



## CASE STUDY

# C-Tek Corporation: Salesforce Sizing and Allocation for Grinding Products

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## Background

C-Tek Corporation was founded in 1889 in Twin Harbors, Minnesota by seven businessmen determined to develop new materials for grinding wheels, sandpaper and abrasives products. Since its inception, the company's lines of business expanded into numerous other, related areas, mainly centered around materials involving either adhesion or abrasion.

From its start in the late 1800's, the company grew entirely through internal innovation and growth to revenue of more than \$20 Billion in 2004. It has always prided itself on producing many small innovations and occasional breakthrough products and providing a climate that encouraged internal entrepreneurship and systemic growth.

Each of the company's 33 lines of business operates its own channels, mixing direct sales with an extensive set of distributor relationships. Each of these lines of business operates as a rather independent business unit, with its own revenue targets and profit and loss statements.

In August of 2004, John Sawyers, Sales Manager for the Grinding Products division of C-Tek, attended a seminar hosted by Penn State's Institute for the Study of Business Market, where he heard about a method for using managerial judgment to determine the best level of selling effort and how to allocate that selling effort. While his business had been growing, he felt that he was not able to keep up with competitors due to no change in his headcount in the past five years. And as his most recent proposals to add to his US salesforce of 52 had been denied, he felt that the "judgmental approach" might be just what he needed to build a more defensible case for an increase in his salesforce size.

## Session Preparation

John met with Professor Gary Lilien of Penn State, who had demonstrated the process using his Marketing Engineering software, ReAllocator. They discussed the need for careful background information-gathering, the assembling of a team of sales managers, sales representatives, marketing planners and product developers to be able to provide the data and environment for performing the analysis.

They also developed a "base team," comprised of John, Paul Stearn, market research manager, and Susan Ellis, planning director.

In those discussions, the base team identified several critical issues. First, they determined that the appropriate unit of analysis would be the sales branch. Sales representatives at Grinding Products work out of 14 sales branches in the US.

Next, they discussed appropriate assumptions for the level of new product development. This was an area of some great concern. Product development had promised but not delivered "breakthrough" products during each of the past four years. They decided to assume a "moderate" level of product development—no breakthrough products, but with product development keeping pace with the developments in the past three years.

Two other critical issues involved the assumed length of the planning horizon. They chose a three-year horizon for all related data, assuming that this would be a reasonable length of time for any new hires or transfers to have their complete impact on the marketplace.

The second critical item involved the assignment of an average profit margin to each of the sales branches. Background work that Susan provided showed that the mix of products sold at each branch did not differ substantially in terms of profit margin, and the company had recently adopted an activity-based costing process that permitted C-Tek to be fairly comfortable in allocating costs to products. However, there was a great deal of discussion about the appropriate assumption of profit margins projected three years into the future. The team decided to use 0.35 as their "best guess", but suggested that Lilien run the analysis with margins running from 0.20 (worst case) to 0.45 (very optimistic).

The average, fully loaded cost for a sales rep at C-Tek was projected to be \$147,000.

## Calibration Session

They organized a calibration session for early February 2005, involving 16 senior sales reps, national sales managers, a product development manager, the division's marketing managers, and two marketing research analysts. After a 1-1/2 hour introduction session, the group broke into four subgroups, each of which built a sales response function for three to four sales branches, by essentially answering the following questions:

What would sales be in three years at this branch with:

- a) No sales force representation?
- b) One fewer sales representative?
- c) The same number of sales representatives?
- d) One more sales representative?
- e) A very large increase in the number of sales representatives?

### Scenarios

Appendix 1 provides details about the background, the process, facilitator instructions and the calibration form used to collect the data.

Appendix 2 provides the data that emerged from the session. (Appendix 3 provides a bit more background about the process).

## Case Study Questions



### Question 1

Using the base data, run analyses for C-Tek, both for an unconstrained analysis and for a fully constrained analysis (reallocation). Develop sensitivity analyses concerning profit margin as well. What alternatives and options does this analysis suggest?

### Question 2

Product development has a breakthrough technology that they claim will increase the size of the market by 20-25% with average profit margins approaching 40% for the full line of products. What would the impact of such a scenario be on your results and recommendations from Q1?

### Question 3

What would you recommend and why?

## Appendix 1: Marketing Effort Sizing and Allocation Process

### Overview

Most companies use judgment and intelligent rules-of-thumb to determine the size and allocation of its marketing and sales force resources. While that approach generally produces adequate results, a systematic disciplined approach to the problem, using specialized computer modeling combined with managerial inputs, generally produces between a 6% and a 15% increase in sales revenue simply by reallocating or redeploying existing resources, with no increase in spending. Greater benefits can be derived by studying both the size of the marketing or sales force level and how those activities should be allocated.

What managers believe about how the market operates can be captured in what we call a market response function, relating level of marketing or selling effort to current or anticipated sales. Framing the marketing or sales force sizing and allocation problem in terms of a sales response function allows us to extract judgments from managers about how they believe the market operates (the sales response functions), while using the computer to determine, given those beliefs, what marketing or sales force sizing and allocation is most cost effective (the optimization procedure).

Appendix 3, an article by Lilien, Rangaswamy and Matanovich, entitled "Harnessing Expert Judgment: Models help build profitability into sales force size and allocation decisions," outlines the approach. This document outlines a process to implement the approach.

### Approach

Each study has three phases: Background, Calibration Meeting and Follow-up

#### **Phase 1: Background Data Collection**

In this phase we jointly determine what the best way to structure the problem will be and how to break down the marketplace into segments (usually some combination of product/market/geography/channel---consistent with the way marketing or sales resources are allocated and measured in the firm). We will need to engage either in a meeting or a teleconference of about 2 hours to address the key issues (unit of analysis, planning horizon, etc) and structure of the program and determine responsibilities, including that of the "client."

The client provides the following information:

- Planned level of effort (marketing expenditure or sales force man-months or man-years) in each segment
- Anticipated sales level in each segment over the planning horizon (probably a year)
- Expected gross profit margin (%) BEFORE subtracting the cost of marketing or selling in each segment
- Planning assumptions for each segment:
  - Market growth
  - New product introduction assumptions

- Competitive and environmental assumptions
- Other general or segment specific market assumptions

The analytic team will provide:

- Templates that should be used to deliver this information as well and briefing forms to be supplied to participants in the Group Calibration Meeting (Phase 2).

### **Phase 2: Calibration Meeting**

The purpose of the calibration is to get the best-pooled judgment of key stakeholders in the sizing and allocation decision problem as inputs to the optimization software.

Such a meeting should involve:

- Marketing or sales manager(s)
- Local sales representatives (if studying the sales force)
- Representatives from marketing (planning) / marketing research / product development
- Internal facilitator (to enable further implementation and follow-up)
- Representative(s) from senior management, with overall budget approval

Attendees should receive communication indicating the objectives of the meeting and a preliminary assignment to prepare them for the task.

The calibration meeting will stretch across two days, with the following rough schedule:

Previous day: Travel, setup and briefing of facilitator. Run through meeting plan.

#### *Meeting Day 1:*

Overview of the approach and proven benefits of the pooled judgment approach to marketing and sales force sizing and allocation.

Discussion of small group tasks

Facilitated pooled judgmental market judgment task (See facilitator instructions and sample calibration form, attached)

Lunch

Continuation of pooled judgment task (if necessary), closing no later than 3 pm

Rest of the day/evening, research team runs analyses and prepares presentation for next day

#### *Meeting Day 2: (about 2-3 hours)*

Feedback/Review of results and implications

Sensitivity analyses

Questions/answers, demonstration of implications of different assumptions

Discussion of implementation process

**Phase 3: Reporting and Follow-up**

The research team produces a report on the process and the recommendations that emerged. That report includes a copy of the software that can be used by the client to run further analyses or to update the recommendations.

### Facilitator Instructions: Sizing and Allocation Exercise

As a group facilitator, your job is to move the group calibration discussion along and to collect and report on the responses. You should be prepared to explain some things

#### Goals:

Marketing and sales effort affects customer choices in the marketplace. Our goal is to determine what levels to set for marketing or selling effort by pooling our judgments on what effect the selling effort is likely to have in the market. Once we have that information, we will be able to use a computer model to see the implications of our combined judgments. In the rest of this note, for specificity, we will consider sales force effort. Analogous instructions hold for advertising/communications spending, promotional spending and the like.

#### Process:

During the pooled judgment phase the process and rules are as follows:

- Open discussion
- Anonymous response
- Consensus unnecessary
- No right or wrong answers--respect one-another's opinions
- Mutual understanding is vital
- Recycle until judgments stabilize
- Report on median response, highest and lowest after each round.

For example:

*What is your best guess about what would be the most likely effect on segment sales relative to reference conditions in 2002 if the level of selling effort in 2005 were to increase from our current plan by adding one additional salesperson? Responses were....*

+8% +12% +13% +9% +10% +11% +16%

*You would report back to the group:*

*"The average (median) response on this round was +11% (fourth highest of the seven responses) with a high of +16% and a low of +8%."*

*Shall we discuss the differences in our assumptions that lead to these different responses?*

In order to get the best out of the exercise; the responses must be reasonable. Remember these are investments and must pay for themselves (either in the short or the long term). To be profitable, marketing investments must return at least  $1/(\% \text{margin})$  to be profitable:

If it costs you \$150,000 for a sales person, and that salesperson brings in \$750,000 in extra sales, you only make money if the profit from those sales exceeds the cost of the sales person, i.e., is greater than that \$150,000 or 20% of sales. At incremental margins of 20% for example, such an investment must return 1/.2 or 5 times their cost in extra sales to be profitable.

The best way to think about selling response is to ask "What would we do with an extra sales person? How many personal visits could we make, how many contacts does it take to capture (or retain) a customer and what is the average sales/customer?"

### **Reference conditions**

We will set the reference conditions as an anchor point so that everyone is working off of the same base assumptions. The analysis will not be very sensitive to the choice of reference conditions, but is very sensitive to our assumptions about what happens in the market when we change from those reference conditions.

### **Other items**

- Separate people from the problem--"Let's look at the market together"
- Get everyone to talk/provide input.
- Ask if anyone has any data that can help (previous sales-effectiveness / benchmarking studies).
- Keep a sense of humor--this exercise should be interesting and fun!

C-Tek Calibration Form

*Sales Branch:* \_\_\_\_\_

Reference Conditions for time frame: 2008

*Reference # Reps (= current size)* \_\_\_\_\_

*Reference Base Sales Level (\$000)* \_\_\_\_\_

*Average Sales/Sales Person (\$000)* \_\_\_\_\_

*Reference Market Potential* \_\_\_\_\_

**Selling Effort Response:**

What would C-Tek market segment sales be at reference conditions but with:

⇒ \$0 Selling Effort? \* \_\_\_\_\_% or \_\_\_\_\_Sales Level (\$000)

⇒ Decrease Selling Effort by \_\_\_\_ salespeople? \_\_\_\_\_% or \_\_\_\_\_Sales Level (\$000)

Reference Selling Effort 100% or \_\_\_\_\_Sales Level (\$000)

⇒ Increase Selling Effort by \_\_\_\_ salespeople? \_\_\_\_\_% or \_\_\_\_\_Sales Level (\$000)

⇒ Very Large (unlimited) Selling Effort? \*\* \_\_\_\_\_% or \_\_\_\_\_Sales Level (\$000)

Minimum # of salespeople that would be possible = \_\_\_\_\_

\**The lowest level you would expect sales to drop to if selling effort was essentially discontinued.*

\*\**The biggest gain in sales (considering competitive response) that you could capture with very large expenditures in selling effort.*

Reference Environmental/Market/Competitive Assumptions:

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## Appendix 2: C-Tek Grinding Products Calibration and Reference Data

This appendix provides both the data from the judgmental calibration exercise (Tables 1 and 2) as well as the additional reference information to create a Reallocation spreadsheet. The table below gives the raw data:

	#of Reps	0	-1	Base	1	Many
LA	5	50.0%	77.5%	100.0%	110.0%	188.0%
SF	4	60.0%	82.5%	100.0%	110.0%	150.0%
Seattle	3	50.0%	77.5%	100.0%	125.0%	162.5%
Boston	4	55.0%	82.5%	100.0%	120.5%	150.0%
Philly	5	52.0%	90.0%	100.0%	112.5%	145.0%
Cleveland	4	45.0%	79.0%	100.0%	127.5%	165.0%
Atlanta	3	49.0%	77.0%	100.0%	130.0%	199.0%
Nashville	3	55.0%	70.0%	100.0%	125.0%	160.0%
High Point	4	38.0%	70.0%	100.0%	129.0%	155.0%
Dallas	3	50.0%	72.0%	100.0%	127.5%	200.0%
Chicago	5	50.0%	75.0%	100.0%	115.0%	130.0%
Cincinnati	3	44.0%	80.0%	100.0%	115.0%	145.0%
St Louis	3	40.0%	70.0%	100.0%	125.0%	145.0%
Twin Cities	3	40.0%	75.0%	100.0%	115.0%	130.0%
Avg.		48.4%	77.0%	100.0%	120.5%	158.9%
Max		60.0%	90.0%	100.0%	130.0%	200.0%
Min		38.0%	70.0%	100.0%	110.0%	130.0%

Table 1: Results from judgmental calibration.

Where

- 0 means there is no selling effort in that sales branch
- -1 means there is 1 sales person fewer than the current level of selling effort
- +1 means there 1 sales person more than the current level of selling effort
- many means there is unlimited selling effort available in that sales branch

For a branch with 3 reps, 33% more or fewer is equivalent to 1 additional or 1 fewer rep, so we can input the results from the calibration session directly.

If a branch has more or less than 3 reps, we must adjust the raw calibration data above before inputting it into our software.

The adjustment procedure is the following:

First consider +1 rep. Call the calibration X (=1.15 or 115% for example)

For a branch with N reps (N=3, 4 5 for example) we adjust X as follows:

$$X^* = 1 + (X - 1) * (N/3)$$

(So if X = 1.15 and we have 4 reps,  $X^* = 1.2$  or 120%)

Similarly, for -1 reps, call the calibration number Y (=.85 or 85%, for example). Here we adjust Y as follows:

$$Y^* = 1 - (1 - Y) * (N/3)$$

(So if Y=.85 and we have 4 reps,  $Y^*=.80$  or 80%)

	#of Reps	0	-33%	Base	+33%	Many
LA	5	50.0%	62.5%	100.0%	116.7%	188.0%
SF	4	60.0%	76.7%	100.0%	113.3%	150.0%
Seattle	3	50.0%	77.5%	100.0%	125.0%	162.5%
Boston	4	55.0%	76.7%	100.0%	127.3%	150.0%
Philly	5	52.0%	83.3%	100.0%	120.8%	145.0%
Cleveland	4	45.0%	72.0%	100.0%	136.7%	165.0%
Atlanta	3	49.0%	77.0%	100.0%	130.0%	199.0%
Nashville	3	55.0%	70.0%	100.0%	125.0%	160.0%
High Point	4	38.0%	60.0%	100.0%	138.7%	155.0%
Dallas	3	50.0%	72.0%	100.0%	127.5%	200.0%
Chicago	5	50.0%	58.3%	100.0%	125.0%	130.0%
Cincinnati	3	44.0%	80.0%	100.0%	115.0%	145.0%
St Louis	3	40.0%	70.0%	100.0%	125.0%	145.0%
Twin Cities	3	40.0%	75.0%	100.0%	115.0%	130.0%

Table 2: Adjusted calibration results.

The software should use the values in Table 2 above.

Table 3, below, provides the additional reference information to analyze the C-Tek situation.

Sales Branch	Current Number of Reps	Planned Sales Level (2008) (\$000)
Los Angeles	5	\$8,250
San Francisco	4	\$5,598
Seattle	3	\$8,703
Boston	4	\$9,464
Philadelphia	5	\$6,777
Cleveland	4	\$9,260
Atlanta	3	\$6,163
Nashville	3	\$6,793
High Point	4	\$4,294
Dallas	3	\$5,372
Chicago	5	\$11,119
Cincinnati	3	\$7,798
St. Louis	3	\$5,557
Twin Cities	3	\$8,772

Table 3: Current Number of Reps and Planned Sales Levels for C-Tek Sales Branches.

## Appendix 3: Harnessing Expert Judgment

MARKETING ENGINEERING

by Gary L. Lilien, Arvind Rangaswamy, and Timothy Matanovich

# Harnessing Expert Judgment

*Models help build profitability into sales force size and allocation decisions.*

In scope and cost, selling is arguably the most important and most costly element in the marketing mix. For many firms, personal selling is the key to marketing strategy implementation. It enables a firm to target its marketing effort selectively to high-value prospects down to the

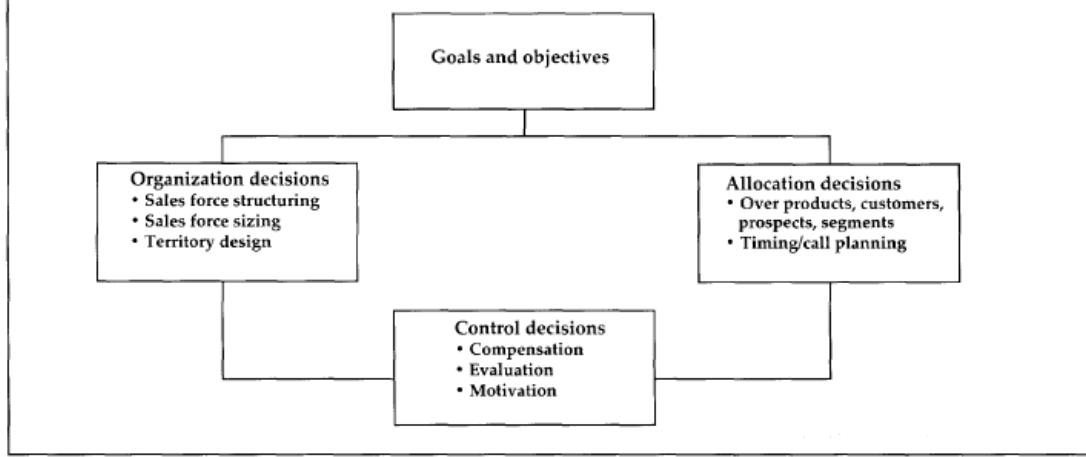
account level. Furthermore, salespeople can position the firm's offering for individual decision makers and capture valuable feedback from those customers.

Exhibit 1 highlights the three major categories of decisions—organization, allocation, and control—for which sales force managers are responsible. The four boxes

and the connecting lines offer a simple way to conceptualize decisions regarding sales force management. The goals and objectives provide the link between the overall strategic plan for the firm and the three sales force decision areas. The bi-directional nature of this link indicates that goals and objectives determine and are

### EXHIBIT 1

#### Sales force management



40 Fall 1998 MARKETING MANAGEMENT

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determined by each decision.

Sales force sizing (how many salespeople?) and allocation (how should total sales effort be allocated to different products, markets, and sales functions?) are fundamental management issues for all sales forces. Fortunately, a number of well-tested models are available to support decision making in this area. Many firms, however, continue to employ intuitive methods even though these models have proved very effective.

