and lowest with the Fuji combination. In the C, and M, ND-sumjet printer ink combination provided the largestTVIR, with the lowest with the Fuji combination. In the Y, ND-sumjet printer ink combination provided the largestTVIR, with the lowest with the GCC combination.



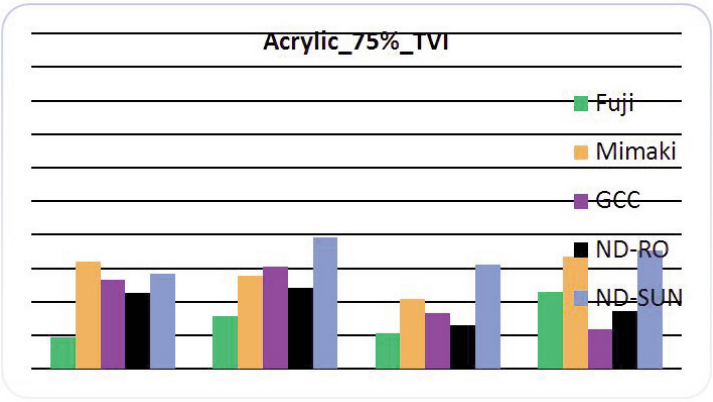


Figure 10. *25% and 75% of Tone Value Increase Ratio for Acrylic*

As shown in Figure 11, for Glass, K, at 25%, performed the greatest TVIR with the Mimaki printer ink combination, and least with the ND-royal combination. The C, and M, had highest TVIR with the ND-sumjet printer ink combination, and least with the Fuji combination. The M had highest TVIR with the Mimaki printer ink combination, and least with the Fuji combination.

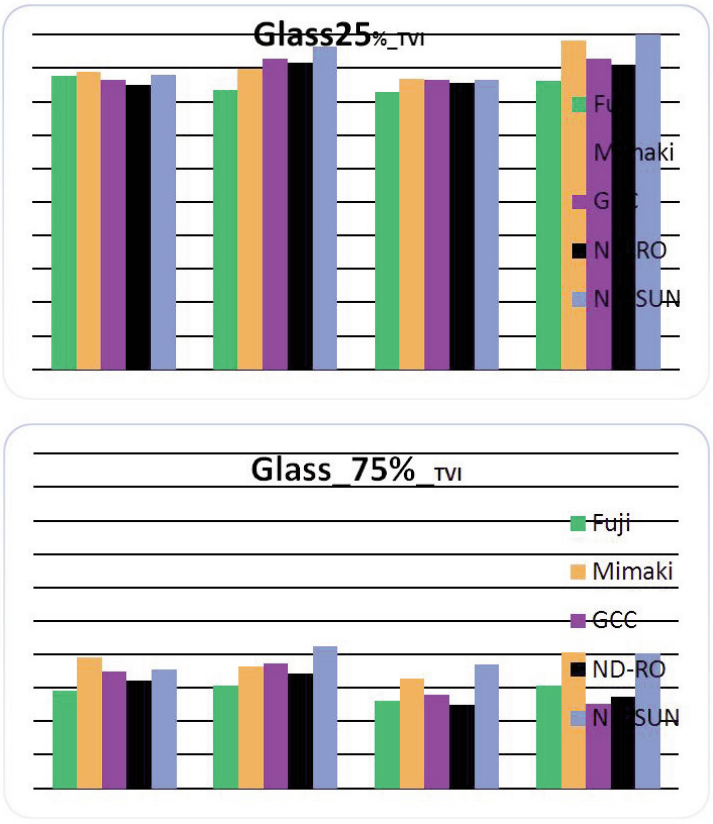


Figure 11. *25% and 75% of Tone Value Increase Ratio for glass*

For Glass, the K, at 75% had highest TVIR with the Mimaki printer ink combination, and lowest with the Fuji combination. The C had the highest TVIR with the ND-sumjet printer ink combination, and lowest with the Fuji combination. The M had the highest TVIR with the ND-sumjet printer ink combination, and lowest with the ND-yoyal combination. The Y had the highest TVIR with the Mimaki printer ink combination, and lowest with the GCC combination.

As shown in Figure 12, the Laminate, K, C, M and Y, at 25%, had highest TVIR with the ND-sumjet printer ink combination, and least with the Fuji combination. For Laminate, K, at 75%, the Mimaki printer ink combination provided greatest TVIR, while the Fuji combination was least. For the C, M, and Y, the highest TVIR resulted with the ND-sumjet printer ink combination, and least with the Fuji.

