A Goal Programming Approach to a Media Mix Advertising Plan: A Case Study of a Private-Practice Health Care Provider

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Abstract

This case study designs and builds an operational model for media mix determination for a private-practice physician's office. The recommended advertising plan is determined via goal programming in order to balance the key issues of size-of-audience reached versus annual and quarterly advertising budgets. Post-optimality / sensitivity analysis is conducted on selected parameters of the model in order to gauge the robustness of the recommended media mix.

Introduction and Purpose

It has been more than 30 years since the use of media advertising by professional service providers (accountants, attorneys, physicians) was formally sanctioned. Historically, many professional associations had prohibited their licensed members from engaging in speech activities that suggested a commercial transaction i.e. advertising [10]. They argued that advertising would have an adverse impact on the image of their profession. Typically, such opposition to physician advertising has focused on such image and ethical issues, while current arguments favoring physician advertising focus on information needs, revenue and competitive issues.

The current status of professional-services advertising came about as a result of the application of existing anti-trust laws and an interpretation of First Amendment to commercial speech. In the mid-'70s, the anti-trust laws were used to strike down the anti-competitive "Code of Ethics", which had allowed professional associations to discipline members who advertised. A landmark Supreme Court ruling [6] established that the anti-trust laws did indeed apply to the 'learned professions' and such professions

were engaged in ‘commerce’. By 1977, the Supreme Court had further ruled that commercial speech was a protected form of expression under the First Amendment; thus states and agencies empowered to act for states (such as professional licensing boards) were prohibited from banning advertising by practicing professionals [16, 2].
The Federal Trade Commission found the American Medical Association had indeed caused substantial harm to the public by restricting advertising by physicians because such restrictions "…served to deprive consumers of the free flow of information about the availability of health care services…" and had suppressed "…the offering of innovative forms of health care…" [1]. The FTC decision was not intended to compel physicians to advertise; rather, it was merely intended to modify the AMA's code of ethics to permit enough advertising to provide patients with "a decisional basis for selecting one doctor as opposed to another."

Today private practice health care providers, like most businesses, will use advertising in order to attract potential customers to its products or services. Media selection involves the allocation of an advertising budget among a variety of media options in such a way as to maximize the number of potential customers reached [12]. Both linear programming and goal programming, have been applied to the purpose of selecting media purchases. In this case study, a particular physician's office is seeking to design and implement an advertising campaign that will enable it to reach the greatest number of potential patients, consistent with its budget. In the past, the media planner simply assessed the available advertising options and chose a mix based upon the subjective analysis, often resulting in a costly advertising program that yielded very small returns. The purpose of this paper is to apply goal programming, as a tool for managing the relationship between exposures and expenses, in determining the optimal selection of media mix for the private-practice office.

Literature Review

Over the last three decades, advertising has become a key component of the business plan of many professionals, who confront many of the same business issues faced by traditional firms, including increased competition, greater knowledge and demands by customers (patients), and a very dynamic economic environment. Interestingly, the yellow pages became the early leader among the advertising media used by professional service providers; Marks and Moon [9] found printed media to be highly preferred to other media. Many studies have sought to assess the evolving attitudes of either customers or providers towards professional-service advertising [4, 9, 10, 11]. They conclude that consumers generally have a positive attitude toward professional advertising, as they believe that it provides them with useful information for making better choices. In a study of self-employed physicians, Rizzo [13] found a comparatively high level of advertising among plastic surgeons relative to other specialists. Moser [11] examined whether age, occupation, income, education, and/or gender of patients account for any significant difference in attitudes toward physicians who advertise. His longitudinal study replicated a similar study done 20 years earlier, and concluded that, while the ethical debate continues, advertising certainly has a constructive place in the health care industry.

In recent years, physicians have become active in marketing their services to the public and conducting such advertising via a number of media including television, yellow pages, highway billboards, web sites, and even e-mail [3]. Recent studies show most physicians who advertise will witness a resulting increase in patient flow and net revenue, even in an increasingly competitive environment [8, 15]. Freedman [5] found that the return on dollars invested by physicians in advertising was four to six times the cost. Consequently, a marketing budget has become critical for most medical practices. Many health care professionals now use marketing consultants or have their own internal marketing/advertising committees [14].

In the optimization literature relating to advertising models, Rifai and Hanna [12] discussed a linear programming model that involves the setting of goals in terms of exposures, reach, frequency of exposures, and frequency distribution of the number of occasions of exposure. Given these goals, their model sought to select the best, or close to the best media portfolio, rather than one based only upon maximizing exposure. Kluyver [7] pointed out that, when formulating maximum effective exposure or weighted exposure schedules, "optimum levels of insertion cannot be obtained for all media without considerable effort (and cost), and boundaries of acceptability are used instead (pp. 27)." In other words, it is not always possible or practical to achieve an exact goal, so parameters are established within which the solution is acceptable. The Media Mix Project of this study follows Kluyver's model by using hard constraints to designate the acceptable parameters and using soft constraints to indicate the most desirable goals.

Assumptions

The data regarding the various media options were obtained from the media sources themselves. It is assumed that the data is true and accurate. Most of the data given was measured monthly, so the model relies upon the ability to extrapolate the data over a three-month period and over a 12-month period.

A significant assumption made in the model formulation is that the past number of exposures from the different media alternatives will remain consistent for the next year. The model also assumes that each exposure on a potential customer has a constant impact, yielding consistent response rates from the audience. Audience duplication and repetition are not taken into consideration in the model, although repetition is typically good.

An annual budget is given for the project, and it is assumed that the yearly budget can be divided evenly among each quarter as no seasonal pattern is presumed.

Variable Explanation

The control variables in this case study are the various media alternatives, from which the physician's office must choose, in order to develop a local advertising campaign. The variables consist of the number of ads placed with specific local media during each of the four quarters of the next fiscal year. The candidate media include local radio stations, local periodical print media (newspapers and magazines), Internet website listings, church bulletins, and the local philharmonic publication. Most variables will be restricted to be general counting integers, while some are simple binary variables. Tables 1 through 6, included in Appendix A, provide a comprehensive list of the variables. The variable names chosen attempt to be descriptive of the particular associated media; in all cases, the last character of the variable name identifies the relevant fiscal quarter, 1 through 4. The model is built with 18 possible media and four quarters, and consequently, a total of 72 variables.

The various media sources were surveyed to determine the number of exposures per month (extrapolated over a three-month period) and the cost per ad, displayed in Table 7 below. Because the number of exposures and the cost per ad remains constant for each quarter for every media source except the Philharmonic books, only the data for Quarter 1 is shown in the table. The same values were used for Quarters 2, 3, and 4.

TABLE 7: Media Alternatives

Media	Total # of Exposures per quarter	Cost ($) per Ad	Media	Total # of Exposures per quarter	Cost ($) per Ad
WAJI1	170070	$37.50	**FWPAR1**	52800	$695.00
WLDE1	181914	$39.87	**YELLOF1**	669	$40.00
FWND1	290400	$148.75	**SUPER1**	1167	$123.00
FWNS1	842700	$214.10	**FWWEB1**	24000	$600.00
ABNE1	59400	$254.00	**STVIN1**	3300	$160.00
TIMDUP1	57000	$254.00	**LADY1**	2400	$287.00
FWNM1	97158	$348.03	**PHB1**	6000	$1,205.00
NILM1	156000	$1,215.00	**PHB2**	4300	$860.00
BUWM1	195900	$1,000.00	**PHB3**	4200	$860.00
MDNM1	12000	$630.00	**PHB4**	5000	$420.00
FWMON1	60000	$1,185.00			

This case will set budgetary targets for the planning year and each component quarter; these financial expense targets can be underachieved without concern. Goal Programming will be used to provide for reluctant overachievement of the budgetary targets should such be warranted. This will necessitate the need for a pair of deviation variables in each budgetary constraint. The notation of "$d_{targetID}$plus' and '$d_{targetID}$minus' will be used to designate the ten deviation variables for the five budgetary targets/goals.

Constraint Development

In a linear programming model, formal constraints capture the environment that the decision maker confronts. Such constraints may limit or prevent certain things from happening and force other things to happen. This case study has the following constraints:

Budgets

The pre-determined budget allocated for advertising expenditure is $30,000 for the year. Given the absence of seasonality, the annual budget is divided equally among the quarters; thus, the quarterly advertising budget is $7500. The following constraints describe the budget for Quarter 1, Quarter 2, Quarter 3, Quarter 4, and the annual budget, respectively. As acknowledged earlier, deviation variables were added to the budget constraints to allow for some flexibility and to not rule out an ideal media mix that oversteps the budget by only a small amount.