### **Intuitive Methods**

Firms often determine the size of their sales force by deciding "what we can afford." Typically they determine how much they can spend by taking a percentage of the forecasted sales for the company. They might base the actual percentage they use on historical norms from within the company or on the selling expense ratios for competitors. Then they divide the average cost of a salesperson into this figure to get the size of the sales force.

In a study of 41 packaged-goods sales forces, the average expense for a sales force was 3.71% of sales, with smaller firms (annual sales of less than \$500 million) spending between 5% and 8% and larger firms spending about half of that.

Another approach firms use to determine the size of the sales force is the "breakdown method," in which the firm divides the sales forecast for the planning horizon by the average revenues generated by a single salesperson in that length of time.

Once the firm has determined the total number of salespeople, it then allocates the total effort—such as total number of calls (visits) available—to accounts and prospects on the basis of their actual or forecasted sales. For example, salespeople may visit accounts with high levels of sales every month and those with low levels of sales once in six months.

Intuitive methods of sizing and allocating sales force effort are unsatisfactory, for two reasons:

- They do not account for the possibility that some accounts or prospects might respond differently from the "average" account.

- They do not take into account that a firm cannot determine the best size for the sales force (i.e., the total sales effort) without knowing how to allocate the total sales effort most effectively.

### **Market-Response Methods**

Market response methods require firms to estimate the relationship between sales effort and sales (i.e., the degree to which the market responds to changes in size and allocation of the sales force) and to codify those relationships within a response model. A market response method can be applied across customers, prospects, market segments, geographic areas, products, and so forth. The firm can then estimate sales-response functions and use these functions to calculate the levels of effort required to maximize profits or to achieve other business objectives. Repeated applications of the model with different numbers of sales people are used to make decisions on the best totals.

### **The Allocation Model**

The sales resource allocation model is a general response modeling approach to the problem of sizing and allocating the sales force effort. This model combines management science techniques with historical data and management judgment to calculate the incremental gain in profitability for each additional amount of sales resource.

Take, for example, an application of the model by Syntex, a global pharmaceutical firm. Syntex was selling seven prescription drugs (e.g., Naprosyn and Anaprox) that it promoted to nine physician specialties (e.g., general practice and dermatology). Syntex was considering increasing its sales force size substantially with the expectation that this would increase the sales of its portfolio of products in the nine physician segments. Exhibit 2 (see page 42) outlines the process used in implementing the Syntex model, which is easily generalized to other firms facing similar problems.

**Calibrating the model.** To calibrate the model, senior managers from the sales, marketing, and research departments estimated the response functions. Following a half-day training session, in which historical evidence of the line

between sales response and sales effort are reviewed, these managers separately answered several questions with respect to how sales of each product would respond to sales efforts and how each physician segment would respond to varying levels of sales effort.

Here's an example of the type of questions they answered: "According to Syntex's strategic plan, if sales force effort is maintained at the current level (indexed to 1) for the next three years, sales of product A would be the planned level (indexed to 1). What would happen to product A's sales (compared with a base of 1 for the present levels) if during the same time period it received (1) No sales effort? (2) One-half the current effort? (3) 50% greater effort? (4) A saturation level of sales effort?"

A computer summarized the responses. After discussing the initial results, the managers contemplated the differences between their own responses and the group mean and completed the questionnaire again. In the Syntex study, the second round led to consensus estimates of model inputs. The end result is a set of sales response functions that estimate product or segment sales for a given level of sales effort.

**Running the model.** The sales response allocation model combines these response functions into a single, unified model that determines the size of the sales force and the allocation of sales effort across products and physician segments by (1) predicting the sales volume and profitability that would result from a particular sales force size and allocation policy and (2) efficiently searching through hundreds of various sales force sizes and allocations within the model to find the profit maximizing solution.

The basic operation of the model is fairly straightforward: Each additional salesperson is assigned to sell the product or visit the specialty that, considering the allocation of the current sales force, would provide the highest incremental contribution to the firm.

Syntex calibrated the model twice—to allocate sales effort first to products and then to physician specialties. Running the model in both modes provided a validity check on the approach. For purposes of

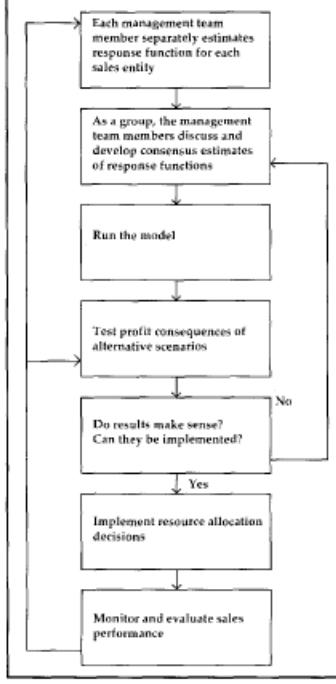
brevity, we will only give the details of the product model.

### Syntex' Product Model

Exhibit 3 illustrates the initial run of the model, the status quo scenario, which assumes that each salesperson costs \$63,000. As currently sized and allocated, the sales force generates sales of \$373 million and profits of \$219 million. For each product, the management team provided consensus estimates for the following:

- Number of sales persons dedicated (base selling effort).
- Dollar value of sales resulting from the recommended sales force size (recommended sales level).
- Per unit profitability (unit margins).

### EXHIBIT 2 Seven-step process for implementing the Syntex Model



- Consensus estimates of sales volume response to changes in sales force size as described previously (base estimates).

The management team was primarily interested in the answer to a single question: What sales force size and allocation across products will optimize profitability for the firm? Exhibit 4 shows the full optimization scenario based on the estimates of the management team. The model indicates sales can be increased by \$113 million, and profitability by \$58 million, a 26% increase over current levels. To achieve that result, sales force size must increase by 73%, to 744 persons, at an incremental cost of nearly \$20 million.

The management team was somewhat incredulous about the outcome. "Could we be underresourcing sales to that degree?" they wondered. At this point, they asked a new question: "To what degree is the increased profitability attributable to reallocation rather than increased size? The model was run again, this time optimizing allocation while holding sales force size at 430 people, resulting in the allocation optimization scenario depicted in Exhibit 5.

The full optimization scenario had both sales force size and allocation contributing to increased profitability. The allocation optimization scenario revealed that 76% of the increased profitability (\$44 million) could be gained simply by reallocating existing resources. The latter analysis shows that Naprosyn had been hugely underresourced, and the model suggested that sales effort be increased by 164%, or 159 people. At the same time, Anaprox was considered to be overresourced, and the model recommended reducing sales effort for this product by 89 people.

Another conclusion to be drawn from analysis of the allocation optimization scenario is that increasing sales force size is not nearly as attractive as it initially appears. An increase of 73%, to 744 people, yields only \$14 million in incremental profit (\$58 million potential gain minus \$44 million gained simply by reallocation) on the \$20 million investment. The sales resource allocation model helped the management team at Syntex identify \$44 million in increased profit

potential with little or no increase in marketing investment.

### Best Uses

In today's competitive environment, firms must justify every investment in terms of opportunity costs. Sales resource allocation modeling is a very useful tool for understanding those costs and the return on sales force investments. However, the model does have some limitations. It is best suited for repetitive buying situations in which the number of calls made to accounts is an important determinant of sales.

In such 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 can get from advertising media. 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.

The same basic approach can be applied more generally to the allocation of other marketing resources (advertising, promotion, direct marketing, and so on) across market segments, geographic entities, and the like. And interactions between segments (sales of razors lead to sales of blades, for example) can be accommodated as well.

A model like this can help marketers profitably harness their intuition about the market without collecting expensive research data. And the increase in profitability from reallocation gain that Syntex experienced is similar to what other firms have found in similar circum-

#### *Editor's Note*

*This is the second article in a series adapted from Marketing Engineering, Computer-Assisted Marketing Analysis and Planning, by Gary L. Lilien and Arvind Rangaswamy (Addison Wesley, 1997).*

## Alternatives

EXHIBIT 3

## Status quo scenario

Syntex Product Model

**Syntex Product Model**  
Unit cost of salesperson \$63,000

Net profit = \$218,827      \$218,827  
(\$5000)

EXHIBIT 4

### Full optimization scenario

Syntex Product Model

Unit cost of salesperson \$63,000

Net profit = \$218,827      \$276,4

**EXHIBIT 5**

### **Allocation optimization scenario**

Syntax Product Model

**Unit cost of salesperson \$63,000**

Segment	Base selling effort	Recommended sales force	Recommended sales level (\$)	Unit margins (0-1)	Constraint	Base estimates				
						None	1/2	1/2+	Sat.	
Naprosyn	96.8	256.4	304,266	0.700	0	0.47	0.68	1.26	1.52	
Anaprox	142.4	53.1	11,952	0.550	0	0.15	0.48	1.20	1.35	
Nor135	52.7	54.3	21,473	0.720	0	0.31	0.63	1.15	1.25	
Nor150	24.1	31.1	39,093	0.720	0	0.45	0.70	1.05	1.10	
Lidex	27.3	35.1	40,294	0.530	0	0.56	0.80	1.11	1.20	
Synalar	29.7	0.0	8,614	0.530	0	0.59	0.76	1.07	1.11	
Nasalide	56.8	0.0	1,680	0.520	0	0.15	0.61	1.46	1.76	
Total	429.8	430.0	427,372		430	430				
Net profit =	\$218,827 (8000)		\$262,872		Profits up 19% No increases in sales force					

Net profit = \$218,827      \$262,872

stances: an 8%-15% improvement in sales. Can you really afford not to use such an approach? ■

## *About the Authors*

**Gary L. Lilien** is Distinguished Research Professor of Management Science at Penn State University, University Park, and Cofounder and Research Director of the university's Institute for Study of Business Markets, a research institute dedicated to advancing the theory and practice of business-to-business marketing. Gary consults with a variety of companies such as Allied Signal, American Cyanamid, AT&T, Hewlett-Packard, and IBM. He has authored nine books and more than 80 professional articles on topics such as business marketing, new product development, marketing models, and bargaining theory.

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**Timothy Matanovich** is president of Market Leaders Group, Golden, Colo. MLG produces executive workshops, provides businesses with marketing decision-making tools, and consults with businesses on marketing and leadership challenges. Tim has worked with companies such as GE, DuPont, and Xerox, to enhance profitability through improved marketing decision making.

## CASE ANALYSIS: C-TEK CORPORATION: SALESFORCE SIZING AND ALLOCATION FOR GRINDING PRODUCTS

C-Tek Corporation was founded in 1889 in Twin Harbors, Minnesota by seven businesspeople determined to develop new materials for grinding wheels, sandpaper, and abrasives products.

- The company's lines of business expanded into numerous other, related areas, mainly centered around materials involving either adhesion or abrasion. From its start in the late 1800's, the company grew entirely through internal innovation and growth to revenue of more than \$20 Billion in 2004.
- The company was known for producing many small innovations and occasional breakthrough products and providing a climate that encouraged internal entrepreneurship and systemic growth.
- Each of the company's 33 lines of business operates its own channels, mixing direct sales with an extensive set of distributor relationships. Each of these lines of business operates as a rather independent business unit, with its own revenue targets and profit and loss statements.
- We are trying to analyze the resource allocation of sales representatives working at Grinding products work in 14 sales branches in the US.
- The average, fully loaded cost for a sales rep at C-Tek was projected to be \$147,000.

### PROBLEM STATEMENT

- 1) Lack of increase in the salesforce to cope with the competition.
- 2) To come up with an objective approach that will convince the management to realize the importance of increase in salesforce size in other words need for systematic resource allocation with assured benefits in terms of margins.
- 3) To identify comparative instructions, that hold for advertising/communications spending, promotional spending, based on the results from the analysis.
- 4) Choosing an appropriate length of time horizon to estimate to evaluate for any new hires or transfers to have their complete impact on the marketplace.

### ALTERNATIVE ANALYSIS

The approach the company used was to calibrate salesforce effort and outcome (impact) response models for each of its locations as the company feels it's appropriate. To perform this analysis, management has chosen to harness their "managerial wisdom" to build their sales response model using set of defined questions and by executing a systematic calibration session. And so, the data we would be using for our analysis is obtained from the above-mentioned approaches.

We will be looking at running different response models calibrating the effort and impact considering the below scenarios. We will be looking at analyzing the sales response using Enginius's resource allocation response functions of **AdBug, Logit, Exponential and Automatic models**. Thus, these three will be acting as **alternatives for our analysis**.

#### Data Format and Description for Alternative Analysis

**Base Scenario**-Give us the base details for each of the 14 locations, number of sales reps the company and current sales. This will be used as a benchmark for later analysis.

**Effort Data**-mentions the different levels of efforts(in this case no of sales reps) for each of 14 locations. We can translate the business scenarios mentioned in the case to different levels of effort for our analysis.

- 1) No sales force representation- **None**
- 2) One fewer sales representative-**Low**
- 3) The same number of sales representatives-**Base**
- 4) One more sales representative and increase in sales reps-**High**.

**Impact Data**-represents the amount of impact on sale for different levels of effort that is based on increase or decrease in sales representatives.

**Segment-specific constraints**- can be given based on our optimization objectives. The only constraint we are giving Enginius in our case is that we cannot have negative number of sales reps.

### 1) Response function of Adbug model

Adbug is an S-shaped functions that allows outcomes to increase very slowly as you increase effort from low levels, and then accelerate rapidly, before eventually reaching a plateau, or saturation level. Referring to exhibits 1A, 1B, 1C in the annexure when there is an increase of 86% of effort in terms of sales reps an increase of 41% in gross margin and 29% increase in net margin is observed. The highest increase is seen in the locations of Atlanta and Dallas in terms of margins.

### 2) Response function of Logit model

Similar to the Adbug response function logit model too is an S-shaped function. Taking reference from results produced by Logit response function Exhibits 2A, 2B and 2C when 89% of effort is employed the gross margins would go up by 49% and the net margins would increase by 38%. Which is quite higher than the exponential response function though the effort is increased by a little. Atlanta and Dallas are the most profitable centers, but with almost equal effort level when compared with the effort of exponential response function i.e., between 7 and 8 sales reps at each of these locations.

### 3) Response function of Exponential model

An Exponential response function increases rapidly at the very beginning, and each additional effort unit has a marginally lower impact than the previous effort unit. Referring to exhibits 3A, 3B, 3C in the annexure when there is an increase of 82.9% of effort in terms of sales reps an increase of 25.1% in gross margin and a very low of 10% increase in net margin is observed. The highest increase is seen in the locations of Atlanta and Seattle in terms of margins.

Hence, based on the results from above three models, it can be concluded that Logit function is giving us the best results when an optimized level of effort is employed, and the effort is employed is not very different in each of the methods though a significant difference is seen in the impact percentages. But, when looked at the recommended effort percentage based on sensitivity analysis, the value is the highest for the Logit model and least for the exponential model.

However, the individual location performance when looked in isolation might give us different results, as we saw that Atlanta and Seattle were most profitable according to exponential model whereas, other two models show Atlanta and Dallas to be the most profitable centers for sale.

	Effort	Impact	Impact(%)	Recommended effort based on Sensitivity analysis
<b>Adbug Response function</b>	86	29	33%	96.5
<b>Logit Response function</b>	89	38	42%	98.3
<b>Exponential response function</b>	83	10	12%	94.5

## LIMITATIONS

- The approach does not consider the impact of productivity of sales rep on revenue generating capabilities.
- The analysis is majorly based on the data obtained using “managerial wisdom” approach and not based on previous sales or historical performance of the locations. There is always a great scope of errors and biases since the judgement can be subjective in many ways.

- Using automatic model for arriving at the best response function may be too generic, as 14 different locations will be considered in aggregation to arrive at this model.
- No criteria or base was used to convert the opinions put forward during the calibration session to objective numbers, it was mostly like a game of wise guessing.
- The pooled judgement process of calibration can involve several limitations when the process has features such as no consensus necessary, respect everyone's opinion, median responses, recycling to stabilize the judgements etc. There is so much room for error and making assumptions without much practical evidence.

## RECOMMENDATIONS

- Based on comparison of results, it is recommended that an **extensive analysis has to be performed for each location** using 3-4 different response functions mentioned above and then compare the effort and impact levels and accordingly make business decisions about resource allocation for each of the location.
- Support base data with some numbers on historical sales performance of the company. Models similar to **allocation model** or more iterative approaches such as **syntex model** can be more beneficial in arriving at more reliable information on right mix of resources to be allocated.
- Take into consideration the **levels of productivity of a sales rep** when estimating their potential to generate sales.
- Consider the message coming from the **unconstrained optimization analysis** from the report before making any business choice with respect to salesforce, as these talk about the optimal number of sales reps for each location to arrive at the best outcome.
- C-tec should consider other resource allocation approaches that would also look at **comparing salesforce effort with other efforts like the impact on sales from other channels of sale** etc. and then decide between investing in hiring more sales reps or on other channels that generated sales without the involvement of sales reps.
- The inputs coming from the **sensitivity analysis** gives us the recommended effort and the margins so obtained by employing recommended level of effort/number of sales reps.  
As per the results coming from the sensitivity analysis it is seen that sometimes-hiring maximum number of sales reps can also decline your margins, this analysis gives us the optimum number of sales reps to be employed (needed) in order to achieve the maximum margins.  
Please refer to Annexure: Sensitivity Analysis.
- Perform a similar analysis for other marketing and sales promotional efforts of C-tec together as a **promotional mix analysis** or in isolation and then decisively choose efforts that would maximize the company's impact on sales.
- This promotional mix analysis could be very beneficial, especially if the company is spending less than \$147,000 dollars to generate the same number of sales.