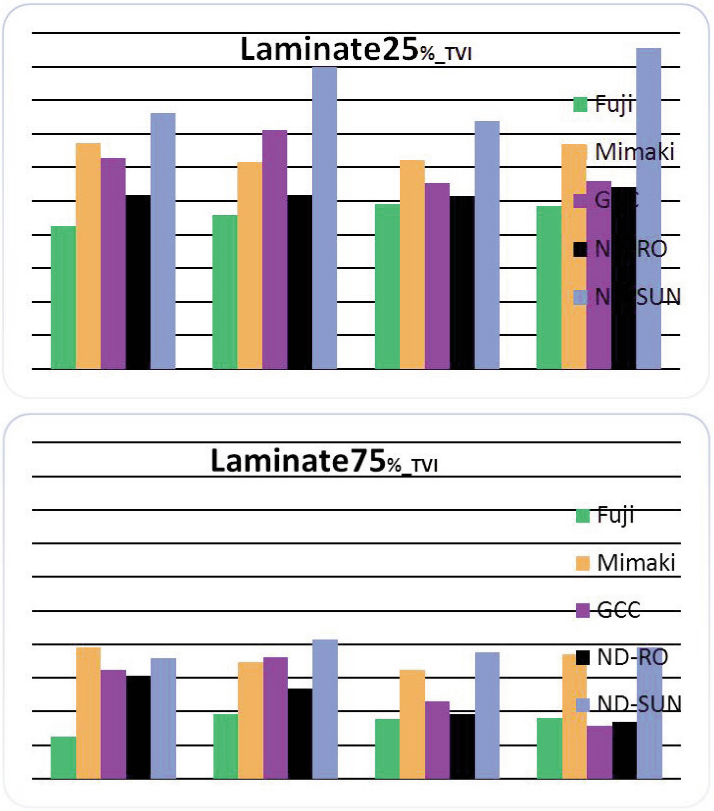
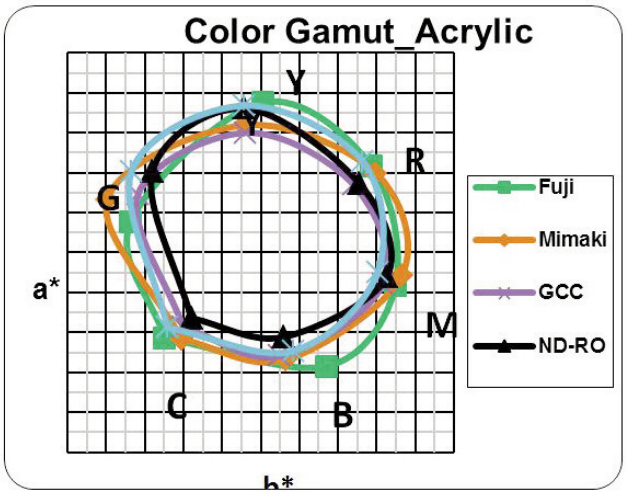


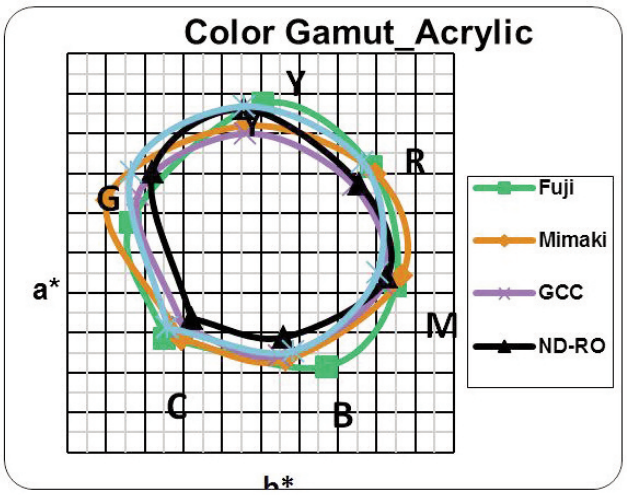
Figure 12. *25% and 75% of Tone Value Increase Ratio for laminate*

From Figure 10, Figure 11 and Figure 12 it can be seen that the Acrylic, Glass and Laminate), at 25% and 75%, for C, M, Y, and K, enjoyed highest TVIR with the Glass, followed by the Laminate and Acrylic.

