

# Resource Allocation: Marketing Engineering Technical Note<sup>1</sup>

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## **Introduction**

A well-designed resource allocation model enables an understanding of the individual and combined effects of marketing resources (or marketing mix elements) such as advertising, sales effort, or price, on a response measure of interest to the company (e.g., sales, profit, customer acquisition, ROI), and the capability to apply this understanding to identify good ways to expend those resources. Resource allocation across the marketing mix elements integrates three modeling concepts: (1) sales response modeling, (2) Estimation/calibration of marketing response functions, and (3) optimizing the use of marketing resources to maximize one or more desirable response measures. For purposes of this note, we focus on resources that can be continuously varied (e.g., advertising expenditure, sales effort, web site investment), rather than on resources that can only be varied only in a discrete manner (e.g., new copy design, introduction of a new product).

## **Response Functions – Specification and Calibration**

At the heart of a resource allocation system are response functions that represent the relationships between one or more marketing mix elements and the corresponding outcome measure in each *sales entity* of interest. A sales entity is anything with which we can associate potential sales for the firm—customer,

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prospect, market segment, geographic area, product sold by the firm, and so forth. If the firm estimates response functions for each such sales entity, it can use these functions to calculate the levels of effort to allocate to each entity to maximize profits or to achieve other objectives. The sum of the effort across a set of non-overlapping entities is then the level of marketing effort or sales resources the firm needs. The firm can divide this total by the average effort (e.g., 750 sales calls per year) to estimate the amount of resources (e.g., salespeople) it needs.

**Specification and calibration of response models:** There are many types of sales response functions used in marketing (see Response Modeling – Marketing Engineering Technical Note) to model sales response in each sales entity. Typically a non-linear S-shaped response function, such as the ADBUDG response model, is a good choice for representing marketing response to advertising and sales effort.

Before response models can be used for resource allocation, they must be calibrated or estimated keeping in mind the context in which they are to be used. If, for example, the objective is to determine the marketing budget for the sales force and the allocation of the total sales force effort across products, then we need to estimate sales response functions that indicate the future sales for each product under different levels of effort the firm might deploy on that product. There are broadly three approaches for estimating response models: (1) statistical estimation using historical data of response behavior, (2) managerial judgment, and (3) experimentation (more common among online firms). Often, a combination of methods (e.g., statistical estimation combined with judgment) works best to account for both the enduring constraints of the marketplace, as well as the opportunities afforded by the future.

**EXAMPLE:**

A common functional form used in resource allocation is the ADBUDG response model, which has the following functional form:

$$r_i(X_i) = b_i + (a_i - b_i) \frac{X_i^{c_i}}{d_i + X_i^{c_i}}, \tag{1}$$

where

$i$  = a sales entity,  $i=1, 2, 3, \dots, I$  (# of sales entities);

$X_i$  =total effort devoted to sales entity  $i$  during a planning period measured in number of calls, indexed so that current effort=1 (for simplicity we treat this as a continuously varying quantity rather than as an integer);

$r_i(X_i)$  =indexed level of sales at entity  $i$  if the salesforce devotes  $X_i$  amount of effort to that entity;

$b_i$  =minimum sales that can be expected with no sales effort allocated to sales entity  $i$ ;

$a_i$  =maximum sales that can be expected with an unlimited amount of sales effort allocated to sales entity  $i$ ;

$c_i$  =parameter that determines the shape of  $r_i(X_i)$ —whether it is concave or S-shaped; and

$d_i$  =an index of competitive effort levels directed toward sales entity  $i$  (the larger this value, the smaller the impact of the firm's own sales effort on sales).

One way to calibrate this model is via nonlinear least squares regression using historical data of both  $X$  and  $r(X)$  in each sales entity. Another approach is to use judgmental methods, which involves asking experienced managers (e.g., from sales, marketing, or marketing research functions) what the response  $r(X)$  will be for various specific levels of  $X$ . Often such calibration is done with reference to a base level of  $X=1$ , for which response  $r(X)$  is 1, e.g., at current levels of effort, we expect to observe the current level of sales. Typically, in judgmental calibration, it is useful to obtain group consensus estimates for the response functions using the Delphi method (Armstrong 2001). With the Delphi method, before asking for the judgmental estimates, it is useful to provide all the participants with a summary of the historical data pertaining to the entity for which the sales response is to be obtained.