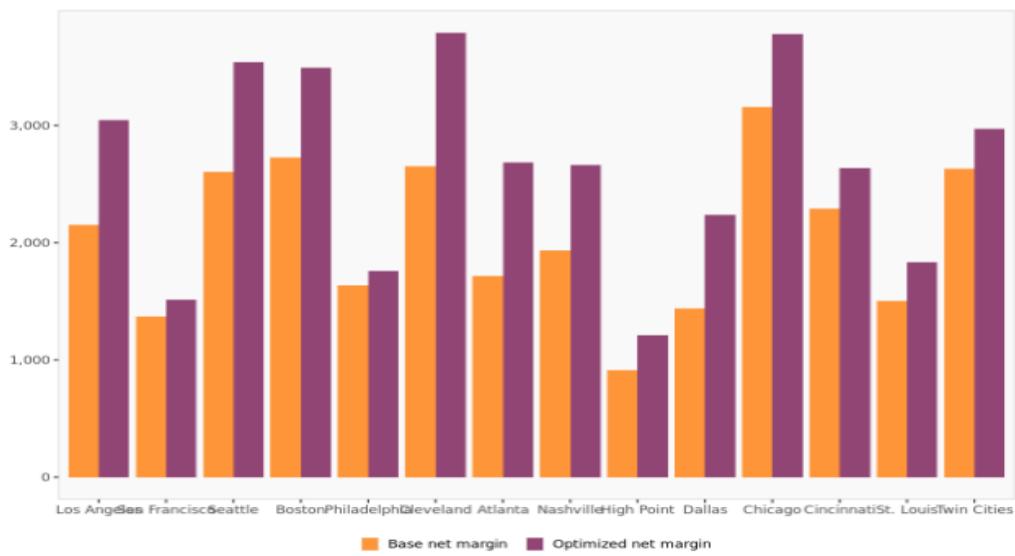
## ANNEXURE

### 1) ABUG RESPONSE FUNCTION-EFFORT AND NET MARGIN ACROSS LOCATIONS

	Base net margin	Optimized net margin	% change in margin
<b>Los Angeles</b>	2 153	3 043	41.4%
<b>San Francisco</b>	1 371	1 512	10.3%
<b>Seattle</b>	2 605	3 541	35.9%
<b>Boston</b>	2 724	3 492	28.2%
<b>Philadelphia</b>	1 637	1 761	7.6%
<b>Cleveland</b>	2 653	3 791	42.9%
<b>Atlanta</b>	1 716	2 686	56.5%
<b>Nashville</b>	1 937	2 662	37.5%
<b>High Point</b>	915	1 213	32.6%
<b>Dallas</b>	1 439	2 235	55.3%
<b>Chicago</b>	3 157	3 782	19.8%
<b>Cincinnati</b>	2 288	2 637	15.2%
<b>St. Louis</b>	1 504	1 835	22.0%
<b>Twin Cities</b>	2 629	2 973	13.1%
<b>Total</b>	28 728	37 163	29.4%

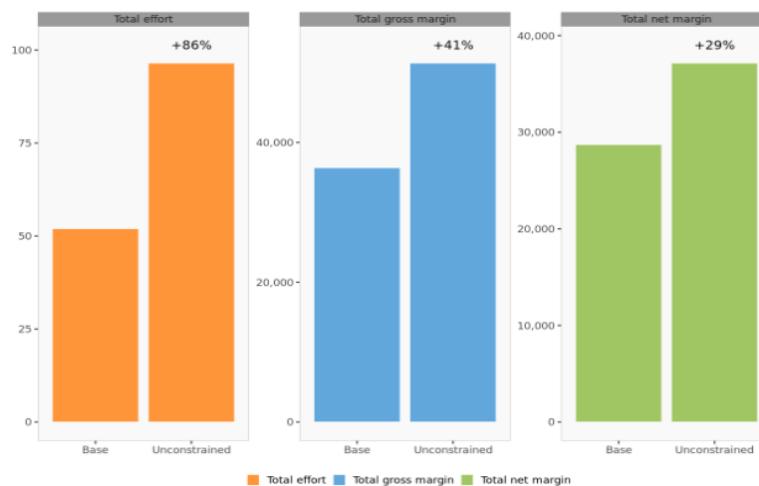
### EXHIBIT 1A

Comparison of net margin in unconstrained optimization.



### EXHIBIT 1B

Comparison of net margin in unconstrained optimization.



### EXHIBIT 1C

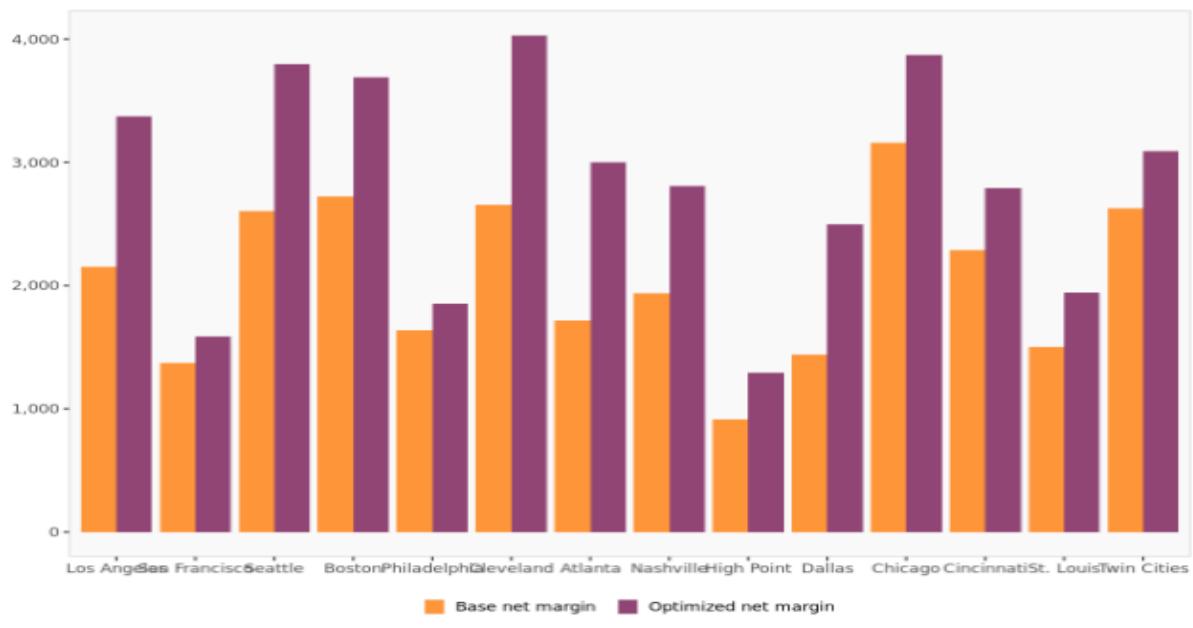
Comparison of scenarios.

## 2) LOGIT RESPONSE FUNCTION-EFFORT AND NET MARGIN ACROSS LOCATIONS

### EXHIBIT 2A.

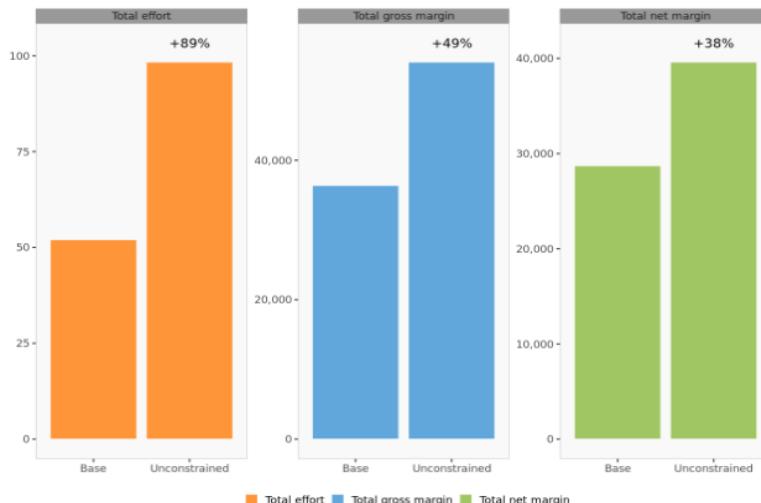
	Base net margin	Optimized net margin	% change in margin
Los Angeles	2 153	3 376	56.8%
San Francisco	1 371	1 588	15.8%
Seattle	2 605	3 796	45.7%
Boston	2 724	3 687	35.3%
Philadelphia	1 637	1 851	13.1%
Cleveland	2 653	4 030	51.9%
Atlanta	1 716	3 003	75.0%
Nashville	1 937	2 805	44.9%
High Point	915	1 291	41.1%
Dallas	1 439	2 495	73.4%
Chicago	3 157	3 870	22.6%
Cincinnati	2 288	2 790	21.9%
St. Louis	1 504	1 941	29.1%
Twin Cities	2 629	3 091	17.6%
Total	28 728	39 616	37.9%

Comparison of net margin in unconstrained optimization.



Comparison of net margin in unconstrained optimization.

### EXHIBIT 2B



Comparison of scenarios.

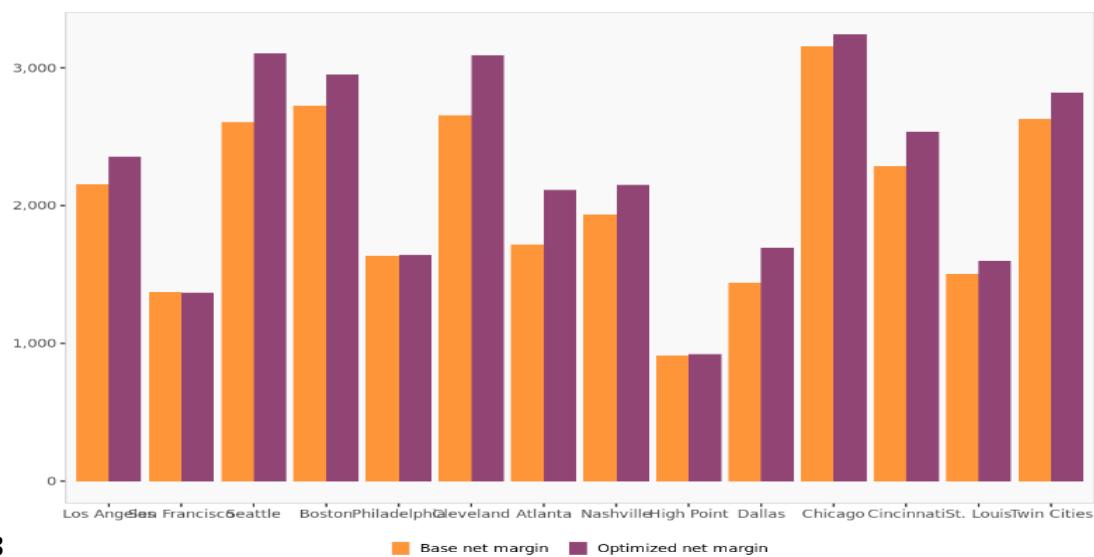
### EXHIBIT 2C

### 3) EXPONENTIAL RESPONSE FUNCTION-EFFORT AND NET MARGIN ACROSS LOCATIONS

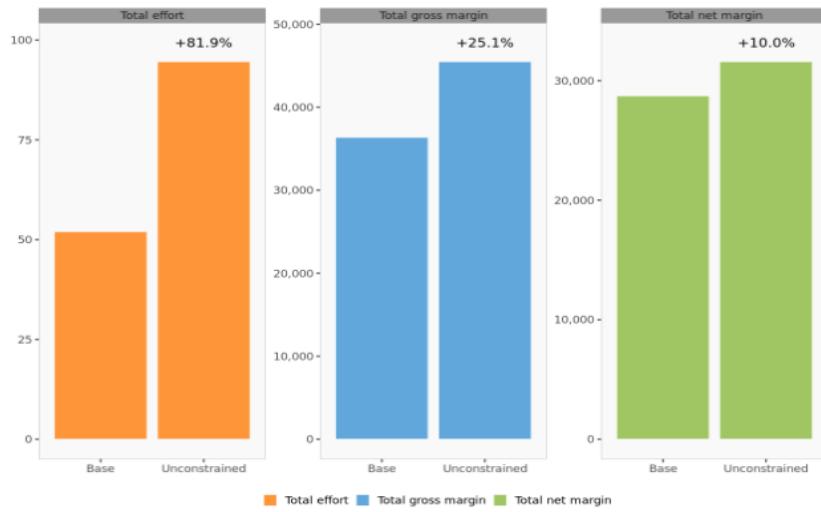
**Exhibit 3A.**

	Base net margin	Optimized net margin	% change in margin
<b>Los Angeles</b>	2 153	2 353	9.3%
<b>San Francisco</b>	1 371	1 368	-0.2%
<b>Seattle</b>	2 605	3 105	19.2%
<b>Boston</b>	2 724	2 951	8.3%
<b>Philadelphia</b>	1 637	1 642	0.3%
<b>Cleveland</b>	2 653	3 091	16.5%
<b>Atlanta</b>	1 716	2 113	23.1%
<b>Nashville</b>	1 937	2 152	11.1%
<b>High Point</b>	915	921	0.6%
<b>Dallas</b>	1 439	1 694	17.7%
<b>Chicago</b>	3 157	3 243	2.7%
<b>Cincinnati</b>	2 288	2 536	10.8%
<b>St. Louis</b>	1 504	1 600	6.4%
<b>Twin Cities</b>	2 629	2 819	7.2%
<b>Total</b>	28 728	31 588	+10.0%

Comparison of net margin in unconstrained optimization.



**Exhibit 3B**



**Exhibit 3C**

Comparison of scenarios.

## ANNEXURE: SENSITIVITY ANALYSIS

### 1) ABUG SENSITIVITY ANALYSIS

	Total effort	Net margin
No effort	0.00	17 787
-90% effort	9.65	21 088
-80% effort	19.30	24 074
-70% effort	28.95	26 709
-60% effort	38.60	29 488
-50% effort	48.25	31 797
-40% effort	57.90	33 791
-30% effort	67.55	35 187
-20% effort	77.20	36 171
-10% effort	86.85	36 952
Recommended	96.50	37 163
+10% effort	106.15	36 958
+20% effort	115.80	36 445
+30% effort	125.45	35 713

Sensitivity analysis.

### 2) LOGIT SENSITIVITY ANALYSIS

	Total effort	Net margin
No effort	0.00	17 632
-90% effort	9.83	20 604
-80% effort	19.67	25 108
-70% effort	29.50	28 006
-60% effort	39.34	30 945
-50% effort	49.17	33 866
-40% effort	59.01	35 209
-30% effort	68.84	37 528
-20% effort	78.67	38 573
-10% effort	88.51	39 306
Recommended	98.34	39 616
+10% effort	108.18	39 326
+20% effort	118.01	38 612
+30% effort	127.85	37 618

Sensitivity analysis.

### 3) EXPONENTIAL SENSITIVITY ANALYSIS

	Total effort	Net margin
No effort	0.00	16 569
-90% effort	9.46	21 056
-80% effort	18.92	23 960
-70% effort	28.37	26 116
-60% effort	37.83	27 785
-50% effort	47.29	29 073
-40% effort	56.75	30 052
-30% effort	66.21	30 767
-20% effort	75.66	31 242
-10% effort	85.12	31 508
Recommended	94.58	31 588
+10% effort	104.04	31 503
+20% effort	113.50	31 272
+30% effort	122.95	30 912

Sensitivity analysis.



# Enginius Resource Allocation

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Bhavya Priya Akula, The University of Tampa

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## Response function calibration

### Los Angeles

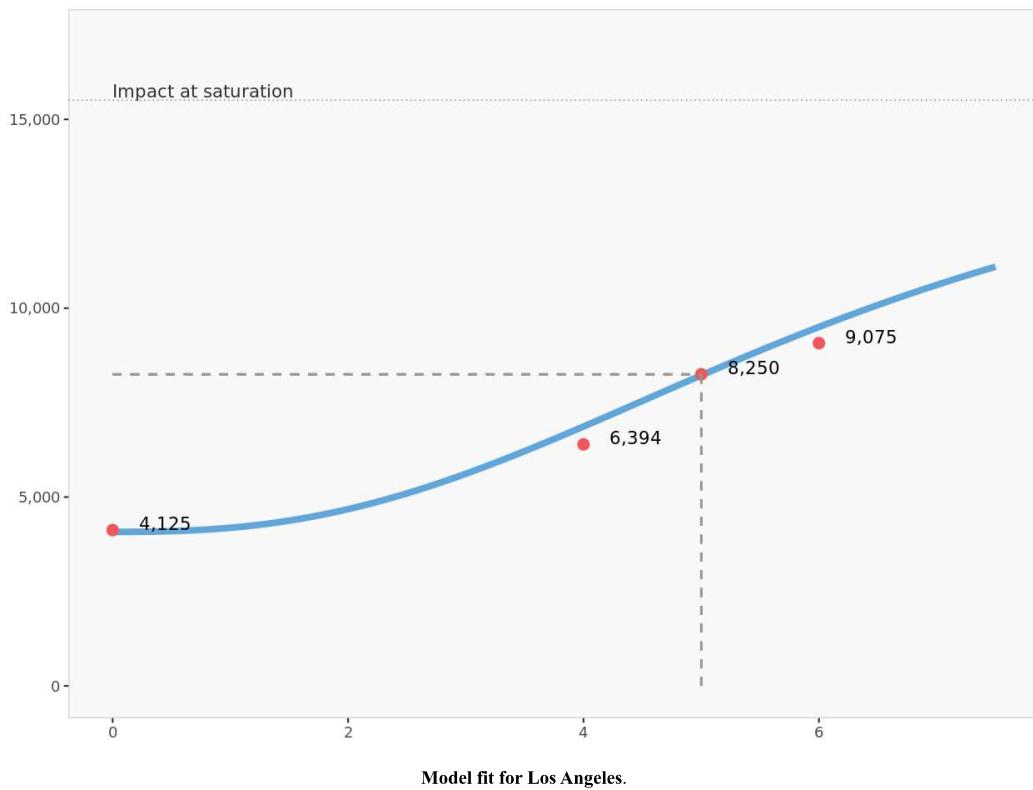
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	15 510	4 077.614	2.538	104.484

Parameters for Los Angeles.

	Effort	Impact	Fit
None	0.00	4 125	4 078
Low	4.00	6 394	6 868
Base	5.00	8 250	8 223
High	6.00	9 075	9 504
Saturation	Saturation	15 510	15 510

Model fit for Los Angeles.



### San Francisco

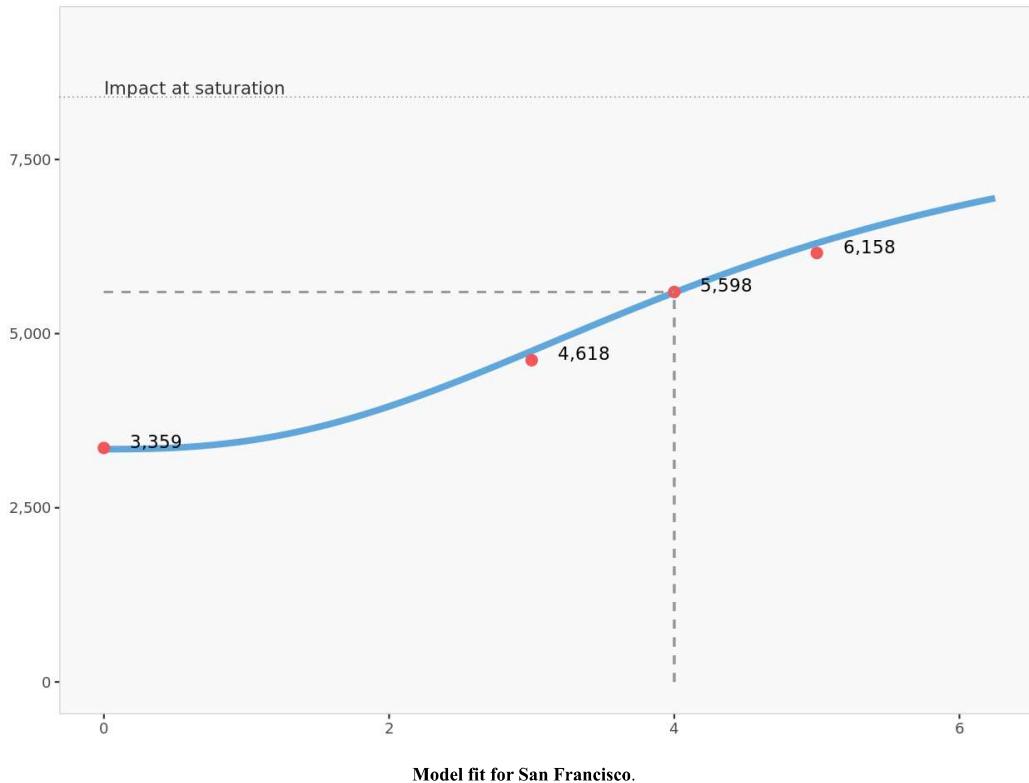
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	8 397	3 341.697	2.534	41.860

Parameters for San Francisco.

