5-6-2013

Packaging print buyer willingness to trade off image quality for environmental benefits

Rattana Mayteekriengkrai

Packaging Print Buyer Willingness to Trade Off Image Quality for Environmental Benefits

By Rattana Mayteekriengkrai

A Thesis submitted in partial fulfillment of the requirements

for the degree of Master of Science

in the School of Media Sciences

in the College of Imaging Arts and Sciences

of the Rochester Institute of Technology

May 6, 2013

Primary Thesis Advisor: Professor Robert Eller

Secondary Thesis Advisor: Professor Bruce Myers

Table of Contents

List of Figures

List of Tables

Abstract

Consumers are increasingly concerned about environmental friendliness, in addition to product quality. However, widely used technologies are not yet capable of producing packaging that combines the highest level of image quality with the highest level of environmental friendliness. As a result, print buyers are forced to trade-off image quality for increased environmental friendliness. The amount of image quality that a print buyer is willing to trade-off for a given improvement in environmental friendliness is unknown. This is a problem for printers and print suppliers who are attempting to develop products without access to this potentially critical empirical design information.

This research addressed the problem of missing design information by conducting a conjoint analysis experiment. From this experiment, the researcher determined the relative value of carbon footprint, VOC emissions, gamut size, and image resolution to print buyers in the folding carton packaging market. In addition, this research determined that print buyers cluster into groups based on their trade-off behaviors.

A sample of 11 industry professionals who either are or have been print buyers participated in the experiment. The results of the experiment were statistically significant at the 95% confidence level for all 11 print buyers. The conjoint analysis resulted in a multiple regression model that predicted print buyer preferences based on four attributes of the printed package being offered: carbon footprint, VOC emission, gamut size, and image resolution. R^2 varied by

participants but ranged between 73% and 97%. Gamut size was the most important of the four attributes examined. On average, gamut size was responsible for 40% of the print buyers' preference. Carbon footprint and VOC emissions both contributed approximately 25% of the print buyers' preference. Finally, image resolution was the least important attribute contributing approximately 10% of the print buyers' preference for an offering. When print buyers were grouped based on their weighting of the relative value of environmental impact and image quality, two favored environmental benefit, four favored image quality, and five weighted image quality and environmental impact approximately equally.

Chapter 1

Introduction

Statement of the Problem

Increasing competition in consumer markets encourages companies to continually redesign products and packaging to fulfill the needs of their customers. Factors that influence consumer purchasing decisions have grown to include the environmental friendliness of both the product and its accompanying packaging. More environmentally friendly products, widely referred to as “green” products, are perceived as high-value products by consumers. Consumers are willing to pay more for green products, and companies that are devoted to improving environmental impact are increasingly attractive to consumers. (e.g., Coddington, 1990; Bench-Larsen, 1996; Eagly & Kulesa, 1997; Sweson & Wells, 1997; Benito, Noya & Paniagau, 1999). Therefore, the majority of consumer product companies would like to improve the environmental friendliness of their products and packaging.

Packaging plays significant role in promoting fast-moving consumer products. Consumers consider packaging to be a part of the product, and the appearance of packaging plays a major role in the perception of product quality. Moreover, unique packaging contributes to product recognition by consumers. For fast-moving consumer products in particular, shoppers often recall which product to purchase based on the graphical appearance of the package, with

color being a particularly critical factor. Image quality is, therefore, critical to the success of consumer facing packaging.

Folding cartons are commonly used to package fast-moving consumer products. Companies who used folding cartons want to attract consumers by presenting themselves and their products as being environmentally friendly. Thus, fast-moving consumer goods companies should prefer folding cartons that combine high image quality with exceptional environmental friendliness. However, achieving this combination of features is challenging for currently existing technologies, and this situation often forces print buyers to make a trade-off between image quality and environmental friendliness. It is, therefore, important for packaging printers to know to what degree print buyers are willing to trade off image quality in order to gain increased environmental benefits. Unfortunately, an extensive search of the literature failed to find the research required providing this, and filling this knowledge gap is the problem addressed in this research.

Background

Awareness of environmental issues is increasingly driving consumer behaviors and subsequent purchasing decisions. Today, many consumers want to know if their purchases lead to environmental problems. This is particularly important in packaging, which many people associate with waste. However, packaging is an essential tool for distributing and promoting many consumer

products. Therefore, consumer product companies are working to improve the environmental friendliness of their packages. This trend is reinforced by the retailers who sell consumer products. For example, the world's number one retailer, Wal-Mart, has elevated its interest in sustainability by providing an environmental scorecard to calculate the environmental impact of product production for the goods that its retail outlet (Walmart, 2011).

The primary obstacle to producing environmentally friendly folding carton packaging is that enhancing environmental benefits usually leads to a decrease in image quality. Specifically, environmentally friendly inks (such as vegetable oil-based inks) limit gamut size and potentially compromise image quality, compared to packages printed with conventional printing inks. Thus, print buyers who want to buy more environmentally friendly packaging find that they are faced with a trade-off between environmental friendliness and image quality.

Reason for Interest

Since folding carton packaging is a large market and green printing is a problem in this market, many members of the folding carton value chain can be expected to have an interest in the subject of this study. The direct benefit of this research for the folding carton value chain is that packaging print buyers, ink producers, and packaging manufacturers will better understand the balance point between environmental benefits and acceptable image quality. Another indirect benefit is that the research methodology can be applied to other packaging

materials, such as flexible packaging, plastic, and corrugated containers. This project is interesting to the researcher because she encountered this problem while working for a folding carton company in Thailand. Learning about the willingness of print buyers to trade off image quality for environmental benefits is, therefore, an important industry problem, which is strongly aligned with the interests of the researcher.

Chapter 2

Theoretical Basis

The problem addressed by the researcher is to understand how print buyers make trade-offs between image quality and environmental benefits when they are forced to choose between the two. This chapter provides the theoretical basis required to understand and investigate such trade-off decisions. The chapter opens with a discussion of the emotional and rational approaches to making a trade-off decision. After concluding that commercially oriented print buyers are more likely to use the rational approach, the chapter describes a widely used model and methodology for investigating rational trade-offs, known as *conjoint analysis*.

Approach to Making Trade-offs

Trade-offs can be described as a phenomenon involving losing one benefit in return for gaining another that is regarded as more desirable. Trade-off analysis can be used to investigate the relative importance of product attributes. Historically, two main theories have been advanced to explain how individuals make trade-offs: the emotional approach and the rational approach.

Emotional Approach

One theory focuses on the emotional aspect of human behavior. Luchs, Brower, and Chitturi (2010) applied this theory to investigate consumer trade-offs between sustainability and functional performance. Their study explains that, when making trade-off decisions, consumers are dealing with feelings of guilt and distress on one hand, versus feelings of virtue and confidence on the other. They feel greater guilt for the absence of sustainability, whereas they feel less confidence when choosing a product with lower performance. It is evident that the role of emotions (such as guilt, distress, and confidence) is different for each individual making a trade-off decision. However, the emotional approach is unable to quantify the value of the characteristics being traded. Research suggests that marketers may use the emotional approach in designing a marketing campaign by exploiting consumer willingness to pay for an emotionally important attribute.

Rational Approach

The second theory focuses on the rational aspect of human behavior (e.g. Luce & Tukey, 1964). The rational individual uses a rational process to choose between two offerings. The five steps needed to utilize the rational approach are:

1. Select the important attributes of the product. For example, for a laptop computer, the weight and size of the screen are normally viewed as important factors.

2. Evaluate each offering to capture the level of these attributes (as shown in Table 1).

Table 1. Attributes and Levels of a Laptop Offering

Laptop (Product)			
Attribute:	Brand	Weight	Screen size
Level 1:	A	2.0 kg.	13 inch
Level 2:	B	2.4 kg.	15 inch

3. Assign a value to each level of each attribute. These individual values are called *part worths*.

4. Calculate the sum of part worths, which is the total value of the offering. The sum of the part worths is commonly referred to as the individual's "preference" for the product.

5. The rational individual chooses the offering with the higher preference (as shown in Table 2).

Table 2. Assign Part Worth for Each Level of Attribute

Laptop					
Brand	Part Worth	Weight	Part Worth	Screen size	Part Worth
A	0.3	2.0 kg.	0.5	15 inch	0.4
B	0.2	2.4 kg.	0.3	13 inch	0.1

Preference of product offering A = 0.3+0.5+0.4 = 1.2

Preference of product offering B = 0.2+0.3+0.1 = 0.6

While the emotional approach may be appropriate for the analysis of some consumer-level purchases, commercial print buyers making decisions as part of their responsibilities in working for large corporations can be expected to make value decisions on a rational basis. As a result, the rational approach to trade-off is used in this research, and the remainder of this theoretical basis is devoted to explaining this approach.

Conjoint Analysis: A Rational Trade-off Model

The conjoint method was based on work done by mathematical psychologists and statisticians Luce and Tukey in 1964.

<u>Background of Conjoint Analysis</u>

Green and Rao (as cited in Orme, 2006) applied Luce and Tukey's 1964 work to solve marketing problems based on a simple additive model for making trade-off decisions. In this model, the level of each attribute in an offering has a

value to the decision maker (its "part worth"), and the value of the offering is the sum of the part worths. In reality, "human decision-making and the formation of preferences are complex, capricious, and ephemeral" (Orme, 2006, p. 25). Nevertheless, over a period of 40 years and tens of thousands of conjoint analysis studies, this simplified model has been proven to predict many human preferences.

Conjoint Analysis Models

Conjoint refers to "joining together" multiple elements of a product in a manner similar to a real-world alternative. The starting point for conjoint analysis is a set of product offerings, comprising several levels of product attributes joined together. During the evaluation process, the product offerings are shown to respondents who are asked to evaluate these offerings by rating them according to their preferences. Preference data from many product offerings can then be used to infer part worths. Researchers can analyze these data by applying statistical tools, such as multiple regression or logit analysis, to analyze the results.

Conducting a Conjoint Analysis Experiment

The generally recognized procedure for conducting conjoint analysis follows five distinct steps:

1. Define Attribute List
2. Develop Survey Design

3. Conduct Survey
4. Analyze Survey to Develop Utilities
5. Predict Participant Preferences

These steps are discussed in detail below.

Define Attribute List

Attributes can be described as the characteristics of a product. Respondents will be asked to rate, rank, or select among several product offerings. The information provided for each product in a conjoint experiment should be clear, specific, and concise. Also, the amount of information should be appropriate, since research has found that the results might be distorted if the information offered has more than six attributes. Another concern is how to select the proper combination between attributes and attribute levels. In order to choose effective combinations, it is advised that the researcher selects attribute levels covering the full range of possibilities for both existing and non-existing products. The selected attributes should be independent because overlapping of attributes results in "double counting" of part worths. For example, the style of a car (sedan, van, etc.) and the number of seats are not wholly independent attributes. Attributes derived and selected from prior published literature can help the researcher to develop relevant non-overlapping attribute sets.

Develop Survey Design

Once the set of attributes has been chosen, the next step is to design the survey. A survey consists of a set of product offerings, which will be shown to and rated by each participant. Research has shown that participants are unable to effectively deal with more than 20 offerings in a single experiment (Orme, 2006). If the product of attributes and levels is less than or equal to 20, a full factorial experimental design can be used. However, if the product of attributes and levels is greater than 20, it is impossible for respondents to evaluate the overload of choices. In this case, the researcher can use a fractional factorial design to acquire the information necessary to infer attribute part worths from a smaller number of comparisons.

Conduct Survey

The steps in conducting a survey are:

1. Select participants for the survey.
2. Prepare offering cards and response forms.
    - Describe each offering (using text, illustrations, or prototypes).
    - Provide a data collection form to collect preferences from participants.
3. Send offering cards and response forms to participants.
4. Collect responses (i.e., survey data).

Analyze Survey Data to Develop Utilities

After collecting all responses, the next step is to analyze the survey data. Analysis is based on an additive model of utility (i.e., the total utility of an offering equals the sum of part worths of the attribute levels in the offering). Next, multiple regression is used to analyze the relationship between the attribute levels of an offering and the respondent's preference for that offering. The multiple regression produces part worths for each attribute level and a constant (which represents the utility of the base offering). In addition, the multiple regression produces an F statistic that can be use to test if the relationship between attribute levels and preferences is real. The regression also will produce an R^2 statistic that shows the percentage reduction in total error attributable to the regression. Finally, the multiple regression equation can be used to predict the preference of the participant for a new offering.

Predict Participant Preferences

For an individual participant, the participant's preference for an offering is predicted by summing the part worths of the attribute levels in the offering. The results of a conjoint analysis are often used to predict preference for alternative offerings or to predict market shares (Cattin & Wittink, 1982). For instance, an individual may be interested to know what the predicted market share of a specific product adaptation would be. Another analysis may study the possible

effects of introducing a new product into the existing market. To predict market share, a population of subjects representing the market is selected, and each subject's preferences are modeled. These models are used to evaluate different sets of product offerings. Market share is predicted based on the percentage of model results that choose a particular product offering over the others presented in the set.

Alternative Conjoint Analysis Models

Conjoint analysis is used as a tool to understand the complexity of consumer decision-making. There are three main approaches used to construct conjoint preference models: Traditional Conjoint Analysis, Adaptive Conjoint Analysis, and Choice-Based Conjoint Analysis.

Traditional Conjoint Analysis

Researchers have suggested that traditional full profile conjoint analysis (also called *Conjoint Value Analysis,* or *CVA*) is limited to evaluating six or fewer attributes (Green & Srinivason, 1978). This method can use paper-and-pencil surveys, or surveys can be conducted by computer. Some alternative conjoint analysis models are interactive and require the survey to be conducted via a computer. In the traditional model, a full profile of product attributes are shown to respondents for each product offering. Respondents evaluate product offerings individually and rate them, based on the respondents' preference for the combination of attributes shown in the offering.

Adaptive Conjoint Analysis

The main advantage of the second approach, Adaptive Conjoint Analysis (ACA), is that it can include a large number of attributes (up to 30) and a large number of levels (more than 7). Researchers found that the ability of respondents to provide consistent and meaningful ratings decreases if they are asked to respond to a survey presenting more than six attributes at a time. ACA solves this problem by combining detailed assessments of attributes and levels with conjoint pairwise comparisons. The ACA survey employs these two steps:

1. Respondents rank or rate the important of attribute levels, and this information is used to identify the most important attribute.
2. Offerings consisting of the most important attributes are presented in pairs for grading using a rating scale.

This model emphasizes the evaluation of products in a systematic, feature-by-feature way, rather than by judging offerings in a whole product context (Orme, 2006). ACA was first implemented by Sawtooth Software. This method requires a face-to-face interview or an online interactive program because the offerings to be evaluated are created based on the responses of each individual participant.

Choice-Based Conjoint Analysis

Choice-Based Conjoint (or CBC) Analysis has become widespread throughout the world. Instead of rating offerings, CBC requires participants to choose between them. Since CBC closely simulates the purchase process in competitive situations, it is viewed by many researchers as being more realistic. This model provides the price sensitivity for each brand and can be used to construct powerful pricing simulators. In the real world, consumers may choose to reject all options if those products or services do not fulfill their requirements. CBC emulates this behavior by giving participants the choice to defer their purchases. Choice-based surveys can be administered via personal computers, Internet surveys, or paper-and-pencil questionnaires (Orme, 2006).

Choosing the Correct Model

Choosing the best conjoint model for the problem being studied depends on the number of attributes that researcher wants to study and the available resources for conducting interviews (such as questionnaires, computer-based tools, or telephony).

The difference among conjoint analysis approaches can be summarized as follows: Traditional conjoint analysis can be only used with six or fewer attributes and is well suited to conducting an experiment using a paper-and-pencil questionnaires. Adaptive conjoint analysis works well with large numbers

of attributes. Therefore, this model is usually used to investigate complicated product and/or service offerings. Lastly, the advantage of CBC analysis is that it allows respondents to select “none of these”, which is close to the expected behavior when products do not meet their needs. CBC is a good tool for providing price sensitivity estimates.

Interpreting Results

The part worth model can be interpreted as the relative importance of attribute/level combinations to an individual. Table 3 illustrates an example of a part worth model for an individual (Individual A). As shown in this table, the attribute that has the greatest value to this individual is Price. The difference in value between the lowest price and the highest price is 4.50, which is larger than the corresponding difference for Brand or Color.