BDG1) 37.50WAJI1 + 39.87WLDE1 + 148.75FWND1 + 214.10FWNS1 + 254ABNE1 + 254TIMDUP1 + 348.03FWNM1 + 1215NILM1 + 630MDNM1 + 1000BUWM1 + 1185FWMON1 + 695FWPAR1 + 40YELLOF1 + 123SUPER1 + 600FWWEB1 + 160STVIN1 + 287LADY1 + 1205PHB1 + d1minus – d1plus = 7500

BGT2) 37.50WAJI2 + 39.87WLDE2 + 148.75FWND2 + 214.10FWNS2 + 254ABNE2 + 254TIMDUP2 + 348.03FWNM2 + 1215NILM2 + 630MDNM2 + 1000BUWM2 + 1185FWMON2 + 695FWPAR2 + 40YELLOF2 + 123SUPER2 + 600FWWEB2 + 160STVIN2 + 287LADY2 + 860PHB2 + d2minus – d2plus = 7500

BGT3) 37.50WAJI3 + 39.87WLDE3 + 148.75FWND3 + 214.10FWNS3 + 254ABNE3 + 254TIMDUP3 + 348.03FWNM3 + 1215NILM3 + 630MDNM3 + 1000BUWM3 + 1185FWMON3 + 695FWPAR3 + 40YELLOF3 + 123SUPER3 + 600FWWEB3 + 160STVIN3 + 287LADY3 + 420PHB3 + d3minus – d3plus = 7500

BGT4) 37.50WAJI4 + 39.87WLDE4 + 148.75FWND4 + 214.10FWNS4 + 254ABNE4 + 254TIMDUP4 + 348.03FWNM4 + 1215NILM4 + 630MDNM4 + 1000BUWM4 + 1185FWMON4 + 695FWPAR4 + 40YELLOF4 + 123SUPER4 + 600FWWEB4 + 160STVIN4 + 287LADY4 + 420PHB4 + d4minus – d4plus = 7500

BGTANN) 37.50WAJI1 + 37.50WAJI2 + 37.50WAJI3 + 37.50WAJI4 + 39.87WLDE1 + 39.87WLDE2 + 39.87WLDE3 + 30.87WLDE4 + 148.75FWND1 +148.75FWND2 + 148.75FWND3 + 148.75FWND4 + 214.10FWNS1 + 214.10FWNS2 + 214.10FWNS3 + 214.10FWNS4 + 254ABNE1 + 254ABNE2 + 254ABNE3 + 254ABNE4 + 254TIMDUP1 + 254TIMDUP2 + 254TIMDUP3 + 254TIMDUP4 + 348.03FWNM1 + 348.03FWNM2 + 348.03FWNM3 + 348.03FWNM4 + 1215NILM1 + 1215NILM2 + 1215NILM3 + 1215NILM4 + 630MDNM1 + 630MDNM2 + 630MDNM3 + 630MDNM4 + 1000BUWM1 + 1000BUWM2 + 1000BUWM3 + 1000BUWM4 + 1185FWMON1 + 1185FWMON2 + 1185FWMON3 + 1185FWMON4 + 695FWPAR1 + 695FWPAR2 + 695FWPAR3 + 695FWPAR4 + 40YELLOF1 + 40YELLOF2 + 40YELLOF3 + 40YELLOF4 + 123SUPER1 + 123SUPER2 + 123SUPER3 + 123SUPER4 + 600FWWEB1 + 600FWWEB2 + 600FWWEB3 + 600FWWEB4 +160STVIN1 + 160STVIN2 + 160STVIN3 + 160STVIN4 + 287LADY1 + 287LADY2 + 287LADY3 + 287LADY4 + 1205PHB1 + 860PHB2 + 420PHB3 + 420PHB4 + d5minus – d5plus = 30000

Media Usage Restriction

Decision models are typically designed to include 'policy' constraints, which reflect the decision maker's imposition on latitude provided for the ultimate recommendation. Forced diversification constraints typically fit that description, whether in financial portfolio models or advertising mix models. In this case, the physician's office has set the policy that no more than 20% of the annual budget should be used on any single media category. Since the 18 media options fall into six media categories, (newspaper, magazine, radio, Internet, church bulletin, and philharmonic books), six constraints will be used to enforce this desire for diversification. As representative of these constraints, the following enforces that cap for radio advertising collectively over the two targeted local stations (WAJI and WLDE):

RADBGT) 30WAJI1 + 30WAJI2 + 30WAJI3 + 30WAJI4 + 31.9WLDE1 + 31.9WLDE2 + 31.9WLDE3 + 31.9WLDE4 – 29.75FWND1 – 29.75FWND2 – 29.75FWND3 – 29.75FWND4 – 42.82FWNS1 - 42.82FWNS2 – 42.82FWNS3 – 42.82FWNS4 - 82FWNS4 – 50.8ABNE1 50.8ABNE2 50.8ABNE3 – 50.8ABNE4 – 50.8TIMDUP1 – 50.8TIMDUP2 – 50.8TIMDUP3 - 50.8TIMDUP4 - 50.8TIMDUP4 - 69.61FWNM1 – 69.61FWNM2 – 69.61FWNM3 – 69.61FWNM4 - 243NILM1 - 243NILM2 - 243NILM3 - 243NILM4 - 126MDNM1 - 126MDNM2 - 126MDNM3 - 126MDNM4 - 200BUWM1 - 200BUWM2 - 200BUWM3 - 200BUWM4 - 237FWMON1 - 237FWMON2 - 237FWMON3 - 237FWMON4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 8YELLOF1 - 8YELLOF2 - 8YELLOF3 - 8YELLOF4 – 24.6SUPER1 – 24.6SUPER2 – 24.6SUPER3 – 24.6SUPER4 - 120FWWEB1 - 120FWWEB2 - 120FWWEB3 - 120FWWEB4 - 32STVIN1 - 32STVIN2 - 32STVIN3 - 32STVIN4 – 57.4LADY1 – 57.4LADY2 – 57.4LADY3 – 57.4LADY4 - 241PHB1 – 172PHB2 - 172PHB3 - 84PHB4 <= 0

Newspaper Availability

The local newspapers *Aboite & About* and *Dupont Valley Times* only have 3 publications per quarter (1 per month). Therefore, the following trivial constraints were used for *Aboite & About* and for *Dupont Valley Times* for each quarter, respectively.

ABNEAV1) ABNE1 <= 3   **TIMDUPA1)** TIMDUP1 <= 3
ABNEAV2) ABNE2 <= 3   **TIMDUPA2)** TIMDUP2 <= 3
ABNEAV3) ABNE3 <= 3   **TIMDUPA3)** TIMDUP3 <= 3
ABNEAV4) ABNE4 <= 3   **TIMDUPA4)** TIMDUP4 <= 3

Magazine Requirement

Past results from advertising in local magazines have been quite positive. Consequently, another policy constraint is to always run at least one but no more than three magazine ads per quarter, so as not to over-saturate the market. Given the six distinct magazine candidates, the following constraints reflect the allowable window of magazine ads for the first quarter; the other quarters are handled in parallel fashion:

MAGMIN1) FWNM1 + NILM1 + BUWM1 + MDNM1 + FWMON1 + FWPAR1 >= 1
MAGMAX1) FWNM1 + NILM1 + BUWM1 + MDNM1 + FWMON1 + FWPAR1 <= 3

Church Bulletin Requirements

The physician is personally involved in two local church congregations (designated STVIN and LADY) and has requested that the possibility of advertising in the churches' weekly bulletins be considered in the model. For political reasons, he established the requirement that if either church bulletin is used then both church bulletins must be used. In other words, an ad must run in either both church bulletins or in neither. The following constraint enforces this policy for Quarter 1; the other quarters have parallel treatment:

CHB1) STVIN1 – LADY1 = 0

Media Diversity Requirements

Past experience in advertising has demonstrated that patients are attracted to the practice through a variety of media. Another policy to maintain a diverse advertising plan is to place at least one ad in each media category per quarter, with the exception of the church bulletins. The following constraints construct this requirement for the newspaper media category (with four paper options) for each of the four quarters; the other categories are treated in parallel fashion. (A constraint for a minimum of one magazine ad per quarter was previously established in the Magazine Requirement above.)

NEWREQ1) FWND1 + FWNS1 + ABNE1 + TIMDUP1 >= 1
NEWREQ2) FWND2 + FWNS2 + ABNE2 + TIMDUP2 >= 1
NEWREQ3) FWND3 + FWNS3 + ABNE3 + TIMDUP3 >= 1
NEWREQ4) FWND4 + FWNS4 + ABNE4 + TIMDUP4 >= 1

Philharmonic Contract Requirements

Advertising contracts with the Philharmonic state that advertisers may choose between two options: to purchase a full season plan (placing an ad in all 4 books) or a half season plan (placing an ad in books 1&2 or books 3&4). It was decided to also limit advertising to just one ad per book. The following constraints limit the selection to one ad per book for books 1&2, ensures that books 1&2 are linked together. Two similar constraints perform this linking function for books 3&4.

PH1) PHB1 + PHB2 <= 2
PHS1) PHB1 – PHB2 = 0

Binary Constraints

Selected variables in the model are binary; the variable is either on or off. When the variable is on, it also means that one ad will be used. For example, for YellowBook.com and for Superpages.com only one listing is necessary per Internet site (similar to the yellow page alphabetical listings in a traditional telephone directory). More than one listing would not make sense. And while the physician requested that the church bulletins be taken into consideration for the advertising plan, he also stated that at most only one ad should be used for each church bulletin. Finally, the Philharmonic books are only printed quarterly, and it was previously established that only one ad may be used per book. In sum, five distinct media alternatives for each of four possible quarters (i.e. twenty of the original 72 decision variables) were restricted to binary values.