4. Color Gamut

Color gamut indicates performance across the color range, with the printing equipment providing its maximal scope of performance across the color range, which is the equipment's color performance capacity. Figure 13 shows five printer ink combinations in Acrylic, Glass and Laminate printed media performance for color gamut. Figure 13 indicates the Laminate color gamut was broadest, followed by Acrylic and Glass. The three kinds of printed media had the broadest scope in G, Y, and R (green, yellow and red) color performance, indicating that for these three kinds of printed media, colors between the G, Y and R (green, yellow and red) range, enjoy better color performance.





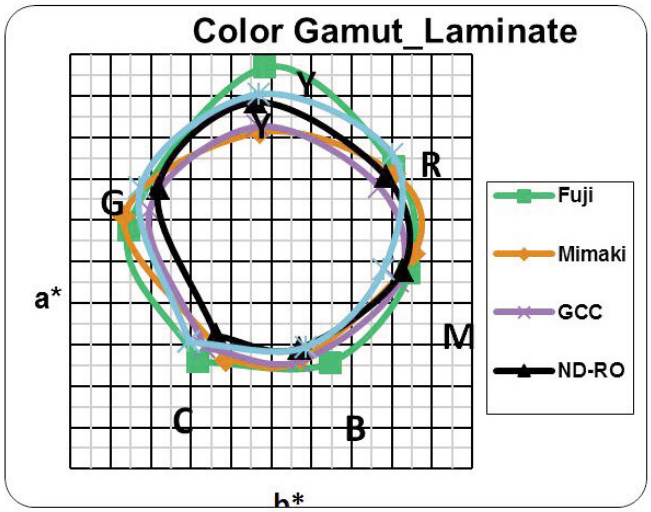


Figure 13. *Color Gamut*

In Acrylic, the best color gamut performance for the Fuji printer ink combinations can be found in the Y, R, M, B and C (yellow, red, magenta, blue and green) range, while for the G (green) color the Mimaki printer ink combination had better color gamut performance. On Glass printed media, color gamut was better with the Mimaki printer ink combinations between the G, Y and R (Green, yellow and red) color range, while for B (blue) color range; the Fuji combination provided better performance. In the Laminate, color gamut was better with the Fuji printer ink combination across the Y, R, M, B, C, and G yellow, red, magenta, blue, blue and green) color range.

Printer ink combination color gamut performance is characterized by: Fuji was best with Acrylic and Laminate color performance, but had poor performance on Glass), especially for Y (yellow) color. With the Mimaki, G (green) color performance was better than for any of the other printer ink combinations on the three printed media. The ND-RO printer ink combination had the least color gamut on Glass.

3.2 Expert interviews compilation

Expert interviews were compiled to analyze "current market conditions", an "industry investment survey", and "future developments and expected effects", resulting in the following consensus views of these experts as to the marketplace and industry.

1. Current market conditions

a. Cross-industry developments

UV wide-format inkjet printers have diversified across traditional cultural paper-based printing, to printing applications on media such as textiles, wood, plastic, leather, and glass, with the industry doing their own processing or outsourcing to OEM vendors. This has resulted in branching out into advertising, building materials, furniture, textiles, 3C products, and many other industries, within the industrial printing fields. UV wide-format inkjet printers apply to a diverse range of industries in the manufacturing process, rather than to its own independent printing industry. In discussing the UV wide-format inkjet, one cannot merely refer to the typical printing industry. Diverse applications for UV wide-format inkjet machines make it like a variant of King Kong, with many flexible uses among different industries, and resulting in the formation of new business models in different markets.

b. The main industry growth trends

Taiwan UV wide-format inkjet printers are mainly used in three major industries: 1. The advertising industry. 2. Building materials industry and 3. 3C products. Smaller growth rates apply in the advertising industry; in addition to the relatively smaller domestic market size, competition is more intense with other formats, such as print ads, where UV inkjet offers no absolute advantage, unless one is using other atypical printed media. In the building materials industry, the UV wide-format inkjet printing and color tone, high-resolution and other advantages are gradually replacing screen printing, and though while fast-growing, the trend has gradually slowed. On Taiwan with our 3C Kingdom, 3C product development in recent years has evolved into new UV wide-format inkjet printing applications for 3C products as an emerging target market.