Table 3. Part Worth Model for an Individual

Part Worth for Individual A					
Brand		Color		Price	
Level	Part Worth	Level	Part Worth	Level	Part Worth
A	0.00	Red	0.00	$50	0.00
B	1.67	Blue	1.11	$100	-2.17
C	3.17			$150	-4.50

Once part worth models for several individuals have been generated, the researcher can identify groups of individuals which share similar views concerning the relative importance of the attributes in the offerings.

Chapter 3

Literature Review

The literature review begins with an overview of the target market for this research, namely the market for folding carton packaging. The trade-off being investigated by the researcher is motivated by consumer behavior, and the subsequent two sections of the literature review focus on this topic. Specifically, the literature review discusses consumers' reaction to packaging graphics and investigates their growing interest in the environment (which is increasingly driving consumer purchasing decisions). Finally, in order to operationalize the research approach, measures of image quality and environmental impact are required. The literature review concludes with a discussion of the salient factors that contribute to image quality and environmental impact, and the techniques used to present different levels of image quality and environmental impact to experimental subjects.

Folding Carton Packaging

The market for folding cartons is large, global, and expected to grow. Some research relevant to this topic can be categorized as studies that examined markets and applications, while other works explored the technologies utilized to produce folding cartons.

Market Size and Applications

Pira International states that global consumption of folding cartons was 40 million tons in 2010. The value of this market is US $78 billion, of which 80% is folding cartons and 15% is micro flute cartons (as cited in Harrington, 2011). Pira expects the average growth rate of the overall folding carton market to be 4.4% per year from 2010 to 2016 (Pira International, 2011). In Brazil, Russia, India, and China (commonly known as *the BRIC countries*), the consumption of folding carton packaging is anticipated to increase by 7.9% between 2010 and 2016 (Pira International, 2007). However, the largest market for folding carton packaging is currently Asia, and, with a projected 6.5% growth in carton board consumption, Asia will be the most significant market in terms of total volume growth (Pira International, 2011).

The primary application for folding cartons is consumer-facing packaging, where image quality is an important characteristic. According to Hachard (2011), packaging is becoming the most important, yet the least expensive, promotional medium. It is the commercial vehicle that lasts longest and has the most impact. Folding cartons are mainly used as secondary packaging for consumer goods, such as frozen food, tobacco, and products for household, healthcare, and personal use (Pira International, 2011). In these applications, folding carton image quality affects both the customers' perception of product quality and the ability of brand owners to attract customers in retail environments.

Folding Carton Technology

Three main printing processes are used in the folding carton industry: offset lithography, gravure printing, and flexographic printing (Keif, 2005).

Offset lithography. Offset lithography's ability to produce high quality images with low tooling cost is the primary reason that it is the most commonly used process for printing folding cartons (Malenke, 2010; Paper Board Packaging Council, n.d.). Another advantage of offset printing is its repeatability; packaging can be printed at various locations with uniform image quality. The maximum run length of sheetfed offset is approximately 1 million impressions (Malenke, 2010).

Gravure printing. Gravure is a comparatively expensive technology due to the cost of engraving and preparing cylinders (Kipphan, 2000). As a result, gravure printing is considered to be economical for extremely long runs (greater than 1 million impressions) of folding cartons (Malenke & Daniel, 2010). Sheet-fed gravure is mainly used in the luxury goods and tobacco markets (ME Printer, 2005). Since gravure can produce unmatched white ink opacity, vivid metallic and fluorescents, and many other specialty effects, it is the preferred technology for printing packages for luxury goods and tobacco products (Argent, 2009).

Flexographic printing. In the past, flexography was regarded as an economical, but relatively low quality, printing process used for corrugated containers. Today, however, the quality of flexographic printing has greatly improved and is now acceptable for a wide range of print buyers. Both short and

long run lengths, including runs of over one million impressions, are possible with flexography (Keif, 2005). In folding cartons, flexography is the second most popular printing technology; 71% of North American folding carton converters used lithography, while 43% used flexography in 2007 (Smith, 2008). Thus, offset lithography and flexography constitute the primary technologies used to print folding cartons in North America, and the present research is limited to these two processes.

Influence of Packaging Graphics on Consumers

Prendergast and Pitt (1996) contend that packaging is one of the aspects that has the greatest influence on consumer buying decisions made at the point of purchase. Rettie and Brewer (2000) state that product marketers recognize that packaging is a critical component of the selling process. From the consumers' point of view, the package *is* the product at the time a purchasing decision is made. This is particularly true for the purchase of low involvement products (i.e., products that consumers do not devote much time to researching before buying), where the impression formed during the consumer's initial contact with the product can have a long-term impact (Silayoi & Speece, 2007). In general, the characteristics of packaging fall into two main categories: its physical characteristics and its graphic characteristics (Ampureo & Vila, 2006).

1. Physical characteristics: the size, shape, and function of the packaging

2. Graphic characteristics: the color, typography, graphical shapes used in, and the images introduced in packaging

In this research, only those attributes related to packing graphics will be studied, and physical characteristics are out of scope.

Effect of Graphics on Consumer Perception

The appearance of the package plays a significant role in the consumers' perception of the value of product. Consumers believe that packaging contributes to positive shopping experiences (Silayoi & Speece, 2004). Brightness and cheerful graphics encourage the consumer to purchase the product, whereas poor graphics can be obstacles to consumer purchasing. Colorful graphics attract the eye. Conversely, pale packaging is often perceived by consumers as being boring and dull (Silayoi & Speece, 2004).

Effect of Color on Perceived Quality and Product Recall

Consumer research reveals that color on packaging influences consumer perceptions because color can be used to represent flavor, nutrition, and the expected level of satisfaction (Silayoi & Speece, 2007). For example, consumers perceive that pale blue is associated with low-fat products and that gold is associated with premium products.

Additionally, researchers have demonstrated that consumers will pay a higher price for colorful or bright packaging. For example, Gelperowic and Beharrell (1994) conducted an experiment with a group of mothers. In this

experiment, mothers were asked to select between two different yogurts for their children based solely on the appearance of the container and the price of the yogurt. The first yogurt container was plain, whereas the second had a bright and cheerful color, but was slightly higher in price. The results showed that 88% of the mothers chose the yogurt in the bright container, even though they had to pay a premium price for it, since they felt that their children would prefer to eat it.

Companies also try to create distinctive product identities in order to make it easy for consumers to recognize their products. This is often done by using a special color or image on their packaging. Silayoi and Speece (2004) showed that a unique color and image is especially important for consumers buying low involvement products, since they tend to remember a product by its color. Applying color as a cue on packaging can arouse a strong association, especially when it is unique to an individual brand. One participant in their research said, "when I am looking for snack foods, color helps me to find product easier…such as I remembered that the color of my kid's favorite biscuit bag was red. So I kept looking the red bag on the shelf" (p. 618).

Effect of Images on Consumer Behavior

In addition to color, visual imagery has a crucial influence on consumer buying decisions (Kupiec & Revell, 2011). To make their product stand out on a shelf, companies strategically use vivid images to stimulate consumer consciousness at the point of purchase. Research shows that consumers pay

more attention to pictures than they do to words (Underwood, Klein & Burke, 2001), so visual images on packaging take on the role of information and can establish expectations among buyers. A high-quality image makes the product memorable and leaves a positive impression with the consumer (Silayoi & Speece, 2007). Moreover, an image can stimulate the consumer's desire to purchase the product when the image is combined with other graphics, including color and typography (Ampuero & Vila, 2006). Images are applied to all levels of products. High-end products tend to use an image of the product to represent itself, while most inexpensive products use images associated with people (Ampuero & Vila, 2006).

Based on the previously cited research, empirical evidence supports the contention that visual imagery and color are essential elements of packaging value and that they strongly impact consumer perception. Thus, color and image detail will be selected as the factors that contribute to image quality for the present research.

The Influence of Environmental Consciousness on Consumer Behavior

Many consumers are adopting new behaviors that reflect increased ecological consciousness and willingness to protect the environment. For example, Chen (2010) concluded that consumers are paying more attention to their pollution-generating activities and are more willing to protect the environment (Chen, 2010). This willingness to protect the environment translates

to a willingness to pay more for environmentally friendly products. In 1989, 67% of consumers were willing to pay 5 to 10% more for green products (Coddington, 1990). Research in subsequent years showed that environmentally conscious consumers were willing to pay 15 to 20% more for ecologically compatible products (Suchard & Polonsky, 1991). In 2009, according to CBS News, consumers intended to double their purchases of environmentally friendly products, and total purchases of environmentally friendly goods were projected to reach $500 billion by year end (CBS News, 2008). The majority of green consumers are married women with at least one child. When questioned, 13.1% of these consumers responded that they are willing to pay higher prices for environmentally friendly products (Laroache, Bergeron & Barbaro-Forleo, 2001). While most scholars indicate that environmentally conscious products create great value from the consumer's point of view (Bench-Larsen, 1996; Eagly & Kulesa, 1997; Sweson & Wells, 1997; Benito, Noya & Paniagau, 1999), a minority emphasizes the negative aspects of green products, pointing out that consumers believe gaining environmental benefit leads to a trading off of functional performance (Coddington, 1993; Schlegelmilch, Bohlen, & Diamantopoulos, 1996; Fuller, 1999). Nevertheless, the weight of evidence supports the fact that consumers do value green products and that they are willing to pay for them with increased price or some compromise of other characteristics.

Measuring Graphic Quality

The next step in the literature review is to operationalize the attributes investigated in this research. As indicated in the previously cited literature, color and image detail are the essential attributes of high quality folding carton images. In order to operationalize these attributes, it is necessary to translate them to measurable performance characteristics.

<u>Measure A1: Color Gamut</u>

Previous research demonstrates the fact that shelf appeal and sales have a strong inter-relationship (Pope, Hsu, & Sigg, 2008). In particular, for fast-moving consumer goods, most consumers make their decisions at the point of purchase. The uniqueness and colorfulness of the package plays a significant role in the consumer's purchasing decision. Therefore, to gain share in the high-end retail market, companies need to improve the quality of their printed products, including the graphics, design features, and color of their packaging (Pope, Hsu, & Sigg, 2008). Gamut size is the main factor related to the colorfulness of a printed package. As gamut size increases, the range of colors available to print an image increases. Thus, a large gamut size is required to reproduce the highly saturated Pantone™ and brand colors used in folding carton packaging.

A number of standard software tools can be used to measure gamut size. For this research, ICC Profile Inspector was used to calculate the volumes of the color spaces used in this study.

Measure A2: Image Resolution (lpi)

Baldassini (2010) stated that resolution refers to the measurement of the ability a device to render fine detail. Image resolution has a direct impact on the quality of image printing on packaging. Low resolution will generate blurry or fuzzy images, leading to unprofessional results and lowered effectiveness (Sczerba, 2010).

Technically, resolution refers to the contrast function between black and white, measured as cycles per millimeters. There are two main factors which impact resolution: the technology used to produce the print and the human visual system (Sigg, 2006). When the frequency of line contrast is increased, the modulation between black and white becomes less, and the human eye perceives lower contrast. As a result, instead of seeing separate lines, the human eye sees a uniform tone when line frequency is 6 lines per millimeter or greater and the image is viewed at a reading distance of 30 centimeters (Sigg, 2006). Therefore, the minimum resolution for a fine halftone screen is 6 lines per

millimeter, or approximately 150 lpi. At resolution less that 150lpi, the human eye detects the halftone screen (Sigg, 2006), and image quality is compromised.

Resolution is limited by substrate and printing technology, so different standards are applied in different applications. Table 4 illustrates halftone frequencies use to print products for general purpose publishing applications.

Table 4. Halftone Frequencies for Printed Products

Halftone Frequency	Application
65 lpi	Low-quality newspapers or newspapers using older printing technology
85 lpi	Medium-quality newspaper and newsletters
100-120 lpi	High-quality newspapers and newsletters
133 lpi	Magazines, books, and better quality newsletters printed on 4-color offset presses
150 lpi	Standard quality brochures and "high-gloss" newsletters printed on 4-color offset presses
175 lpi	Very high-quality 4-color offset printing

Comparing Offset Lithography and Flexography

Gamut Size. Since the gamut sizes achievable using environmentally friendly technologies are still evolving, three standard gamuts were used to simulate a range of gamut sizes that might be encountered in folding carton printing. SWOP was chosen to represent a gamut typical of offset printing on

high quality board. GRACoL was chosen to represent a larger gamut, which might be achieved with high quality flexography, and SNAP was chosen to represent a smaller gamut corresponding to the use of environmentally friendly inks. While none of these gamuts precisely matches an actual folding carton gamut, the purpose of this research is to investigate the willingness of print buyers to trade off image quality for environmental benefit. The use of standard gamuts supports this objective by making it easier for other researchers to compare the gamuts achieved using environmentally friendly technologies to the ones investigated in this study. The gamut sizes (in cubic L*a*b* units) of the gamuts used in this research were calculated using ICC Profile Investigator. They are: GRACoL = 405K units, SWOP = 357K units, and SNAP = 73K units.

Resolution. The Flexographic Image Reproduction Specifications & Tolerances (FIRST) specification and General Requirements for Applications in Commercial Offset Lithography (GRACoL) were used as references to compare flexographic and lithographic image resolutions. Table 5 shows a comparison of folding carton production between offset lithography standards and flexography standards under best and worst conditions. Based on this table, two resolutions, 100 LPI and 150LPI, were chosen to represent a range of resolutions that might be encountered in folding carton packaging.

Table 5. Comparison of Folding Carton Production Standards

Guidebook	Condition	Substrate	LPI
GRACoL	Best	Grade 1 and 2 Premium gloss/ dull coated	175
GRACoL	Worst	Grade 5 coated	133
FIRST	Best	Solid Bleached Sulfate (SBS) board	120-175
FIRST	Worst	Coated Recycled Board (CRB) board	110-133

Measuring Environmental Impact

Global warming is considered to be a potentially serious environmental problem. Greenhouse gases (GHG) can be measured by converting them to equivalent amounts of carbon dioxide (CO_2) in terms of their contribution to global warming (Sustain graph, n.d.). Greenhouse gases are produced by a wide range of industrial activities, including manufacturing, transportation, and sewage treatment (PrintCity, 2010). In the 21st century, efforts to decrease GHG emissions and to create a sustainable society have become priorities for many individuals, industries, and governments. Therefore, carbon footprint assessment is considered to be a key measure of the impact that a product or a service has on the environment (Print City, 2010).

Nonetheless, utilizing only the carbon footprint is inadequate when assessing whether the benefits of a product balance its environment impact. Based on a recently published assessment of printing lifecycle impact, volatile organic compound (VOC) emissions are the second biggest print-related

contributor to environmental damage (Pihkola, et al., 2010). VOC emissions are, therefore, chosen as a second measure of environmental impact.

Measure B1. Carbon Footprint

Carbon footprint is a measure of all GHGs generated by the activities required to produce a product. It is expressed as equivalent tons (or kgs) of carbon dioxide (Sustain Graph, n.d.). Two methods have been developed to calculate the carbon footprint of a product (Li, 2009):

1. Environmental Product Declaration, including the environmental impact of raw material acquisition, energy use/efficiency, content of chemical substances, air emission, and waste generation (Manzini, et al., 2004).
2. PAS 2050, developed by the British Standards Institute, which provides a consistent method to determine life cycle GHG emissions associated with a product (Pacific Northwest Pollution Prevention Resource Center, n.d.).

Measure B2. Volatile Organic Compound (VOC) Emissions

VOC emissions create offensive odors and can result in health issues among employees and people living in proximity to the emission sources (EPA Victoria, 2004). The three main VOC sources in printing processes are (Eastern Research Group, 2002) :

1. Pre-press, including the plate preparation process. The chemical substances used in this process include developers, fixers,

photographic processing solutions, and cleaning solutions, which can all contribute to VOC emissions. Nevertheless, the VOC emissions generated in the pre-press process are insignificant when compared to the VOC emissions inherent in the press operations.

