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Applications of operations research in advertising media

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ABSTRACT

Undoubtedly one of the most crucial functions in a service or product's life is the prospect of it being most efficiently marketed to its potential customers. This makes advertising one of the most important functions of a firm. Efficient and effective marketing involves soliciting and engaging best possible market segments and providing vital information about the product's existence to existing and prospective users. Any advertising endeavor is structured in a manner that it has a powerful impact on the segments targeted in a given budgetary constraint and a set of quantitative, qualitative constraints. The paper talks about the use of linear programming models and regression analysis which are used in the optimum selection of media to maximize profits under given budgetary constraints. It also talks about the limitations of using the above-mentioned techniques. In an ever-changing, competitive environment and the existence of various products that have to be marketed by the same firm, operations research provides flexibility in decision making by providing various alternative feasible solutions.

1. INTRODUCTION

In this paper, we talk about how operations research techniques are used and can further be used in advertising.

According to Robert Goodell Brown, "Operations Research is the quantitative study of the operations of a complex organization and the prediction of the effects of changes in conditions for the guidance of executives in obtaining the maximum effectiveness from available resources." (Brown, 1951)

However, it must be taken into consideration that operations research is not just quantitative data. With further research in the field researchers are coming up ways and techniques to incorporate qualitative values as a part of the operations research models to ensure that the optimal solutions found can be incorporated in real life in fields wherein have such values play an important role in decision making, thus increasing the scope of operations research exponentially.

2. THE ORIGIN OF OPERATIONS RESEARCH

Even though operations research is believed to have been developed by the Royal Air Force during World War II for the development of radar defense systems, the roots of its origin can be traced way back. Various researchers and scientists, like Archimedes (III century, B.C.), Frederick Taylor(1890), Henry Gannt to name a few came up with techniques to optimize operations in their particular fields of work, ultimately leading to the origin of operations research.

3. APPLICABILITY AND THE SCOPE OF OPERATIONS RESEARCH

In the foreseeable future, operations research is expected to be a part of the decision making of almost all leading companies, many times being the differentiator between the market leader in a sector and the others.

Operations research is essentially used to optimize operations of an organization. Operations research techniques are being used for optimal utilization of raw material, human capital, optimal location of factories and plants etc. and can hence find applicability in almost all fields.

4. OVERVIEW OF THE INDUSTRY

4.1 Advertising

The term advertising can be legally defined as paid forms of communication that are distributed at the initiative of economic operators (by means of television, radio, newspapers, banners, mail, Internet, etc.) as part of an intentional and systematic effort to affect individual attitudes and choices in relation to the consumption of goods and services.

4.2 Various advertising channels

(i) Traditional Channels

- Publications – newspapers, magazines, journals
- Radio and television

- Billboards
- Telephones
- Postal Service
- Word of mouth publicity

(ii) New media channels
- Websites / Blogs/Vlogs
- Social media – Facebook, Twitter, YouTube
- Email
- Mobile
- Search
- Videoconferencing

4.3 Need for OR in advertising
The National Federation of Independent Business, USA informs that "most" businesses allocate between 2 and 5 percent of sales specifically for advertising and these values are expected to grow rapidly with the increase in accessibility to any number of media platforms.

With such amount of money being invested in advertising, it is important to find out optimal ways of investing this money to get maximum benefit out of the investment.

This would include deciding the mix of the media channels used to advertise, the investment in each, who should advertise, the target market for the product and the target audience etc.

Also, advertisements have a great impact on the brand image and the perception of the company and play a major role in the Segmentation, Targeting and Positioning of a company.

Thus in-efficient advertising strategies not only lead to a monetary setback but have a multi-faceted impact.

5. ADVERTISING PROCESS: AN UNDERSTANDING (*Calvin Coolidge in the New York Public Library, n.d.*):
For developing an advert, the following 11 steps need to be followed:
1. Briefing – Involves the SWOT analysis of the product and the company
2. Knowing the Objective – Purpose of the ad
3. Research- Look for information related to the industry, market behavior and SWOT analysis of competitors
4. Target Audience- Identifying customers based on various segmentations
5. Media Selection – choosing an appropriate media channel in order to reach out to the target audience
6. Setting the Budget – In terms of finances so that the company doesn't make a loss
7. Designing and Creating the ad
8. Perfection – re-examining the ad to prepare it for the market
9. Assigning the time and place of the ad- in order to get maximum reach
10. Execution
11. Performance – Analysis of customer's responsiveness.

In the above procedure Operations research is used in media selection, setting the budget, Assigning time and place and performance. However, this research paper will primarily focus on how operation research is applied in the media selection and budgeting aspect of the advertising procedure.