Non-Negativity

The non-negativity constraints prevent the occurrence of an impractical solution, such as running a negative number of ads each quarter.
In sum, the model has a total of 47 constraints (not including non-negativity constraints), 39 of which are non-trivial constraints. The entire model can be found in Appendix B.

Objective Function

Goal programming was used to solve the model so that two goals with different priorities could be achieved. The two goals that the model sought to achieve were:
1) minimize the overachievement deviations of the quarterly and annual budget constraints, and 2) maximize the number of exposures generated from the media selection.

The first goal was achieved by running the model with the following objective function:

Minimize ∑ overachievement deviations of the five budget targets
(subject to the previously discussed constraints)

Minimizing the overspending for each quarter is important, but it is more critical that the annual budget was not exceeded. Therefore, because keeping to the annual budget was determined by the physician to be twice as important as keeping to each individual quarterly budget, a penalty weight coefficient of 2 was used for the deviation variable associated with the overachievement of the annual budget (i.e. d1plus + d2plus + d3plus + d4plus + 2d5plus)

The second goal was to maximize the annual number of exposures generated from the media selection. The total exposures from each media alternative for each quarter were added together in the following objective function:

Maximize ∑ exposures from media alternatives
(subject to the previously discussed constraints)

In order to enforce the first priority objective function (minimizing the overachievement of the quarterly and annual budgets) a constraint was added for the second objective function (i.e. G1) d1plus + d2plus + d3plus + d4plus + 2d5plus = optimal solution value from initial run).

Conceptual Model

The goal of the advertising campaign was to maximize the total number of annual exposures generated from an advertising plan while also minimizing overspending of the budget, subject to: annual and quarterly budgets and media usage requirements and limitations.

Using Goal Programming, the model appeared as:
Minimize: the overachievement of Quarter 1 budget, plus the overachievement of Quarter 2 budget, the overachievement of Quarter 3 budget, the overachievement of Quarter 4 budget, the overachievement of the annual budget (which is twice as important as each quarterly budget)
Subject to:
$\sum cost_{Q1}$ does not exceed Quarter i budget; i=1-4 (yet overachievement is reluctantly permitted)
$\sum cost_{Q1,Q2,Q3,Q4}$ does not exceed Annual budget; (yet overachievement is reluctantly permitted)
$\sum ad_i$ does not exceed 20% of budget (for each media category)
$\sum ad_{Aboite}$ $\sum ad_{Dupont}$ does not exceed 3 for each quarter
$\sum ad_{magazines}$ is at least 1 but no more than 3 each quarter
$\sum ad_{YellowBook}$ and $\sum ad_{Superpages}$ may only equal 0 or 1 for each quarter
$\sum ad_{STVIN}$ and $\sum ad_{LADY}$ must each be no greater than 1 and $\sum ad_{STVIN}$ must = $\sum ad_{LADY}$
$\sum ad_{PHB1}$ and $\sum ad_{PHB2}$ must each be no greater than 1 and $\sum ad_{PHB1}$ must = $\sum ad_{PHB2}$
$\sum ad_{PHB3}$ and $\sum ad_{PHB4}$ must each be no greater than 1 and $\sum ad_{PHB3}$ must = $\sum ad_{PHB4}$

Equation Model

Since this model is designed to capture two intents in distinct priorities, it is submitted to the optimization software (LINDO) sequentially by priority level.

First Priority Goal: The first priority intent is to minimize the overachievement deviation of the budget constraints.
i.e. MIN d1plus + d2plus + d3plus + d4plus + 2d5plus
subject to: {for the complete constraint set of 72 equations, see Appendix B}

Once that optimal solution has been established, the focus shifts to the second priority goal.

Second Priority Goal: The second goal is to **maximize annual exposures** (while maintaining the optimal value of the first goal) was achieved with the following objective function.

MAX

170070WAJI1 + 170070WAJI2 + 170070WAJI3 + 170070WAJI4 + 181914WLDE1 + 181914WLDE2 + 181914WLDE3 + 181914WLDE4 + 290400FWND1 + 290400FWND2 + 290400FWND3 + 290400FWND4 + 842700FWNS1 + 842700FWNS2 + 842700FWNS3 + 842700FWNS4 + 58400ABNE1 + 58400ABNE2 + 58400ABNE3 + 58400ABNE4 + 57000TIMDUP1 + 57000TIMDUP2 + 57000TIMDUP3 + 57000TIMDUP4 + 97158FWNM1 + 97158FWNM2 + 97158FWNM3 + 97158FWNM4 + 156000NILM1 + 156000NILM2 + 156000NILM3 + 156000NILM4 + 195900BUWM1 + 195900BUWM2 + 195900BUWM3 + 195900BUWM4 + 12000MDNM1 + 12000MDNM2 + 12000MDNM3 + 12000MDNM4 + 60000FWMON1 + 60000FWMON2 + 60000FWMON3 + 60000FWMON4 + 52800FWPAR1 + 52800FWPAR2 + 52800FWPAR3 + 52800FWPAR4 + 24000FWWEB1 + 24000FWWEB2 + 24000FWWEB3 + 24000FWWEB4 + 669YELLOF1 + 669YELLOF2 + 669YELLOF3 + 669YELLOF4 + 1167SUPER1 + 1167SUPER2 + 1167SUPER3 + 1167SUPER4 + 3300STVIN1 + 3300STVIN2 + 3300STVIN3 + 3300STVIN4 + 2400LADY1 + 2400LADY2 + 2400LADY3 + 2400LADY4 + 6000PHB1 + 4300PHB2 + 4200PHB3 + 5000PHB4

subject to: the same set of 72 constraints used in the first priority phase, plus a new restriction that enforces the optimal objective function value found in the first phase. This is accomplished via the inclusion of:

G1) d1plus + d2plus + d3plus + d4plus + 2d5plus = 0

Optimal Solution

After 1628 iterations and 89 branches through the "Branch and Bound" enforcement of the integer requirements, the multi-period advertising portfolio model produced the results summarized in Table 8 below. These values represent the recommended level of ads to purchase and the resulting deviations from the budgetary targets.

First Priority Goal: Objective Function = 0.0000

Because the first goal only sought to minimize the overachievement of the budget deviations, the value of the objective function is the only important output to be drawn from this initial run. Moreover, we learn that a mix of ads satisfying the constrained environment, without budget overruns, is indeed possible. The next optimization run addressed exposures while enforcing the optimal value of the first priority objective function (i.e. zero cost overruns).

Second Priority Goal: Objective Function Value = 55,952,240

Table 8: Optimal Portfolio of Advertisements

Variable	# of Ads	Variable	# of Ads	Variable	# of Ads
Radio Ads		Local Web-Based Ads		Local Magazine Ads	
WLDE1	89.000000	**FWWEB1**	2.000000	**FWNM1**	3.000000
WLDE2	4.000000	**FWWEB2**	5.000000	**FWNM4**	1.000000
WLDE3	79.000000	**YELLOF1**	1.000000	**BUWM2**	3.000000
WLDE4	23.000000	**YELLOF3**	1.000000	**BUWM3**	3.000000
Newspaper Ads		**YELLOF4**	1.000000	Positive Deviation Variables	
FWNS2	2.000000	**SUPER1**	1.000000	**D1minus**	20.48
FWNS4	19.000000	**SUPER1**	1.000000	**D2minus**	27.32
ABNE1	3.000000	**SUPER3**	1.000000	**D3minus**	5.27
ABNE4	3.000000	**SUPER4**	1.000000	**D4minus**	60.06
TIMDUP1	3.000000	Local Philharmonic Ads		**D5minus**	320.13
TIMDUP2	3.000000	**PHB3**	1.000000		
TIMDUP3	3.000000	**PHB4**	1.000000		
TIMDUP4	3.000000				

The resulting slack or surplus associated with each constraint is reported in Table 9 below; this enables the identification of binding constraints.