2. On-press, including make ready, printing, and cleaning processes. During printing, VOCs can be generated as ink is transferred to the substrate and dried. If VOC generating solvents are used in the printing process, a significant percentage of the VOCs generated during printing can be captured and recovered or incinerated. In addition, VOCs can be generated by the cleaners and solvents used to clean the press. Because cleaning requires free access to press components, capturing VOCs during cleaning is more difficult than capturing VOCs during press operation.
3. Post-press finishing processes, including cutting, folding, collating, binding, and perforation. Binding (equivalent to the box forming step in folding carton finishing) is considered to be the process with the highest potential to generate VOC emissions due to the use of adhesives in this step. Other post-press processes with the potential to generate VOCs are coating and laminating.

Comparing Offset Lithography with Flexography

Carbon footprint. Although no single study has compared the carbon footprint associated with offset printing to the footprint associated with flexographic printing, such a comparison can be made by combining the result of two studies. Pihkola, Nors, and Kujanpaa (2010) calculated the carbon footprint of paper-based print products produced using offset printing and gravure printing. This study concludes that the carbon footprint of offset printing is 25.6 g/ m^2, whereas the carbon footprint of gravure printing is 30 g/m^2. Another study compared the carbon footprint of flexographic printing and gravure printing on clear plastic (Vieth & Barr, 2008). Because printing on clear plastic requires two layers of white ink, in addition to lesser amount of process and spot color inks, the carbon footprint associated with printing on clear plastic is several times higher than the carbon footprint associated with printing on paper. This study concludes that that flexo printing generates a carbon footprint of 40 g/ m^2, whereas gravure printing produces 115 g/m^2. Normalizing for the difference in substrates, the carbon footprint of flexo on paper is approximately 10 g/m^2.

VOC emissions. In 1990, the EPA in collaboration with all 50 US states developed a program (Title V) to control air pollution and VOC emissions in the printing industry. The thresholds established by Title V require all printing processes to be limited to 50 tons of VOC generation per year. The limit of material usage in oil-based printing (offset) is 7,125 gallons (approximately 59,493 lbs.) of solvent, whereas the limit on solvent usage in water-based

printing (flexography) is 200,000 lbs (EPA, 2010). In other words, VOC emissions in oil-based lithography are much higher than VOC emissions in water-based flexography, and this is reflected in a more restrictive limit on the use of oil-based litho solvents.

How Printing Environmental Footprints Are Being Improved

Printing ink manufacturers are responding to the demand for more environmentally friendly products by developing environmentally friendly inks for a variety of printing processes.

Environmentally Friendly Inks. Environmentally friendly inks from alternative resources are gaining acceptance in offset lithography. These inks include soy-based, vegetable oil-based, and bioethanol-based inks. (Print City, 2008). In addition, water-based inks have been used in flexography since the late 1980's. The two types of inks of particular interest in the folding carton market segment are:

1. Vegetable oil-based inks. Today offset inks are typically mineral oil-based. The preferred environmentally friendly alternative ink for offset lithography is currently soy-based due to its accessibility and affordable price. However, the use of soy or other vegetable oils in lithographic inks is still a challenging issue. Vegetable oil-based inks are less printable and produce less saturated colors. Faced with these problems, printers use a combination mineral oil and vegetable oil to

maintain printability. Currently, a mixture of 58-68% soy-based ink with 32-42% mineral oil–based ink is the best that can be achieved (Erhan & Bagby, 1994).

2. Water-based inks. Solvent-based flexographic inks are 70% solvent. When water-based inks replace conventional solvent-based inks, the percentages of solvent used in the printing process drops to 3-5% (European Commission, 2009), greatly reducing the amount of VOC emissions generated in the printing process.

Presenting Environmental Impact

Equivalency calculators provide an effective technique for communicating carbon footprint and VOCs use in everyday terms. For example: 1000 tons of CO_2 emissions can be equated to the emissions from the electricity used to power 136 homes for a year, or the annual greenhouse gas emissions from 189 passengers vehicles (EPA, 2011).

<u>Calculating CO_2 Equivalents for Folding Carton Printing</u>

The consumption of folding cartons by fast moving consumer product companies in the US was 8 million tons in 2010 (Graphic Packaging International, 2012). Since the carbon footprint of alternative printing technologies (in CO_2/m^2) has been documented in an earlier section, the remaining tasks are:

1. to convert 8 million tons to square meters,
2. to calculate the tons of CO_2 produced in printing this amount of folding carton stock,
3. to estimate the tons of CO_2 attributable to a typical large consumer goods company, and finally
4. to translate such a company's carbon footprint into everyday terms using an equivalency calculator.

To calculate the number of square meters per ton (S) for a given carton stock weight (grammage), this research used the following formula (ArjoWiggins. n.d.) :

The standard grammage range of folding carton stock is between 230 and 350 g/m^2 (Paper Info, 2012). The researcher selected 300 grams/m^2 as a representative grammage for calculating environmental impact. Applying the ArjoWiggins formula yields:

$$S\ m^2/ton = \frac{1{,}000{,}000\ g/ton}{grammage\ g/m^2} \tag{1}$$

Therefore, in 2010, folding carton consumption in the US was approximately:

$$S = \frac{1{,}000{,}000\ \ g/ton}{300\ \ g/m^2} = 3{,}333\ m^2/ton \tag{2}$$

The next step was to develop a measure of environmental impact that would be more meaningful for study participants -- the impact of printing a single, large consumer product company's folding carton volume. Proctor and Gamble (P&G),

the largest US consumer product company, provided the starting point for this estimate. P&G disclosed that one product line (Tide detergent) consumes approximately 33,000 tons of carton board per year. P&G has approximately 50 product lines, of which 19 were judged to be primary users of carton board boxes (P&G, 2011). Since Tide is one of Proctor and Gamble's largest product lines, it was assumed that an average product line would use half as much folding carton packaging as Tide. Based on these assumptions, P&G's annual folding carton consumption was estimated to be:

$$33{,}000\ tons\ x\ \frac{19}{2} = 313{,}500\ tons$$

Based on this estimate, P&G's use of folding carton constitutes ~4% of the US market:

$$\frac{Total\ folding\ carton\ consumption\ of\ P\&G}{US\ folding\ carton\ consumption} = \frac{313{,}500\ tons}{8{,}000{,}000\ tons} \approx 4\% \qquad (3)$$

These estimates are consistent with P&G's sustainability report which shows that the total shipments of P&G products were approximately 23,300,000 tons in 2011 (P&G, 2011). This corresponds to approximately 2,000,000-3,000,000 tons of total packaging consumption (assuming that packaging constitutes 10-15% of total product weight).

P&G is by far the largest producer of consumer products in the US. When the researcher estimated the folding carton consumption of the next tier of consumer

product companies, the annual folding carton consumption per companies ranged between 30% and 60% of P&G's folding carton usage. Based on this range, the folding carton share of a typical large consumer product company was modeled as 1.8% of total US folding carton consumption (i.e., 45% of P&G's 4% share). Using this estimate, a typical large consumer product company would consume 8,000,000 x 1.8% = 144,000 tons of folding cartons each year.

The next step converted 144,000 tons to square meters in this way: 144,000 x 3,333 = 480 million m^2 of folding cartons. The carbon footprint associated with producing this volume of folding cartons using the technologies studied in this research is summarized in Table 6 below.

Table 6. Carbon Footprints Using Alternative Printing Processes.

Printing Process	CO_2 Generation (g/m^2)	CO_2 Generation (tons)
Mineral oil-based offset	25.6	480M m^2 x 25.6 g /m^2 = 12,288 MT
Vegetable oil-based offset	16	480M m^2 x 16 g /m^2 = 7,680 MT
Water-based flexo	10	480M m^2 x 10 g /m^2 = 4,800 MT

Finally, the tonnages shown in Table 6 were translated into everyday equivalents using the EPA Greenhouse Gas Equivalencies Calculator (EPA, 2012). The equivalence chosen was the electricity required to power one home for one year (6.68 metric tons CO_2 per home/yr). As shown in Table 6, the tons of CO_2 were

divided by the tons of CO_2 per home, then rounded to calculate the equivalent environmental impacts, as shown in Table 7.

Table 7. Carbon Footprint Equivalents

Printing Process	CO_2 Generation (tons)	CO_2 Generation (homes)
Mineral oil-based offset	12,288	1850
Vegetable oil-based offset	7,680	1150
Water-based flexo	4,800	750

<u>Calculating VOC Equivalents</u>

EPA Victoria (2004) characterizes VOC/Dry Ink ratios as follows:

- Water-Based Flexography

  1 kg of VOC used per 1 kg of Solid (Dry) Ink deposited 1:1 Very Good

- Vegetable Oil-Based Offset Lithography

  1.5 kg of VOC used per 1 kg of Solid (Dry) Ink deposited 1.5:1 Good

- Mineral Oil-Based Offset Lithography

  3 kg of VOC used per 1 kg of Solid (Dry) Ink deposited 3:1 Average

In order to apply these ratios, it is first necessary to calculate the dry ink volume covering 1 m^2 of substrate. Assuming a 1 micron thick ink film (typical of litho and flexo printing):

$$\text{Ink film volume/m}^2 = (10^{-6}\text{ m x 1m x 1m})\text{ /m}^2 = 10^{-6}\text{ m}^3\text{/m}^2 = 1\text{ cm}^3\text{/m}^2$$

The next step is to calculate the VOC emissions associated with printing one year's worth of carton packaging for the U.S. market (8,000,000 tons of folding cartons), assuming a dry ink density of 1.22g/cm^3:

VOC emissions [g] = Area [m^2] x ink weight/area [g/m^2] x VOC/dry ink ratio where ink weight per area [g/m^2] = ink volume per area [cm^3/m^2] x density [g/cm^3].

For water-based flexo ink:

$$\mathrm{W} = 8{,}000{,}000\ \mathrm{tons} \times 3{,}333\ (\mathrm{m}^2\ /\mathrm{tons}) \times 1\ \ (\mathrm{cm}^2\ /\mathrm{m}^2\ ) \times 1.22\ (\mathrm{g/cm}^2\ ) \times \quad (4)$$

$$1\mathrm{gVOC/gDryink}\ = 3.25 \times 10^{10}\mathrm{g\ VOC} = 3.25\ \mathrm{x}\ 10^{7}\ \mathrm{kg\ VOC}$$

For vegetable oil-based ink:

$$W\ = 8{,}000{,}000\ tons \times 3{,}333\ (m^2\ /tons) \times 1\ \ (cm^2\ /m^2\ ) \times 1.22\ (g/cm^2\ ) \times \quad (5)$$

$$1.5 gVOC/gDryink\ = 4.88 \times 10^{10} g\ VOC = 4.88\ x\ 10^{7}\ kg\ VOC$$

Offset mineral oil-based ink:

$$W\ = 8{,}000{,}000\ tons \times 3{,}333\ (m^2\ /tons) \times 1\ \ (cm^2\ /m^2\ ) \times 1.22\ (g/cm^2\ ) \times \quad (6)$$

$$3 gVOC/gDryink\ = 9.75 \times 10^{10} g\ VOC = 9.75\ x\ 10^{7}\ kg\ VOC$$

The EPA (2000) indicates an average VOC emission of car per year = 35 kg. Other EPA estimates are smaller, typically in the range of 12-15 kg per year. For

purposes of this research, a conversion factor of 35 kg of VOCs per car was used, since this results in the lowest estimate of the number of cars needed to equal the calculated folding carton emissions. Using this equivalence:

VOC emissions using flexographic water-based ink =

$$3.25 \times 10^7 \text{ kg VOC} / 35 \text{ kg/car} = 928{,}000 \text{ cars} \quad (7)$$

VOC emissions using offset vegetable oil-based ink =

$$4.88 \times 10^7 \text{ kg VOC} / 35 \text{ kg/car} = 1{,}394{,}000 \text{ cars} \quad (8)$$

VOC emissions using offset mineral oil-based ink =

$$9.75 \times 10^7 \text{ kg VOC} / 35 \text{ kg/car} = 2{,}785{,}000 \text{ cars} \quad (9)$$

Since the folding carton demand for a typical large consumer product company is approximately 1.8% of the total US folding carton demand, the numbers shown above can be scaled to represent the environmental impact of a single large consumer product company, as shown in Table 8.

Table 8. VOC Impact of Folding Carton Printing for a Large Company

Printing Process	Total VOCs (Equivalent Car Emissions)	Large Consumer Prod Company (Equivalent Car Emissions)
Mineral oil-based offset	2,785,000	2,785,000 X 0.018 ≈ 50,000 cars
Vegetable oil-based offset	1,394,000	1,394,000 X 0.018 ≈ 25,000 cars
Water-based flexo	928,000	928,000 X 0.018 ≈ 16,667 cars

Summary

Achieving the highest level of printing quality with the lowest environmental cost is challenging for today's printing technology. Frequently, print buyers are forced to make a trade-off between image quality and environmental friendliness. This research will investigate the print buyers' trade-off behavior in the folding carton market. In addition, it is likely that the results from this analysis could help to clarify the balance point between environmental friendliness and print quality for consumer product companies.

Chapter 4

Research Objectives

Research Objectives

Based on the foregoing discussion, the researcher's efforts were directed to answering these research questions:

1. Determine the relative value of carbon footprint, VOC emissions, gamut size, and image resolution to print buyers in the folding carton packaging market.
2. Determine whether all print buyers have the similar trade-off behaviors, or if they cluster into groups based on their trade-off behaviors.

Limitations

This research only investigated the attributes of carbon footprint, VOC emissions, gamut size, and image resolution. Conjoint analysis provided relative values for each of these attributes, but studies involving other sets of attributes cannot be easily compared with the results obtained in this study.

The packaging market investigated in this research is limited to folding carton packaging. The market is further limited to North America.

Samples were produced on a Kodak Approval digital proofer and, therefore, represent simulation of actual printed folding cartons.

Chapter 5

Methodology

Overview

Traditional conjoint analysis was used to investigate the willingness of print buyers to trade off image quality for environmental benefit. The levels of image quality and environmental benefit investigated are based on three printing processes used in the folding carton market: water-based flexography, traditional mineral oil-based offset lithography, and the emerging alternative of vegetable oil-based offset lithography.

A flowchart summarizing the methodology employed for this research is shown in Figure 1. As this flowchart illustrates, the methodology was implemented in these five steps:

1. Prepare offering cards
2. Select participants (print buyers)
3. Conduct pilot test
4. Conduct full-scale experiment
5. Analyze results and answer research questions

The methodology discussion follows this flowchart, with each stage being covered in a separate section.