Operations Research is used in the field of advertising by formulating and analysing various models using empirical methods determining parameters, adhering to given constraints; to derive a quantitative solution to media scheduling, advertisement budgeting and selection of media for communication to have maximized and effective outreach to the desired segmented market.

Before we get into the models, it is important for us to understand the working and constituents of the media industry. The main objective of communication firms or the advertising division of a firm is to gain maximum and effective media coverage for its clients/firm. Media coverage mediums are also segmented as shown in table 1:

Table 1: Mediums of Media Coverage (obtained through a questionnaire)

Medium	Further Segmentation

Print	• Newspaper
	  1. Financial
	  2. Mainline
	  3. Regional
	• Magazines
	  1. Business
	  2. Generic
	  3. Segment-specific such as lifestyle, entertainment, sports, traveling etc.
	  4. Special purpose magazines

Electronic	1. News channels –English & Hindi
	2. Business News channels – English & Hindi
	3. Regional News channels
	4. Infotainment channels
Digital	1. Digital publishing media houses – Business, Generic, and Segment-specific
	2. Branded Content Portals
	3. Social Media platforms

Table 1 shows the three broad categories of media reach and a further broken down genre specific structure of each medium. Since we will be focusing on advertising budgeting models, it is vital to realize that each medium has a different cost from the other. Additionally, each medium further fragments will have a difference in cost. This is mainly because different genres have a difference in their reach, demand, availability etc. For example, a mainline newspaper will have a wider range of viewers (pan India) than a regional newspaper, social media platforms would only be useful for an audience using this media that too if advertisements are strategically placed using analytics.

6. LITERATURE REVIEW
Various researchers have worked over varying time periods in areas of media planning, optimal and effective advertising and decision making using operations research methods and mathematical models.

Vidale and Wolfe studied the response of sales to advertising and formulated a model consistent with a series of experiments on many products and various media; using the parameters of Sales Decay Constant, Saturation level and Response Constant. This research has been useful in the allocation of advertising budgets and analyzing Advertising campaigns. The mathematical model was useful in computing quantities needed to carry out a comparative evaluation of different promotional campaigns. (Advertising, 1957)

Peter J. Danaher, Andre Bonfrer, and Sanjay Dhar explain how competitive advertising impacts brand sales. Competitive advertising (advertisements by competing brands in short period) had been to have a definite impact on the advertisement recall and brand recognition. However, finding out the impact on sales requires mathematical modeling and calculations. These models help find out the advertisement elasticity of a particular product without consideration for other factors (including the competitive advertisements) impacting sales. A primary research conducted in a supermarket in Chicago and authors conclude that that having one more competitor advertise is often more harmful to a local brand's advertising effectiveness than if the current number of advertising brands increase their total advertising volume (Peter J. Danaher, 2008) .

Sunoo and Lin conducted to research the primary objective of which was to utilize a standard empirical method to determine optimal advertising spending levels; the advertising is in the context of short-term i.e a year or two. The relationship between advertising spending and customer promotion was also assessed. It was concluded that alternate advertising plans were important for determining optimal advertising spending as well as maintaining the given objective of profit or sales maximization. (D. H. Sunoo, 1979)

Various mathematical models were developed by researchers to come up with the optimal amounts a firm should spend on advertising.

Basu and Batra came up with a regression-based function to allocate a company's advertisement cost optimally to the various brands under the company, with upper and lower caps on the spending of each cap. (Basu, 1988)

Danaher and Rust formulated a model aimed at maximizing the return on investment. They calculated the spending on advertising by considering a diminishing return on advertising. (Danaher, 1996)
Royo et al. considered cross product elasticity and proposed a model to enhance advertising investment in the various media channels for multiple products. (Beltran-Royo, 2013)

Bass and Lonsdale carried out a sensitivity analysis by including constraints on upper bounds on a number of insertions, media budgets and minimum segment exposures bounds, on a linear media planning model they proposed to maximize weighted exposure under budgetary limitations. (Bass, 1966)

De Kluyver imposed rigid constraints on the upper bounds on the number of insertions, media budgets, segment exposures, and their equivalents, thus reformulating the Bass and Lonsdale model as a goal programming model. (DeKluyver, 1979). Sugandha Aggarwal et al. proposed a model to allocate advertising budgets to the different products of a company based on the STP of the products which would help in the allocation of the media channels. The CPE of advertising of one product on another one and the media efficiency factor are included in the model formulation. A case study is also discussed to show the applicability and feasibility of the model. (P. C. Jha, 2016)

Decision making based on operations research can tend to ignore intangible qualitative values lowering the feasibility of the solution found.