//end Example

## **Optimizing Resource Deployment**

A response function merely indicates the response on an outcome measure that the firm is likely to achieve at various potential levels of effort deployment. By itself, it provides no guidance on how much effort should be deployed to a

particular entity. Typically, a firm has many entities competing for the same resource, and it has to evaluate alternative ways of deploying the same resource across different entities. To do this systematically, we specify an optimization model, which allocates a resource across entities to optimize a specific objective (e.g., short-term profit, customer retention). There are many different types of optimization models used in marketing (e.g., linear programs, nonlinear optimization, integer programs, stochastic optimization, multi-objective optimization), each appropriate in different contexts. We illustrate resource optimization in the context of sales force effort allocation in two different contexts: (1) A single salesperson making decisions about how much effort s/he should devote to each account (customer). (2) Company management deciding how big a sales force it should have, and how it should deploy that total effort across products and markets.

### **Call Planning for a Salesperson**

CALLPLAN (Lodish 1971, 1974) is an interactive call-planning system that helps salespeople to determine how many calls to make to each client and prospect (equivalently, to each category of clients and prospects) in a given time period to maximize the returns from their calls. The system determines call frequencies with respect to an *effort* period, which is the planning period used by the salesperson (e.g., one quarter). The model is based on the assumption that the expected sales to each client and prospect over a *response* period, which is the planning period of the firm (e.g., a year), is a function of the average number of calls per effort period during that response period. The response period selected should be long enough to accommodate potential carryover effects from each effort period.

***Specifying the response functions:*** We will use a simple version of CALLPLAN based on the ADBUDG response function to illustrate the central issues.

CALLPLAN tries to develop an effective way for the salesperson to allocate effort across the different accounts. The model assumes that the salespeople seek to maximize contribution (profits) from their selling efforts; however, they have limited time and therefore they wish to use this resource as effectively as possible. A sales territory is assumed to be divided into mutually exclusive geographic areas (e.g., zip codes). The salesperson makes trips to some or all areas in the territory in each effort period. In each trip to an area the salesperson incurs variable costs for expense items such as travel and lodging.

In a trip to an area, the salesperson calls on any given account at most once.

Before we describe the formal model, we define its parameters:

$n_j$  = number of trips per effort period to area  $j$ , where  $j=1, 2, 3, \dots, J$ .

Because the salesperson calls on an account at most once during a trip,  $n_j$  is also equal to the maximum number of calls made to any account in territory  $j$ ;

$c_j$  = variable costs incurred when making a trip to area  $j$ ;

$t_i$  = time that the salesperson spends with the customer when making a call to account  $i$  ( $t_i$  may be set to be the same for all customers);

$U_j$  = time it takes to get to area  $j$ ;

$e$  = number of effort periods in a response period (if the effort period is a month and the response period is a year, then  $e=12$ );

$T$  = total work time available to a salesperson in an effort period, which includes both selling and nonselling times;

$a_i$  = a customer-specific profit-adjustment factor that reflects the profit contribution of sales to that customer.

$r_i(X_i)$  = ADBUDG response model for each account  $i$  (other concave or S-shaped functions can also be used).

The optimization model maximizes profits ( $Z$ ) for a single sales territory taking into account both the costs of visiting the accounts and the expected contribution from all the accounts and prospects:

Find the set of  $X_i$  to

$$\text{maximize total profit contribution margin } Z = \sum_i a_i r_i(X_i) - e \sum_j n_j c_j, \quad (2)$$

subject to

$$\sum_i X_i t_i + \sum_j n_j U_j \leq T, \quad (3)$$

$$n_j = \max_i (X_i \text{ in geographic area } j), \quad (4)$$

$$LB_i \leq X_i \leq UB_i \quad (5)$$

Constraint (3) ensures that the total time (call time plus travel time) used in

an effort period does not exceed the time available to the salesperson; constraint (4) equates the number of trips to territory  $j$  to the maximum number of calls made to any specific account in that territory, thus ensuring that in any trip to territory  $j$  the salesperson does not call on any account more than once; constraint (5) allows the salesperson to incorporate judgment-based lower and upper bounds on the number of calls made to any account  $i$  in an effort period.

**Model usage:** It is useful to first run the model with no upper bounds in constraint (5) and with a lower bound of 0 for all  $i$ . Then the model is likely to suggest that the salesperson never call on some accounts and call on some accounts too often. The salesperson may feel that such an allocation is not reasonable and can then specify minimum and maximum constraints for each account to modify these results. These judgments account for the effects of factors not explicitly included in the model. (For example, some accounts may be beta-test sites that help with testing a new product before release. However, sales effort on those accounts may not necessarily lead to increased sales.)