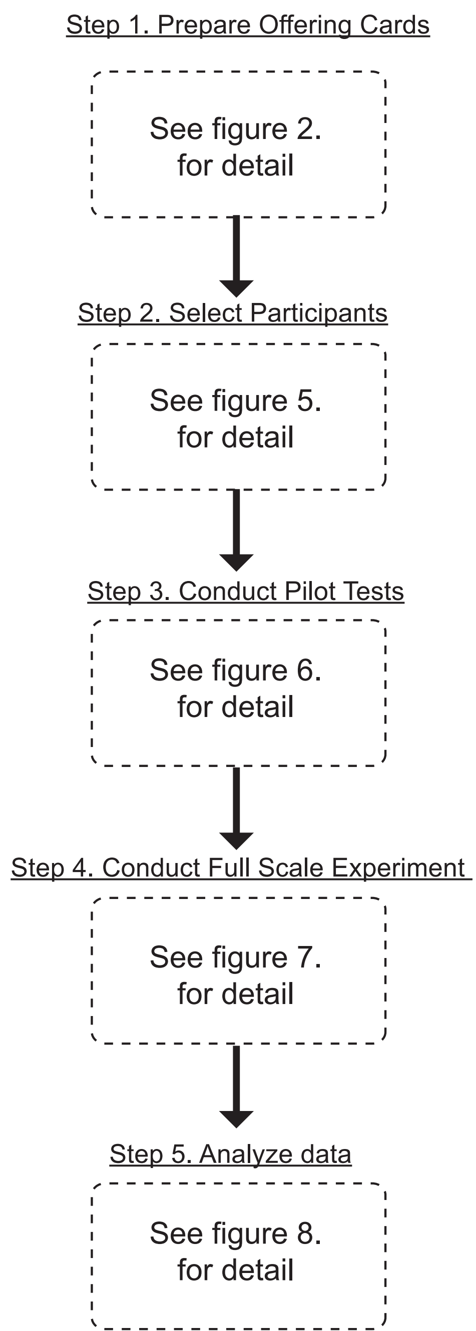


Figure 1. Methodology Flowchart

Step 1. Prepare Offering Cards

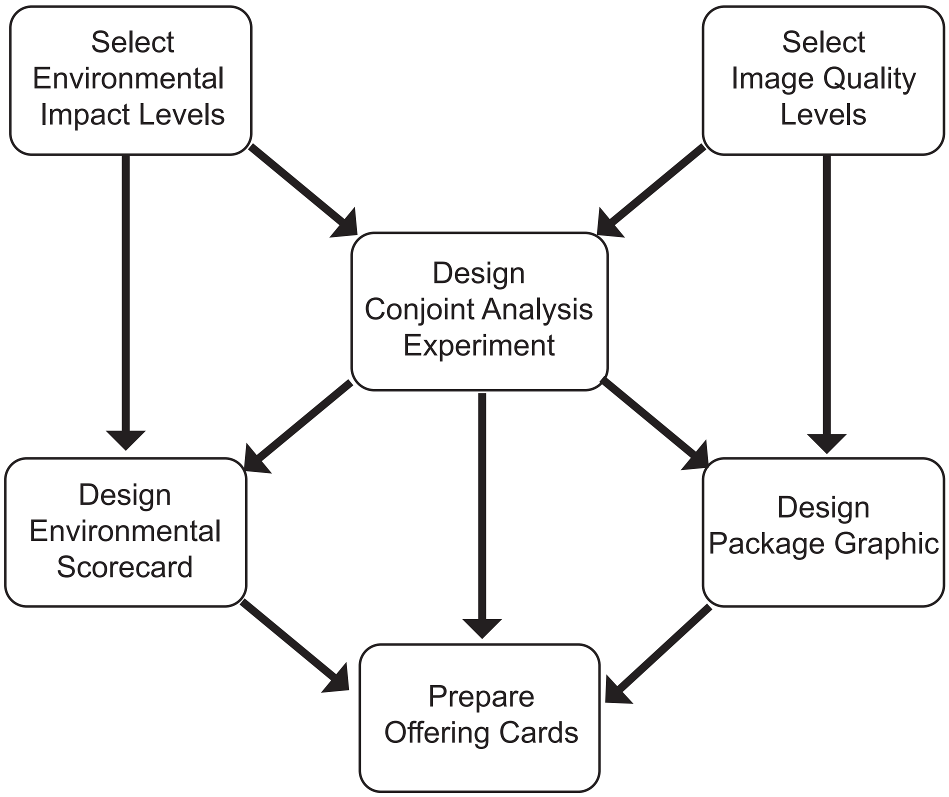


Figure 2. Prepare Offering Cards

The steps of the offering card preparation are:

Step 1.1. Select Environmental Impact Levels.

Based on the findings of the literature review, these two attributes of environmental benefits were selected for this conjoint experiment: (1) VOC emissions, which capture the short-term environmental impact of

printing and (2) carbon footprint, which captures its long-term environmental impact.

VOCs are organic contaminates which contribute to air pollution and respiratory problems for human beings. As discussed, the printing process is a primary source of VOCs. During printing, VOCs are generated when drying printed materials and cleaning the press.

As shown in Table 8, three levels of VOC emissions were chosen based on the technologies available to print folding cartons. These levels are represented as the equivalent VOC emissions of cars per year for a large consumer product company:

1. Mineral oil based offset is equivalent to 50,228 cars per year, or approximately 50,000 cars.
2. Vegetable oil based offset is equivalent to 25,085 cars per year, or approximately 25,000 cars.
3. Water based flexo is equivalent to 16,742 cars per year, or approximately 16,667 cars.

A press carbon footprint is the amount of carbon dioxide and greenhouse gases generated in printing. Carbon dioxide and greenhouse gases contribute to global warming. The printing process is major source of carbon dioxide through energy consumption and incineration of VOCs. As shown in Table 7, there are these 3 levels of carbon footprint:

1. Mineral oil-based offset, which is equivalent to electricity used by approximately 1,850 homes
2. Vegetable oil-based offset, which is equivalent to electricity used by approximately 1,150 homes
3. Water-based flexo, which is equivalent to electricity used by approximately 750 homes

Step 1.2. Select image quality levels.

The literature review shows that the brightness and colorfulness of packaging is directly related to the perceived value of a product. Thus, gamut size, the attribute most closely related to the brightness and colorfulness of images on packaging, is selected as the first measure of image quality. In this experiment, GRACoL, SWOP, and SNAP are selected to represent different gamut sizes. Another attribute is image resolution; high image quality required high image resolution. Since consumers perceive packaging as a part of the product, the quality of image on packaging also affects the perception of product quality. In this experiment 150 lpi is selected as a high quality image resolution, whereas 100 lpi is selected as a low one.

Step 1.3. Design conjoint analysis experiment.

The experiment was designed as a conjoint analysis with four attributes. In this experiment, the researcher assigned three levels for VOC emissions, three levels for carbon footprint, three levels for gamut size, and two levels for resolution. The resulting design is shown in Table 9.

Table 9. Conjoint Analysis Design

Level	Resolution (lpi)	Gamut Size	CO_2	VOCs
0	100	SNAP	750	16,667
1	150	SWOP	1,150	25,000
2	-	GRACoL	1,850	50,000

The total number of offerings is 3 x 3 x 3 x 2 = 54 offerings. However, research shows that the maximum number of offering cards that a respondent can be expected to evaluate is 20 (Orme, 2006). Therefore, the universe of 54 offerings was reduced to 18 offerings by using a fractional factorial experimental design[1]. The fractional factorial design was developed in two steps. First, the three variables with three levels were treated as a 3^3 experiment and a 1/3 fractional design was chosen for this experiment. Table 10 shows how the 27 possible combinations of

[1] According to Montgomery, (2005): "A factorial experiment…is an experimental strategy

3 levels (Gamut size) x 3 levels (CO_2) x 3 levels (VOCs) can be divided to create 1/3 fractional design

Table 10. Fractional Factorial Experiment Design

$\mu = 0$		$\mu = 1$		$\mu = 2$	
000	SNAP, 750, 16,667	100	SWOP, 750, 16,667	200	GRACoL, 750, 16,667
012	SNAP, 1,150, 25,000	112	SWOP, 1,150, 50,000	212	GRACoL, 1,150, 50,000
101	SWOP, 750, 25,000	201	GRACoL, 750,25,000	001	SNAP, 750, 25,000
202	GRACoL, 750, 50,000	002	SNAP, 750, 50,000	102	SWOP, 750, 50,000
021	SNAP, 1,850, 25,000	121	SWOP, 1,850, 25,000	221	GRACoL, 1,850, 25,000
110	SWOP, 1,150, 16,667	210	GRACoL, 1,150, 16,667	010	SNAP, 1,150, 16,667
122	SWOP, 1,850, 50,000	222	GRACoL, 1,850, 50,000	022	SNAP, 1,850, 50,000
211	GRACoL, 1,150,25,000	011	SNAP, 1,150, 25,000	111	SWOP, 1,150, 25,000
220	GRACoL, 1,850, 16,667	020	SNAP, 1,850, 16,667	120	SWOP, 1,850, 16,667

In this experiment, the researcher selected column 1 ($\mu = 0$), because it contains offering 122, which is good representation of the current printing situation. SWOP is typical of a high quality of folding carton gamut, while conventional mineral oil-based offset generates the highest environmental impact. This design was then repeated at two levels of image resolution to produce a final design containing 18 offering cards. Table 11 summarizes the final design.

Table 11. Basic Fractional Factorial Design

Offering Card No.	Gamut Size	Resolution (lpi)	CO_2 Equivalent (homes)	VOC Equivalent (Cars)
1	SNAP	100	750	16,667
2	SNAP	100	1,150	25,000
3	SWOP	100	750	25,000
4	GRACoL	100	750	50,000
5	SNAP	100	1,850	25,000
6	SWOP	100	1,150	16,667
7	SWOP	100	1,850	50,000
8	GRACoL	100	1,150	25,000
9	GRACoL	100	1,850	16,667
10	SNAP	150	750	16,667
11	SNAP	150	1,150	25,000
12	SWOP	150	750	25,000
13	GRACoL	150	750	50,000
14	SNAP	150	1,850	25,000
15	SWOP	150	1,150	16,667
16	SWOP	150	1,850	50,000
17	GRACoL	150	1,150	25,000
18	GRACoL	150	1,850	16,667

Finally, the design was randomized using the RANDBETWEEN function in Excel. The randomized sequence is shown in Table 12, and the final experimental design is summarized in Table 13.

Table 12. Randomized Offering Cards

Offering Card Number	Randomized Sequence
1	4
2	14
3	15
4	6
5	8
6	9
7	5
8	11
9	7
10	18
11	1
12	17
13	2
14	3
15	16
16	10
17	13
18	12

Table 13. Final Design by Offering Card

Offering Card Number	Gamut Size	Resolution (lpi)	CO_2 Equivalent (homes)	VOC Equivalent (Cars)
1	GRACoL	100	750	50,000
2	SNAP	150	1,850	25,000
3	SWOP	150	1,150	16,667
4	SWOP	100	1,150	16,667
5	GRACoL	100	1,150	25,000
6	GRACoL	100	1,850	16,667
7	SNAP	100	1,850	25,000
8	SNAP	150	1,150	25,000
9	SWOP	100	1,850	50,000
10	GRACoL	150	1,850	16,667
11	SNAP	100	750	16,667
12	GRACoL	150	1,150	25,000
13	SNAP	100	1,150	25,000
14	SWOP	100	750	25,000
15	SWOP	150	1,850	50,000
16	SNAP	150	750	16,667
17	GRACoL	150	750	50,000
18	SWOP	150	750	25,000

Step 1.4. Design Environmental Impact Score Card.

In order to present a clear environmental impact picture, CO_2 and VOC equivalents were converted to percentage reductions in impact compared to conventional printing technology. Table 14 documents the calculations of percentage reduction.

Table 14. Percentage Reduction of Environmental Impact

Printing Technology	Percentage of CO_2 Reduction Calculation	Percentage of VOC emission Reduction Calculation
Conventional Oil-Based Offset	$\frac{1{,}850-1{,}850}{1{,}850}\times 100 = 0\%$	$\frac{50{,}228-50{,}228}{50{,}228}\times 100 = 50\%$
Vegetable Oil-Based offset	$\frac{1{,}850-1{,}167}{1{,}850}\times 100 = 37\%$	$\frac{50{,}228-25{,}085}{1{,}850}\times 100 = 50\%$
Water-based Flexo	$\frac{1{,}850-730}{1{,}850}\times 100 = 60\%$	

These percentages are displayed graphically on the offering cards as shown in Figure 3.

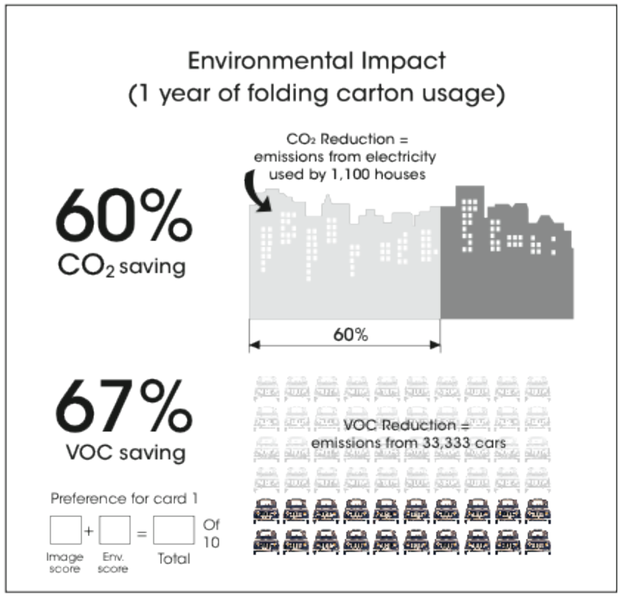


Figure 3. Sample of Environmental Score Card

Step 1.5 Design Packaging Graphic

The design objectives for the packaging graphic presented on the offering cards are that:

- The image should be sensitive to differences in gamut size and resolution.
- The image should represent a modern design typical of the folding cartons found in the US market.

The RIT17 test target was used to assess the effect of differences in resolution and gamut sizes. Orange was determined to be the color which is the most sensitive to changes in gamut size. Additionally, highly detailed images (such as brush, grass, and tree shadows) were shown to be

sensitive to resolution differences. Appendix A shows the RIT17 test target, which was used to demonstrate these differences.

Figure 4 shows the packaging design that the researcher created to satisfy these design objectives:

- Oranges were selected as design elements that would be sensitive to differences in gamut size.
- White flowers were selected to represent differences in gamut white points. Additionally, flower details were selected for their sensitivity to differences in resolution.
- Orange leaves were selected as design elements because their highlight details are sensitive to different gamut sizes.
- Gradient color was used. Larger gamut sizes result in smoother color gradients than do smaller ones. A gold gradient was included in the design to show this difference.
- Fine detail was rendered. The field of flowers is sensitive to differences in resolution.
- A modern appearance typical of folding cartons in the U.S. market was presented. This objective was accomplished by inviting professional print buyers from consumer product companies to comment on the design and assist the researcher with the development of the design.

Figure 4. Final Folding Carton Design

Step 1.6. Prepare Offering Cards.

Offering cards representing the combinations of image quality and environmental impact attributes selected for the fractional factorial design were printed using the Kodak Approval digital proofer. The Approval was chosen for this experiment because of its ability to produce consistent halftone prints over the full range of image qualities being investigated in this research. Appendix B shows a sample-offering card.

Step 2. Select Participants (Print Buyers)

The process used to acquire participants for this research is depicted in Figure 5.

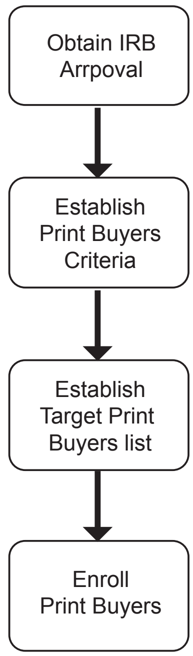


Figure 5. Select Participants

<u>Step 2.1. Obtain RIT Institutional Review Board Approval.</u>

To conduct an experiment involving the use of human subjects, the researcher was required to obtain permission from the Institutional Review Board (IRB) at RIT. Accordingly, the researcher prepared and submitted *Form A: Request for IRB Review of Research Involving Human Subjects* to the Human Subjects Research Office (HSRO). HSRO granted approval on November 2, 2012.

Step 2.2. Establish Criteria for Selecting Print Buyers.

Print buyers in this experiment were required to meet each of these criteria:

- Folding cartons must be used in their business
- Their product range must include fast-moving consumer products

Step 2.3. Establish Target Print Buyers Lists.

Print buyers in this experiment were selected by the RIT Packaging Department. The researcher presented the objectives and procedures involved in this study to the Chair of the Packaging Department who endorsed the research and took a lead role in acquiring participants for the experiment.

Step 2.4. Enroll Print Buyers

Candidate print buyers (who meet all of the selection criteria) were enrolled using the following process:

2.4.1 The Chair of the Packaging Department introduced the experiment to potential participants by sending an email to them. The email included (1) a PDF describing what the participant would gain from participating in the experiment, (2) a link to an enrollment video designed to engage the participant in the research, and (3) an IRB informed consent document. (The PDF and informed

consent document used in the experiment can be found in Appendix C.) Potential participants who were willing to participate in the experiment indicated their agreement by responding to the email.

2.4.2. After obtaining the agreements to participate, the researcher provided each participant with the materials and instructions required to participate in the experiment. (See also Step 4.1.)

Step 3. Conduct Pilot Tests

Figure 6 depicts the two-phased pilot used to validate the experimental approach prior to launching the full-scale experiment.

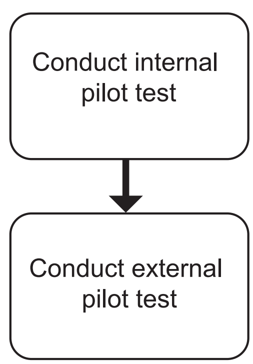


Figure 6. Conduct Pilot Test

The procedures used to pilot the experiment are described below.