Ralph L. Keeney talks about using values in decision making through OR. He talks about including values in operations research models to make the decisions more effective and feasible to adopt in real life. Values are necessary to build a quantitative objective

function, which provides the basis for evaluating alternatives. Values are also used in deciding how to build any OR model. Perhaps most important, but sometimes not explicitly recognized, values-our values as operations researchers-are essential in choosing and defining the problems that we address. The paper talks about one of the major problems while developing the models. It is the tradeoff between qualitative and quantitative gains. It is difficult to assess what is the qualitative gain for extra spending (quantitative). (Keeney, 1994)

7. METHODOLOGY

This paper focuses on how Operations Research is implemented in one of the many processes of advertising that is advertising budgeting. It examines the characteristics of the media and advertising sector through information provided by a questionnaire which was answered by an advertising and PR professional.

The primary research was conducted in the form of a questionnaire. Secondary research involved the use of and reference of various research papers based on the scope of Operations Research in advertising. It also included reference to websites for further clarity about the functioning of the industry and some conceptual elucidations.

This paper uses the Linear programming model to explain the maximizing reach of an advert. Linear Programming is a mathematical model that involves the optimization of an objective function with respect to certain constraints or restrictions (generally equalities). The linear programming model so formulated has been solved using Microsoft Excel's Solver package, Simplex LP method. It requires the:
- The decision variable to be clearly defined
- All possible constraints should be identified and considered

The Linear programming model is founded on several assumptions:
1. Proportionality
2. Additivity
3. Continuity
4. Certainty
5. Finite Choices

8. SIGNIFICANCE

An optimum advertising with an effective operations research technique is very significant as it goes hand in hand with how the product or the service performs. There are several different components of the company/product which are affected by an optimum advertising.
- **Goodwill**
  Advertising is in effect investment in goodwill i.e. the rate of change in goodwill is proportional to the amount of money spent on advertising. We assume advertising which increases goodwill whereas the effect of time which decreases the goodwill.
- **Within the product**
  Many products have a way of getting the same product advertised while it is in use. Products like Video games allow creators of the same to add algorithms which use OR techniques to add different layers of advertisement. This happens when the creator customizes levels to maximize the degree of layers to the advertisement within those levels.

Advertisements by competing brands have a definitive impact on brand recognition. However, finding out the impact on sales requires mathematical modelling and calculations. (Peter J. Danaher, 2008)

The terms 'coverage' and 'impact', might sound very similar to a layman, but these are very different when it comes to reaching out to the consumers. 'Coverage' means the number of people who have seen the advertisement, this means each consumer counts as "n1". Whereas, 'impact' means the number of time "n1" has seen those advertisements. Generally speaking, total impacts and coverage cannot be simultaneously maximized for a fixed cost. The problems of securing maximum impact and maximum coverage in an intense campaign of short duration for a fixed outlay are discussed.

It is also being seen that alternate advertising plans were important for determining optimal advertising spending as well as maintaining the given objective of sales or profit maximization.

While optimizing the sales of advertising slots sold by TV or internet companies amounts to collecting as much revenue as possible from a finite inventory under uncertain demand. This situation yields interesting operations research issues. An exploitation compromise has to be found between placing advertisements with known high rates and testing new advertisements which may have even higher probabilities.

9. ANALYSIS
9.1 The LPP Model

The firm has a product to advertise and has identified various media through which it will do so. In modern-day marketing, there is an extensive use of online platforms for marketing products. The firm wishes to advertise using Search Engine Optimisation (SEO), AdWords, TV advertisements and social media platforms/networks. Linear programming is used to formulate an objective function that seeks to maximise the return on investment on the total advertising expenditure, while allocating funds from the mentioned budget to all the selected media; subject to constraints.

The total market size, consisting of existing and potential customers (estimate) is one million people. The budget allotted to advertising through these media is USD 1500000.