Table 9: Resulting Slack / Surplus for Each Constraint

Constraint	Slack / Surplus	Constraint	Slack / Surplus	Constraint	Slack / Surplus
BDG1	0.000000	TIMDUPA1	0.000000	RADREQ1	88.000000
BGT2	0.000000	TIMDUPA2	0.000000	RADREQ2	3.000000
BGT3	0.000000	TIMDUPA3	0.000000	RADREQ3	78.000000
BGT4	0.000000	TIMDUPA4	0.000000	RADREQ4	22.000000
BGTANN	0.000000	MAGMIN1	2.000000	NEWREQ1	5.000000
NEWBGT	10.509975	MAGMIN2	2.000000	NEWREQ2	4.000000
MAGBGT	230.489883	MAGMIN3	2.000000	NEWREQ3	2.000000
RADBGT	0.360056	MAGMIN4	0.000000	NEWREQ4	24.000000
INTBGT	2963.010010	MAGMAX1	0.000000	INTREQ1	3.000000
CHUBGT	7759.009766	MAGMAX2	0.000000	INTREQ2	5.000000
PHBBGT	6495.009766	MAGAMX3	0.000000	INTREQ3	1.000000
ABNEAV1	0.000000	MAGAMX4	2.000000	INTREQ4	1.000000
ABNEAV2	3.000000	CHB1	0.000000	PH1	2.000000
ABNEAV3	3.000000	CHB2	0.000000	PHS1	0.000000
ABNEAV4	0.000000	CHB3	0.000000	PH2	0.000000
		CHB4	0.000000	PHS2	0.000000
				G1	0.000000

The slack/surplus values reported above that have a value of 0.000000 are indicative of binding constraints. The slack/surplus values greater than 0.000000 are non-binding constraints. For example, row NEWBGT has a positive slack value of 10.509975, meaning that the optimal solution mix leaves $10.509975 in the newspaper budget's proportionate cap; consequently, this was not a binding issue.
The objective function value indicates 55,952,240 is the greatest number of exposures per year that can be generated by the advertising plan. The objective of the campaign design was to maximize the total number of exposures per year while also minimizing overspending of the budget. Therefore, it is not surprising that it chose some of the media alternatives with the highest number of exposures per dollar spent. (See Table 10 below for illustration.) Not all of the variables in the basis follow that logic, but there were several media requirements and limitations that affected the outcome.

TABLE 10: Exposures Per Dollar

Media	Total # of Exposures per quarter	Cost ($) per Ad	Ratio Exposures per $
WAJI1,2,3,4	170070	$37.50	4535.200000
***WLDE1,2,3,4**	181914	$39.87	4562.678706
FWND1,2,3,4	290400	$148.75	1952.268908
***FWNS1,2,3,4**	842700	$214.10	3936.011210
***ABNE1,2,3,4**	59400	$254.00	233.858268
***TIMDUP1,2,3,4**	57000	$254.00	224.409449
***FWNM1,2,3,4**	97158	$348.03	279.165589
NILM1,2,3,4	156000	$1,215.00	128.395062
***BUWM1,2,3,4**	195900	$1,000.00	195.900000
MDNM1,2,3,4	12000	$630.00	19.047619
FWMON1,2,3,4	60000	$1,185.00	50.632911
FWPAR1,2,3,4	52800	$695.00	75.971223
***YELLOF1,2,3,4**	669	$40.00	16.725000
***SUPER1,2,3,4**	1167	$123.00	9.487805
***FWWEB1,2,3,4**	24000	$600.00	40.000000
STVIN1,2,3,4	3300	$160.00	20.625000
LADY1,2,3,4	2400	$287.00	8.362369
PHB1	6000	$1,205.00	4.979253
PHB2	4300	$860.00	5.000000
***PHB3**	4200	$860.00	4.883721
***PHB4**	5000	$420.00	11.904762

* Variables in the basis

We note that the recommended portfolio includes some of each candidate media except for the church bulletins. The collection includes quarterly radio ads (all with the same station), quarterly newspaper ads, with a heavy emphasis on the fourth quarter, quarterly magazine ads, with a reduced emphasis on the fourth quarter, quarterly web-based ads, with emphasis on the first half of the year, and philharmonic ads placed in just books 3 and 4 (i.e. the 'half-season' option). This portfolio can be achieved without any budget overruns.

The included policy constraints did not require the church bulletins to be used; their absence in the optimal solution indicates that these ads do not receive a large amount of exposure relative to the cost of purchasing the ads. If the decision is made to continue to advertise in the church bulletins, for either personal or political reasons, it will be with the knowledge that it is not part of the recommended optimal mix.

The proposed media mix differs significantly from the existing mix. Currently, the physician has large amounts of advertising dollars invested in only one or two media at a time, and the mix changes frequently. This practice is indicative of a lack of experience with advertising and the vulnerable nature of the physician's office to impulsive decision making about local media. Also, driven by a fear that the return on investment will be low, long term commitments to any single advertising plan are rarely made. The substantial differences between the current plan and the recommended optimal mix are precisely the reason this study was necessary.

Sensitivity Analysis

Sensitivity analysis tests to see how the changes made to the parameters of model affect the optimal solution. Sensitivity analysis for the advertising portfolio model seeks to answer the following specific questions:

1. How will a change in the number of exposures generated from WLDE radio ads during Quarter 4 (WLDE4) affect the optimal solution? (i.e. a change in one selected objective function coefficient)
2. How will a change in the total annual budget affect the optimal solution? (i.e. a change in one right-hand-side target value)

Because the model enforced integer values via 'Branch and Bound', a meaningful and automated sensitivity analysis could not be obtained. Instead, it is necessary to "revise & resubmit" the model multiple times while varying one parameter in order to gauge its impact.

The first revision dealt with a change in a coefficient for the objective function. The optimal solution did not include any radio ads for WAJI for any quarter. The cost per ad for WAJI ($37.50) was less than the cost per ad for WLDE ($39.87), but WLDE delivered more exposures per dollar spent (4562.678606 Exp/$) than WAJI provided (4535.2 Exp/$), so it was not surprising that WLDE was chosen over WAJI. In order to determine how much the coefficient of WLDE4 affects the value of the objective function, it was changed and the model was resubmitted. In the first scenario, the number of exposures generated from WLDE4 is dropped from 181,914 to 90,000. (This could be result of the radio station going off air about halfway through the fourth quarter; or perhaps the station does not play Christmas music and so their listenership drops during the month of December.) In the second scenario, the number of exposures generated from WLDE4 is increased to 190,000. (Perhaps the station plays only Christmas music during Quarter 4, increasing the number listeners.) The same constraints were used from the original model. The results are displayed in Table 11.

Table 11: Varying a Coefficient in the Objective Function

Coefficient of WLDE4	Objective Function Value	Difference from Optimal Obj. Function Value
90,000	55,903,420	lose 48,820 exposures
181,914	55,952,240	0
190,000	55,973,720	gain 21,480 exposures

The results of Table 11 demonstrate a significant drop of 48,820 in the objective function value if WLDE were to lose listeners in Quarter 4. It also shows that an increase in this coefficient by 9,000 exposures for the quarter improves the objective function value by more than 21,000. The objective function value changes significantly in both scenarios, because the Basis also changes. The variables in the Basis when WLDE4 exposures drop to 90,000, and the variables in the basis when WLDE4 exposures rise to 190,000 are shown in Table 12 below. When just the value changes in response to the coefficient changes, just the value is highlighted; when the composition of the Basis changes as well, both the variable name and the value are highlighted.

TABLE 12: Comparison of the BASIS as One Coefficient Varies

Coeff of WLDE4 = 90,000		Coeff of WLDE4 = 181,914 (original case)		Coeff of WLDE4 = 190,000	
Variable	**Value**	**Variable**	**Value**		**Value**
***WAJI3**	1.000000	**WAJI3**	0.000000	**WAJI3**	0.000000
***WAJI4**	20.000000	**WAJI4**	0.000000	**WAJI4**	0.000000
***WLDE1**	32.000000	***WLDE1**	89.000000	***WLDE1**	69.000000
***WLDE2**	18.000000	***WLDE2**	4.000000	***WLDE2**	17.000000
***WLDE3**	125.000000	***WLDE3**	79.000000	***WLDE3**	74.000000
WLDE4	0.000000	***WLDE4**	23.000000	***WLDE4**	35.000000
***FWNS1**	2.000000	**FWNS1**	0.000000	**FWNS1**	0.000000
FWNS2	0.000000	***FWNS2**	2.000000	**FWNS2**	0.000000
FWNS3	0.000000	**FWNS3**	0.000000	***FWNS3**	2.000000
***FWNS4**	19.000000	***FWNS4**	19.000000	***FWNS4**	19.000000
***ABNE1**	3.000000	***ABNE1**	3.000000	***ABNE1**	3.000000
***ABNE4**	3.000000	***ABNE4**	3.000000	**ABNE4**	0.000000
***TIMDUP1**	3.000000	***TIMDUP1**	3.000000	***TIMDUP1**	3.000000
***TIMDUP2**	3.000000	***TIMDUP2**	3.000000	***TIMDUP2**	3.000000
***TIMDUP3**	3.000000	***TIMDUP3**	3.000000	***TIMDUP3**	2.000000
***TIMDUP4**	3.000000	***TIMDUP4**	3.000000	***TIMDUP4**	3.000000