Step 3.1 Conduct Internal Pilot Test

The researcher tested the experimental methodology with Professors from School of Media Sciences and Packaging Department. The participants were given an envelope containing the instructions and a set of offering cards. Next, they were asked to watch the instructional video, assign preferences to the offering cards, and record their results in an Internet-based survey and data collection tool without assistance from the researcher. The Internet-based data collection tool used in the present study was Surveymonkey. After they had completed the experiment, the researcher interviewed the participants to identify problems and opportunities to improve the experiment. One of the Professors participating in the experiment was formerly a packaging procurement executive, and his data is included in the results of the experiment. The remaining data were discarded.

Step 3.2. Conduct External Pilot Test

After developing offering cards and instructions, the researcher conducted an external pilot test with two packaging print buyers who have a personal relationship with a professor in RIT's Packaging Department. After they agreed to participate in the experiment, two packages of offering cards and printed instructions were mailed to them. Next, an email with a link to the instructional video and SurveyMonkey was sent to them.

Finally, they completed the experiment by assigning preferences to each offering card and submitting the survey results to SurveyMonkey. The results from the external pilot test participants are real data and are included in the results of the experiment.

Step 4. Conduct Full-Scale Experiment

The full-scale experiment follows the step shown in Figure 7.

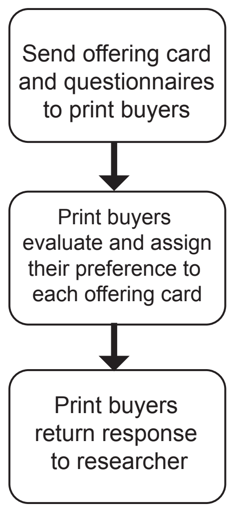


Figure 7. Conduct Full-Scale Experiment

4.1 Send Offering Cards and Questionnaires to Print Buyers

Each of the print buyers enrolled in the experiment was sent offering cards by US mail and instructions by e-mail. Appendices D and E show the instructional email and the SurveyMonkey data collection instrument, respectively.

4.2 Print Buyers Assign Preferences to Offering Cards

Participants evaluated each offering in the fractional factorial design and provided their preference scores for these offerings (ranking from 0-10, with 10 as the most preferred and 0 as the least preferred). Their responses were captured in SurveyMonkey.

Step 4.3. Print Buyers Return Responses to Researcher

Participants returned their responses to the researcher by submitting their results using SurveyMonkey.

Step 5. Analyze Data

The steps used to analyze experimental results and answer the research questions are shown in Figure 8.

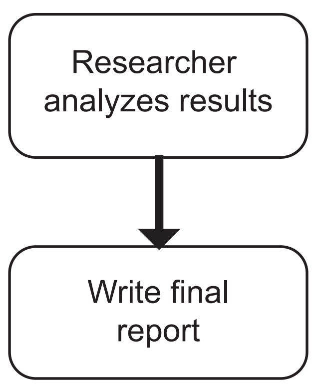


Figure 8. Analyze Data

Step 5.1. Researcher Analyzes Results.

The researcher created a spreadsheet, which used multiple linear regression to calculate part worth utilities for each level of each attribute.

- As a first step, attributes were replaced by dummy variables, which could be analyzed using multiple linear regression. A separate dummy variable was created for each level of each attribute. For each attribute, the full set of dummy variables are linearly dependent, and linearly dependent variables cannot be used in a regression analysis. This problem was resolved by eliminating one dummy variable for each attribute. Table 15 documents the resulting encoded data format, which was used to feed the multiple linear regression model.

Table 15. Excel Spreadsheet with Encoded Data

Sample	Gamut		Resolution	CO_2		VOCs		Preferences
	SNAP	GRACoL	150 lpi	1150 homes	1650 homes	25000 cars	50,000 cars	
1	1	0	1	1	0	1	0	6
2	0	1	1	0	0	0	1	6
3	1	0	1	0	1	1	0	4
4	1	0	0	0	0	0	0	8
5	0	0	0	0	1	0	1	5
6	0	1	0	0	0	0	1	6
7	0	1	0	0	1	0	0	6
8	1	0	0	0	1	1	0	5
9	0	0	0	1	0	0	0	8
10	0	0	1	0	1	0	1	3
11	0	1	0	1	0	1	0	8
12	0	1	1	0	1	0	0	6
13	0	1	1	1	0	1	0	6
14	1	0	0	1	0	1	0	6
15	0	0	0	0	0	1	0	7
16	0	0	1	1	0	0	0	7
17	0	0	1	0	0	1	0	7
18	1	0	1	0	0	0	0	7

- The Microsoft Excel LINEST function was used to find the best fit regression equation for the data in this table. The equation for this function is:

$$y= m_1x_1 +m_2x_2+\ldots.+ b$$

Where y is the dependent value, each x_n is an independent value,

m_n is the coefficient corresponding to each x_n value, and b is a constant.

Applying this tool, we could predict the preference score based on the seven dummy-coded independent variables. The equation for the model is:

$Y = b + m_1 (SNAP) + m_2(GRACoL) + \ldots + m_7(VOCs=50{,}000 \text{ cars})$

Where Y is the predicted preference for the offering card, b is the constant or intercept term, and m_1 through m_7 are part worth utilities for level of each attribute.

In this formulation of the model, coefficients for the reference levels are equal to 0. The Excel LINEST function produces a table (Table 16) displaying the individual coefficients, together with the variable required to assess the statistical significance of the resulting equation.

Table 16. Conjoint Analysis with Multiple Regressions in Excel

Coeff. 7 PW (50,000 cars)	Coeff. 6 PW (25,000 cars)	Coeff. 5 PW (1500 homes)	Coeff. 4 PW (1000 homes)	Coeff. 3 PW (150 lpi)	Coeff. 2 PW (GRACoL)	Coeff. 1 PW (SNAP)	Constant
-1.75	-0.63	-2.83	-1.04	0.22	1.17	-2.04	8.47
SE Coeff7	SE Coeff6	SE Coeff5	SE Coeff4	SE Coeff3	SE Coeff2	SE Coeff1	SE Constant
0.21	0.16	0.17	0.18	0.14	0.17	0.18	0.20

R^2	SE of Y Estimate
0.99	0.29
F Test Statistic	F Test df
94.79	10.00
Regression SS	Residual SS
7.14	0.86

- Finally the results of the multiple regressions were interpreted as the value model for a single individual. To illustrate this step, the results shown in Table 17 are interpreted below.

Table 17. Excel Coefficient Interpreted as Part Worths

Part Worth for Individual A							
Gamut size		Resolution		CO_2		VOC	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	133	0.00	650 homes	0.00	10000 cars	0.00
SNAP	-2.04	150	0.22	1,150 homes	-1.04	25000 cars	-0.63
GRACoL	1.17			1,650 homes	-2.83	50000 cars	-1.75

Based on the data presented, Individual A considers gamut size to be the most important attribute because the range of its part worth values (-2.04 to 1.17) is the largest of any attributes. Using this approach, we observed that CO_2 is the second most important attribute, followed by VOC emissions, and, finally, by resolution.

- In addition, R^2 measures the amount of variation explained by the multiple regression equation. In this case, $R^2 = 0.99$ indicates a strong relationship between the attributes (gamut size, resolution, CO_2, and VOCs) and individual A's preferences.

Additionally, at $\alpha = 0.05$ with seven degrees of freedom in the numerator and ten degrees of freedom in the denominator.

$F_{.05} = 3.14$. The F statistic = 94.79 which is greater than the critical value of F (3.14). From this, we concluded that there is a significant relationship between the predicted preference and the attributes.

- Finally, the results are summarized in an easy-to-understand graphic format shown in Appendix F.

Step 5.2. Write final report.

The results of the conjoint analysis provided the quantitative data required to answer the research questions. The researcher combined these data with data from other sources to develop implications and to draw conclusions.

Chapter 6

Results

Overview

The methodology described in Chapter 5 was implemented by the researcher over a three month period between February and April 2013. Two experiments were conducted in order to prepare for and validate the full-scale experiment. Details are described below.

Pilot Experiment

The researcher conducted a pilot experiment with two RIT professors on February 13, 2013, in the Color Management System Lab (CMS Lab) at RIT. Participants received an email to introduce the thesis experiment. A PDF file and video introducing the experiment were attached to the email as well as an informed consent document. After responding that they agreed to participate, the participants were sent an instructional email with a link to an instructional video and to a data collection form in SurveyMonkey. Participants conducted the experiment without further guidance while the researcher observed their actions during the experiment. After completing the experiment, the participants were questioned concerning their experience and provided feedback as follow:

(1) The offering card could be improved by dividing the allocation of preferences into two parts, image quality and environmental benefit. The offering card was revised as illustrated in Figure 9 below.

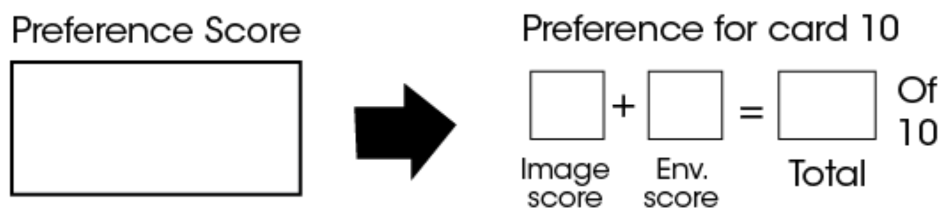


Figure 9. Develop Offering Card From Pilot Experiment

(2) SurveyMonkey should be modified to prevent participants from entering more than one preference for a single offering card. In response to this suggestion, the researcher modified SurveyMonkey to allow only one response per preference.

<u>Beta Participants</u>

After modifying the offering cards and updating SurveyMonkey, the researcher conducted a limited scale experiment with participants who were or had had experience as print buyers. Three beta participants were chosen: an RIT professor who had experience as a print buyer and two print buyers in Rochester, NY who were former colleagues of this professor. The RIT professor first completed the experiment himself, then contacted his former colleagues. Both print buyers agreed to participate in the beta experiment. Table 18 summarizes the timeline required to complete this portion of the experiment.

Table 18. Beta Experiment Events

Date	Event
Tue, Feb 19	RIT Professor calls beta participants
Wed, Feb 20	Researcher sends two sets of offering cards to beta participants
Fri, Feb 22	Researcher sends instructional email to beta participants
Wed, Feb 27	Researcher sends reminder email to beta participants
Mon, Mar 4	Beta participants complete the experiment
Tues, Mar 5	Researcher analyzes results

Full-Scale Experiment

Three groups of print buyers were selected to participate in the full-scale experiment. Eighteen RIT alumni were contacted through the Packaging Department and asked to enroll print buyers from their companies in the experiment. Three responses were received. Seven print buyers were contacted by RIT's Center for Integrated Manufacturing. Five responses were received. Finally, Finally, Six Asian companies were contacted by the researchers' sponsoring company in Thailand. These included four Asian affiliates of multinational consumer goods companies. Six responses were received.

Results

Responses from beta and full-scale participants were combined and analyzed following the process outlined in Step 5.1 of the methodology. The results of this analysis are summarized below by research objective.

Research Objective 1

The first research objective, “Determine the relative value of carbon footprint, VOC emissions, gamut size, and image resolution to print buyers in the folding carton packaging market” was fulfilled by gathering the data shown in Table 19 below.

Table 19. Summarized Individual Results

Participant No.	Percentage of offering value attributable to:				R^2	*F* Test Statistic
	CO_2 Impact	VOC Impact	Gamut Size	Image Resolution		
1	21.3	5.8	60	12.9	92%	16.66
2	15	18	62	5	95%	26.91
3	45	24	21	10	79%	5.47
4	30.6	34.5	33.2	1.7	73%	3.93
5	23.7	9.1	29.8	37.3	73%	3.88
6	20.1	24.6	39.5	15.9	76%	4.65
7	27.4	29.7	34.7	8.1	83%	6.79
8	10.8	16.3	63.3	9.6	79%	5.26
9	25.7	37.9	35.1	1.2	95%	25.7
10	31.3	35.8	27.6	5.2	90%	12.6
11	34.3	27.9	34	3.8	97%	43.5
12	16.4	29.9	49	4.7	87%	9.32
13	10.1	12.4	77.5	0	92%	16.04
14	20.2	30.3	41.4	8.1	85%	7.97
15	38.4	28.8	32.8	0	89%	11.79
16	11	24.8	44	20.2	81%	6.26
17	26.7	33.4	34	5.9	88%	10.78
Average	24%	25%	42%	9%		

The total population of responses was first analyzed for statistical significance using an *F* Test. The critical value of *F* at the 95% confident level is 3.14. The *F* statistic obtained for all participants in the experiment was higher than 3.14. This means that the relationship between the predicted preferences and the attributes used to predict them is meaningful and can be used to represent the actual tradeoff behavior of the participants. Next, the coefficient of determination (R^2)

was calculated for each participant. The range of R^2s obtained, 73%-97% shows that the multiple regression model explains a significant portion of the trade-off behavior. Appendices F through P show the graphical results of the experiment for each participant.

To answer the research question, the average tradeoff behavior for all participants was first examined. Based on this metric, gamut size was the most important single factor, with an average contribution equal to 42% of the total preference score. Among individual participants, the contribution of gamut size to the participant's preference for an offering ranged from 21% to 77.5%. Carbon footprint and VOC emissions tied for the second most important, contributing 24% and 25% of total value respectively. The range of carbon footprint contribution varied from 10% to 45%. Compared to the range of contribution for gamut size, the range of contribution for carbon footprint overlaps but is generally lower than the range for gamut size. The range of contribution for VOC emissions, 9% to 34%, is similar to but slightly below the range observed for carbon footprint. Finally, print buyers could not consistently observe the effect of reducing image resolution from 150 lpi to 100 lpi, and placed the least value (9% of total preference on average) on this attribute.

Research Objective 2

The second research objective was to "Determine if all print buyers have the similar trade-off behaviors or if they cluster into groups based on their trade-

off behaviors." To pursue this objective, a new metric, Image Quality minus Environmental Impact (IQ-EI), was created to group print buyers based on their observed trade-off behaviors. This metric subtracts the combined carbon footprint and VOC emission percentages (a measure of the value that the participant places on environmental impact) from the combined gamut size and image resolution percentages (a measure of the value that the participant places on image quality). As an example, if 50% of the participant's total preference was based on Image Quality and 50% was based on Environmental Impact, the participant's IQ-EI score would be zero (50 - 50). Using this metric, participants were grouped as follows:

1. Environmentally Concerned: IQ-EI from -100 to -33
2. Balanced: IQ-EI from -33 to 33
3. Image Quality Conscious: IQ-EI from 33 to 100

Figure 10 summarizes the distribution of participants obtained from the experiment.

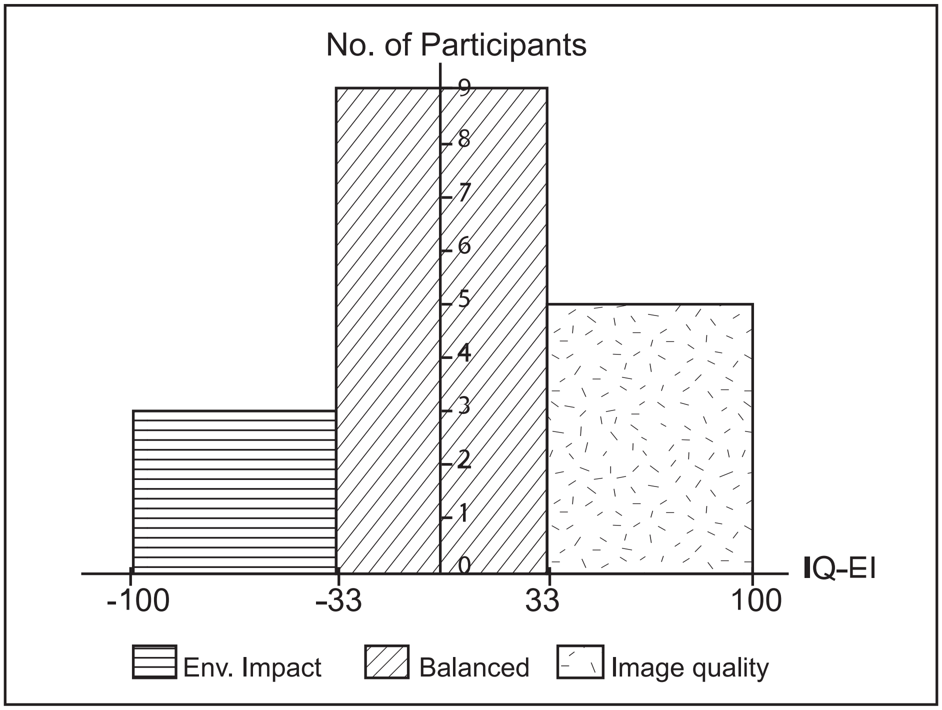


Figure 10. Print Buyer Group by Trade-Off Behavior

As Figure 10 shows, the participants did cluster into groups based on their trade-off behaviors. No single trafe-off behavior dominated the results obtained. Nine of the seventeen participants displayed balanced trade-off behavior, while the remaining eight participants favored either image quality (five participants) or environmental benefit (three participants).