	Effort	Impact	Fit
None	0.00	3 359	3 342
Low	3.00	4 618	4 751
Base	4.00	5 598	5 590
High	5.00	6 158	6 299
Saturation	Saturation	8 397	8 397

Model fit for San Francisco.



## Seattle

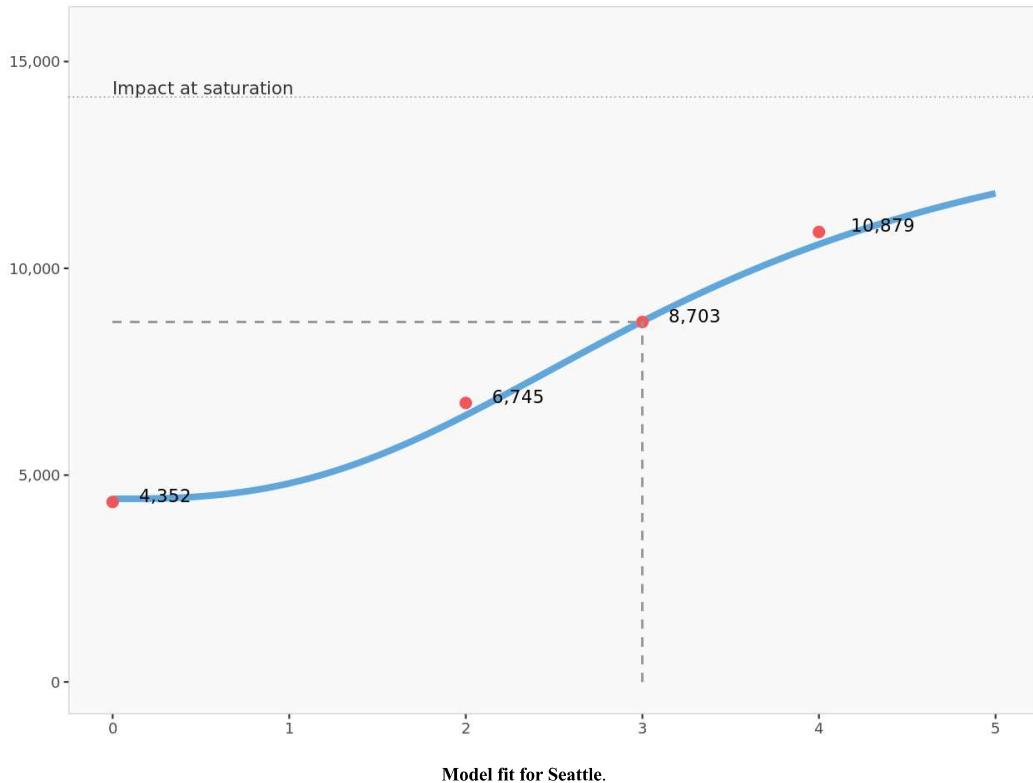
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	14 142	4 427.955	2.718	25.028

Parameters for Seattle.

	Effort	Impact	Fit
None	0.00	4 352	4 428
Low	2.00	6 745	6 450
Base	3.00	8 703	8 718
High	4.00	10 879	10 582
Saturation	Saturation	14 142	14 142

Model fit for Seattle.



Model fit for Seattle.

**Boston**

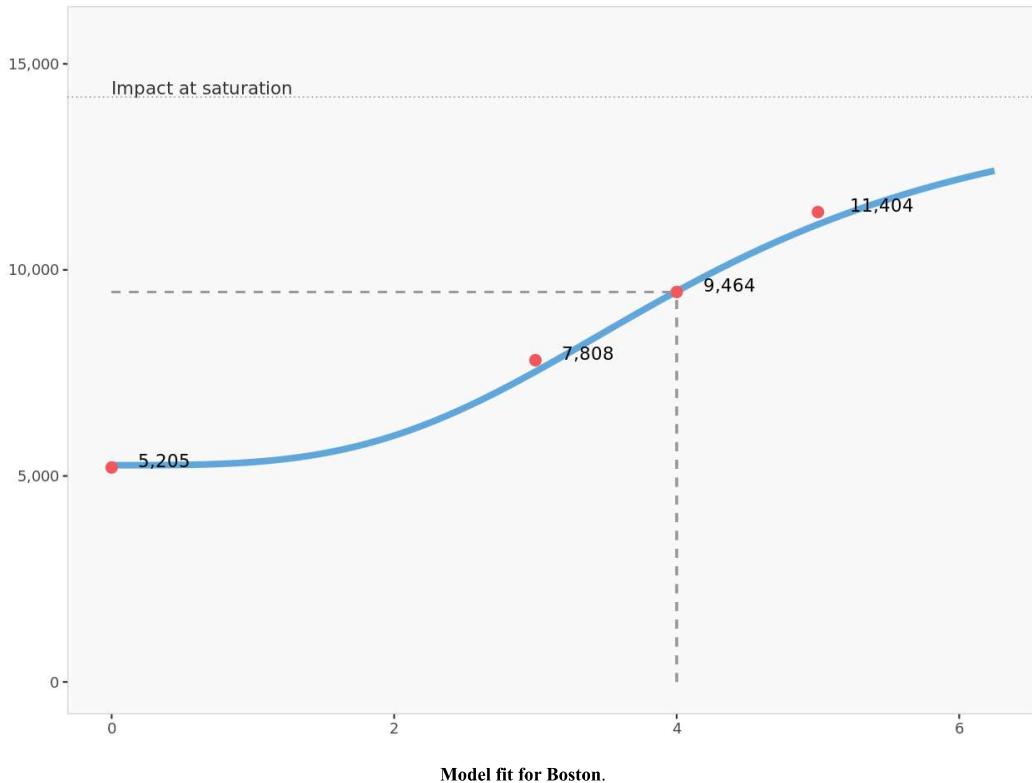
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	14 196	5 260	3.354	116.797

Parameters for Boston.

	Effort	Impact	Fit
None	0.00	5 205	5 260
Low	3.00	7 808	7 532
Base	4.00	9 464	9 480
High	5.00	11 404	11 105
Saturation	Saturation	14 196	14 196

Model fit for Boston.



## Philadelphia

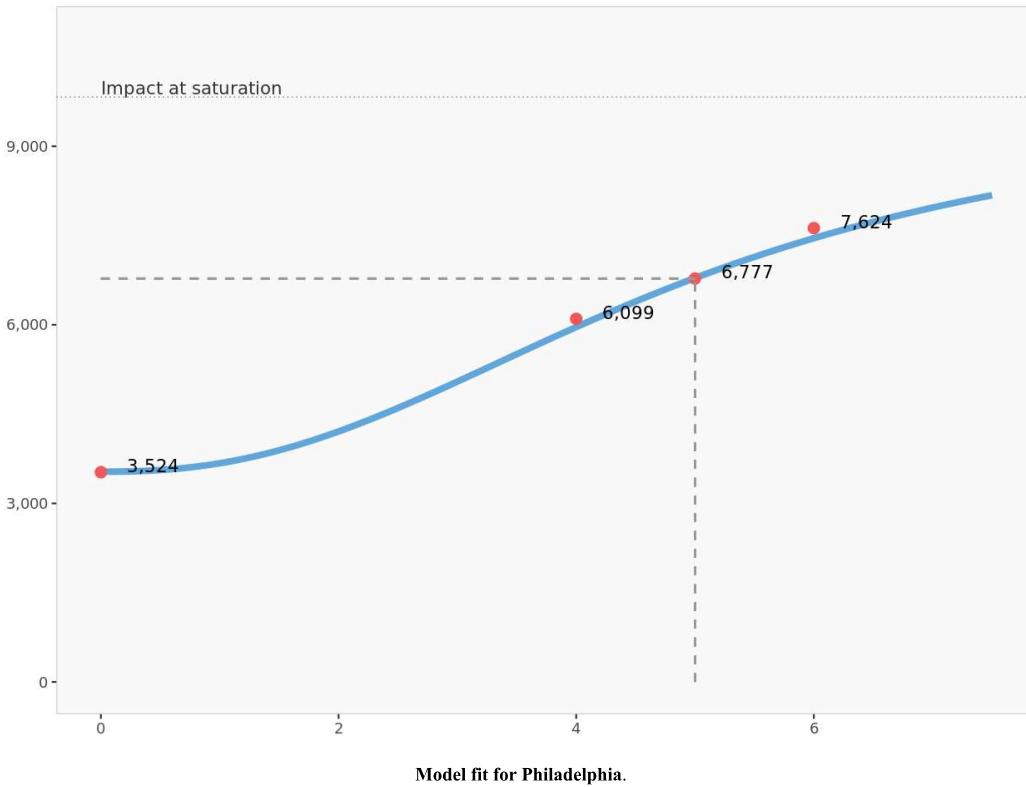
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	9 827	3 532	3.26	2.385

Parameters for Philadelphia.

	Effort	Impact	Fit
None	0.00	3 524	3 532
Low	4.00	6 099	5 962
Base	5.00	6 777	6 786
High	6.00	7 624	7 454
Saturation	Saturation	9 827	9 827

Model fit for Philadelphia.



## Cleveland

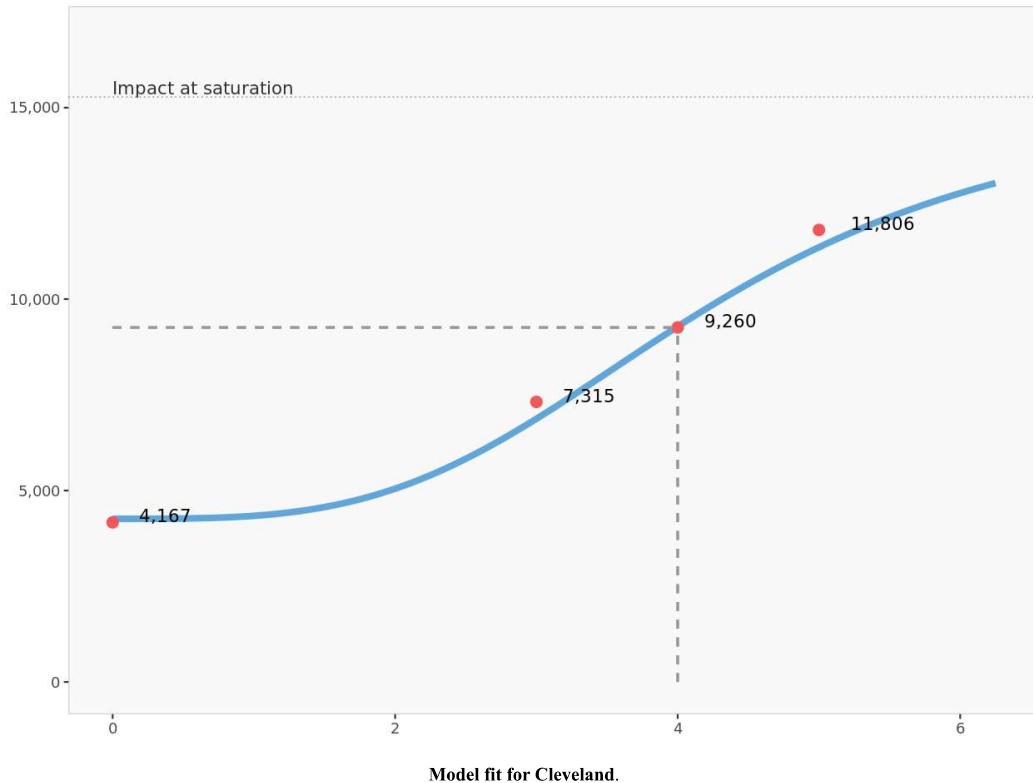
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	15 279	4 261.983	3.446	141.698

Parameters for Cleveland.

	Effort	Impact	Fit
None	0.00	4 167	4 262
Low	3.00	7 315	6 875
Base	4.00	9 260	9 284
High	5.00	11 807	11 354
Saturation	Saturation	15 279	15 279

Model fit for Cleveland.



## Atlanta

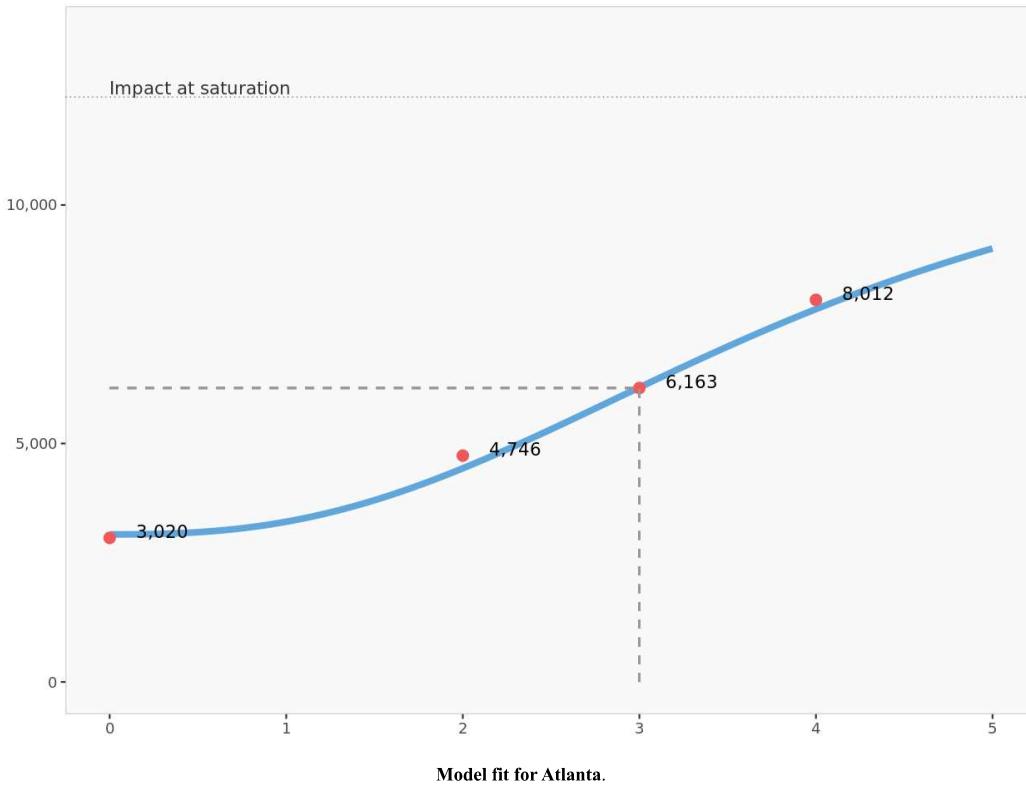
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	12 264	3 094.079	2.577	33.534

Parameters for Atlanta.

	Effort	Impact	Fit
None	0.00	3 020	3 094
Low	2.00	4 746	4 479
Base	3.00	6 163	6 175
High	4.00	8 012	7 817
Saturation	Saturation	12 264	12 264

Model fit for Atlanta.



## Nashville

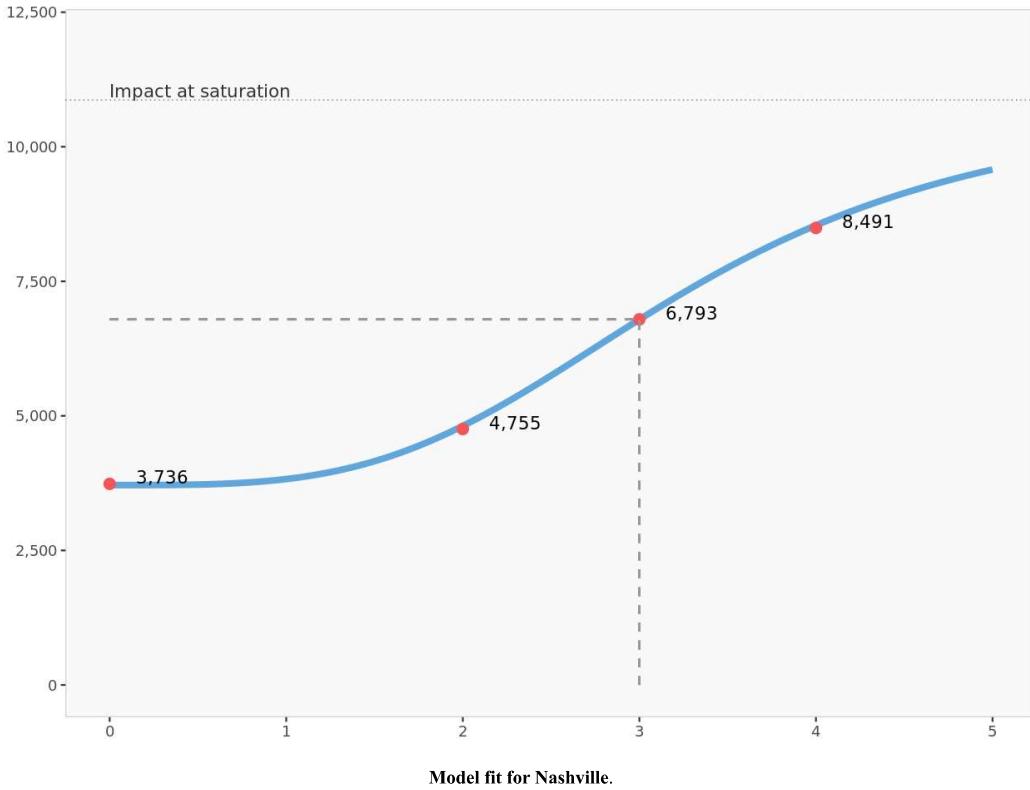
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	10 869	3 713.657	3.513	62.872

Parameters for Nashville.

	Effort	Impact	Fit
None	0.00	3 736	3 714
Low	2.00	4 755	4 813
Base	3.00	6 793	6 791
High	4.00	8 491	8 540
Saturation	Saturation	10 869	10 869

Model fit for Nashville.