FWNM1	0.000000	***FWNM1**	3.000000	**FWNM1**	0.000000
***FWNM3**	2.000000	**FWNM3**	0.000000	***FWNM3**	1.000000
***FWNM4**	2.000000	***FWNM4**	1.000000	***FWNM4**	2.000000
***BUWM1**	3.000000	**BUWM1**	0.000000	***BUWM1**	2.000000
***BUWM2**	3.000000	***BUWM2**	3.000000	***BUWM2**	3.000000
BUWM3	0.000000	***BUWM3**	3.000000	***BUWM3**	1.000000
***FWWEB1**	2.000000	***FWWEB1**	2.000000	***FWWEB1**	2.000000
***FWWEB2**	5.000000	***FWWEB2**	5.000000	***FWWEB2**	5.000000
***FWWEB3**	1.000000	**FWWEB3**	0.000000	**FWWEB3**	0.000000
YELLOF1	0.000000	***YELLOF1**	1.000000	**YELLOF1**	0.000000
YELLOF2	0.000000	**YELLOF2**	0.000000	***YELLOF2**	1.000000
YELLOF3	0.000000	***YELLOF3**	1.000000	***YELLOF3**	1.000000
***YELLOF4**	1.000000	***YELLOF4**	1.000000	**YELLOF4**	0.000000
SUPER1	0.000000	***SUPER1**	1.000000	**SUPER1**	0.000000
SUPER2	0.000000	***SUPER2**	1.000000	**SUPER2**	0.000000
SUPER3	0.000000	***SUPER3**	1.000000	**SUPER3**	0.000000
SUPER4	0.000000	***SUPER4**	1.000000	***SUPER4**	1.000000
***PHB3**	1.000000	***PHB3**	1.000000	***PHB3**	1.000000
***PHB4**	1.000000	***PHB4**	1.000000	***PHB4**	1.000000
D1MINUS	71.960022	**D1MINUS**	20.480099	**D1MINUS**	24.970074
D2MINUS	20.340019	**D2MINUS**	27.319992	**D2MINUS**	20.210018
D3MINUS	0.690136	**D3MINUS**	5.270084	**D3MINUS**	5.390068
D4MINUS	2.039886	**D4MINUS**	60.059910	**D4MINUS**	35.589924
D5MINUS	95.030060	**D5MINUS**	320.130035	**D5MINUS**	401.160004

*Variables in the basis

We note that reducing the effective audience reached by WLDE has brought the second radio station into the Basis. Each permutation recommends that the local Sunday newspaper still takes precedence over the daily paper, but with quite different quarterly ads, save for the fourth quarter. The actual recommended set of magazine ads changes dramatically, yet the Lakes Magazine, the MD News Magazine and the local Parenting Magazine are never recommended. The mix of Internet ads is also dependent upon this chosen parameter. While all cases recommend the same use of the philharmonic ads, and all share an avoidance of use of the church bulletins, we do find considerable responsiveness to plausible changes in the exposures (objective function coefficient) from WLDE4.

Sensitivity analysis was also performed by varying the right hand side value for one of the constraints. Because the model was tightly controlled by the budget constraints, the value of the annual budget constraint was selected to be changed in order to observe its impact.

In the first permutation, the annual budget constraint was decreased from $30,000 to $25,000. The change decreased the objective function value to 48,132,230 exposures per year. The second permutation increased the annual budget constraint by $5,000 to a new value of $35,000. The change increased the objective function value to 55,970,238 exposures per year. In each permutation, new variables entered the basis, creating a new media mix. These comparative results are in Table 13 below. As with the earlier analysis, when just the value changes in response to the parameter changes, just the value is highlighted; when the composition of the Basis changes as well, both the variable name and the value are highlighted.

TABLE 13: Comparison of the BASIS as One RHS Target Varies

RHS of Annual Budget = $25,000		RHS of Annual Budget = $25,000 (original case)		RHS of Annual Budget = $35,000	
Variable	**Value**	**Variable**	**Value**	**Variable**	**Value**
***WLDE1**	1.000000	***WLDE1**	89.000000	***WLDE1**	117.000000
***WLDE2**	3.000000	***WLDE2**	4.000000	***WLDE2**	18.000000
***WLDE3**	5.000000	***WLDE3**	79.000000	***WLDE3**	42.000000
***WLDE4**	132.000000	***WLDE4**	23.000000	***WLDE4**	18.000000
***FWNS1**	6.000000	**FWNS1**	0.000000	**FWNS1**	0.000000
***FWNS2**	8.000000	***FWNS2**	2.000000	**FWNS2**	0.000000
***FWNS3**	8.000000	**FWNS3**	0.000000	***FWNS3**	2.000000
***FWNS4**	2.000000	***FWNS4**	19.000000	***FWNS4**	19.000000
***ABNE1**	3.000000	***ABNE1**	3.000000	***ABNE1**	3.000000
ABNE4	0.000000	***ABNE4**	3.000000	***ABNE4**	3.000000
***TIMDUP1**	3.000000	***TIMDUP1**	3.000000	***TIMDUP1**	3.000000
***TIMDUP2**	3.000000	***TIMDUP2**	3.000000	***TIMDUP2**	3.000000
***TIMDUP3**	3.000000	***TIMDUP3**	3.000000	***TIMDUP3**	3.000000
***TIMDUP4**	3.000000	***TIMDUP4**	3.000000	***TIMDUP4**	3.000000
***FWNM1**	3.000000	***FWNM1**	3.000000	***FWNM1**	2.000000
***FWNM2**	2.000000	**FWNM2**	0.000000	**FWNM2**	0.000000
***FWNM4**	1.000000	***FWNM4**	1.000000	***FWNM4**	2.000000
BUWM2	0.000000	***BUWM2**	3.000000	***BUWM2**	3.000000
***BUWM3**	3.000000	***BUWM3**	3.000000	***BUWM3**	3.000000
***FWWEB1**	6.000000	***FWWEB1**	2.000000	***FWWEB1**	1.000000
***FWWEB2**	2.000000	***FWWEB2**	5.000000	***FWWEB2**	5.000000
***FWWEB3**	1.000000	**FWWEB3**	0.000000	**FWWEB3**	0.000000
YELLOF1	0.000000	***YELLOF1**	1.000000	**YELLOF1**	0.000000
***YELLOF2**	1.000000	**YELLOF2**	0.000000	**YELLOF2**	0.000000
YELLOF3	0.000000	***YELLOF3**	1.000000	**YELLOF3**	0.000000
***YELLOF4**	1.000000	***YELLOF4**	1.000000	***YELLOF4**	1.000000
SUPER1	0.000000	***SUPER1**	1.000000	**SUPER1**	0.000000
SUPER2	0.000000	***SUPER2**	1.000000	**SUPER2**	0.000000
SUPER3	0.000000	***SUPER3**	1.000000	**SUPER3**	0.000000
***SUPER4**	1.000000	***SUPER4**	1.000000	**SUPER4**	0.000000
***PHB3**	1.000000	***PHB3**	1.000000	***PHB3**	1.000000
***PHB4**	1.000000	***PHB4**	1.000000	***PHB4**	1.000000
D1MINUS	7.439968	**D1MINUS**	20.480099	**D1MINUS**	15.150127

D2MINUS	2969.530029	**D2MINUS**	27.319992	**D2MINUS**	20.340019
D3MINUS	805.849976	**D3MINUS**	5.270084	**D3MINUS**	15.260033
D4MINUS	115.930130	**D4MINUS**	60.059910	**D4MINUS**	34.379906
D5MINUS	86.749756	**D5MINUS**	320.130035	**D5MINUS**	5247.129883

* Variables in the basis

Each of the annual budgetary permutations shares certain commonalities with the original case, these include: 1) all propose only one radio station (WLDE) yet with quite different quarterly recommendations; 2) all use the Sunday newspaper rather than the daily paper; 3) use of neighborhood papers, local magazines, and philharmonic ads (and absence of church bulletin ads) show considerable stability; 4) the most responsive set of recommended ads appears to be the mix of those using the Internet.

In sum, by using a ‘revise and resubmit’ approach on selected parameters, we are able to formalize the impact on both the final recommended media mix and the resulting exposures that might be attributed to changes in such parameters in the design of the model. Sensitivity analysis enables the decision maker to make informed responses to changes in a dynamic world. While such post-optimality analysis has been done above only for two parameters of interest, it could be undertaken for any/all of the parameters around which the model is built.

Conclusions and Directions for Future Research

The purpose of the advertising portfolio model was to discover the optimal mix of media alternatives to maximize exposures given budget constraints and media usage requirements and limitations. Goal programming was implemented by introducing deviation variables to the budget constraints to allow for flexibility in the solution. The solution produced from the model is meaningful and will guide the physician’s office in purchasing advertising space in the various media sources. The media sources used for this model were all sources with which the physician was already familiar. Further research could be done to investigate other media alternatives available in the area, including television, email, and direct mail advertising.

It may also be worthwhile to re-discuss some of the constraints that require a minimum amount of a certain media source or that limit the use of a media source. Rather than diversify the mix in that manner, perhaps a quality rating system could be used, and only media that meet a specific quality requirement may be used.

Optimization modeling has seemingly endless potential for developing and solving models that can assist in making optimal business decisions. The health-care industry has only begun to link its relatively recent open attitude regarding advertising with optimization techniques that can assist the medical practitioner ‘do the best it can with what it has to work with’. The ‘prognosis is good’ for a contributing role for advertising in this professional service industry.