Chapter 7

Summary and Conclusions

Summary

A conjoint analysis experiment was conducted to investigate print buyer willingness to trade-off image quality for environmental benefits. The results of this experiment were used to fulfill the research objectives of this study:

1. Determine the relative value of carbon footprint, VOC emissions, gamut size, and image resolution to print buyers in the folding carton packaging market.
2. Determine if all print buyers have the similar trade-off behaviors or if they cluster into groups based on their trade-off behaviors.

An *F* Test determined that the trade-off behaviors observed in the experiment were significant at the 95% confidence level for all participants. Subsequently, coefficients of determination (R^2) were calculated for each participant. Based on the results of this analysis, the multiple regression models account for 70 to 95+ percent of the observed trade-off behavior. The combination of statistical significance and high coefficients of determination means that the multiple regression models developed from the experimental data represent the real trade-off behaviors of the participants and can be used to fulfill the research objectives.

The multiple regression models developed from the experimental data show that most print buyers viewed gamut size to be the most important contributor to the perceived value of an offering. CO_2 and VOCs were tied as the second most important contributors. On the other hand, print buyers did not assign significant value to differences in image resolution within the limits explored in this experiment.

The results of the experiment show that print buyers can be clustered into three groups based on their trade-off behaviors. The majority of print buyers recognized the environment as an important factor in their trade-off behavior (i.e. either flavored the environment or weighted the value of environmental impact equal to the value of image quality). Nevertheless, slightly less 30% of the print buyers who participated in this experiment favored image quality over environmental impact.

Implications, Limitation, and Future Research

One implication of the present research is that gamut size is an important attribute for print buyers in the assessment of consumer-facing packaging. In contrast, image resolution exhibited less influence in the context of the present research design. These findings could influence brand owners and packaging designers, especially as they look to design and develop packaging for more environmentally friendly production methods. Maintaining and even expanding

gamut size may be prioritized in packaging development, while image resolution may take a lesser role.

A second implication of the present research is that a small portion of the print buyers involved in this experiment valued environmental friendliness over image quality. These print buyers may be willing to adapt their products to more environmentally friendly manufacturing processes, and may be early adopters for environmentally friendly printing products.

The primary limitation of the research conducted in this experiment is that, the number of participants was relatively small. A strategic decision was made in the design of the present study to include only respondents who were working professionals in the development of consumer-facing packaging. It is recognized that this group of individuals is particularly difficult to access, and even if reached the time constraints associated with their positions could make them reluctant to take the time to voluntarily participate in the research. The research approach favored the relevance of the participants over a strategy that would increase numbers by including respondents working in more peripheral roles. Future researchers may choose to employ alternate strategies that could possibly reach larger numbers of respondents. A second limitation is that the results of the conjoint analysis used in this research are limited to the four attributes studied and cannot be easily extended to include new attributes. On the other hand, the research shows that the relationships among the four attributes studied and print

buyer preferences are real. Third, this research is limited to folding carton printing for fast moving products. Finally, the print samples were prepared using a Kodak Approval instead of a conventional printing press. Of these limitations, increasing the sample size and extending the study to additional markets such as flexible packaging offer the greatest potential for future research.

Bibliography

American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. (ASHRAE). (2003). *ASHRAE Applications Handbook.* Chapter 17, Printing Plants.

Ampuero, O. and Vila, N. (2006). Consumer perceptions of product packaging. *Journal of Consumer Marketing, 23* (2),100 – 112.

Argent, D. (2009). *Gravure versus flexo printing: Part 2*. Retrieved from http://pffc-online.com/processmanagement/7352-gravure-versus-flexo-0809

ArjoWiggins. (n.d.). *Standard Conversions*. Fine Paper House. Retrieved from http://www.arjowigginscastingpapers.com/ArjoWigginsCastingPapers/media/DownloadDocuments/Standard-Conversions.pdf

Bair, R. (1995). *Reproduction from digital images: Tips for best results.* The Stock Resolution. Retrieved from http://www.tssphoto.com/repro.html.

Baldassini, P. (2010). *Image resolution: Part 1*. Paul Baldassini Fine Art Contemporary Realist Painting. Studio Journal. Retrieved from http://baldassinifineart.blogspot.com/2010_09_26_archive.html.

Bech-Larsen, T. (1996). Danish consumers' attitudes to the functional and environmental characteristics of food packaging. *Journal of Consumer Policy, 19*, 339-63.

Benito Go´mez, C., Noya, F.J. and Paniagua, A. (1999). *Actitudes y comportamientos hacia elmedioambiente en Espana: Opiniones y Actitudes, 25,* Centro de Investigaciones Sociolo´gicas, Madrid.

BSI British Standards. (2008). *Guide to PAS 2050: How to assess the carbon footprint of goods and services.* Crown 2008 and Carbon Trust 2008.

CBS News. (2008). *A closer look at green products manufacturers are making more environmentally friendly products, but not all stand up to the test*. Retrieved from www.cbsnews.com/stories/2008/05/18/eveningnews/main4105507.shtml

Chen, Y.S. (2010), The drivers of green brand equity: Green brand image, green satisfaction, and green trust. *Journal of Business Ethics, 93,* 2, 307-19.

Coddington, W. (1993). *Environmental Marketing*. New York, NY: McGraw-Hill.

Eagly, A.H. and Kulesa, P. (1997). Attitudes, attitude structure, and resistance to change. in Bazermann, M.H., Messick, D.M., Tenbrunsel, A.E. and Wade-Benzoni, K.A. (Eds), *Environment, Ethics, and Behavior* (pp. 122-53). San Francisco, CA: The New Lexington Press.

Eastern Research. (2002). *Preferred and alternative methods for estimate air emission from the printing, packaging, and graphic art industry*. Vol. 2, Chapter 15.

Environmental Protection Agency. (2002). *Overview of flexographic printing*. Retrieved from http://www.epa.gov/dfe/pubs/flexo/ctsa/ch2-overview.pdf

EPA. (2010). *Final rule: Prevention of significant deterioration and Title V greenhouse gas tailoring rule* . Retrieved from http://www.epa.gov/nsr/documents/20100413fs.pdf

EPA Victoria. (2004). *Information bulletin: Minimizing VOC emission from Victoria Printing Industry.* Retrieved fromhttp://epanote2.epa.vic.gov.au/EPA/publications.nsf/515bc2fde7bf93f44a2565b6001ee896/7b4002bc092350ebca256dd30012ffef/$FILE/940.pdf

EPA. (2011). *Greenhouse Gas Equivalencies Calculator.* Environmental Protection Agency. Retrieved from http://www.epa.gov/cleanenergy/energy-resources/calculator.html

EPA. (2012). *Greenhouse gas equivalencies calculator*. Retrieved from http://www.epa.gov/cleanenergy/energy-resources/calculator.html

EPA. (2012). *Transportation and Air Quality*. Environmental Protection Agency. Retrieved from http://www.epa.gov/oms/consumer/f00013.htm (cited in http://en.wikipedia.org/wiki/Motor_vehicle_emissions#cite_note-25)

Erhan, S., Bagby, M. (1994). Vegetable-oil-based printing ink formulation and degradation. *Industrial Crops and Products: An International Journal, 2.*

European Commission. (2009). Guidance on VOC substitution and reduction for activities covered by the VOC Solvents Emissions Directive*. AEA Energy & Environment.*

Fuller, D.A. (1999). *Sustainable marketing.* Thousand Oaks, CA: Sage Publications.

Green, P.E., Srinivasan, V. (1978). Conjoint analysis in consumer research: Issues and outlook. *Journal of Consumer Research, 5,* 103–123.

Harrington, R. (2011). *BRIC nations to lead folding cartons growth.* Retrieved from http://www.foodproductiondaily.com/Packaging/BRIC nations-to-lead-folding-carton-growth-report.

Imram, N. (1999). The role of visual cues in consumer perception and acceptance of a food product. *Nutrition and Food Science*, *5*, 224-228.

Johnson. R. (1974). Trade-off analysis of consumer values. *Journal of Marketing Research, 11*, 121-71.

Johnson R. (1987). Adaptive conjoint analysis*. In Sawtooth Software Conference Proceedings*, pp. 253-265. Sun Valley, Idaho: Sawtooth Software.

Keif, M. (2005). Identify high-volume printing processes. *Visual Communication Journal, pp.* 35-42. International Graphics Arts Education Association, Inc.

Kipphan, H. (2000). *Handbook of print media*, pp. 978-979. Springer-Verlag Berlin Heidelberg.

Kupiec, B. and Revell, B. (2001*).* Measuring consumer quality judgments. *British Food Journal. 3,* 1, 7-22.

Laroche, M., Bergeron J., and Barbaro-Forleo G., (2001), Targeting consumer who willing to pay more for environmentally friendly froducts. *Journal of Marketing, 18,* 6, 503-520.

Leung, M., Liu, C., Chan, A. (2005). Occupational exposure to volatile organic compounds and mitigation by push-pull local exhaust ventilation in printing plants. *Journal of Occupational Health*, 540-547.

Li, X . (2009). *Current Developments of carbon footprint concepts and methodologies – Possibilities for Volvo Trucks to produce greenhouse gas emission accounting information based on environmental declarations*. Master of Science Thesis, ESA127 Report No. 2009:3, Department of Energy and Environment, Division of Environmental Systems Analysis, Chalmers University of Technology, Göteborg, Sweden.

Luce, D. and J. Tukey. (1964). Simultaneous conjoint measurement: A new type of fundamental measurement. *Journal of Mathematical Psychology, 1*, 1-27.

Luchs, M., Brower, J., Chitturi, R. (2010). *Trading-off sustainability: Choice and willingness-to-pay given a trade-off between sustainability and functional performance*. AMA Marketing & Public Policy Conference.

Malenke, D., Daniel, G. (2010), A comparison of folding carton printing substrates and appropriate application. *Brand Packaging*. Retrieved from http://www.brandpackaging.com/Articles/Case_Studies/BNP_GUID_9-5-2006_A_10000000000000805552

Marilyn A. B, Southworth, F., and Sarzynski, A. (2011). *Shrinking the carbon footprint of metropolitan America*. Brookings Institution Metropolitan Policy Program.

ME Printer, (2005). *Flexo and Gravure Press Manufacturers Share the Forum*. Retrieved from http://www.meprinter.com/EN/Images/Archive/510 Flexo%20and%20Gravure%20press%20manufacturers%20share%20the%20forum.pdf

Montgomery, D. (2005). *Design and Analysis of Experiments (Sixth edition)*. Arizona State University. John Wiley & Sons, Inc.

Nazdar. (n.d.). *Ultra violet Ink technical manual*. Narzdar. Retrieved from http://www.nazdar.com/UV_CURING_Inks_061215.pdf

Orme, B.K. (2006). *Getting Started with conjoint analysis: Strategy for product and pricing research*. Research Publisher.

Paper Info. (2012). *Carton Board*. Paper Info the World of Paper. Retrieved from http://www.paperinfo.eu/index.php?option=com_k2&view=itemlist&task=category&id=27:carton-board&Itemid=207

Pira International. (2011). *Study forecasts BRIC presents high-growth opportunities for folding cartons*. Retrieved from http://www.paperage.com/2011news/06_07_2011pira_study.html

Pacific Northwest Pollution Prevention Resource Center. (n.d.). *Climate change rapid response research service.* Retrieved from http://pprc.org/research/climatechange/rr-pas2050.pdf

Pihkola, H., Nors M., Kujanpaa M., et al. (2010). *Carbon footprint and environmental impacts of print products from cradle to grave results from the LEADER Project (Part 1)*, p. 253. VTT Technical Research Center of Finland.

Pope, B., Hsu, F., and Sigg, F. (2008). Color gamut quantified: A new approach to analyzing color gamut. *Test Targets. RIT School of Print Media Publication, (8*), 27-32.

Prendergast, P.G. and Pitt, L. (1996). Packaging, marketing, logistics and environment: Are there trade-offs? *International Journal of Physical Distribution & Logistics Management, (26),* 6, 60-72.

PrintCity. (2008). *PrintCity special report: Sustainable, energy & environment: Frequently asked questions.* PrintCity Gmbh + Co.

Schlegelmilch, B.B., Bohlen, G.M., and Diamantopoulos, A. (1996). The link between green purchasing decisions and measures of environmental consciousness*. European Journal of Marketing, 30*, 5, 35-55.

Sczerba, R. (2010). Image resolution: Best practice forum. *The Innovative Instructor.* Center for Educational Resource. Retrieved from http://www.cer.jhu.edu/ii/InnovInstruct-BP_ImageRez.pdf

Sigg, F. (2006). Testing for resolution and contrast. *Test Targets 6.0,* 1-5. RIT School of Print Media Publication.

Silayoi, P. and Speece, M. (2004). Packaging and purchase decisions: An exploratory study on the impact of involvement level and time pressure. *British Food Journal, 106,* 8, 607-628.

Silayoi, P. and Speece, M. (2007). The important of packaging attribute: A conjoint analysis approach. *European Journal of Marketing, 41,* 11/12, 1495-1517.

Sustain Graph. (n.d.). *Report: Available life cycle tools for the European graphic industry and key factors for their implementation.* Retrieved from http://www.sustaingraph.com/project

Svendsen K. and Rognes, K. S. (2000). Exposure to organic solvents in the offset printing industry in Norway. *Annals of Occupational Hygiene, 44,* 119-124.

Swenson, M.R. and Wells, W.D. (1997), Useful correlates of pro-environmental behavior. In Goldberg, M.E., Fishbein, M, and Middlestadt, S.E. (Eds), *Social Marketing, Theoretical and Practical Perspectives,* pp. 91-109. Mahwah, NJ: Lawrence Erlbaum.

Rettie, R. and Brewer, C. (2000). The verbal and visual components of package design. *Journal of Marketing Research, (36),* 1, 56-70.

Star Packaging. (n.d.). *Design and file preparation for flexographic printing*. Retrieved from http://www.starpackagingcorp.com/forms/Star-Design-Prep-Guide.pdf

Underwood, R., Klein, N., and Burke, R. (2001). *Packaging communication: Attention effects of product imagery*. *Journal of Product & Brand Management, (10),* 7, 403-22.

Veith, S. and Barr, S. (2008), *Life assessment: Flexographic and rotogravure printing comparison & flexographic place imaging technology*. Dupont Engineering Research Technology (DuET).