c. Environmental issues and slogans

UV wide-format inkjet printing has competitive advantages from being 1. Environmentally friendly, 2 fast, and 3 using multivariate printed materials, with its environmental advantages of defeating the need for water-based ink and solvent-based inks. It does not contain volatile organic compounds (VOCs) and thus conforms to global promotion of environmental protection issues, as manufacturers are forced to focus on the development of environmentally friendly printing. But while emphasizing UV environmental issues, the real potential for UV environmentally-friendly printing remains somewhat open to question. Although with UV inkjet printing there are no volatile organic compounds (VOCs), or other foul smells in the process of printing, the odor is still harmful to humans and the environment. In production

and manufacturing, there are no absolute zero pollution processes, so if industry merely pursue the latest environmental trend, or the vapidity of consumer preferences, committing investments without understanding the UV inkjet market conditions, it may be easy for investments to fail, or fail to develop appropriate customer bases.

d. A trend does not necessarily equate to an influx of money and new business

UV wide-format inkjet printing in recent years has become a trend, with more and more investors investing in the equipment, but does this necessarily mean that UV inkjet industry will have huge profits to be made? The answer is: not necessarily. A manufacturer with more than 10 years in the UV industry exclaimed: "On the surface it seems the UV inks offer advantages from being environmentally friendly and deployment in a variety of applications, but in fact solely relying on an UV inkjet to make money is not feasible. In recent years more and more people are investing in the machines, many investors liking the industry's prospects, but the actual return on the investment is not great. Indeed more and more seem to reflect a reckless willingness to bet all one's eggs." At present, everyone is busy testing the market's waters, with many at the let's "try" phase, blindly following the trend in search of a target market, but first having a mature market, and then investing, would be the more prudent approach.

2. Industry investment survey

a. Industry participant type – print output centers and factories

If you consider industry participant classifications of buyers of UV wide-format inkjet printers, they can be divided into small print output centers and large factories. The following discusses their types, internal conditions, external markets, and potential problems.

- Types

UV wide-format inkjet printer has the advantage of permitting customization, diversification, so small output centers purchasing this equipment can use the new process to produce a small amount of a variety of products, in line with the changing needs of the consumer marketplace. Facing the digital transformation of traditional factories, importing these digitization processes to replace the traditional screen printing, results in decisions to purchase the UV wide-format inkjet printers. In addition, the UV wide-format inkjet printer is used for proofing applications.

- Internal conditions

The print output center is facing a new process transformation, and large factories are facing the digital transformation of their processes. Print output center personnel come from the traditional printing industry, and plant personnel come from manufacturers, coming from two different industries, and constructing respectively different internal conditions and merits in regard to their work style. The print output center has advantages for imaging and color management, but face great obstacles in product development know-how and media properties, especially in the development of different products, to understand the various properties of the materials and processes is a huge burden for the print output center. While traditional manufacturers understand their material and process features, digitization, transformation, imaging and color management all pose a long learning curve. So whether for the small print output center or a large factory, both are still trying to adapt to using this new equipment.

- External markets

Large-scale factory orders originate among one's original customers, by merely restructuring processes, there can be a stable source of clients. But print output centers need to develop sources, customizable, small, sophisticated and high value-added products to attract consumers. To maintain operations they need a sizeable business volume and orders, with most using internet platforms, marketing and promotional efforts to expand their market presence.

- Potential problems

Print output centers not only have market issues and materials adaption issues, but also another potential problem with the production line. When UV wide-format inkjet printing presses use special materials, they typically need to go through post-processing as well as pre-treatment procedures and printing processes. General print output centers simply cannot buy the entire production line equipment, and therefore need to work with manufacturers to complete production operations. Otherwise, the machine itself can only undertake the printing business, and not directly provide finished products.

In summary, traditional manufacturers buy UV wide-format inkjet printing presses but must adapt their pre and post processing production lines, while their original customer base makes them appear more likely to survive. The average small print output center faces issues from the new materials, processes and unstable order conditions, meaning it is easy for operations to fail.

b. Willingness To Invest

Manufacturers' willingness to invest in UV wide-format inkjet printers are divided into the following three factors: product and production considerations, traditional processes' environmental pressures and, entrepreneurial decisions.

• Product And Production Considerations

(1) Creative new effects: In the face of the diverse needs of the marketplace, the diversity of UV applications helps to develop new products with creativity to meet the needs of customers. Therefore there is a strong willingness to invest in UV wide-format inkjet printing.

(2) Overhead costs (small run production, proofing): For the production of a small runs, UV wide-format inkjet has a lower cost, and also can be applied in large quantities of pre-press proofing.

