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How to Find Optimal Combinations of Brand Components

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Background: Consumer products are often viewed as combinations of components drawn from categories such as features, benefits, and imageries. Successful marketing of brands depends on skill in choosing these combinations. The staggering number of combinations that can result from even a relatively small number of components is not always appreciated. For example, with only 60 components in these combinations, there are over a quintillion (10^{18}) of them - if there was one penny for every combination, the pennies would cover the surface of the earth twice if laid out side by side! Nevertheless, there are techniques available to consider these astronomically large numbers of alternative combinations to find the single best combination or a small group of actionable alternatives.

Although regression-based techniques such as conjoint analysis are useful in situations where the numbers of components are relatively small, such tools are not well-suited to handling problems of the larger type described above[1]. Fortunately, these problems can be analyzed using techniques from the mathematical field of graph theory[2,3]. Graph theory has grown substantially because of its applications to internet search, social networking, and national security. The purpose of this report is to demonstrate the use of graph theory to optimize products built around sparkling fruit juice beverages.

Scenario: You are a consumer insights manager within a soft drink company that plans to launch a line of carbonated fruit juice beverages. At this preliminary stage of development, you are considering 15 possible flavors, 22 benefits, and 23 imagery variables within this product line. This number of items is typical of projects of this type on which you work, and you plan to allow combinations of items within categories (e.g., two flavors mixed together) as well as across categories (e.g., a flavor and a benefit). The goal of the project is to find high quality combinations of at most six items, with at least one item from each category included. These combinations of at least one flavor, at least one benefit, and at least one imagery will serve as starting points for future product development.

For this project, there are 60 components and it is immediately apparent that size considerations will prevent you from using conjoint analysis. An alternative is to rank the items within categories and choose the most appealing items. But this approach would ignore the compatibility or incompatibility of items within combinations and would fail to discover unusual products with high appeal.

Graph Theory: Graph theory is the study of connections between items and we consider a *connection* to be a pairwise relationship between them. In the beverage project, these connections represent compatibility, but connections could represent suitability, appropriateness, social acquaintance, or any other relationship that either holds or does not hold for each pair of items under consideration. Once the connections within a set of items are determined, we use the connections between the items to form a *graph*. See Figure 1. The information as to which items are connected can be stored in a *connectivity matrix* - Table 1 corresponds to the graph in Figure 1.

	A	B	C	D	E	F	G
A		1	0	1	1	0	0
B	1		1	1	1	1	0
C	0	1		1	1	1	0
D	1	1	1		1	0	1
E	1	1	1	1		1	0
F	0	1	1	0	1		0
G	0	0	0	1	0	0	

Table 1. Adjacency matrix corresponding to the graph in Figure 1.

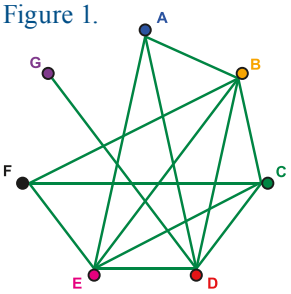

Figure 1. Example of a graph with 7 items.

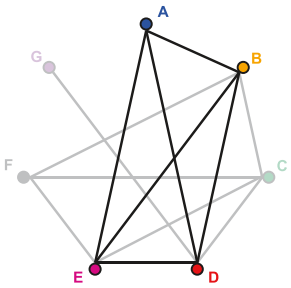

Figure 2. A clique within a graph (ABDE).

Within a graph, a *clique* is a collection of items that is fully connected. See Figure 2. In general, cliques may or may not be contained within larger cliques, but a *maximal* clique is one that is not contained in any larger clique. Applying this perspective to consumer science, we consider a product to be a combination of the component choices it represents, and we look for cliques.

The Beverage Problem: Table 2 contains the components in each of the three categories - flavors, benefits, and imageries - from which the product combinations will be formed[4]. We need only consider pairs of components instead of full combinations[5,6] and this fact allows us to only consider 1770 possible pairs. Even so, this is still a reasonably large number of pairs (more than you could ask a single consumer to evaluate in a single session) and your first step is to further reduce the problem size. Inspection of Table 2 shows significant redundancy (e.g., invigorating ≈ energizing, strong ≈ robust). Thus, if some components could be eliminated as redundant then it may not be necessary to evaluate all 1770 pairs.