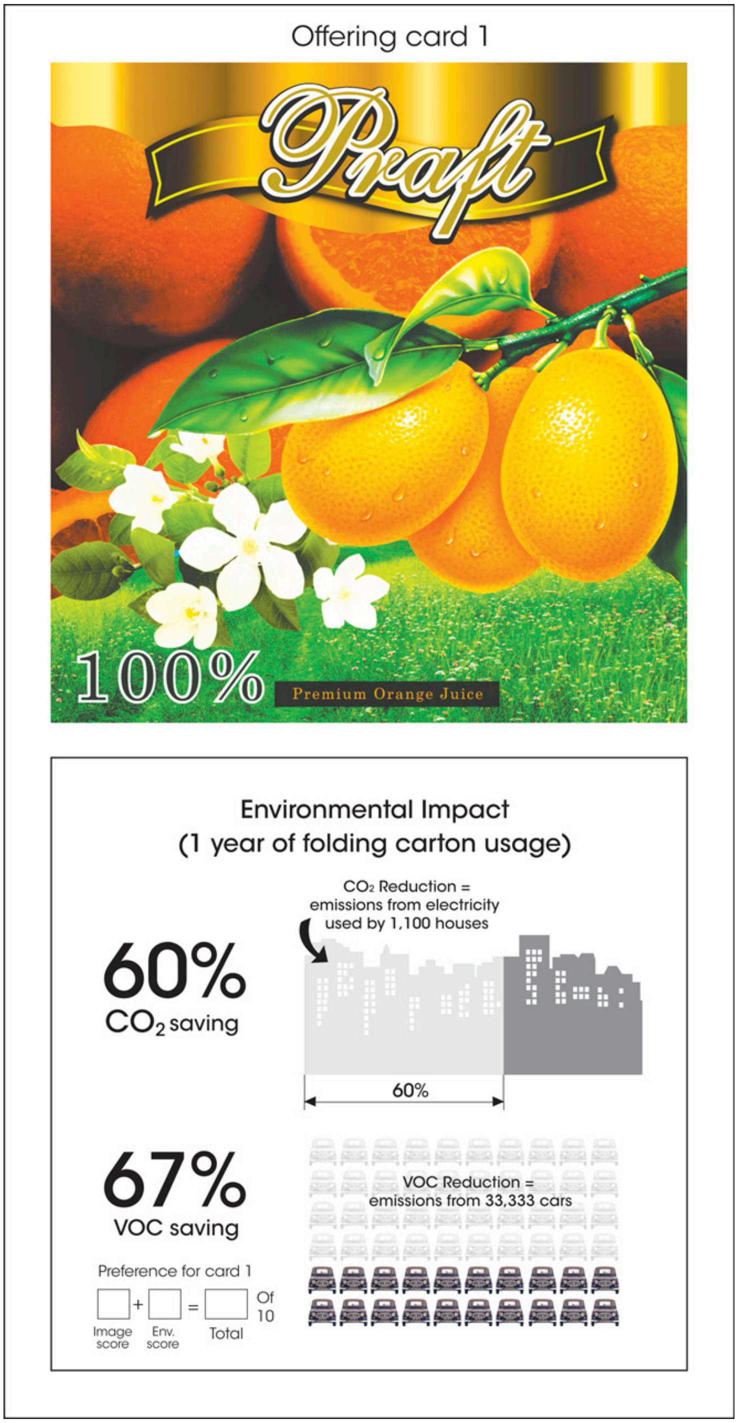
Walmart. (2011), *Building the Next Generation Walmart…Responsibly*. Global Responsibly Report. Walmart Store, Inc

Appendix A

RIT17 Test Target

Appendix B

Sample Offering Card



Appendix C

Informed Consent Document

PROJECT TITLES An Investigation of Print Buyer Willingness to Trade-off Image Quality With Environmental Benefit in Package Printing.

INTRODUCTION

You are invited to join a research study to explore trade-off behavior of packaging procurement executives between image quality and environmental benefits. Please take whatever time you need to discuss the study with anyone you wish. The decision to join, or not to join, is up to you.

WHAT IS INVESTIGATED IN THE STUDY

The participant will be asked to view a short environmental video explaining the experiment and will be given a proof of the image used in the experiment. The participants will then be shown approximately 20 offering cards and asked to provide a preference rating for each card. Rating will be collected in a questionnaire.

You can stop participating at any time. If you stop you will not lose any benefits.

RISKS

This study involves the following risks.

Very likely: Minor eyestrain

Less Likely but serious: None

Rare: None

There may also be other risks that we cannot predict.

BENEFITS TO TAKING PART IN THE STUDY?

It is reasonable to expect the following benefits from this research: Participants will gain an understanding about the environmental impact of print and the willingness of other packaging procurement executives to trade-off image quality for environmental benefits. In addition, it is likely that the results from this analysis will help to explain the balance point between image quality and environmental benefit for technology providers who are engaged in reducing the environmental impact of printing.

CONFIDENTIALITY

Your name will not be used when data form these studies are published. Every effort will be made to keep your research records and other personal information confidential.

We will take the following steps to keep information about you confidential, and to protect it from unauthorized disclosure, tampering, or damage: Data will be collected and reported by observer number only.

INCENTIVES

Participants will be provided the results of this research.

YOUR RIGHTS AS A RESEARCH PARTICIPANT?

Participation in this study is voluntary. You have the right not to participate at all or leave the study at any time. Deciding not to participate or choosing to leave the study will not result in any penalty or loss of benefits to which you are entitled, and it will not harm your relationship with the researcher and any other faculty member.

If you decide to leave the study, the procedure is: inform the researcher that you are no longer interested in participating in this research.

CONTACTS FOR QUESTION OR PROBLEMS?

You can contact Rattana Mayteekriengkrai (call 585-732-8238 or email Rxm7603@rit.edu) or Professor Robert Eller (call 585-755-0555 or email rjeppr@rit.edu) at anytime if you have any questions about the study, any problems, unexpected physical or physical or psychological discomforts, any injuries, or think that something unusual or unexpected in happening.

CONSENT OF SUBJECT (or Legally Authorized Representative)

Signature of Subject or Representative Date

Upon signing, the subject or the legally authorized representative will receive a copy of this form, and the original will be in the subject's research record.

Appendix D

Instructional E-mail

Thank you for agreeing to participate in this experiment.

The purpose of this email is to provide the information that you will need to conduct the experiment. Before reading further please check to ensure that you have received an envelope containing the offering cards that you will evaluate. If you have not received this envelope please contact me at rxm7603@rit.edu or 585-732-8238.

To participate in the experiment, please follow these steps:

1. Watch the instructional video by clicking on this link http://rxm7603.cias.rit.edu/video2.html

2. Follow the instructions in the video and assign a preference score to each offering card.

3. Record your preferences by clicking the following link https://www.surveymonkey.com/s/FRGZ6Y8

4. Fill in the electronic data submission form. (The software used to submit your results is a general-purpose survey tool call “SurveyMonkey”. The data submission form is actually a survey.)

5. Send the form to me by clicking the “Done” button at the end of the survey.

6. After you complete the survey, you can dispose of the offering cards or keep them if you prefer.

Appendix E

SurveyMonkey

An Investigation of Print Buyer Willingness to Trade-off Image Quality With Environmental Benefit in Package Printing

1. Participant's information

Name:

Company:

2. What kind of your business?

□ Food & Beverage □ Households □ Office Supply

□ Toys □ Beauty and Healthcare

□ Other, Please specific……….

3. What percentage of your total packaging consists of folding cartons?

□100% □80-90% □ 60-70% □50% □ Lower than 50%

4. Please estimate the value of folding carton used by your company each year.

□$100 million + □$50- $99 million+ □ $25-$49 million+

□$10 - $24 million+ □$1-$9 million+ □ Less than $1 million

5. Please assign your preference of the offering card (ranking from 0-10, 0= lease preference, 10= most preference)

Offering card 1

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 2

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 3

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 4

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 5

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 6

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 7

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 8

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 9

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 10

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 11

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 12

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 13

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 14

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 15

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 16

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 17

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

Offering card 18

□0 □1 □2 □3 □4 □5 □6 □7 □8 □9 □10

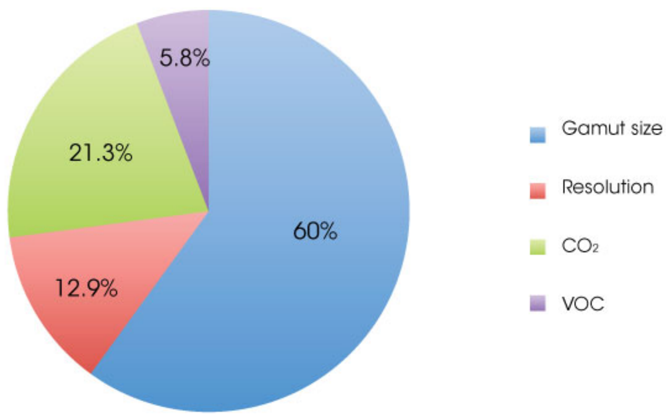
Appendix F

Participant 1 Results

Analysis Result

Name of Participant Participant 1 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-0.42	2.17	2.58	60
Resolution	-0.56	0.00	0.56	12.9
CO_2	-0.83	0.08	0.92	21.3
VOC	-0.25	0.00	0.25	5.8

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-0.42	150	-0.56	1,150 homes	0.08	25,000 cars	-0.25
GRACoL	2.17			1,850 homes	-0.83	50,000 cars	0.00

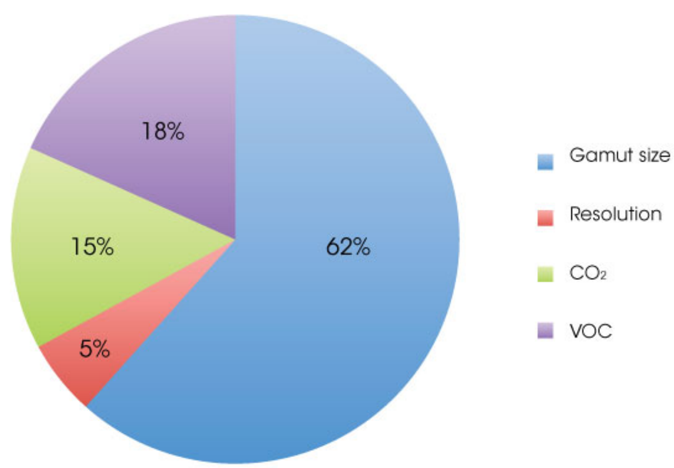
Appendix G

Participant 2 Results

Analysis Result

Name of Participant ___Participant 2___ Company ______________

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-3.81	2.50	6.31	62
Resolution	0.00	0.56	0.56	5
CO_2	-1.50	0.00	1.50	15
VOC	-1.88	0.00	1.88	18

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-3.81	150	0.56	1,150 homes	-0.81	25,000 cars	-0.44
GRACoL	2.50			1,850 homes	-1.50	50,000 cars	-1.88

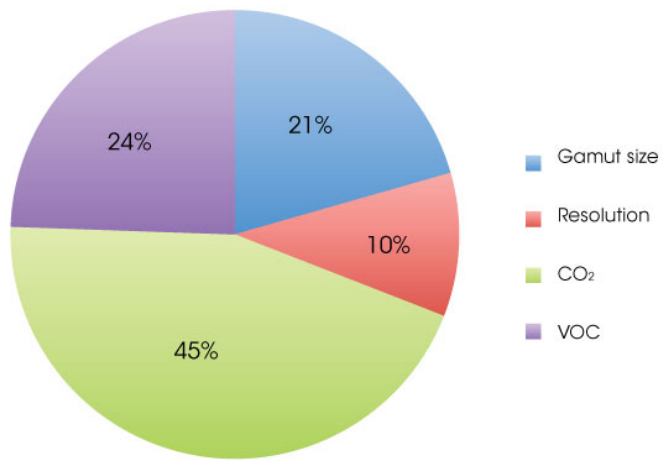
Appendix H

Participant 3 Results

Analysis Result

Name of Participant: Participant 3 Company: ______

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-1.10	0.00	1.10	21
Resolution	0.00	0.56	0.56	10
CO_2	-2.17	0.23	2.40	45
VOC	-0.88	0.44	1.31	24

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-1.10	150	0.56	1,150 homes	-0.23	25,000 cars	0.44
GRACoL	-0.33			1,850 homes	-2.17	50,000 cars	-0.88

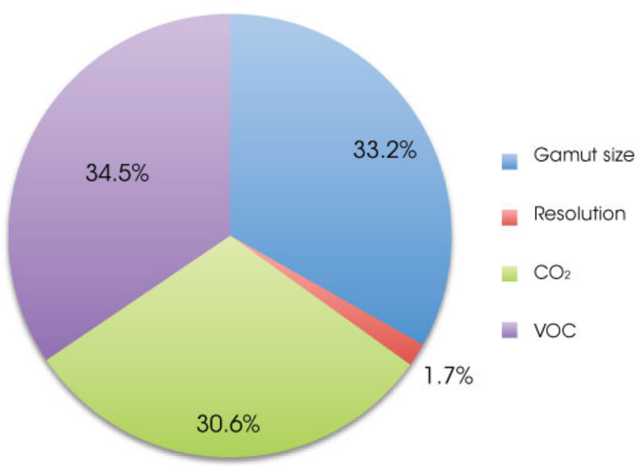
Appendix

Participant 4 Results

Analysis Result

Name of Participant ______ Participant 4 ______ Company ____________

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-1.83	0.33	2.17	33.2
Resolution	- 0.11	0.00	0.11	1.7
CO_2	-2.00	0.00	2.00	30.6
VOC	-2.25	0.00	2.25	34.5

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-1.83	150	-0.11	1,150 homes	-0.50	25,000 cars	-0.25
GRACoL	0.33			1,850 homes	-2.00	50,000 cars	-2.25

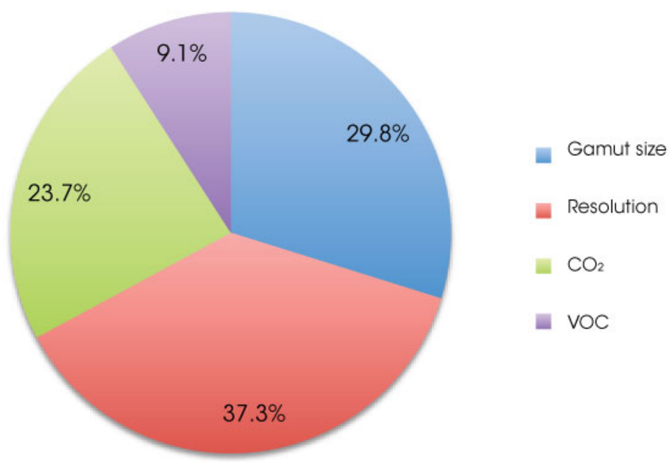
Appendix J

Participant 5 Results

Analysis Result

Name of Participant: Participant 5 Company: ____

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-2.04	0.00	2.04	29.8
Resolution	0.00	2.56	2.56	37.3
CO_2	-0.50	1.13	1.63	23.7
VOC	-0.50	0.13	0.63	9.1

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-2.04	150	2.56	1,150 homes	1.13	25,000 cars	0.13
GRACoL	-0.33			1,850 homes	-0.50	50,000 cars	-0.50

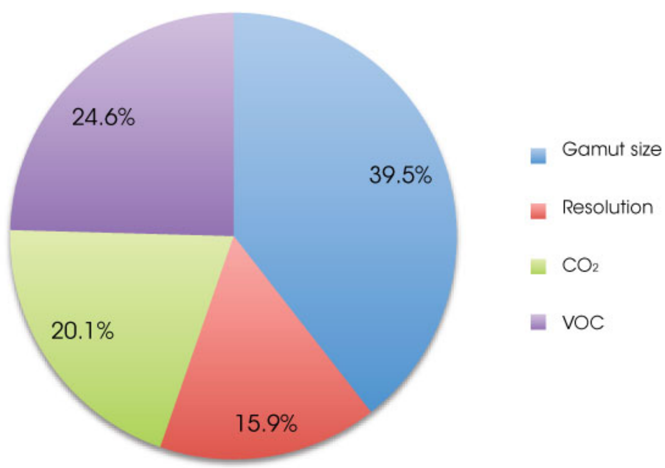
Appendix K

Participant 6 Results

Analysis Result

Name of Participant ____Participant 6____ Company ____________

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-2.21	0.00	2.21	39.5
Resolution	0.00	0.89	0.89	15.9
CO_2	-1.00	0.13	1.13	20.1
VOC	-1.13	0.25	1.38	24.6

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-2.21	150	0.89	1,150 homes	1.13	25,000 cars	-1.13
GRACoL	-0.17			1,850 homes	-1.00	50,000 cars	0.25