(3) Shorten the delivery time: In traditional processes, from plate making, screens, or molds, to printing, and post-processing there a large number of complex procedures, but through the digitization provided by the UV wide-format inkjet process, one can shorten the delivery time.

(4) Quality improvement: The high-resolution inkjet may provide better printing quality, relative to screen printing for continuous tone color, and UV ink surfaces are dry and do not affect the printed media, providing more vivid color performance.

(5) Demands for customization: Customized manufacturing provides advantages through digital printing to meet changing market trends and deliver the individual creativity demanded in the digital era.

• Traditional Processes' Environmental Pressures

(1) Film, utilities and other rising overhead costs encourage the trend to switch digital: With the rise of environmental consciousness and the trend for evolving from traditional to digital methods, traditional film and process materials are used less and less, so there cost will be more, and are bound to be eliminated. Traditional process utilities consumption losses are also much higher than for the digital process, thus forcing the inevitable transformation of the traditional process.

(2) Traditional manufacturing process staff are hard to find, and process control is difficult: Compared to traditional printing personnel requirements for professionalism, digital printing system process permit relatively simple

manipulation, easy staff education and training, and modern youth are not interested in traditional printing, so that the traditional process staffing is hard to find.

(3) Traditional process sewage and noise problems: As environmental awareness expands and demands are placed to improve the traditional process emissions from sewage and noise standards, there are bound to be more and more restrictions, exacerbating the environmental pressures on the traditional processes.

(4) Facility expenses and sites option: The digital process plant and equipment require much less of a space footprint than the traditional production line demands, thus providing more choices for sites.

• Entrepreneurial Decisions

The emergence of the UV wide-format inkjet printing has permitted entrepreneurs to enter many different industries, such as the textile industry, glass industry, or building materials industry. With these investors' new ideas and creativity, it is possible to experiment with new methods and innovate the design of new products.

In summary, the pressure from the transformation of traditional industries, as environmental awareness expands, and market conditions demand ever more innovative ideas, the UV wide-format inkjet has begun to sprout development in many different industries.

c. The Investment Threshold

• Capital Equipment Threshold

When investors consider investing in UV equipment, they consider the UV equipment: (1) Printability, (2) Equipment prices, (3) Maintenance and post processing requirements and (4) Material overhead costs.

(1) Printability: Different brands of presses and combination of different brands of ink or nozzles are needed for different printing on different printability media. For example the Mimaki exhibits good fitness for textile printing, and the ND-RO and ND-sumjet maker began in woodworking, so their UV inkjet series is highly appropriate for wood media. So it is important to carefully consider market demand requirements in the decision calculus before procurement.

(2) Equipment prices: International brand UV wide-format inkjet printers, cost about NT$6-8 million (about US $200-265,000), while domestically produced printers cost about NT$ 3 million (about US$100,000) or so, thus where printing quality is comparable, the price may be the first consideration.

(3) Maintenance and post-processing requirements: Another manufacturer indicated they were concerned with factors such as upgrading and maintenance of the equipment. Generally investors will not continue to purchase new equipment, so equipment upgrades and maintenance are important considerations for investors. Overreliance on a well known brand of the equipment may arise, or selection of brands with a broader domestic maintenance base for easier maintenance may be chosen.

(4) Materials overhead costs: The price of ink is one important factor why UV inkjet printing is not universal, the ink overhead is costly, and so as the cost remains high the long-term cost considerations compel many to choose domestic brand inks with domestic brand models. International equipment will normally require the use of the same brand of ink, but with the higher ink elasticity of the domestic models there are no hard and fast rules.

• Internal Threshold

(1) Sites: UV wide-format inkjet printers, although enjoying a smaller footprint than the traditional process requirements for the production line, yet because of their magnitude limits, procuring companies still must have a sufficiently broad site, though staffing requirements are less, so for typical sites, staff of two or three is sufficient.

(2) The cost of UV wide-format inkjet printing equipment and supplies means that procuring companies still need to have a sufficient amount of capital in order to meet the burden of the equipment maintenance and supplies operational overhead.

(3) Technology: Human capital requirements for UV wide-format inkjet machines are not great, with personnel training and education more convenient and simpler, as well as easier to control.

(4) Market orientation: Before procurement it is imperative to have a clear position on market demand requirements, so if one will be an OEM or self-branded producer; and using wood (ND) or textiles (Mimaki). It is also critical to consider market familiarity. From the woodworking origins of ND, there familiarity with wood media, have meant they could

specialize in wood media equipment. It is then possible to rely on equipment and printed media capabilities to develop distribution and marketing presence.