A salesperson should include both accounts and prospects in a calling portfolio. However, prospects typically respond weakly to sales efforts as compared with existing accounts; therefore the model will tend to exclude them from the calling plans it develops. One way to give adequate treatment to both is to run the model separately for accounts and for prospects: Run the analysis for prospects by setting aside time equal to  $T_P < T$  in constraint (3) to be allocated to prospects. Do the same for accounts by setting aside time equal to  $T_A$  for existing accounts such that  $T_A + T_P = T$ , the total time available to the salesperson. A comparison of the results with and without time set aside for prospects shows how much of the current profit the salesperson is willing to forgo to cultivate long-term prospects.

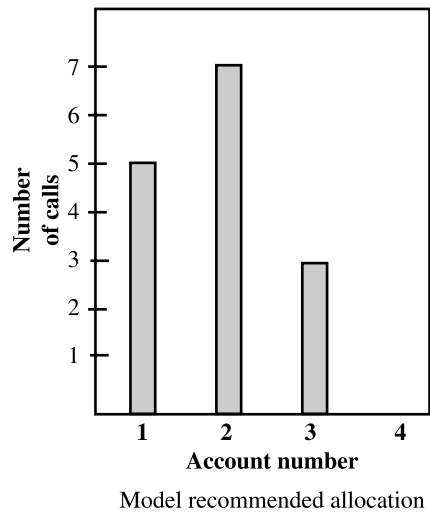
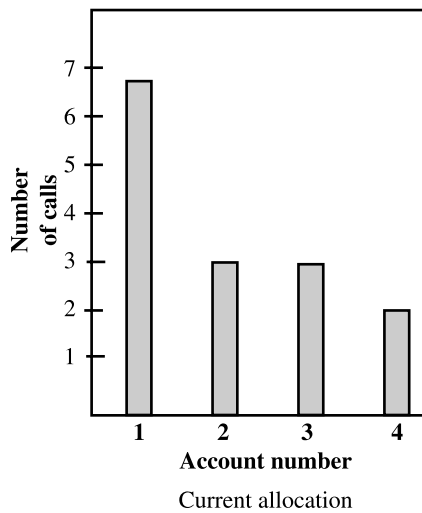
#### **EXAMPLE**

To understand the “incremental analysis” the CALLPLAN model uses to determine the optimal allocation of effort, consider a simple example with four accounts, summarized in Exhibit 1. Suppose that the salesperson is currently devoting 15 calls to these accounts as shown, bringing in total sales of \$11,985. If the cost of a single sales call is \$200, the net contribution is then \$8,985.

|                   |   | Number of calls |      |     |     |     |     |     |     |     |     |
|-------------------|---|-----------------|------|-----|-----|-----|-----|-----|-----|-----|-----|
|                   |   | 1               | 2    | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
| Account<br>number | 1 | 100             | 300  | 600 | 400 | 300 | 225 | 160 | 110 | 70  | 50  |
|                   | 2 | 1400            | 1100 | 850 | 650 | 490 | 360 | 250 | 165 | 85  | 15  |
|                   | 3 | 3600            | 1800 | 800 | 200 | 100 | 75  | 50  | 40  | 30  | 25  |
|                   | 4 | 180             | 170  | 160 | 150 | 140 | 135 | 130 | 125 | 120 | 115 |

The numbers in each row of the matrix correspond to the response function for that account, showing incremental contribution per call at that call level.

- Indicates marginal contributions at current level of deployment
- Indicates marginal contributions at the optimal level of deployment



**EXHIBIT 1**

Example of optimization procedure in CALLPLAN. The table at the top is a numerical representation of sales-response functions in four accounts. The bar charts at the bottom show the current and model-recommended allocation of effort to the four accounts when the salesperson makes a total of 15 calls.

An optimization procedure would allocate the first call to account 3, which has the highest marginal contribution (\$3,600). It will also allocate the second call to this account, which has the next highest marginal contribution (\$1,800). The third to the fifth calls will be allocated to account 2 with a total contribution of \$3,350, the sixth call to account 3, the seventh and eighth calls to account 2 with a total contribution of \$1,140, the ninth to twelfth calls to account 1 with a total contribution of \$1,400, the thirteenth to account 2, the fourteenth to account 1, and the fifteenth call to account 2. This allocation procedure

results in total contributions of \$13,000 with a net contribution (after paying for the sales calls) of \$10,000, which represents a 11.3 percent improvement over the current net contribution of these 15 calls.