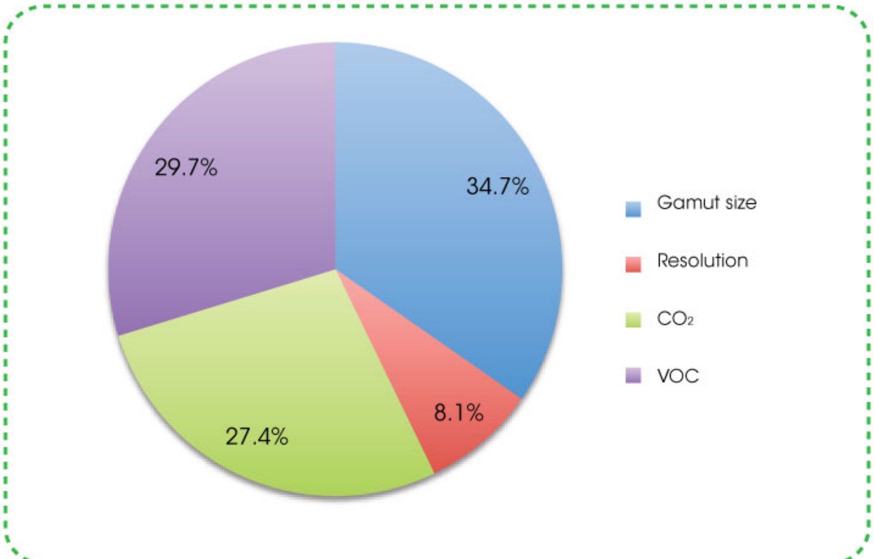
Appendix L

Participant 7 Results

Analysis Result

Name of Participant Participant 7 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-1.23	0.67	1.90	34.7
Resolution	0.00	0.44	0.44	8.1
CO_2	-1.50	0.00	1.50	27.4
VOC	-1.63	0.00	1.63	29.7

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-1.23	150	0.44	1,150 homes	-1.06	25,000 cars	-0.94
GRACoL	0.67			1,850 homes	-1.50	50,000 cars	-1.63

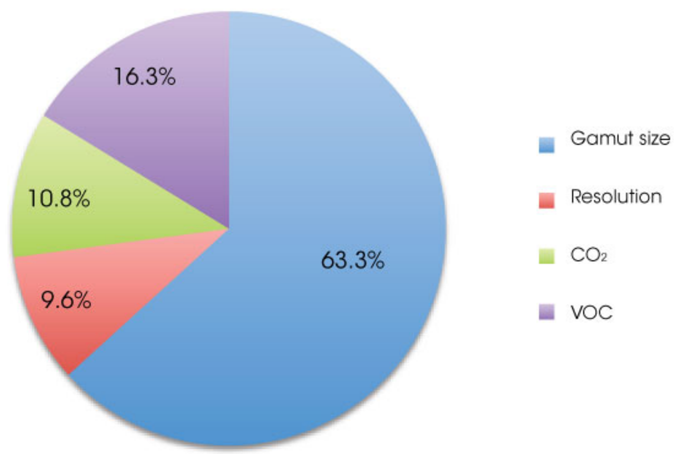
Appendix M

Participant 8 Results

Analysis Result

Name of Participant ___Participant 8___ Company ________

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-2.92	0.00	2.92	63.3
Resolution	-0.44	0.00	0.44	9.6
CO_2	0.00	0.50	0.50	10.8
VOC	0.00	0.75	0.75	16.3

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-2.92	150	-0.44	1,150 homes	-0.25	25,000 cars	0.75
GRACoL	-0.33			1,850 homes	-0.50	50,000 cars	0.50

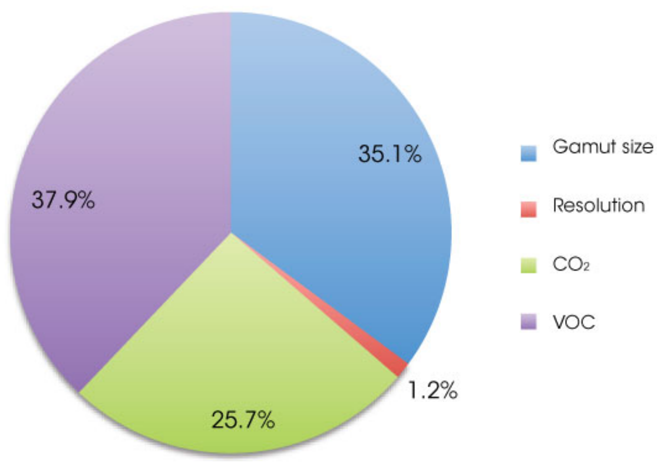
Appendix N

Participant 9 Results

Analysis Result

Name of Participant Participant 9 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-3.19	0.00	3.19	35.1
Resolution	-0.11	0.00	0.11	1.2
CO_2	0.00	2.33	2.33	25.7
VOC	-0.56	2.88	3.44	37.9

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-3.19	150	-0.11	1,150 homes	0.98	25,000 cars	-0.56
GRACoL	-0.50			1,850 homes	2.33	50,000 cars	2.88

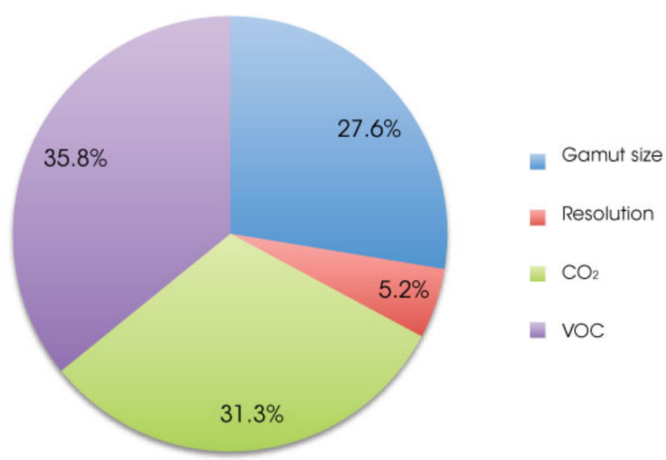
Appendix O

Participant 10 Result

Analysis Result

Name of Participant: Participant 10　Company: ____________

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-2.94	0.00	2.94	27.6
Resolution	0.00	0.56	0.56	5.2
CO_2	-3.33	2.33	3.33	31.3
VOC	-3.63	0.19	3.81	35.8

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-2.94	150	0.56	1,150 homes	-1.60	25,000 cars	0.19
GRACoL	0.00			1,850 homes	-3.33	50,000 cars	-3.63

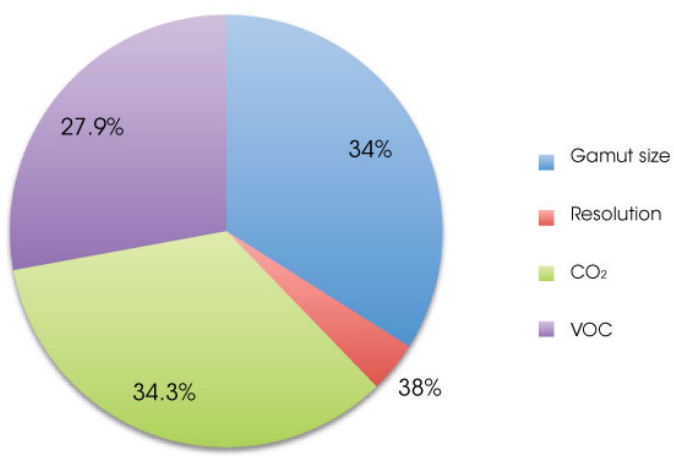
Appendix P

Participant 11 Results

Analysis Result

Name of Participant Participant 11 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-1.65	0.33	1.98	34.0
Resolution	0.00	0.22	0.22	3.8
CO_2	-2.00	0.00	2.00	34.3
VOC	-1.63	0.00	1.63	27.9

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-1.65	150	0.22	1,150 homes	-0.81	25,000 cars	-0.19
GRACoL	0.33			1,850 homes	-2.00	50,000 cars	-1.63

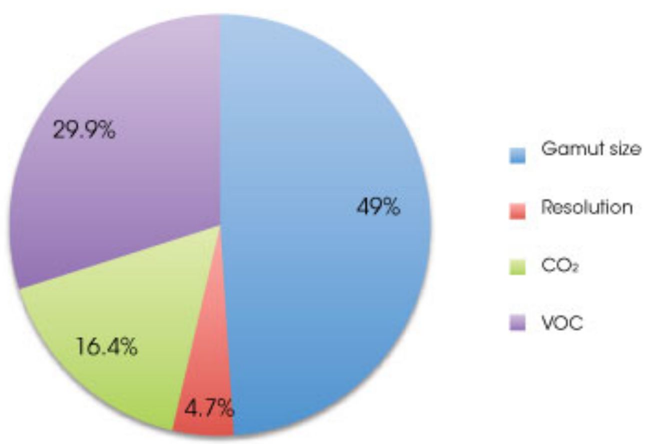
Appendix Q

Participant 12 Results

Analysis Result

Name of Participant Participant 12 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-2.65	0.83	3.48	49.0
Resolution	0.00	0.33	0.33	4.7
CO_2	-1.17	0.00	1.17	16.4
VOC	-2.13	0.00	2.13	29.9

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-2.65	150	0.33	1,150 homes	-0.15	25,000 cars	-0.19
GRACoL	0.83			1,850 homes	-1.17	50,000 cars	-2.13

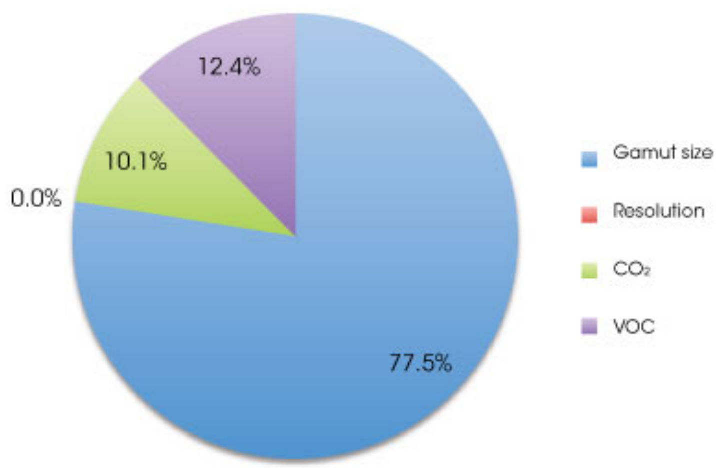
Appendix R

Participant 13 Results

Analysis Result

Name of Participant Participant 13 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-4.29	1.17	5.46	77.5
Resolution	0.00	0.00	0.00	0.00
CO_2	0.00	0.71	0.71	10.1
VOC	0.00	0.87	2.13	12.4

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-4.29	150	0.00	1,150 homes	0.71	25,000 cars	0.87
GRACoL	1.17			1,850 homes	0.67	50,000 cars	0.50

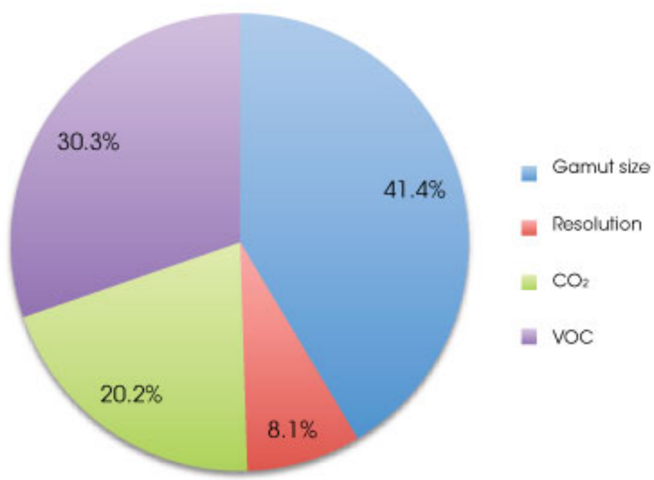
Appendix S

Participant 14 Results

Analysis Result

Name of Participant: Participant 14 Company: ______

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-1.04	0.67	0.71	77.5
Resolution	0.00	0.33	0.33	0.00
CO_2	-0.83	0.00	0.83	20.2
VOC	-1.25	0.00	1.25	30.3

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-1.04	150	0.33	1,150 homes	-0.04	25,000 cars	-1.13
GRACoL	0.67			1,850 homes	-0.83	50,000 cars	-1.25

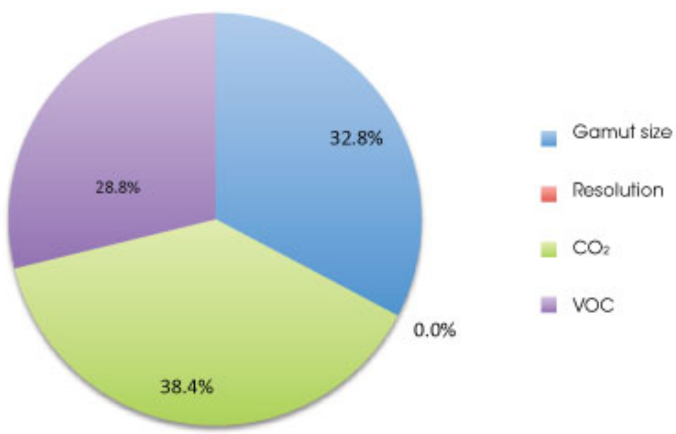
Appendix T

Participant 15 Results

Analysis Result

Name of Participant Participant 15 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-1.56	0.00	1.56	32.8
Resolution	0.00	0.00	0.00	0.00
CO_2	-1.83	0.00	1.83	38.4
VOC	-1.38	0.00	1.38	28.8

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-1.56	150	0.00	1,150 homes	-0.73	25,000 cars	-0.19
GRACoL	-0.50			1,850 homes	-1.83	50,000 cars	-1.38

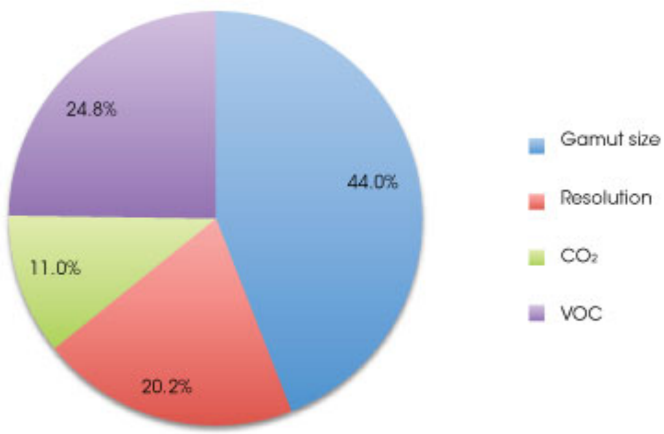
Appendix U

Participant 16 Results

Analysis Result

Name of Participant__Participant 16__________ Company____________________

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-0.83	1.83	2.67	44.0
Resolution	0.00	1.22	1.22	20.2
CO_2	-0.67	0.00	0.67	11.0
VOC	-1.50	0.00	1.50	24.8

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-0.83	150	1.22	1,150 homes	-0.33	25,000 cars	-0.50
GRACoL	1.83			1,850 homes	-0.67	50,000 cars	-1.50

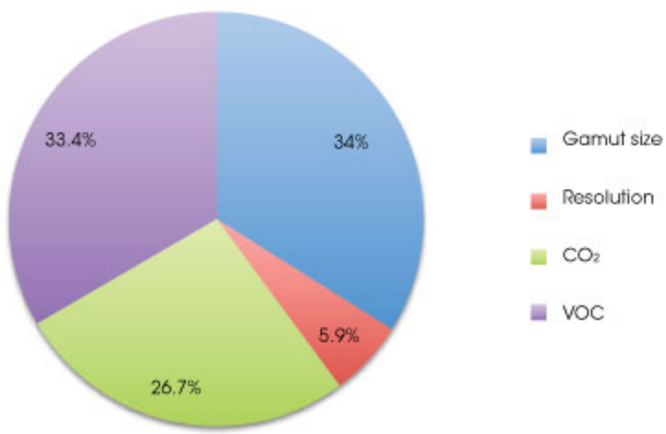
Appendix P

Participant 17 Results

Analysis Result

Name of Participant Participant 17 Company

Percentages of Total Value by Attribute



Calculation of Percentages

Attribute	min	max	Range	Percentages
Gamut size	-2.54	0.00	2.54	34.0
Resolution	0.00	0.44	0.44	5.9
CO_2	-2.00	0.00	2.00	26.7
VOC	-2.50	0.00	2.50	33.4

Value by Level & Attribute (Individual Part Worths)

Gamut size		Resolution		CO_2		VOCs	
Level	Part Worth	Level	Part Worth	Level	Part Worth	Level	Part Worth
SWOP	0.00	100	0.00	750 homes	0.00	16,667 cars	0.00
SNAP	-2.54	150	0.44	1,150 homes	-0.88	25,000 cars	-0.38
GRACoL	-0.33			1,850 homes	-2.00	50,000 cars	-2.50