The management has taken certain decisions based on qualitative factors, such as the efficacy of the media, outreach etc. An advertising specialist was consulted to know the approximate expected return on investment and the no. of customers that are exposed to the advertisement per dollar spent on it. The details are given as follows:

Table 2

Media	No. of customers per dollar
TV Advertisements	2.5
Search Engine Optimization	2.1
AdWords	0.9
Social media networks	3

Table 3

Media	The expected return on investment (%)
TV Advertisements	9
Search Engine Optimization	14
AdWords	10
Social media networks	5

The following decisions were taken by the management considering qualitative factors and minimum requirements of certain media.
- The primary focus of the management is Search engine marketing, using Search engine optimisation and Adwords. Hence there is a preferred allocation of minimum 60% of the advertising expenditure on these media.
- There is a cap on social media advertising, it should not exceed 15% of the total budget.
- The minimal contract for the social network agency is USD 80000.
- The search engine marketing agencies have quoted a range between 70000- 220000 USD

Variables: let x1, x2, x3, x4 be the amounts allotted to each media

Objective function: to maximise return on investment (sum product of individual ROIs and respective funds allotted)

Constraint equations are as follows:
- x1+x2+x3+x4 ≤ 1500000 (total budgetary constraint)
- 0.6 x1– 0.4 x2 – 0.4 x3 +0.6 x4 ≤0 (search engine marketing constraint)
- $-0.15x1 -0.15x2 -0.15x3 +0.75x4 \leq 0$ (social media budget constraint)
- $x4 >= 800000$ (minimal social network contract constraint)
- $x2+x3 >= 900000$ (Preferred budget allocation constraint)
- $700000 \leq x2 \leq 2200000$ (SEO quotation constraint)

The above formulation is solved using MS-Excel, using Solver. The method used in solver is simplex LP.

Table 4: The budget allocations arrived at to maximise return on investment

Media	Budget
TV Advertisements	0
Search Engine Optimization	70000
AdWords	1014444.444
Social media networks	80000

1164444 USD is spent according to the above plan. This has generated a return on investment of USD 115244.4444. This is done by deciding an optimal mix of the media taking into consideration all the factors.
It can be observed that the budget allotted to TV Advertisements is nil, this is because the objective function is to maximise return on investment and there is no constraint with regards to the minimum budget that has to be vested in this medium.

Using regression models: Regression models can be effectively used to predict a relationship between sales response and different levels of advertising. When coupled with marginal purchase equations, we can determine various levels of short-term advertising where profit is maximized and costs are minimized. In relation to television advertising, actual gross rating points of consumers could be tallied with customer's actual purchases to determine the efficacy of the existing advertisement program. This analysis renders different results when carried out during the daytime and night time. Regression is utilized as it seeks to provide a quantitative relationship of variables such as retention, sales etc with different budgets allotted to different media.

The various factors that are taken into consideration while formulating a linear programming model or a regression model are quantitative and qualitative. The quantitative parameters include the overall budget and individual costs, primarily. The qualitative factors include segmentation of market, demography, tastes, and preferences of customers, length of the commercial, competitors' advertisements etc.

10. EVALUATION

In general, the models can be used to allocate advertising budget amongst several competing products based on demand, consumer perceived effectiveness etc. The budget allocations work in a way to maximize media exposure for the product. If all qualitative parameters are taken into account, the very dynamic model can be constructed. Media planning and scheduling can then be performed according to viewership, customers' retention of the advertisement from previous advert campaigns and according to the possible ever-changing, dynamic nature of the sector due to the existence of possible competitors (direct or indirect). Models provide various alternatives to the management thereby ensuring flexibility and a cost-benefit analysis of all possible, feasible alternatives thereby making decision making more effective as well as based on certain quantitative parameters.

11. LIMITATIONS

The use of linear programming as a sole method of advertising problems has several limitations. It is difficult to come up with an objective function i.e. certain objective functions when quantified may be too complex. It might not be possible to express all constraints as a linear relationship. Certain coefficients which are qualitative and subjective in nature cannot be accurately estimated, for example, perceived consumer effectiveness. LPP is based on an assumption of constant returns to a factor, which is not always true.

12. CONCLUSION

Operations research is used in scientific decision making as it quantifies the cost-benefit and optimum alternative decisions which can be taken subject to given constraints. OR methodologies such as linear programming, stochastic models, multiple regression models, knapsack problems, scheduling algorithms and goal programming are widely used in determining the optimal level of advertisement spending, the correct media to be selected with respect to consumer perceived effectiveness, segmentation of the market. All these decisions are subject to certain constraints mostly of funds and allocation constraints. LPP is formulated to either maximize the exposure of the advertisement to its customers, the profits which would accrue with relation to projected sales due to advertising or to minimize the cost of advertising. OR methods companies are adopting include advanced inferential techniques such as ANOVA, multiple and logistic regression and factor analysis. OR is also used to find a suitable method to contact customers thereby minimizing contact timing. In an age of growing information, OR is used to make the correct information available to the correct person based on various data analytics techniques combined with search engine optimization. This has lead to more efficient, customized advertising which is extremely effective.

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