## High Point

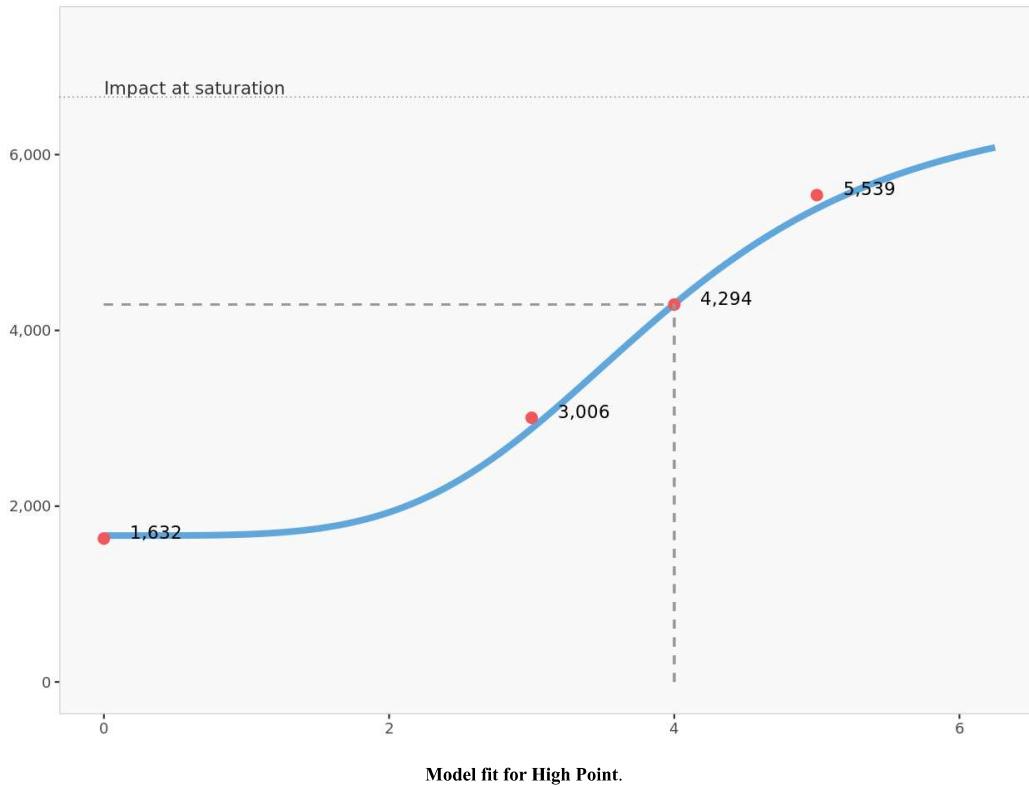
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	6 656	1 665.619	4.321	356.939

Parameters for High Point.

	Effort	Impact	Fit
None	0.00	1 632	1 666
Low	3.00	3 006	2 883
Base	4.00	4 294	4 301
High	5.00	5 539	5 387
Saturation	Saturation	6 656	6 656

Model fit for High Point.



## Dallas

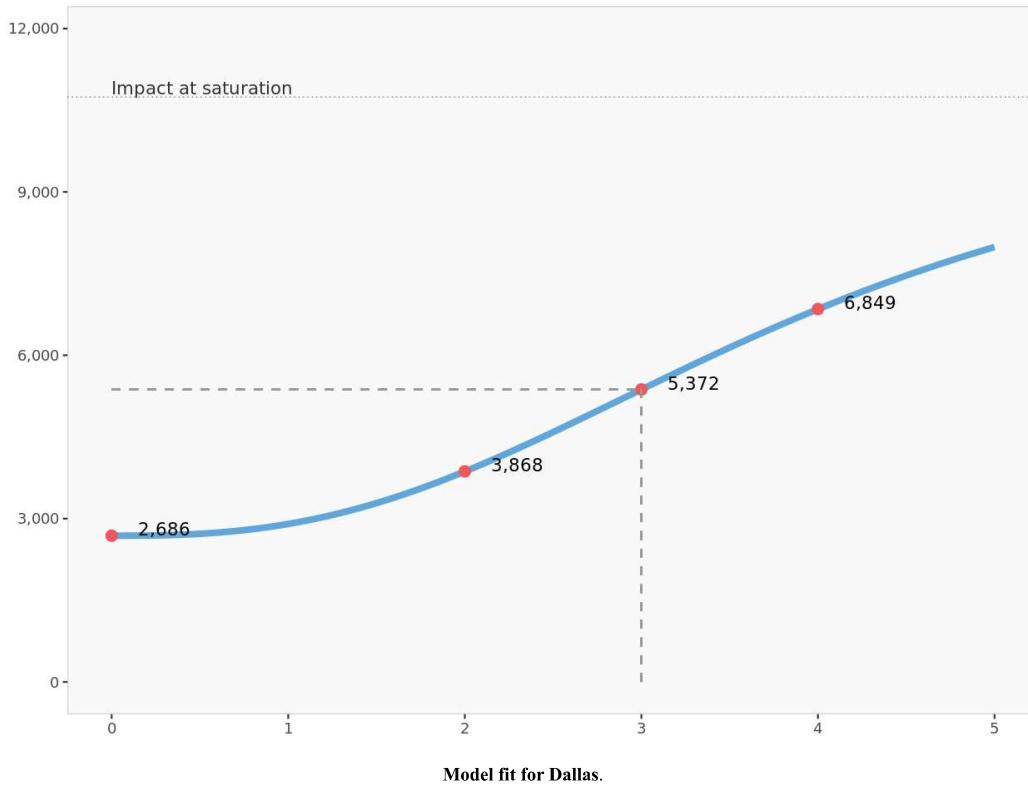
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	10 744	2 686	0.98	36.280

Parameters for Dallas.

	Effort	Impact	Fit
None	0.00	2 686	2 686
Low	2.00	3 868	3 866
Base	3.00	5 372	5 372
High	4.00	6 849	6 848
Saturation	Saturation	10 744	10 744

Model fit for Dallas.



## Chicago

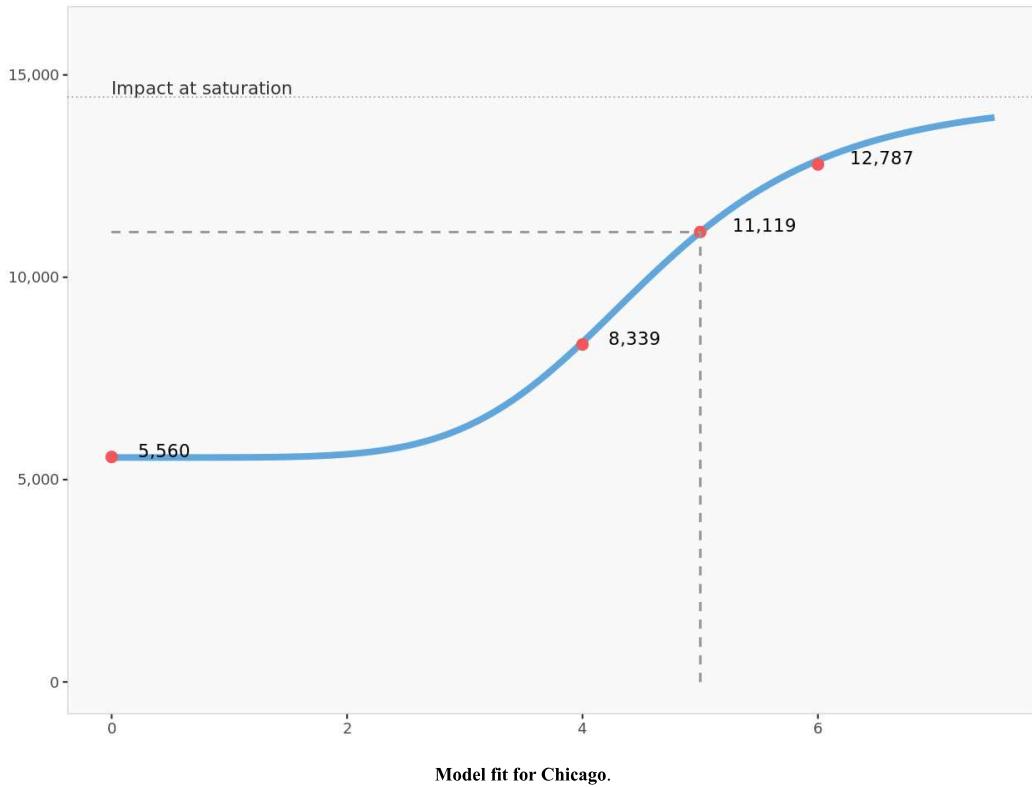
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	14 455	5 546,338	5,674	5 543,889

Parameters for Chicago.

	Effort	Impact	Fit
None	0.00	5 560	5 546
Low	4.00	8 339	8 395
Base	5.00	11 119	11 115
High	6.00	12 787	12 890
Saturation	Saturation	14 455	14 455

Model fit for Chicago.



## Cincinnati

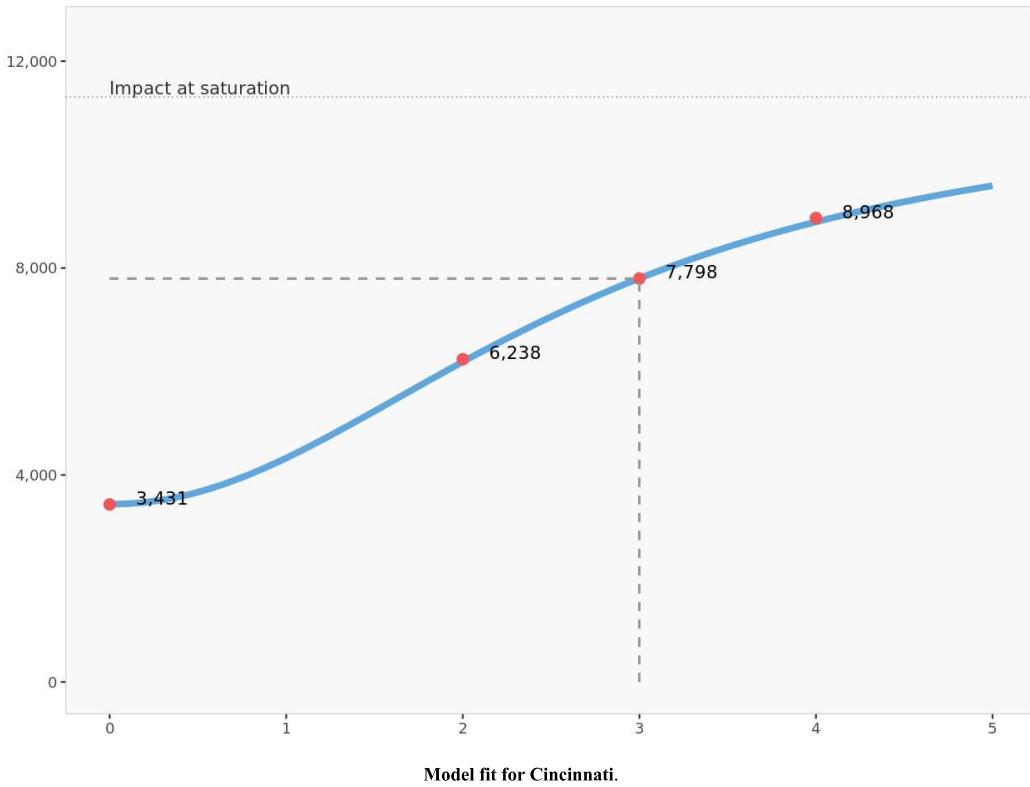
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
<b>Parameters</b>	11 307	3 436.954	2.072	7.824

Parameters for Cincinnati.

	Effort	Impact	Fit
<b>None</b>	0.00	3 431	3 437
<b>Low</b>	2.00	6 238	6 188
<b>Base</b>	3.00	7 798	7 802
<b>High</b>	4.00	8 968	8 893
<b>Saturation</b>	Saturation	11 307	11 307

Model fit for Cincinnati.



### St. Louis

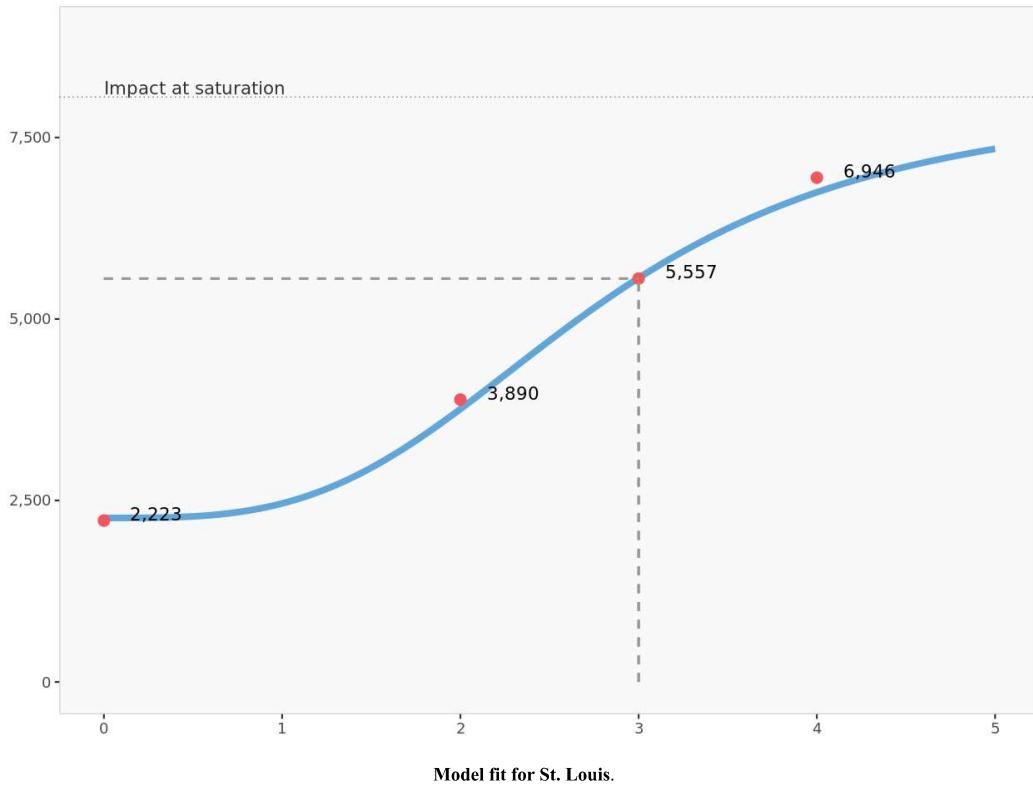
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	8 058	2 259	3.292	28.056

Parameters for St. Louis.

	Effort	Impact	Fit
None	0.00	2 223	2 259
Low	2.00	3 890	3 760
Base	3.00	5 557	5 565
High	4.00	6 946	6 745
Saturation	Saturation	8 058	8 058

Model fit for St. Louis.



## Twin Cities

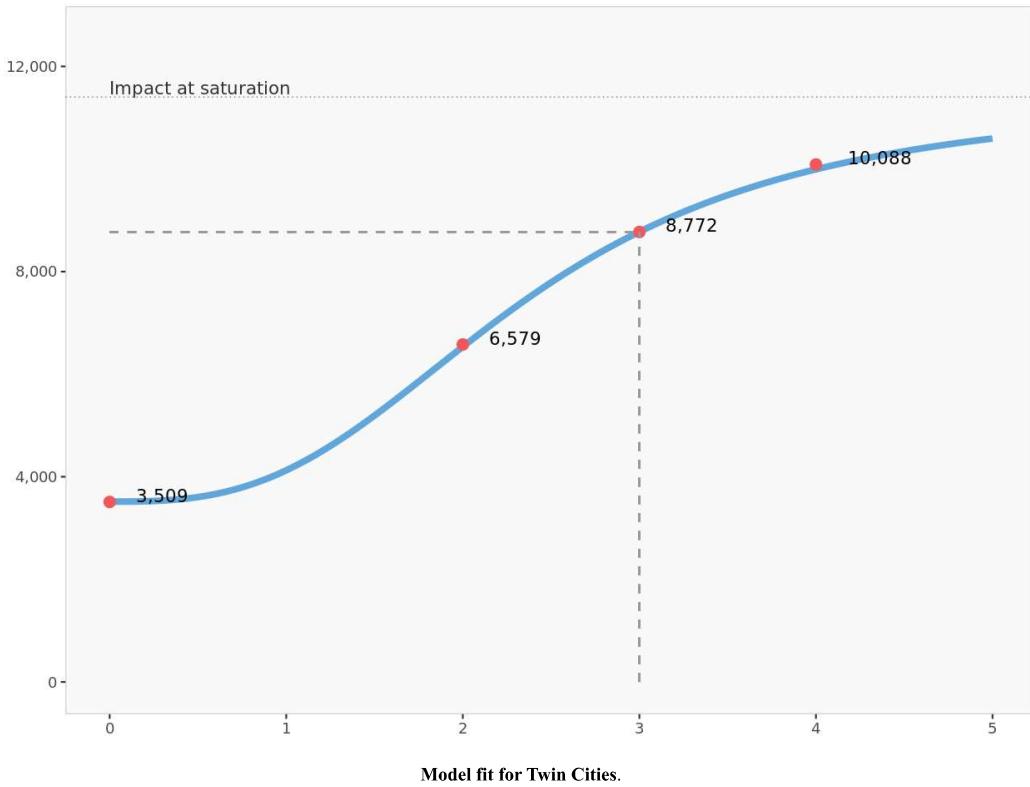
Model used: adbudg

	Ceiling	Floor	Slope	Intercept
Parameters	11 404	3 515.955	2.889	11.940

Parameters for Twin Cities.

	Effort	Impact	Fit
None	0.00	3 509	3 516
Low	2.00	6 579	6 536
Base	3.00	8 772	8 775
High	4.00	10 088	9 994
Saturation	Saturation	11 404	11 404

Model fit for Twin Cities.



## Base scenario

---

	Current number of reps	Current sales (\$000)	Cost per sales rep (\$000)	Margin	Cost of effort	Gross margin	Net margin
<b>Los Angeles</b>	5.00	8 250	147.00	0.35	735	2 888	2 153
<b>San Francisco</b>	4.00	5 598	147.00	0.35	588	1 959	1 371
<b>Seattle</b>	3.00	8 703	147.00	0.35	441	3 046	2 605
<b>Boston</b>	4.00	9 464	147.00	0.35	588	3 312	2 724
<b>Philadelphia</b>	5.00	6 777	147.00	0.35	735	2 372	1 637
<b>Cleveland</b>	4.00	9 260	147.00	0.35	588	3 241	2 653
<b>Atlanta</b>	3.00	6 163	147.00	0.35	441	2 157	1 716
<b>Nashville</b>	3.00	6 793	147.00	0.35	441	2 378	1 937
<b>High Point</b>	4.00	4 294	147.00	0.35	588	1 503	915
<b>Dallas</b>	3.00	5 372	147.00	0.35	441	1 880	1 439
<b>Chicago</b>	5.00	11 119	147.00	0.35	735	3 892	3 157
<b>Cincinnati</b>	3.00	7 798	147.00	0.35	441	2 729	2 288
<b>St. Louis</b>	3.00	5 557	147.00	0.35	441	1 945	1 504
<b>Twin Cities</b>	3.00	8 772	147.00	0.35	441	3 070	2 629
<b>Total</b>	52.00	103 920			7 644	36 372	28 728

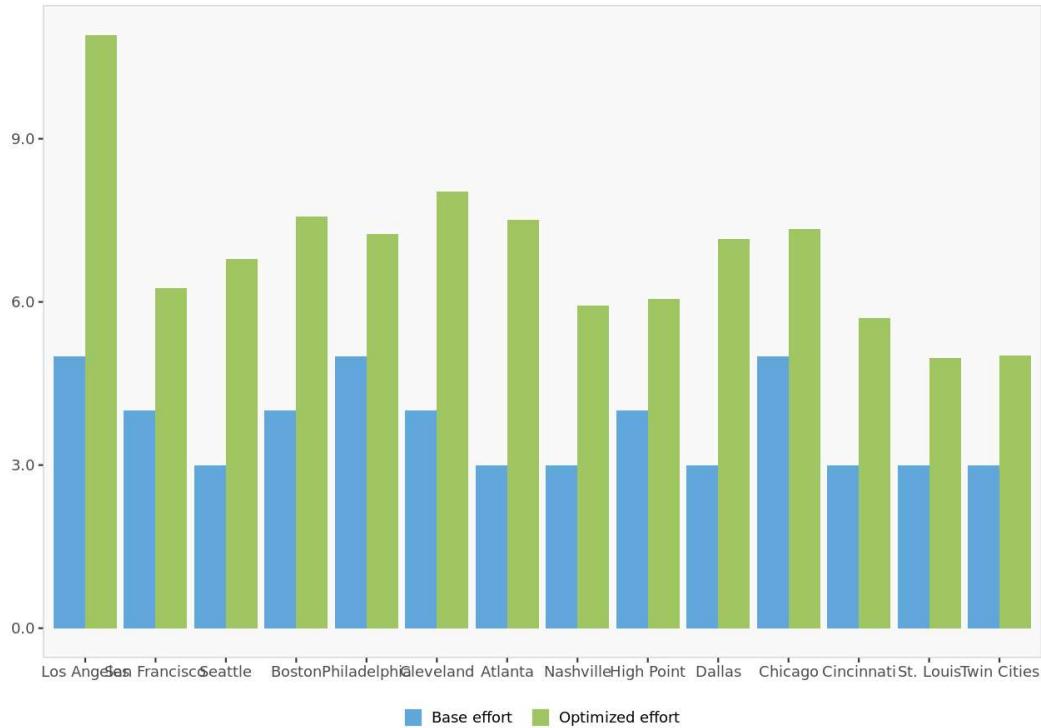
Base scenario table.