Note that the model recommends making no calls on account 4. The firm could use less costly methods such as telemarketing to contact such accounts. Note also that it would not pay to make any call whose marginal contribution would be less than \$200, the cost of a call. Let us explore what would happen if the salesperson were able to make more than 15 calls. Then the eighteenth call will be to account 4, with a marginal contribution of \$180. Thus the maximum number of calls the salesperson makes to this set of accounts should be 17. (If the salesperson makes only 15 calls to these accounts, the opportunity loss of not making the sixteenth and seventeenth calls is equal to \$25, the net contribution of making the two additional calls. The sixteenth call would be to account 1, and the seventeenth to account 3.)

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## Resource Planning for Sales Force Management

The salesforce management problem allocates the effort of the entire salesforce to sales entities to maximize firm profits over a planning horizon, subject to several constraints. We call to the model below ReAllocator to focus attention on the combination and sizing and allocation of effort.

Each run of the model requires a constraint specifying a proposed salesforce size. This constraint ensures that the model allocates effort in the best way possible for a given salesforce size. The base model follows:

Find the set of  $X_i$ 's to

$$\text{maximize } Z = \sum_{i=1}^I r_i(X_i) S_i a_i - CF(\text{profits}), \quad (6)$$

subject to

$$\sum_{i=1}^I X_i e_i = F(\text{salesforce size constraint}), \quad (7)$$

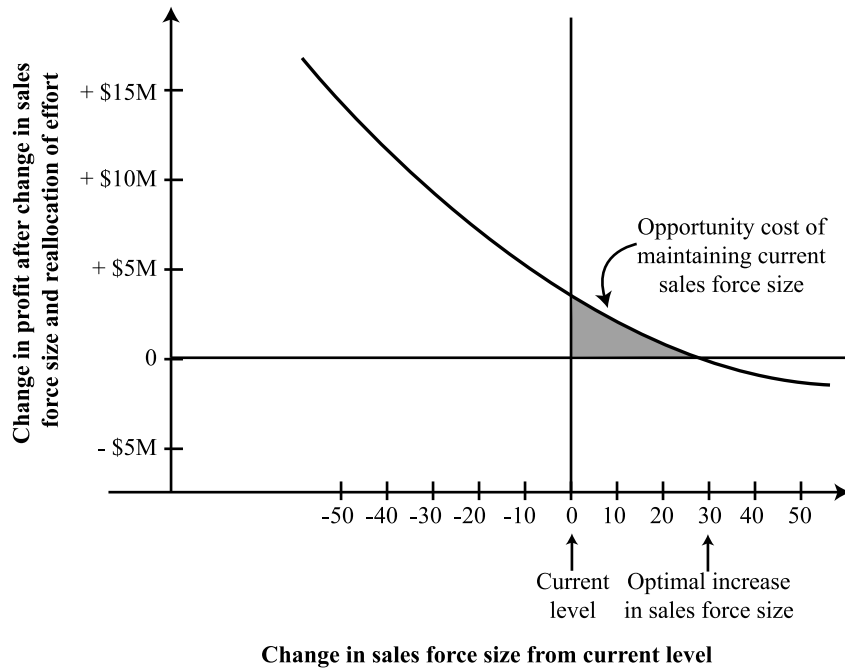
where

$S_i$  = forecasted sales for entity  $i$  according to the strategic plan;

$a_i$  = contribution margin per incremental dollar of sales for sales entity  $i$ ;  
 $C$  = full costs (salary, benefits, etc.) of a single salesperson;  
 $F$  = planned salesforce size (number of salespeople); and  
 $e_i$  = planned deployment of sales effort to entity  $i$  according to the strategic plan.

$r_i(X_i)$  = ADBUDG response model for each account  $i$  (other concave or S-shaped functions can also be used).

The base model gives the optimal allocation of effort for any given salesforce size  $F$ . This model is then solved repeatedly for various levels of  $F$ , and the firm should keep adding salespersons as long as the incremental profit associated with each person is positive. At the optimal level of salesforce size, the marginal profit of an additional salesperson is 0 (Exhibit 2).



**EXHIBIT 2**

This graph shows how the results from ReAllocator can be organized to indicate (1) the opportunity cost (the shaded area) of maintaining the salesforce at the current level and (2) the required change to the current salesforce size to maximize profits.