Appendix A: The Decision Variables

Table 1: Radio Alternatives

Variable Symbol	Variable Description	Variable Type
WAJI1	Number of 60s radio ads on WAJI in Quarter 1	Counting Integer
WAJI2	Number of 60s radio ads on WAJI in Quarter 2	Counting Integer
WAJI3	Number of 60s radio ads on WAJI in Quarter 3	Counting Integer
WAJI4	Number of 60s radio ads on WAJI in Quarter 4	Counting Integer
WLDE1	Number of 60s radio ads on WLDE in Quarter 1	Counting Integer
WLDE2	Number of 60s radio ads on WLDE in Quarter 2	Counting Integer
WLDE3	Number of 60s radio ads on WLDE in Quarter 3	Counting Integer
WLDE4	Number of 60s radio ads on WLDE in Quarter 4	Counting Integer

Table 2: Newspaper Alternatives

Symbol	Variable Description	Variable Type
FWND1	Number of 2x5 ads in the daily newspaper in Quarter 1	Counting Integer
FWND2	Number of 2x5 ads in the daily newspaper in Quarter 2	Counting Integer
FWND3	Number of 2x5 ads in the daily newspaper in Quarter 3	Counting Integer
FWND4	Number of 2x5 ads in the daily newspaper in Quarter 4	Counting Integer
FWNS1	Number of 2x5 ads in the Sunday newspaper in Quarter 1	Counting Integer
FWNS2	Number of 2x5 ads in the Sunday newspaper in Quarter 2	Counting Integer
FWNS3	Number of 2x5 ads in the Sunday newspaper in Quarter 3	Counting Integer
FWNS4	Number of 2x5 ads in the Sunday newspaper in Quarter 4	Counting Integer
ABNE1	Number of 1/4 page ads in Aboite & About newspaper in Quarter 1	Counting Integer
ABNE2	Number of 1/4 page ads in Aboite & About newspaper in Quarter 2	Counting Integer
ABNE3	Number of 1/4 page ads in Aboite & About newspaper in Quarter 3	Counting Integer
ABNE4	Number of 1/4 page ads in Aboite & About newspaper in Quarter 4	Counting Integer
TIMDUP1	Number of 1/4 page ads in Dupont Valley Times newspaper in Quarter 1	Counting Integer
TIMDUP2	Number of 1/4 page ads in Dupont Valley Times newspaper in Quarter 2	Counting Integer

TIMDUP3	Number of 1/4 page ads in Dupont Valley Times newspaper in Quarter 3	Counting Integer
TIMDUP4	Number of 1/4 page ads in Dupont Valley Times newspaper in Quarter 4	Counting Integer

Table 3: Magazine Alternatives

Symbol	Variable Description	Variable Type
FWNM1	Number of 1/2 page ads in FW Newspapers Magazine in Quarter 1	Counting Integer
FWNM2	Number of 1/2 page ads in FW Newspapers Magazine in Quarter 2	Counting Integer
FWNM3	Number of 1/2 page ads in FW Newspapers Magazine in Quarter 3	Counting Integer
FWNM4	Number of 1/2 page ads in FW Newspapers Magazine in Quarter 4	Counting Integer
NILM1	Number of 1/2 page ads in Northern IN Lakes Magazine in Quarter 1	Counting Integer
NILM2	Number of 1/2 page ads in Northern IN Lakes Magazine in Quarter 2	Counting Integer
NILM3	Number of 1/2 page ads in Northern IN Lakes Magazine in Quarter 3	Counting Integer
NILM4	Number of 1/2 page ads in Northern IN Lakes Magazine in Quarter 4	Counting Integer
BUWM1	Number of 1/3 page ads in Business Women Magazine in Quarter 1	Counting Integer
BUWM2	Number of 1/3 page ads in Business Women Magazine in Quarter 2	Counting Integer
BUWM3	Number of 1/3 page ads in Business Women Magazine in Quarter 3	Counting Integer
BUWM4	Number of 1/3 page ads in Business Women Magazine in Quarter 4	Counting Integer
MDNM1	Number of 1/4 page ads in MD News Magazine in Quarter 1	Counting Integer
MDNM2	Number of 1/4 page ads in MD News Magazine in Quarter 2	Counting Integer
MDNM3	Number of 1/4 page ads in MD News Magazine in Quarter 3	Counting Integer
MDNM4	Number of 1/4 page ads in MD News Magazine in Quarter 4	Counting Integer
FWMON1	Number of 1/4 page ads in FW Monthly Magazine in Quarter 1	Counting Integer
FWMON2	Number of 1/4 page ads in FW Monthly Magazine in Quarter 2	Counting Integer
FWMON3	Number of 1/4 page ads in FW Monthly Magazine in Quarter 3	Counting Integer

FWMON4	Number of 1/4 page ads in FW Monthly Magazine in Quarter 4	Counting Integer
FWPAR1	Number of 1/4 page ads in FW Parenting Magazine in Quarter 1	Counting Integer
FWPAR2	Number of 1/4 page ads in FW Parenting Magazine in Quarter 2	Counting Integer
FWPAR3	Number of 1/4 page ads in FW Parenting Magazine in Quarter 3	Counting Integer
FWPAR4	Number of 1/4 page ads in FW Parenting Magazine in Quarter 4	Counting Integer

Table 4: Internet Alternative

Symbol	Variable Description	Variable Type
FWWEB1	Number 160x9 ads on FortWayne.com in Quarter 1	Counting Integer
FWWEB2	Number 160x9 ads on FortWayne.com in Quarter 2	Counting Integer
FWWEB3	Number 160x9 ads on FortWayne.com in Quarter 3	Counting Integer
FWWEB4	Number 160x9 ads on FortWayne.com in Quarter 4	Counting Integer
YELLOF1	Number of website listings on YellowBook.com in Quarter 1	Binary Integer
YELLOF2	Number of website listings on YellowBook.com in Quarter 2	Binary Integer
YELLOF3	Number of website listings on YellowBook.com in Quarter 3	Binary Integer
YELLOF4	Number of website listings on YellowBook.com in Quarter 4	Binary Integer
SUPER1	Number of website listings on Superpages.com in Quarter 1	Binary Integer
SUPER2	Number of website listings on Superpages.com in Quarter 2	Binary Integer
SUPER3	Number of website listings on Superpages.com in Quarter 3	Binary Integer
SUPER4	Number of website listings on Superpages.com in Quarter 4	Binary Integer

Table 5: Church Bulletin Alternatives

Symbol	Variable Description	Variable Type
STVIN1	Number of 3x3 ads in St. Vincent Catholic Church bulletin in Quarter 1	Binary Integer
STVIN2	Number of 3x3 ads in St. Vincent Catholic Church bulletin in Quarter 2	Binary Integer
STVIN3	Number of 3x3 ads in St. Vincent Catholic Church bulletin in Quarter 3	Binary Integer
STVIN4	Number of 3x3 ads in St. Vincent Catholic Church bulletin in Quarter 4	Binary Integer
LADY1	Number of 3x3 ads in Our Lady of Good Hope Catholic Church bulletin in Quarter 1	Binary Integer
LADY2	Number of 3x3 ads in Our Lady of Good Hope Catholic Church bulletin in Quarter 2	Binary Integer
LADY3	Number of 3x3 ads in Our Lady of Good Hope Catholic Church bulletin in Quarter 3	Binary Integer
LADY4	Number of 3x3 ads in Our Lady of Good Hope Catholic Church bulletin in Quarter 4	Binary Integer

Table 6: Philharmonic Book Alternatives

Symbol	Variable Description	Variable Type
PHB1	Number of 1/3 page ads in FW Philharmonic Book 1 (Quarter 1)	Binary Integer
PHB2	Number of 1/3 page ads in FW Philharmonic Book 2 (Quarter 2)	Binary Integer
PHB3	Number of 1/3 page ads in FW Philharmonic Book 3 (Quarter 3)	Binary Integer
PHB4	Number of 1/3 page ads in FW Philharmonic Book 4 (Quarter 4)	Binary Integer

Appendix B: The Full Equation Model

First Goal:

The following is the full equation model for the first goal to minimize the overachievement deviation of the budget constraints.