## Unconstrained optimization

### Effort

	Base effort	Optimized effort	% change in effort
<b>Los Angeles</b>	5.00	10.91	118.2%
<b>San Francisco</b>	4.00	6.25	56.2%
<b>Seattle</b>	3.00	6.79	126.3%
<b>Boston</b>	4.00	7.58	89.4%
<b>Philadelphia</b>	5.00	7.25	45.0%
<b>Cleveland</b>	4.00	8.03	100.8%
<b>Atlanta</b>	3.00	7.52	150.5%
<b>Nashville</b>	3.00	5.94	98.0%
<b>High Point</b>	4.00	6.06	51.5%
<b>Dallas</b>	3.00	7.15	138.4%
<b>Chicago</b>	5.00	7.35	46.9%
<b>Cincinnati</b>	3.00	5.70	89.9%
<b>St. Louis</b>	3.00	4.97	65.7%
<b>Twin Cities</b>	3.00	5.02	67.2%
<b>Total</b>	52.00	96.50	85.6%

Comparison of effort in unconstrained optimization.



Comparison of effort in unconstrained optimization.

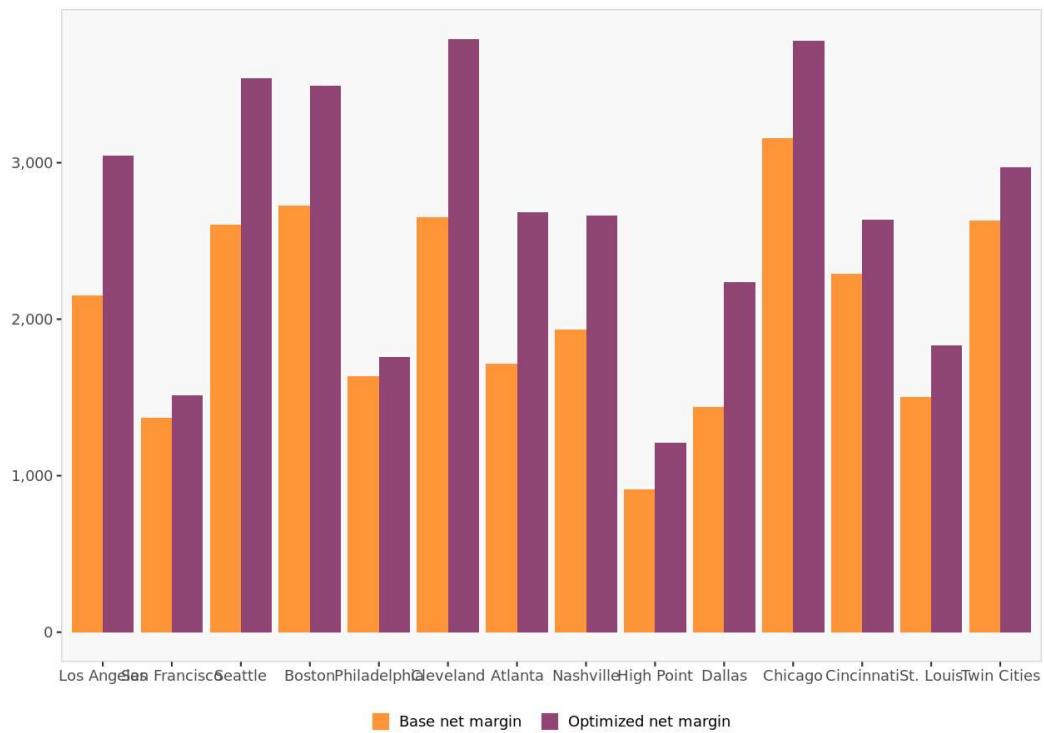
### Net margin

	Base net margin	Optimized net margin	% change in margin
<b>Los Angeles</b>	2 153	3 043	41.4%
<b>San Francisco</b>	1 371	1 512	10.3%
<b>Seattle</b>	2 605	3 541	35.9%
<b>Boston</b>	2 724	3 492	28.2%
<b>Philadelphia</b>	1 637	1 761	7.6%
<b>Cleveland</b>	2 653	3 791	42.9%
<b>Atlanta</b>	1 716	2 686	56.5%
<b>Nashville</b>	1 937	2 662	37.5%
<b>High Point</b>	915	1 213	32.6%
<b>Dallas</b>	1 439	2 235	55.3%

## Resource Allocation

<b>Chicago</b>	3 157	3 782	19.8%
<b>Cincinnati</b>	2 288	2 637	15.2%
<b>St. Louis</b>	1 504	1 835	22.0%
<b>Twin Cities</b>	2 629	2 973	13.1%
<b>Total</b>	28 728	37 163	29.4%

Comparison of net margin in unconstrained optimization.



Comparison of net margin in unconstrained optimization.

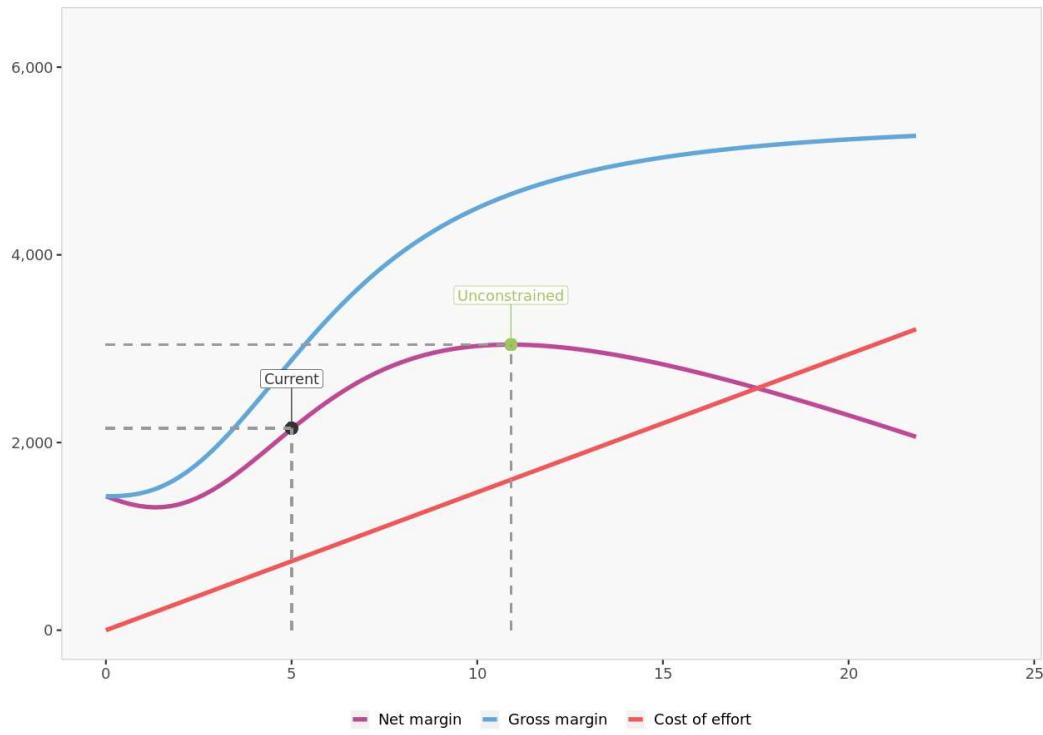
## Constrained optimization

---

The unconstrained solution does not violate any of the user-specified constraints. Therefore, imposing constraints would not change the recommended solution, and is not required.

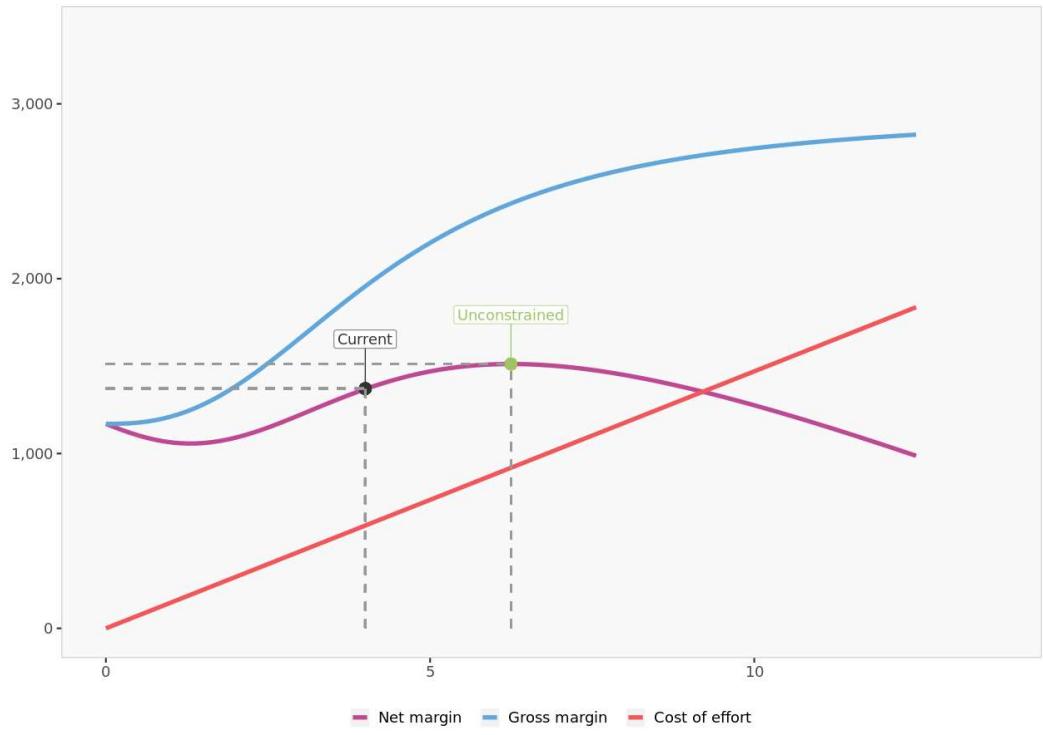
## Comparison of scenarios

### Los Angeles: scenarios



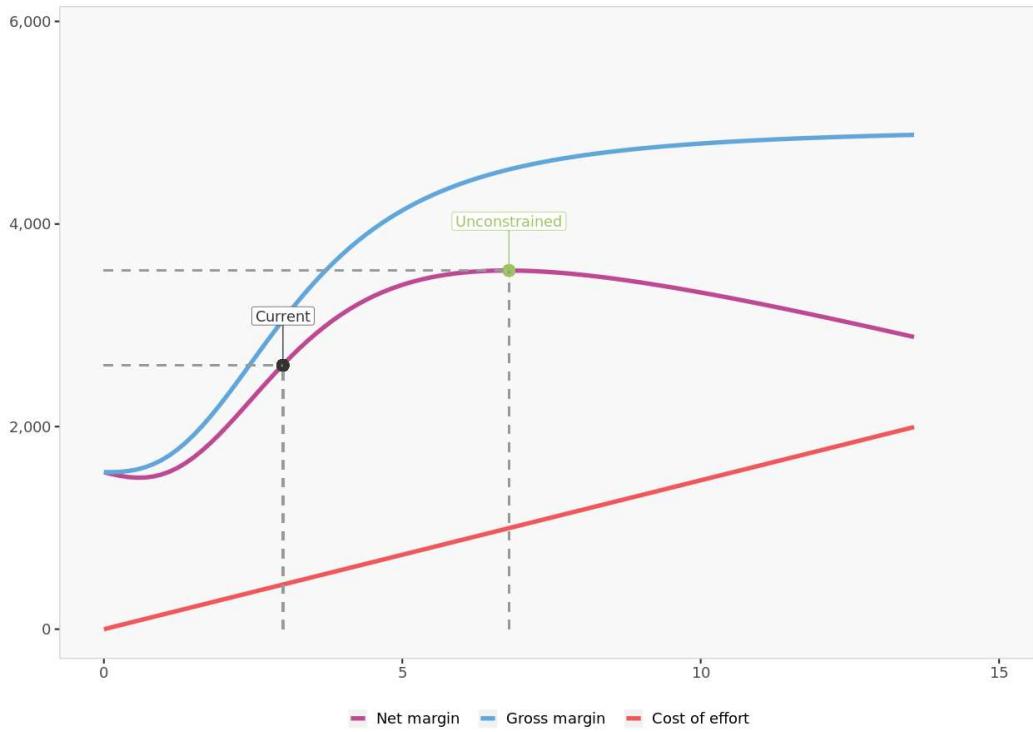
Los Angeles: scenarios.

### San Francisco: scenarios

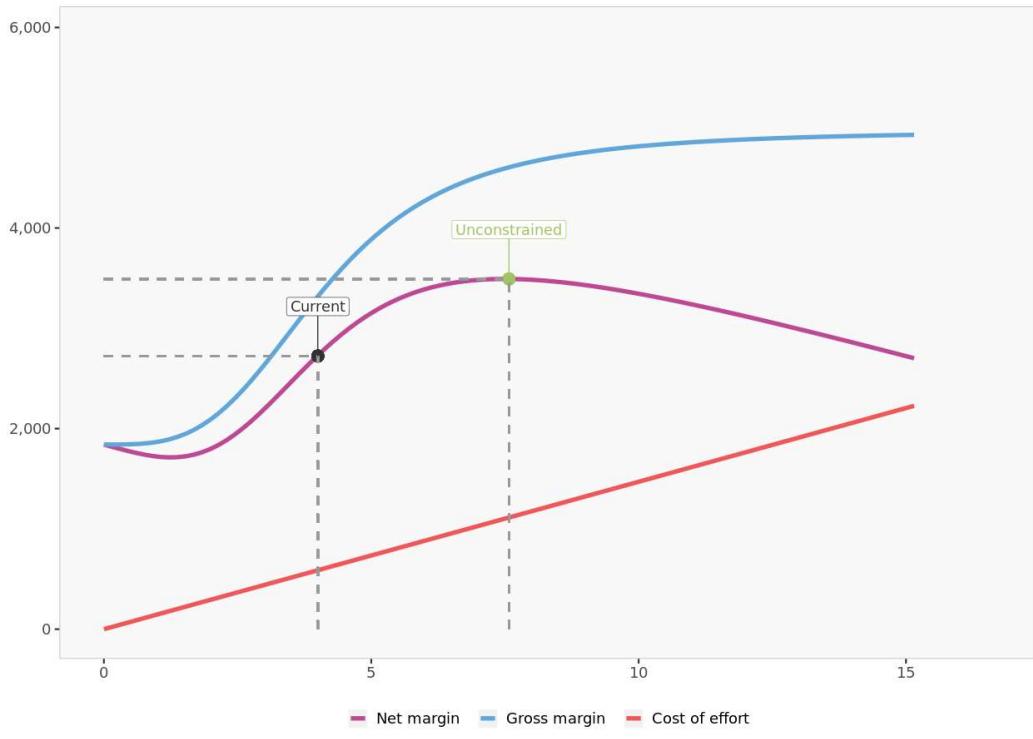


San Francisco: scenarios.

### Seattle: scenarios

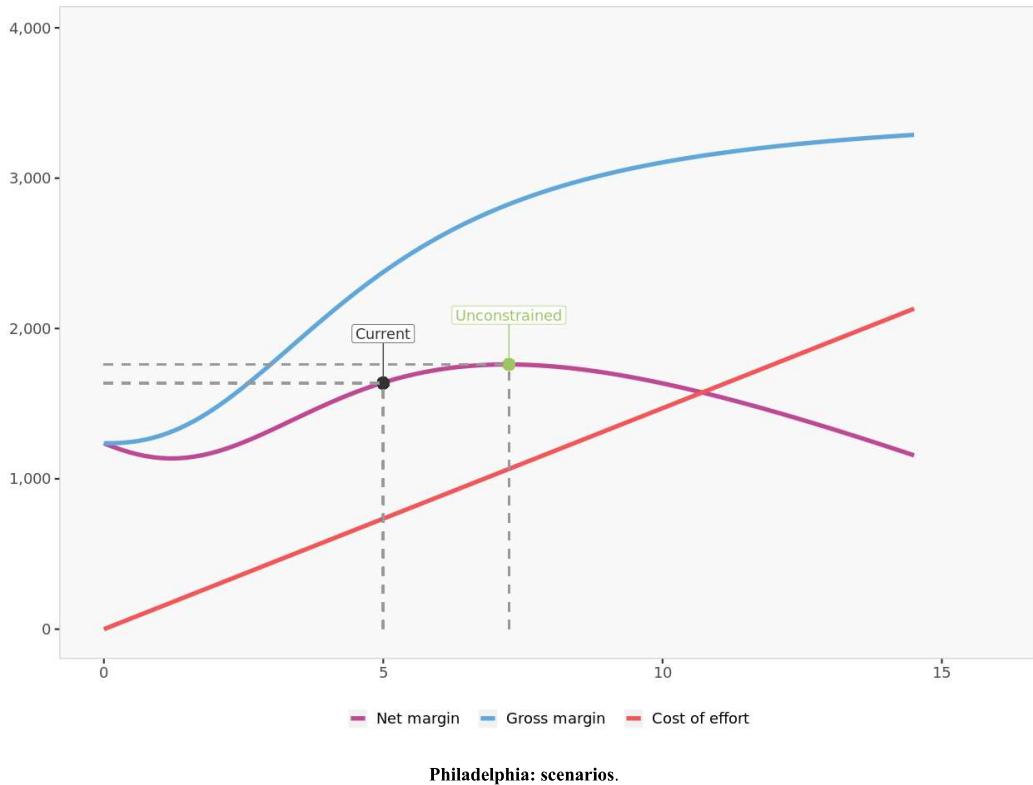


Seattle: scenarios.