Constraint (7) can include more entity-level constraints. For example, the constraints might include minimum and maximum levels of effort allocated to any particular entity. The modified constraint set can be specified as follows:

$$\sum_{i=1}^I X_i e_i \leq F, \quad (8)$$

$$LB_i \leq X_i e_i \leq UB_i. \quad (9)$$

$LB_i$  and  $UB_i$  are the lower and upper bounds on effort devoted to any particular sales entity. For example, the firm might specify that total effort devoted to product A should not exceed the equivalent of 100 salespersons (UB) and be at least 50 (LB).

**Model usage:** ReAllocator can be used both for determining the size of the sales force ( $F$ ) as well as the allocation of that total effort across products, markets, or other sales entities. Indeed, the strength of the model is its ability to help management to determine both the total effort, as well as, the appropriate ways to allocate that effort. The model can also be used to assess the overall value of the salesforce. It doesn't make sense to increase the sales force size, if those salespeople are not utilized for the maximum benefit for the firm.

In today's competitive environment, firms must justify their investments in terms of their opportunity costs. One way to meaningfully estimate opportunity cost in the context of salesforce investment is by computing the difference between profits calculated for effort levels corresponding to the selected salesforce size and the profits the firm would earn by expending zero sales effort on all sales entities (all upper bounds set to 0).

In some situations, there will be interactions between the entities of interest, which broadly fall in two categories: complementary effects (positive synergies) or substitution effects (negative synergies). For example, sales force effort on two complementary products will likely benefit both, whereas sales force effort on two substitutable products sold by the firm is likely to cannibalize sales of both products. As another example, in the pharmaceutical industry, the positive or negative experience that specialists have with new drugs affects the prescribing behavior of the much-larger population of general practitioners. Recognizing that phenomenon, many pharmaceutical companies target key

specialists with promotions, hoping for positive spillover effects to the more general physician population.

One way to extend the Syntex resource allocation model to account for interactions is by introducing co-efficients,  $\{b_{ki}\}$ , into the response model, where

$b_{ki}$  = effect that an incremental dollar of spending on sales entity  $k$  has on sales entity  $i$  relative to the direct effect of spending in entity  $i$  ( $1 > b_{ki} > -1$ ). The restriction on  $b_{ki}$  ensures that the absolute magnitude of the complementarity or substitutability effect is less than the direct effect.

Then, ReAllocator is modified as follows (paralleling equations (6 – 9):

Let  $X_i$  be the (indexed) level of marketing resource (number of salespeople, \$000 of ad spending, etc.). The problem is then:

Find the set of  $X_i$ 's to

$$\text{Maximize } Z = \sum_{i=1}^I \left[ r_i \left( X_i + \sum_{k \neq i} b_{ki} X_k \right) S_i a_i - d_i X_i e_i \right] \quad (10)$$

where  $b_{ki}$  is defined as above

$d_i$  is the cost per unit of  $X_i$

and the other terms are as defined earlier. Again, constraints of the form:

$$\sum_{i=1}^I X_i e_i \leq F \quad (\text{total resource constraint}), \text{ and} \quad (11)$$

$$LB_i \leq X_i e_i \leq UB_i \quad (\text{sales entity constraint}) \quad (12)$$

can be imposed.

Even with these enhancements, ReAllocator has several limitations. It is best suited for repetitive buying situations where the number of calls made to accounts is an important determinant of sales. In repetitive buying situations

the purchase cycle is short, customers buy from an assortment of products, and the salesperson provides a much more sophisticated version of reminder advertising than one gets from other media such as TV. Here the regular contacts with customers help cement relationships and allow the salesperson to recognize potential problems in advance and deal with them. Some common examples of sales calls in repetitive buying situations are pharmaceutical reps calling on physicians, packaged goods salespeople calling on grocery stores, agricultural product reps calling on stores and farmers, and industrial parts reps calling on distributors.

## **Summary**

In this technical note we described the use of response models in resource allocation, and illustrated their application in the context of sales effort allocation. The approach described here can be used for allocating the overall marketing budget, or for allocating a marketing mix element (e.g., media spend) to different products, markets, or other sales entities. The basic concepts of market response modeling, calibration/estimation, and optimization of one or more objectives, can be used in addressing more complex problems in resource allocation. There are many areas of marketing where resource allocation models are becoming critical, including shelf-space management, campaign planning and management, media planning, and lead management, to name a few.

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