MIN d1plus + d2plus + d3plus + d4plus + 2d5plus
ST
BDG1) 37.50WAJI1 + 39.87WLDE1 + 148.75FWND1 + 214.10FWNS1 + 254ABNE1 + 254TIMDUP1 + 348.03FWNM1 + 1215NILM1 + 630MDNM1 + 1000BUWM1 + 1185FWMON1 + 695FWPAR1 + 40YELLOF1 + 123SUPER1 + 600FWWEB1 + 160STVIN1 + 287LADY1 + 1205PHB1 + d1minus – d1plus = 7500
BGT2) 37.50WAJI2 + 39.87WLDE2 + 148.75FWND2 + 214.10FWNS2 + 254ABNE2 + 254TIMDUP2 + 348.03FWNM2 + 1215NILM2 + 630MDNM2 + 1000BUWM2 + 1185FWMON2 + 695FWPAR2 + 40YELLOF2 + 123SUPER2 + 600FWWEB2 + 160STVIN2 + 287LADY2 + 860PHB2 + d2minus – d2plus = 7500

BGT3) 37.50WAJI3 + 39.87WLDE3 + 148.75FWND3 + 214.10FWNS3 + 254ABNE3 + 254TIMDUP3 + 348.03FWNM3 + 1215NILM3 + 630MDNM3 + 1000BUWM3 + 1185FWMON3 + 695FWPAR3 + 40YELLOF3 + 123SUPER3 + 600FWWEB3 + 160STVIN3 + 287LADY3 + 420PHB3 + d3minus – d3plus = 7500
BGT4) 37.50WAJI4 + 39.87WLDE4 + 148.75FWND4 + 214.10FWNS4 + 254ABNE4 + 254TIMDUP4 + 348.03FWNM4 + 1215NILM4 + 630MDNM4 + 1000BUWM4 + 1185FWMON4 + 695FWPAR4 + 40YELLOF4 + 123SUPER4 + 600FWWEB4 + 160STVIN4 + 287LADY4 + 420PHB4 + d4minus – d4plus = 7500
BGTANN) 37.50WAJI1 + 37.50WAJI2 + 37.50WAJI3 + 37.50WAJI4 + 39.87WLDE1 + 39.87WLDE2 + 39.87WLDE3 + 30.87WLDE4 + 148.75FWND1 +148.75FWND2 + 148.75FWND3 + 148.75FWND4 + 214.10FWNS1 + 214.10FWNS2 + 214.10FWNS3 + 214.10FWNS4 + 254ABNE1 + 254ABNE2 + 254ABNE3 + 254ABNE4 + 254TIMDUP1 + 254TIMDUP2 + 254TIMDUP3 + 254TIMDUP4 + 348.03FWNM1 + 348.03FWNM2 + 348.03FWNM3 + 348.03FWNM4 + 1215NILM1 + 1215NILM2 + 1215NILM3 + 1215NILM4 + 630MDNM1 + 630MDNM2 + 630MDNM3 + 630MDNM4 + 1000BUWM1 + 1000BUWM2 + 1000BUWM3 + 1000BUWM4 + 1185FWMON1 + 1185FWMON2 + 1185FWMON3 + 1185FWMON4 + 695FWPAR1 + 695FWPAR2 + 695FWPAR3 + 695FWPAR4 + 40YELLOF1 + 40YELLOF2 + 40YELLOF3 + 40YELLOF4 + 123SUPER1 + 123SUPER2 + 123SUPER3 + 123SUPER4 + 600FWWEB1 + 600FWWEB2 + 600FWWEB3 + 600FWWEB4 +160STVIN1 + 160STVIN2 + 160STVIN3 + 160STVIN4 + 287LADY1 + 287LADY2 + 287LADY3 + 287LADY4 + 1205PHB1 + 860PHB2 + 420PHB3 + 420PHB4 + d5minus – d5plus = 30000
NEWBGT) 119FWND1 +119FWND2 + 119FWND3 + 119FWND4 + 171.28FWNS1 + 171.28FWNS2 + 171.28FWNS3 + 171.28FWNS4 - 7.5WAJI1 - 7.5WAJI2 - 7.5WAJI3 - 7.5WAJI4 - 7.97WLDE1 - 7.97WLDE2 - 7.97WLDE3 - 7.97WLDE4 - 82FWNS4 – 50.8ABNE1 50.8ABNE2 50.8ABNE3 – 50.8ABNE4 – 50.8TIMDUP1 – 50.8TIMDUP2 – 50.8TIMDUP3 - 50.8TIMDUP4 - 69.61FWNM1 – 69.61FWNM2 – 69.61FWNM3 – 69.61FWNM4 - 243NILM1 - 243NILM2 - 243NILM3 - 243NILM4 - 126MDNM1 - 126MDNM2 - 126MDNM3 - 126MDNM4 - 200BUWM1 - 200BUWM2 - 200BUWM3 - 200BUWM4 - 237FWMON1 - 237FWMON2 - 237FWMON3 - 237FWMON4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 8YELLOF1 - 8YELLOF2 - 8YELLOF3 - 8YELLOF4 – 24.6SUPER1 – 24.6SUPER2 – 24.6SUPER3 – 24.6SUPER4 - 120FWWEB1 - 120FWWEB2 - 120FWWEB3 - 120FWWEB4 - 32STVIN1 - 32STVIN2 - 32STVIN3 - 32STVIN4 – 57.4LADY1 – 57.4LADY2 – 57.4LADY3 – 57.4LADY4 - 241PHB1 – 172PHB2 - 172PHB3 - 84PHB4 <= 0
MAGBGT) 278.42FWNM1 + 278.42FWNM2 + 278.42FWNM3 + 278.42FWNM4 + 972NILM1 + 972NILM2 + 972NILM3 + 972NILM4 + 504MDNM1 + 504MDNM2 + 504MDNM3 + 504MDNM4 + 800BUWM1 + 800BUWM2 + 800BUWM3 + 800BUWM4 + 948FWMON1 + 948FWMON2 + 948FWMON3 + 948FWMON4 + 556FWPAR1 + 556FWPAR2 + 556FWPAR3 + 556FWPAR4 - 7.5WAJI1 - 7.5WAJI2 - 7.5WAJI3 - 7.5WAJI4 - 7.97WLDE1 - 7.97WLDE2 - 7.97WLDE3 - 7.97WLDE4 – 29.75FWND1 – 29.75FWND2 – 29.75FWND3 – 29.75FWND4 – 42.82FWNS1 - 42.82FWNS2 – 42.82FWNS3 – 42.82FWNS4 - 82FWNS4 – 50.8ABNE1 50.8ABNE2 50.8ABNE3 – 50.8ABNE4 – 50.8TIMDUP1 – 50.8TIMDUP2 – 50.8TIMDUP3 - 50.8TIMDUP4 - 8YELLOF1 - 8YELLOF2 - 8YELLOF3 - 8YELLOF4 – 24.6SUPER1 –

24.6SUPER2 – 24.6SUPER3 – 24.6SUPER4 - 120FWWEB1 - 120FWWEB2 - 120FWWEB3 - 120FWWEB4 - 32STVIN1 - 32STVIN2 - 32STVIN3 - 32STVIN4 – 57.4LADY1 – 57.4LADY2 – 57.4LADY3 – 57.4LADY4 - 241PHB1 – 172PHB2 - 172PHB3 - 84PHB4 <= 0

RADBGT) 30WAJI1 + 30WAJI2 + 30WAJI3 + 30WAJI4 + 31.9WLDE1 + 31.9WLDE2 + 31.9WLDE3 + 31.9WLDE4 – 29.75FWND1 – 29.75FWND2 – 29.75FWND3 – 29.75FWND4 – 42.82FWNS1 - 42.82FWNS2 – 42.82FWNS3 – 42.82FWNS4 - 82FWNS4 – 50.8ABNE1 50.8ABNE2 50.8ABNE3 – 50.8ABNE4 – 50.8TIMDUP1 – 50.8TIMDUP2 – 50.8TIMDUP3 - 50.8TIMDUP4 - 50.8TIMDUP4 - 69.61FWNM1 – 69.61FWNM2 – 69.61FWNM3 – 69.61FWNM4 - 243NILM1 - 243NILM2 - 243NILM3 - 243NILM4 - 126MDNM1 - 126MDNM2 - 126MDNM3 - 126MDNM4 - 200BUWM1 - 200BUWM2 - 200BUWM3 - 200BUWM4 - 237FWMON1 - 237FWMON2 - 237FWMON3 - 237FWMON4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 8YELLOF1 - 8YELLOF2 - 8YELLOF3 - 8YELLOF4 – 24.6SUPER1 – 24.6SUPER2 – 24.6SUPER3 – 24.6SUPER4 - 120FWWEB1 - 120FWWEB2 - 120FWWEB3 - 120FWWEB4 - 32STVIN1 - 32STVIN2 - 32STVIN3 - 32STVIN4 – 57.4LADY1 – 57.4LADY2 – 57.4LADY3 – 57.4LADY4 - 241PHB1 – 172PHB2 - 172PHB3 - 84PHB4 <= 0

INTBGT) 32YELLOF1 + 32YELLOF2 + 32YELLOF3 + 32YELLOF4 + 98.4SUPER1 + 98.4SUPER2 + 98.4SUPER3 + 98.4SUPER4 + 480FWWEB1 + 480FWWEB2 + 480FWWEB3 + 480FWWEB4 – 7.5WAJI1 - 7.5WAJI2 - 7.5WAJI3 - 7.5WAJI4 - 7.97WLDE1 - 7.97WLDE2 - 7.97WLDE3 - 7.97WLDE4 – 29.75FWND1 – 29.75FWND2 – 29.75FWND3 – 29.75FWND4 – 42.82FWNS1 - 42.82FWNS2 – 42.82FWNS3 – 42.82FWNS4 - 82FWNS4 – 50.8ABNE1 50.8ABNE2 50.8ABNE3 – 50.8ABNE4 – 50.8TIMDUP1 – 50.8TIMDUP2 – 50.8TIMDUP3 - 50.8TIMDUP4 - 50.8TIMDUP4 - 69.61FWNM1 – 69.61FWNM2 – 69.61FWNM3 – 69.61FWNM4 - 243NILM1 - 243NILM2 - 243NILM3 - 243NILM4 - 126MDNM1 - 126MDNM2 - 126MDNM3 - 126MDNM4 - 200BUWM1 - 200BUWM2 - 200BUWM3 - 200BUWM4 - 237FWMON1 - 237FWMON2 - 237FWMON3 - 237FWMON4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 32STVIN1 - 32STVIN2 - 32STVIN3 - 32STVIN4 – 57.4LADY1 – 57.4LADY2 – 57.4LADY3 – 57.4LADY4 - 241PHB1 – 172PHB2 - 172PHB3 - 84PHB4 <= 0