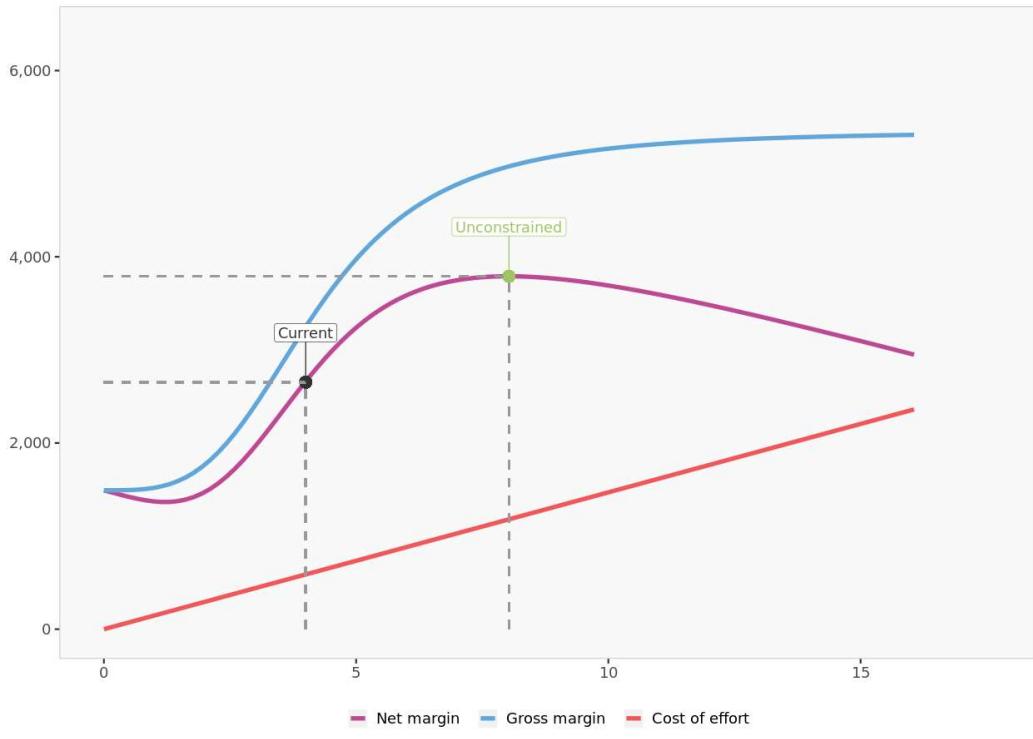
**Boston: scenarios**

Boston: scenarios.

**Philadelphia: scenarios**

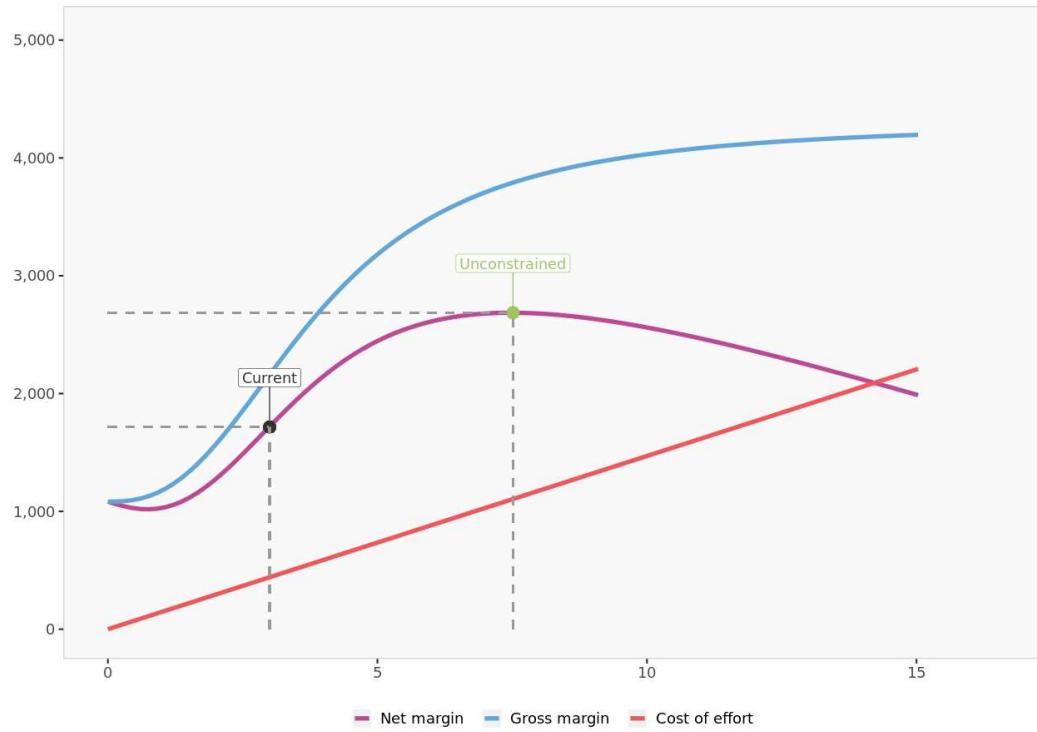


Philadelphia: scenarios.

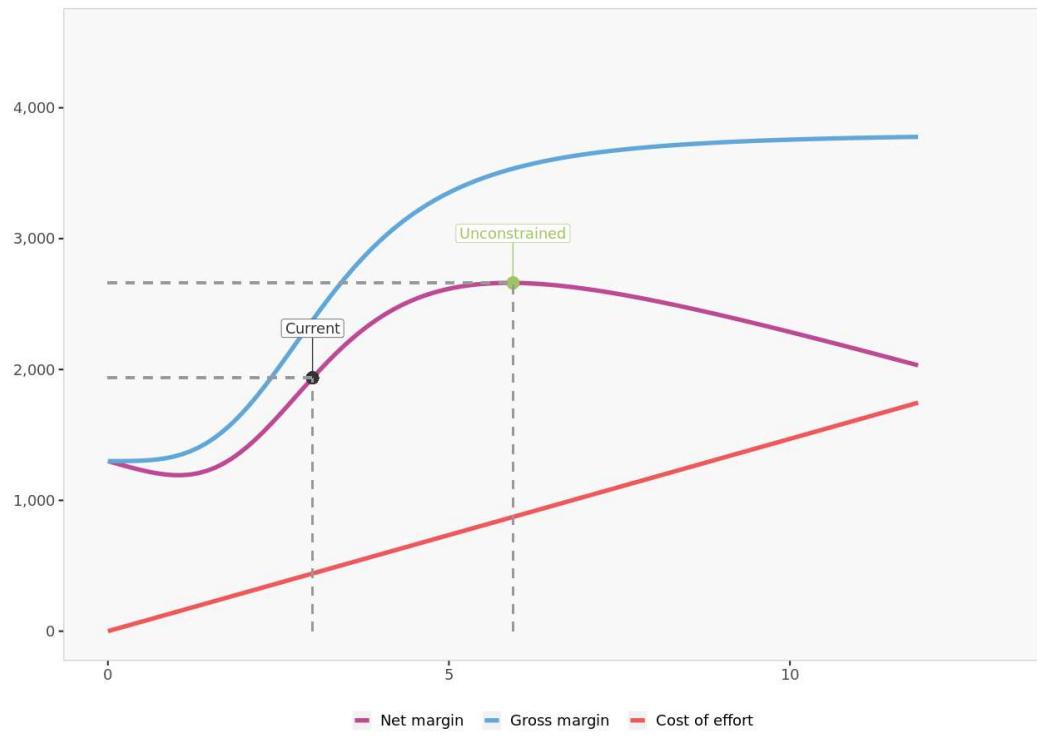
**Cleveland: scenarios**

Cleveland: scenarios.

**Atlanta: scenarios**

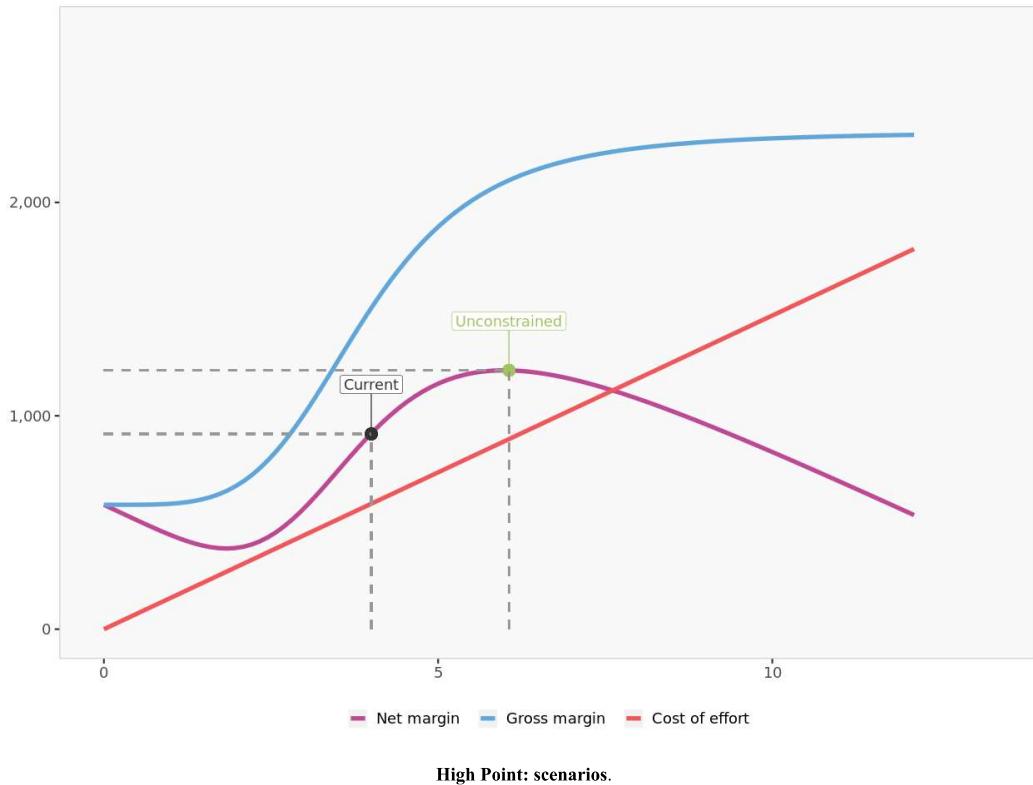


Atlanta: scenarios.

**Nashville: scenarios**

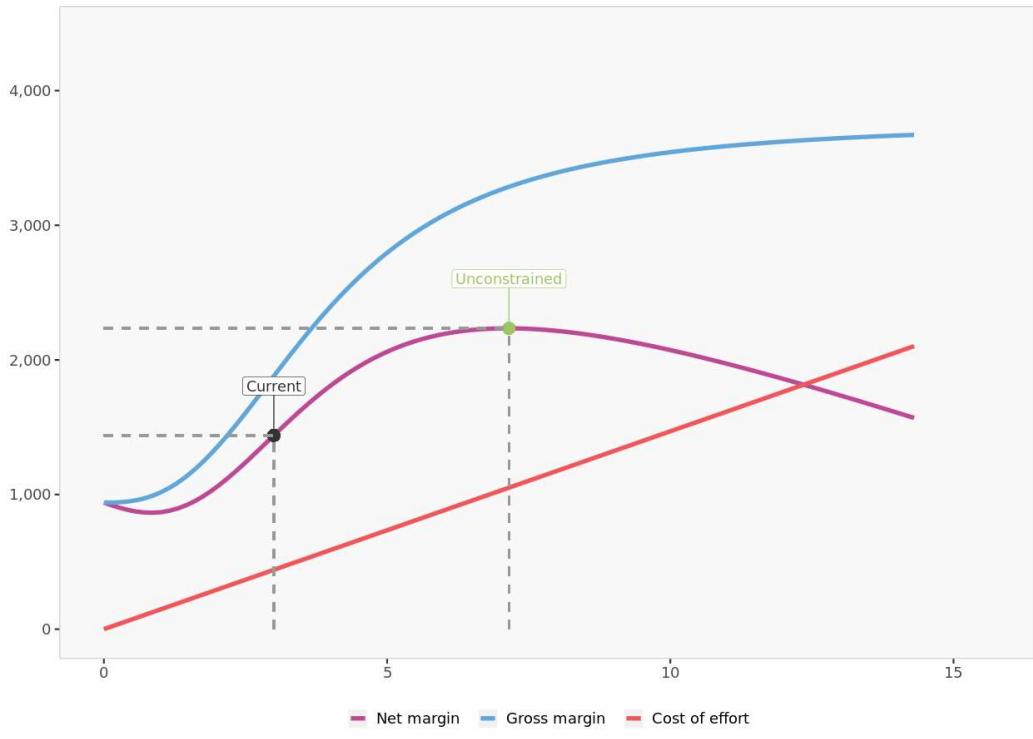
Nashville: scenarios.

**High Point: scenarios**



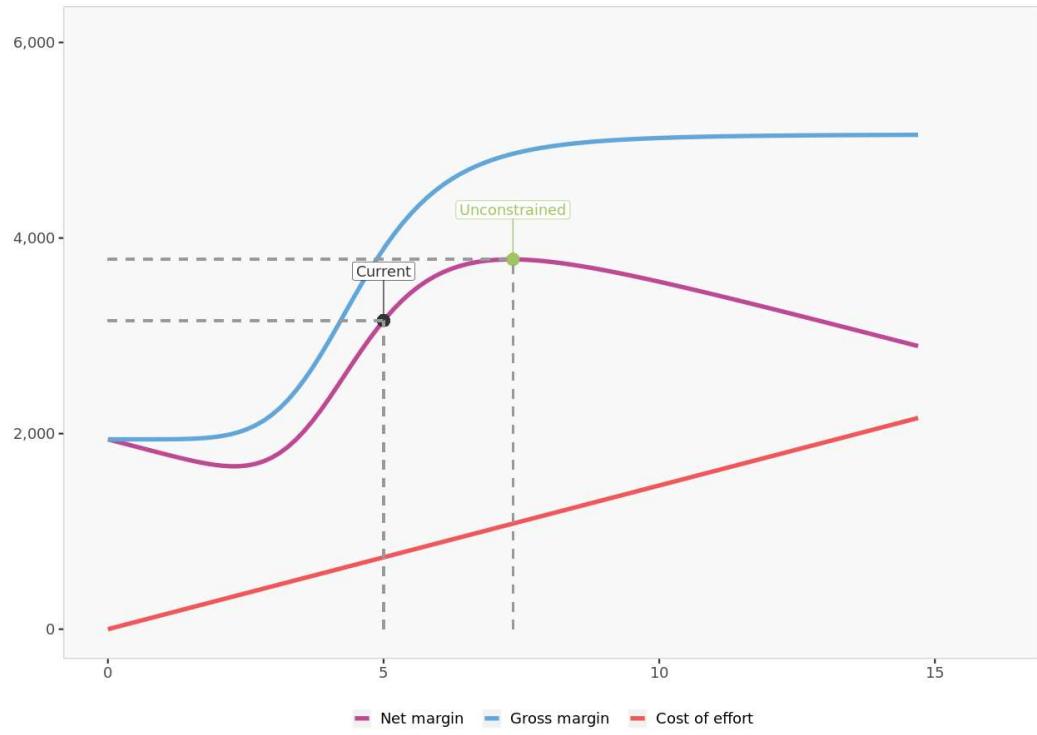
**High Point: scenarios.**

### Dallas: scenarios

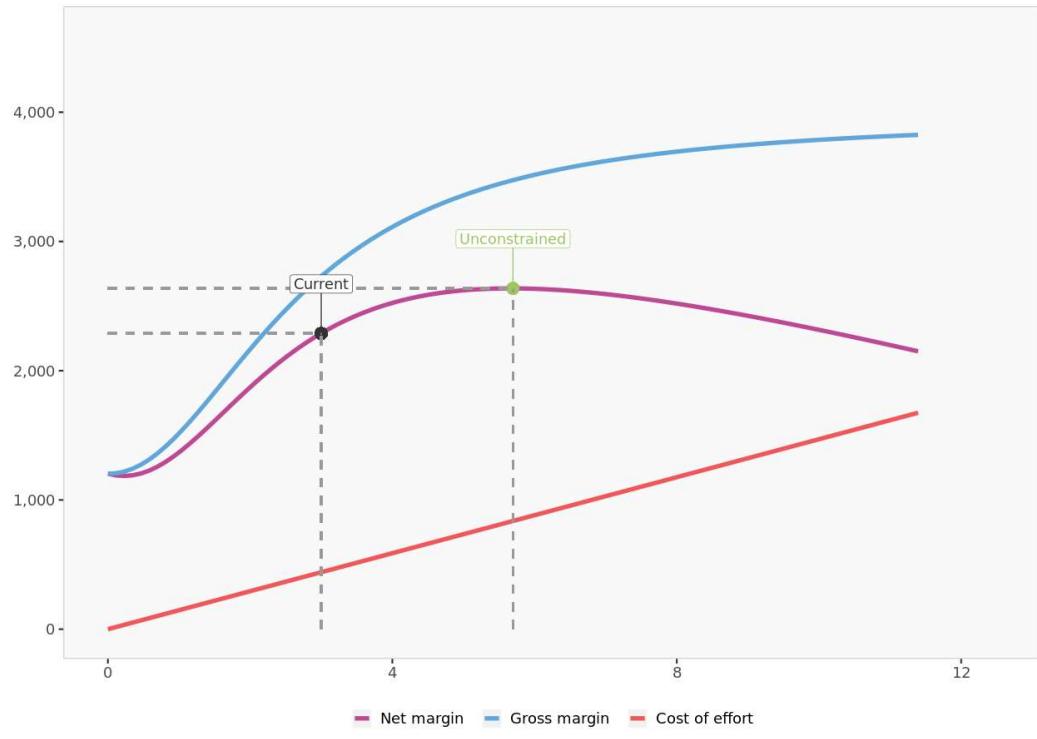


**Dallas: scenarios.**

### Chicago: scenarios

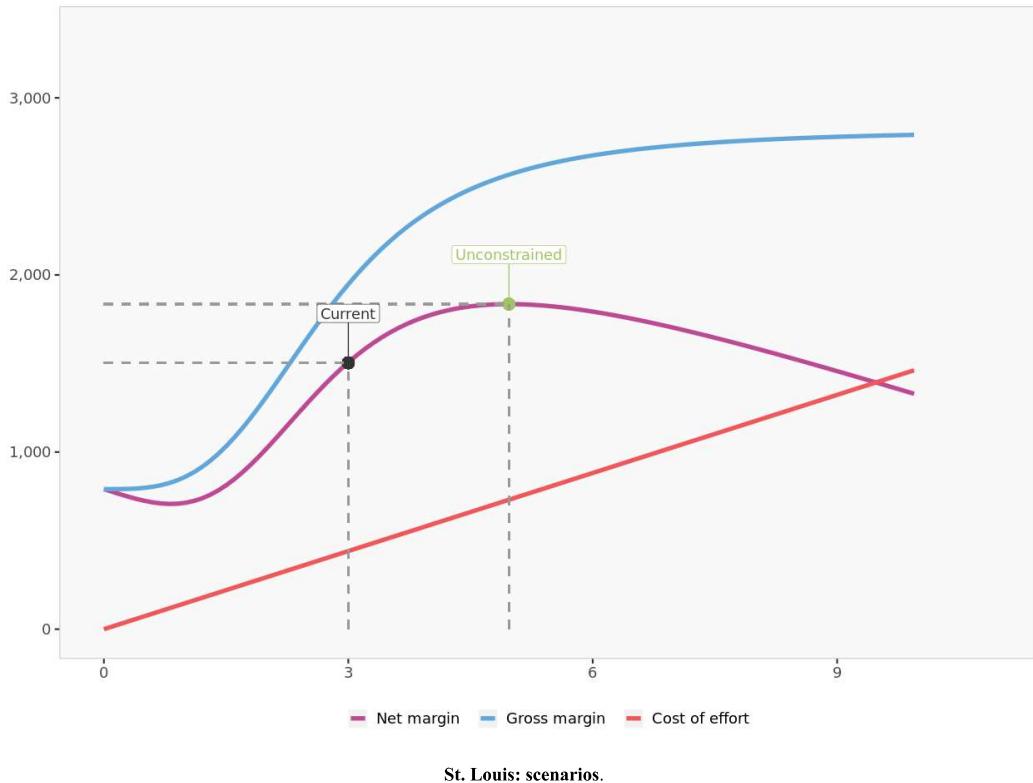


Chicago: scenarios.