(5) Innovative ideas: The multiple applications of the UV wide-format inkjet machines, mean that procurement of the UV wide-format inkjet machines require innovative thinking, distinct from the traditional process, innovatively seeking new methods and new product applications, to open up new markets.

In summary, investors should be aware of their market positioning as the most important factor to determine the requirements for their equipment and supplies procurement decisions.

3. Future developments and expected benefits

UV wide-format inkjet currently faces its greatest difficulties from the dual factors of the high equipment prices and high ink costs. But as the trend for UV environmental friendliness gradually matures, with the greater popularity in the U.S. and European markets for the concepts of environmental protection, the Asian market will be subject to the same pressure to advance awareness for environmental protection, and driven by the social environment we can expect changes to industrial development. As our domestic concepts adapt and overhead costs decline, UV wide-format ink jet will replace the traditional process or screen printing.

Taiwan is a large OEM factory on behalf of global industry, as a lower threshold for printing develops, large companies will deploy these systems widely glass production, tile factories, the manufacturer of 3C products, optoelectronics, power plants, tanneries, etc., each with their own procurement possibilities for these UV wide-format inkjet devices.

Ink costs and improved technology will largely determine the developing path of UV inkjet printing. In terms of overhead costs: UV wide-format inkjet printing ink cost reductions or with higher wage costs, manufacturers deploying such systems will be substantially increased. In respect to ink printability improvements: the development and application, of other special inks, such as conductive inks, biochemical ink, fluorescent ink, adhesive ink, and other developments and skills enhancements, will open up larger and more diverse applications in the UV inkjet marketplace.

4. Study recommendations

1. Advice to industry

This study's experimental findings, indicate that UV inkjet printing applied to Acrylic, Glass and Laminate, and other printed materials, yielded a TVIR curve with significant variance from plain paper TVIR, with the tone amplified most significantly with the bright tones, so it is recommended that industry can refer to the results of this study to further highlight needs for tone amplification for optimal printing quality control.

From our experiments in this study on five manufacturers' typical printing processes, and not for adjusted printing processes for special printed materials, we found room for improvement exists still for uniform ink distribution on Acrylic, Glass and Laminate printing media. We recommend that industry enhance their ordinary pre-print processes, to obtain better color gamut performance and print quality.

The study found that UV wide-format inkjet printer ink combinations across Acrylic, Glass and Laminate printing media yielded varying color space, so it is recommended that industry adapt according to the needs of the various printing products production requirements, relying on this study's findings as reference for optimal printer and ink combinations.

Due to the tremendous variety of the UV wide-format inkjet printing industry production, this study suggests industry fully consider prior to UV wide-format inkjet printing investments or procurement, their applicable market profile in the UV wide-format inkjet printing industry to target their procurement or investment to their specific market needs, and development of integrated front-end production lines.

2. Future Research Directions

In this study, largely in consequence of time and manpower constraints, we were only able to consider the dimensions of Solid Ink Density, Print Contrast, Dot Gain / TVI and Color Gamut, as indicators for print quality characteristics, so follow-up study is proposed for digital printing quality specifications (ISO13660) for graphic detail quality, and to increase the types of printed materials under study. This study also found that the UV ink and non-paper printed media still have some room for improvement in uniform ink application, so it is recommended to further consider pre-press processing requirements.

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Reference

2010 〝Production Value by Country and Printing Process. by Printing Industries of America, 2010, 2010 Forecast: Technology, Trends, Tactics, p. 95.

Briggs, J. C., Klein, A. H., and Tse, M. K.2009 〝
2009 Print Shipments (Preliminary) by Printing Industries of America, 2009, 2009 Forecast: Technology, Trends, Tactics, p. 1

Engeldrum, P. G.
1994. "The Color between the Dots," The Society for Imaging Science and Technology, pp. 545-551.

Hsieh, Y.C.
1997"Factors Affecting Dot Gain on Sheet-Fed Offset Presses," Visual Communications Journal, pp. 39-49.

Lamparter, W. C.
2009"Print Volume Erosion Continues: Digital Print Process Share Growth Stalls in Competitive, Faltering Economy,"2009 Forecast: Technology, Trends, Tactics: Printing Industries of America.

Southworth, M., and Southworth, D.
1989"Quality and Productivity in The Graphic Arts,"Livonia, NY: Graphic Arts Puclishing Co.