CHUBGT) 128STVIN1 + 128STVIN2 + 128STVIN3 + 128STVIN4 + 229.6LADY1 + 229.6LADY2 + 229.6LADY3 + 229.6LADY4 – 7.5WAJI1 - 7.5WAJI2 - 7.5WAJI3 - 7.5WAJI4 - 7.97WLDE1 - 7.97WLDE2 - 7.97WLDE3 - 7.97WLDE4 – 29.75FWND1 – 29.75FWND2 – 29.75FWND3 – 29.75FWND4 – 42.82FWNS1 - 42.82FWNS2 – 42.82FWNS3 – 42.82FWNS4 - 82FWNS4 – 50.8ABNE1 50.8ABNE2 50.8ABNE3 – 50.8ABNE4 – 50.8TIMDUP1 – 50.8TIMDUP2 – 50.8TIMDUP3 - 50.8TIMDUP4 - 50.8TIMDUP4 - 69.61FWNM1 – 69.61FWNM2 – 69.61FWNM3 – 69.61FWNM4 - 243NILM1 - 243NILM2 - 243NILM3 - 243NILM4 - 126MDNM1 - 126MDNM2 - 126MDNM3 - 126MDNM4 - 200BUWM1 - 200BUWM2 - 200BUWM3 - 200BUWM4 - 237FWMON1 - 237FWMON2 - 237FWMON3 - 237FWMON4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 8YELLOF1 - 8YELLOF2 - 8YELLOF3 - 8YELLOF4 – 24.6SUPER1 – 24.6SUPER2 – 24.6SUPER3 – 24.6SUPER4 - 120FWWEB1 -

120FWWEB2 - 120FWWEB3 - 120FWWEB4 - 241PHB1 – 172PHB2 - 172PHB3 - 84PHB4 <= 0
PHBBGT) 964PHB1 + 688PHB2 + 688PHB3 + 336PHB4 – 7.5WAJI1 - 7.5WAJI2 - 7.5WAJI3 - 7.5WAJI4 - 7.97WLDE1 - 7.97WLDE2 - 7.97WLDE3 - 7.97WLDE4 – 29.75FWND1 – 29.75FWND2 – 29.75FWND3 – 29.75FWND4 – 42.82FWNS1 - 42.82FWNS2 – 42.82FWNS3 – 42.82FWNS4 - 82FWNS4 – 50.8ABNE1 50.8ABNE2 50.8ABNE3 – 50.8ABNE4 – 50.8TIMDUP1 – 50.8TIMDUP2 – 50.8TIMDUP3 - 50.8TIMDUP4 - 50.8TIMDUP4 - 69.61FWNM1 – 69.61FWNM2 – 69.61FWNM3 – 69.61FWNM4 - 243NILM1 - 243NILM2 - 243NILM3 - 243NILM4 - 126MDNM1 - 126MDNM2 - 126MDNM3 - 126MDNM4 - 200BUWM1 - 200BUWM2 - 200BUWM3 - 200BUWM4 - 237FWMON1 - 237FWMON2 - 237FWMON3 - 237FWMON4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 139FWPAR1 - 139FWPAR2 - 139FWPAR3 - 139FWPAR4 - 8YELLOF1 - 8YELLOF2 - 8YELLOF3 - 8YELLOF4 – 24.6SUPER1 – 24.6SUPER2 – 24.6SUPER3 – 24.6SUPER4 - 120FWWEB1 - 120FWWEB2 - 120FWWEB3 - 120FWWEB4 - 32STVIN1 - 32STVIN2 - 32STVIN3 - 32STVIN4 – 57.4LADY1 – 57.4LADY2 – 57.4LADY3 – 57.4LADY4 <= 0
ABNEAV1) ABNE1 <= 3
ABNEAV2) ABNE2 <= 3
ABNEAV3) ABNE3 <= 3
ABNEAV4) ABNE4 <= 3
TIMDUPA1) TIMDUP1 <= 3
TIMDUPA2) TIMDUP2 <= 3
TIMDUPA3) TIMDUP3 <= 3
TIMDUPA4) TIMDUP4 <= 3
MAGMIN1) FWNM1 + NILM1 + BUWM1 + MDNM1 + FWMON1 + FWPAR1 >= 1
MAGMIN2) FWNM2 + NILM2 + BUWM2 + MDNM2 + FWMON2 + FWPAR2 >= 1
MAGMIN3) FWNM3 + NILM3 + BUWM3 + MDNM3 + FWMON3 + FWPAR3 >= 1
MAGMIN4) FWNM4 + NILM4 + BUWM4 + MDNM4 + FWMON4 + FWPAR4 >= 1
MAGMAX1) FWNM1 + NILM1 + BUWM1 + MDNM1 + FWMON1 + FWPAR1 <= 3
MAGMAX2) FWNM2 + NILM2 + BUWM2 + MDNM2 + FWMON2 + FWPAR2 <= 3
MAGMAX3) FWNM3 + NILM3 + BUWM3 + MDNM3 + FWMON3 + FWPAR3 <= 3
MAGMAX4) FWNM4 + NILM4 + BUWM4 + MDNM4 + FWMON4 + FWPAR4 <= 3
CHB1) STVIN1 – LADY1 = 0
CHB2) STVIN2 – LADY2 = 0
CHB3) STVIN3 – LADY3 = 0
CHB4) STVIN4 – LADY4 = 0
RADREQ1) WAJI1 + WLDE1 >= 1
RADREQ2) WAJI2 + WLDE2 >= 1
RADREQ3) WAJI3 + WLDE3 >= 1
RADREQ4) WAJI4 + WLDE4 >= 1
NEWREQ1) FWND1 + FWNS1 + ABNE1 + TIMDUP1 >= 1
NEWREQ2) FWND2 + FWNS2 + ABNE2 + TIMDUP2 >= 1
NEWREQ3) FWND3 + FWNS3 + ABNE3 + TIMDUP3 >= 1
NEWREQ4) FWND4 + FWNS4 + ABNE4 + TIMDUP4 >= 1
INTREQ1) YELLOF1 + SUPER1 + FWWEB1 >= 1

INTREQ2) YELLOF2 + SUPER2 + FWWEB2 >= 1
INTREQ3) YELLOF3 + SUPER3 + FWWEB3 >= 1
INTREQ4) YELLOF4 + SUPER4 + FWWEB4 >= 1
PH1) PHB1 + PHB2 <= 2
PHS1) PHB1 – PHB2 = 0
PH2) PHB3 + PHB4 <= 2
PHS2) PHB3 – PHB4 = 0
END

Second Goal:

The second goal (to maximize annual exposures while maintaining the first goal) was achieved with the following objective function.

MAX
170070WAJI1 + 170070WAJI2 + 170070WAJI3 + 170070WAJI4 + 181914WLDE1 + 181914WLDE2 + 181914WLDE3 + 181914WLDE4 + 290400FWND1 + 290400FWND2 + 290400FWND3 + 290400FWND4 + 842700FWNS1 + 842700FWNS2 + 842700FWNS3 + 842700FWNS4 + 58400ABNE1 + 58400ABNE2 + 58400ABNE3 + 58400ABNE4 + 57000TIMDUP1 + 57000TIMDUP2 + 57000TIMDUP3 + 57000TIMDUP4 + 97158FWNM1 + 97158FWNM2 + 97158FWNM3 + 97158FWNM4 + 156000NILM1 + 156000NILM2 + 156000NILM3 + 156000NILM4 + 195900BUWM1 + 195900BUWM2 + 195900BUWM3 + 195900BUWM4 + 12000MDNM1 + 12000MDNM2 + 12000MDNM3 + 12000MDNM4 + 60000FWMON1 + 60000FWMON2 + 60000FWMON3 + 60000FWMON4 + 52800FWPAR1 + 52800FWPAR2 + 52800FWPAR3 + 52800FWPAR4 + 24000FWWEB1 + 24000FWWEB2 + 24000FWWEB3 + 24000FWWEB4 + 669YELLOF1 + 669YELLOF2 + 669YELLOF3 + 669YELLOF4 + 1167SUPER1 + 1167SUPER2 + 1167SUPER3 + 1167SUPER4 + 3300STVIN1 + 3300STVIN2 + 3300STVIN3 + 3300STVIN4 + 2400LADY1 + 2400LADY2 + 2400LADY3 + 2400LADY4 + 6000PHB1 + 4300PHB2 + 4200PHB3 + 5000PHB4

ST
BDG1)…
.
. as before
.

PHS2) PHB3 – PHB4 = 0
G1) d1plus + d2plus + d3plus + d4plus + 2d5plus = 0
END

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