Flavors	Apple, Blackberry, Blueberry, Cherry, Grape, Grapefruit, Lemon, Lime, Mango, Orange, Peach, Pineapple, Pomegranate, Raspberry, Strawberry
Benefits	All-natural, Becoming popular, Clean-tasting, Delicious, Energizing, Fizzy, Goes down easy, Good when hanging out, Good-tasting, Invigorating, Low-carb, Refreshing, Relaxing, Reviving, Rewarding, Satisfying, Social, Stimulating, Thirst-quenching, Uplifting, No harsh taste, Would recommend
Imageries	Abundance, Admire, Appeals to me, Aromatic, Authentic, Breezy, Classic, Crisp, Desperate, Different, Distinctive taste, Fresh, Healthy, Let loose, Light, Masculine,Patriotic, Quality, Robust, Smooth, Sophisticated, Strong, Strong heritage

Table 2. Flavors, benefits and imageries.

Independent Sets: One way to reduce redundancy is to consider which items are not related, and to search for sets of items that are fully unconnected. These "anti-cliques" are called *independent sets*. Independent sets occur when there are no connections at all between the items of a set. By reversing the connections in a graph to form the so-called complement graph, we can find independent sets easily by finding cliques in the complement. Figure 3 shows a graph and its complement. In your project, you plan to use these ideas in a preliminary experiment, in order to identify sets of items that are as non-redundant as possible.

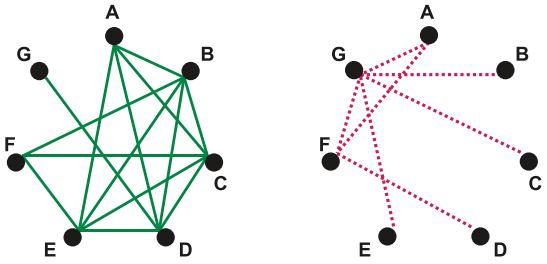

Figure 3. A graph and its complement.

Reducing Redundancy: Within the 15 flavors there are 105 pairs, within the 22 benefits there are 231 pairs, and within the 23 imageries there are 253 pairs. You arrange for internal experts to rate how similar or different the pairs of components are, within each category. After aggregating this similarity data, you conduct a search for independent sets within each category to find subsets of flavors, benefits, and imageries that are as different as possible from each other, according to the assessments of your internal experts. This search yields the lists of components given in Table 3. Since there are now only 25 items, there are now only 300 pairs within and across categories. It is now possible to design a consumer study in which each consumer evaluates each pair in a single session. Even though the number of items has been reduced, the number of possible combinations, 32 million, is still large.

Flavors	Apple, Blueberry, Cherry, Lime, Mango, Orange, Peach, Pineapple, Pomegranate
Benefits	All-natural, Fizzy, Goes down easy, Low-carb, Relaxing, Reviving, Satisfying, Social
Imageries	Abundance, Authentic, Breezy, Classic, Crisp, Healthy, Let loose, Smooth

Table 3. Flavors, benefits and imageries after independent set analysis using graph theory.

		Flavors	Benefits	Imageries
Combination	1	Apple, Cherry	Goes down easy, Relaxing, Satisfying	Smooth
	2	Cherry, Lime	Reviving	Crisp
	3	Mango, Peach	Relaxing, Satisfying	Healthy, Smooth
	4	Apple, Cherry	Satisfying	Classic, Healthy, Smooth
	5	Orange, Peach	Satisfying	Classic, Healthy, Smooth

Table 4. The best five of 25 maximal cliques that have at least one component from each category after dropping "all-natural."

Application of Graph Theory to the Beverage Problem: In your consumer study, you present pairs of components along with the question:

> *"In thinking about sparkling fruit juice beverages, for each pair of items please indicate whether you think they go well together."*

The pairs of components are presented in a forced-choice CATA format, in which 30 pairs are shown at a time and consumers are forced to select "Yes" or "No" for each pair[7]. You obtain responses from 1000 consumers in a nationwide internet survey using a randomized design. From these responses, you construct a compatibility matrix which shows the degree to which the pairs of components are compatible. Using a thresholding procedure[8], graph theory can now be applied to find cliques of size 6 but none of size 7, subject to the constraint that at least one component must come from each category. In the initial analysis, you discover that "All-natural" is in every maximal clique, so you decide that it should be used in every consumer communication. You then remove all pairs involving "All-natural" and re-run the analysis. Table 4 shows the top five of the 25 combinations identified by this graph theoretic search, when the combinations are ordered by overall compatibility.

Conclusion: In this report we focused on a specific example using graph theory to reduce the number of combinations based on three categories of flavors, benefits, and imageries from an astronomical number to a small set with maximum appeal. This is the information that you will then use to proceed to the next steps of development for your carbonated fruit juice beverage line. The analytic tools used in this report are very general, and apply whenever combinations of compatible items are considered to produce an appealing product.

References and Notes

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