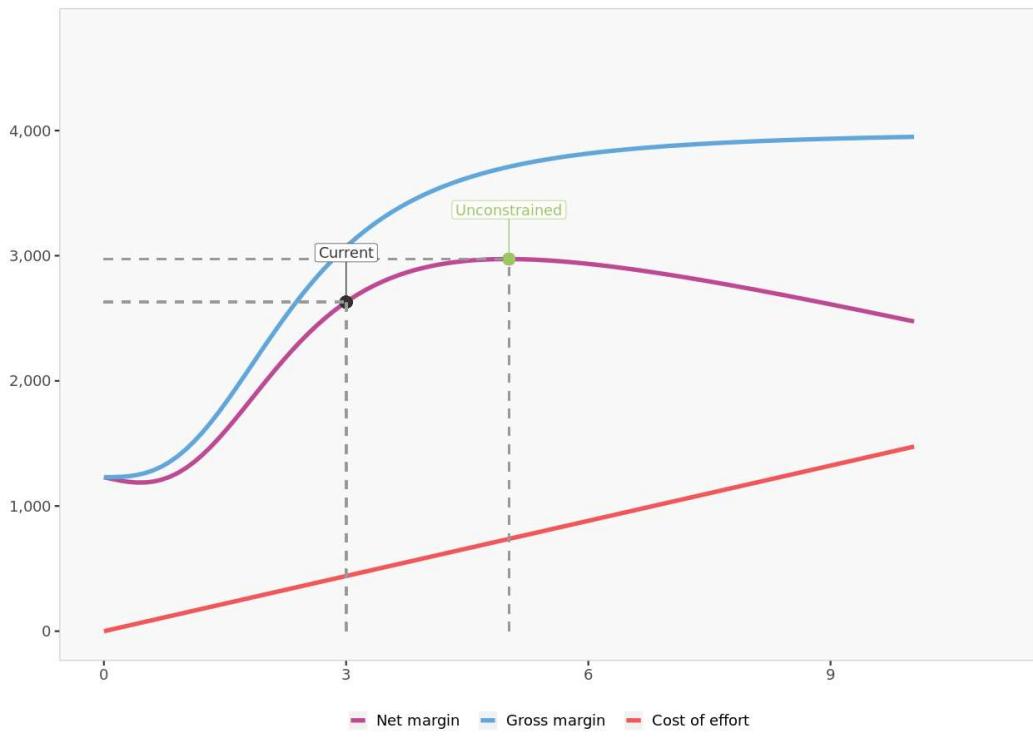
**Cincinnati: scenarios**

Cincinnati: scenarios.

**St. Louis: scenarios**



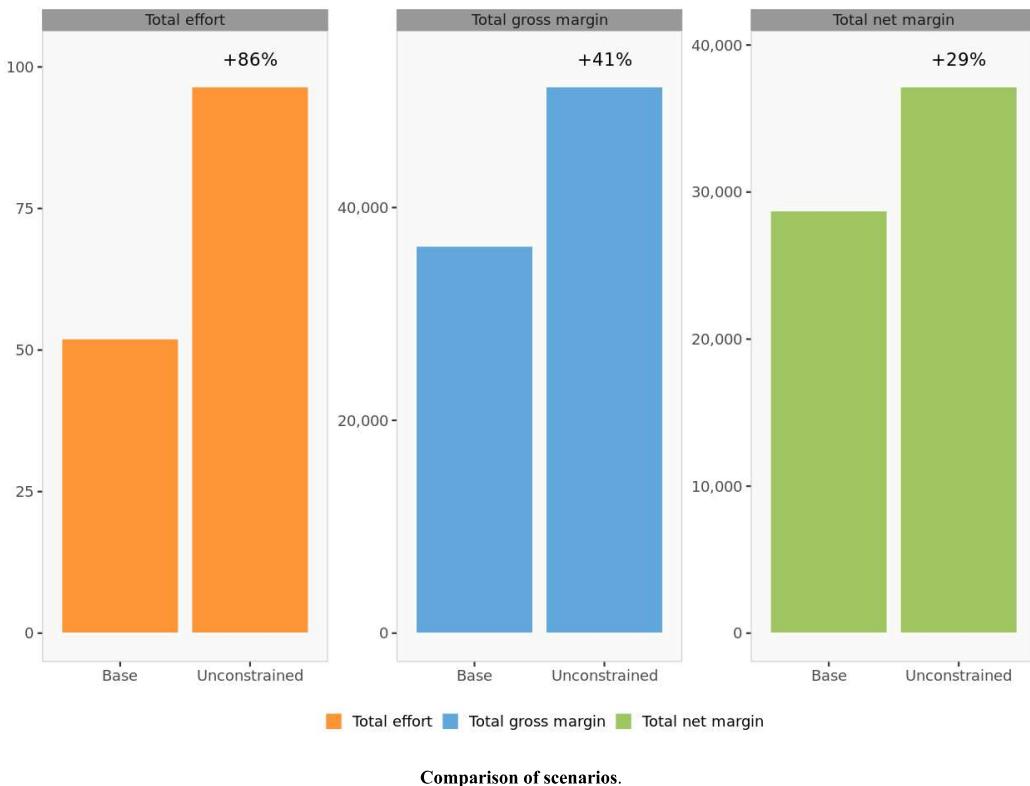
St. Louis: scenarios.

**Twin Cities: scenarios**

Twin Cities: scenarios.

**Comparison of scenarios**

## Resource Allocation

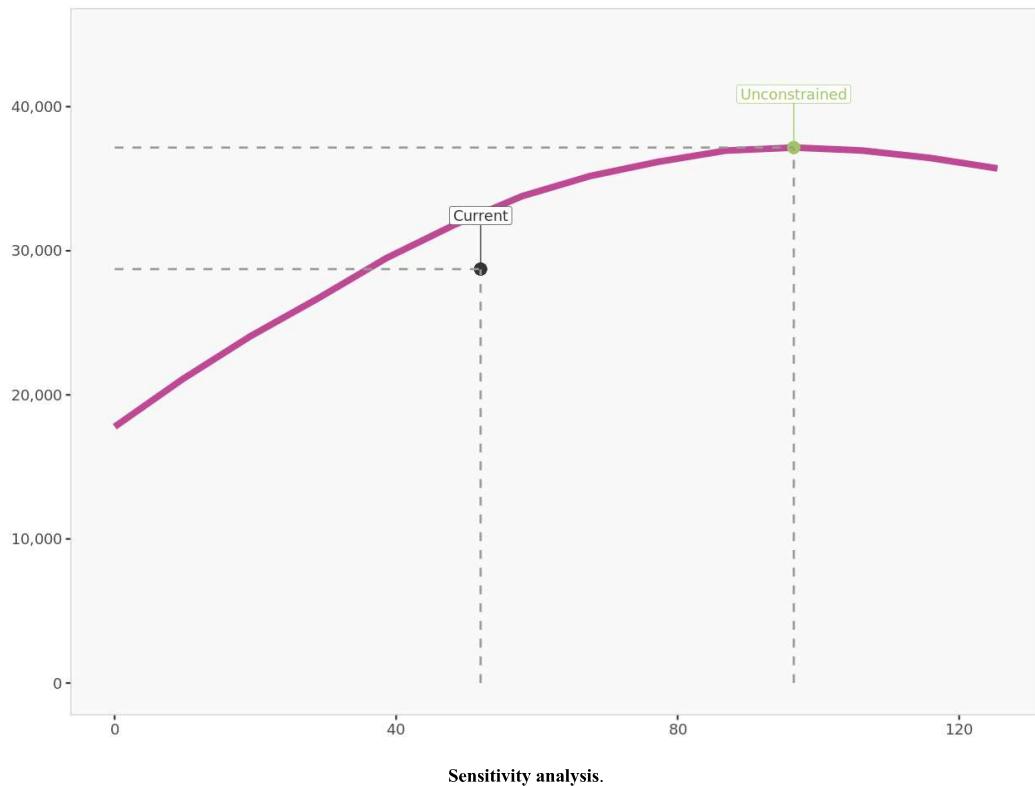


Comparison of scenarios.

## Sensitivity analysis

	Total effort	Net margin
No effort	0.00	17 787
-90% effort	9.65	21 088
-80% effort	19.30	24 074
-70% effort	28.95	26 709
-60% effort	38.60	29 488
-50% effort	48.25	31 797
-40% effort	57.90	33 791
-30% effort	67.55	35 187
-20% effort	77.20	36 171
-10% effort	86.85	36 952
Recommended	96.50	37 163
+10% effort	106.15	36 958
+20% effort	115.80	36 445
+30% effort	125.45	35 713

Sensitivity analysis.



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# Enginius

## Resource Allocation

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## Response function calibration

### Los Angeles

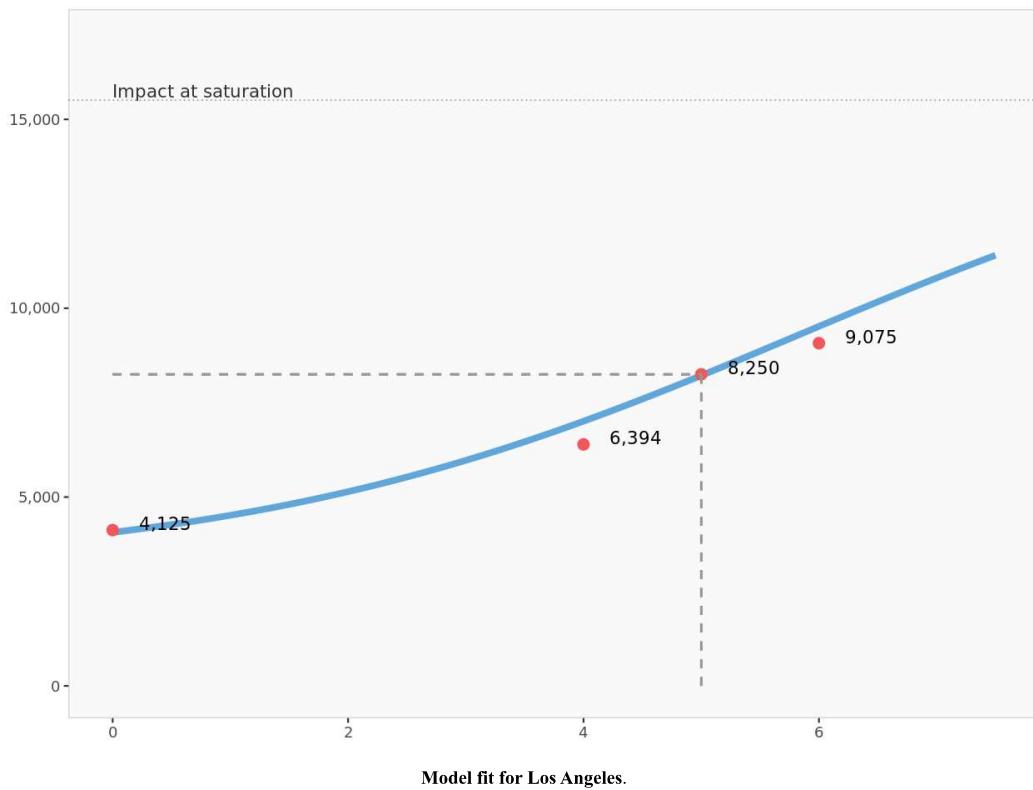
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	15 510	3 094.303	0.423	-2.467

Parameters for Los Angeles.

	Effort	Impact	Fit
None	0.00	4 125	4 065
Low	4.00	6 394	7 008
Base	5.00	8 250	8 218
High	6.00	9 075	9 520
Saturation	Saturation	15 510	15 510

Model fit for Los Angeles.



### San Francisco

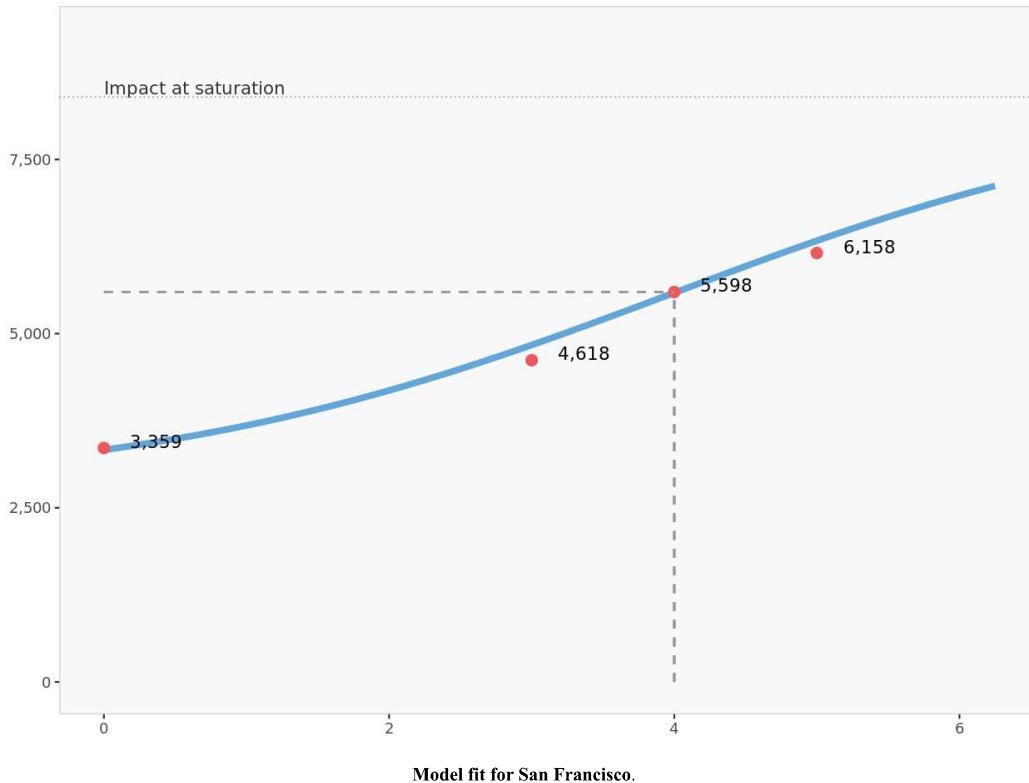
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	8 397	2 748.985	0.543	-2.163

Parameters for San Francisco.

	Effort	Impact	Fit
None	0.00	3 359	3 332
Low	3.00	4 618	4 837
Base	4.00	5 598	5 586
High	5.00	6 158	6 334
Saturation	Saturation	8 397	8 397

Model fit for San Francisco.



## Seattle

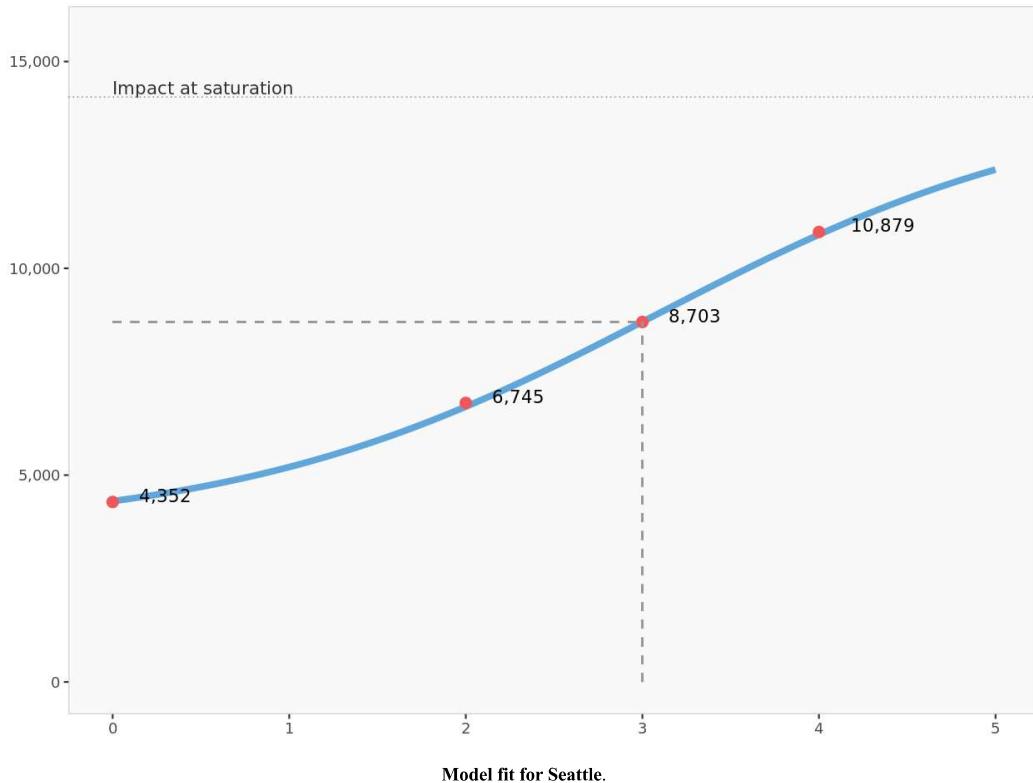
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	14	142	3	633.688
	0.838	-2.583		

Parameters for Seattle.

	Effort	Impact	Fit
None	0.00	4 352	4 372
Low	2.00	6 745	6 656
Base	3.00	8 703	8 707
High	4.00	10 879	10 814
Saturation	Saturation	14	142
		14	142

Model fit for Seattle.



Model fit for Seattle.

**Boston**

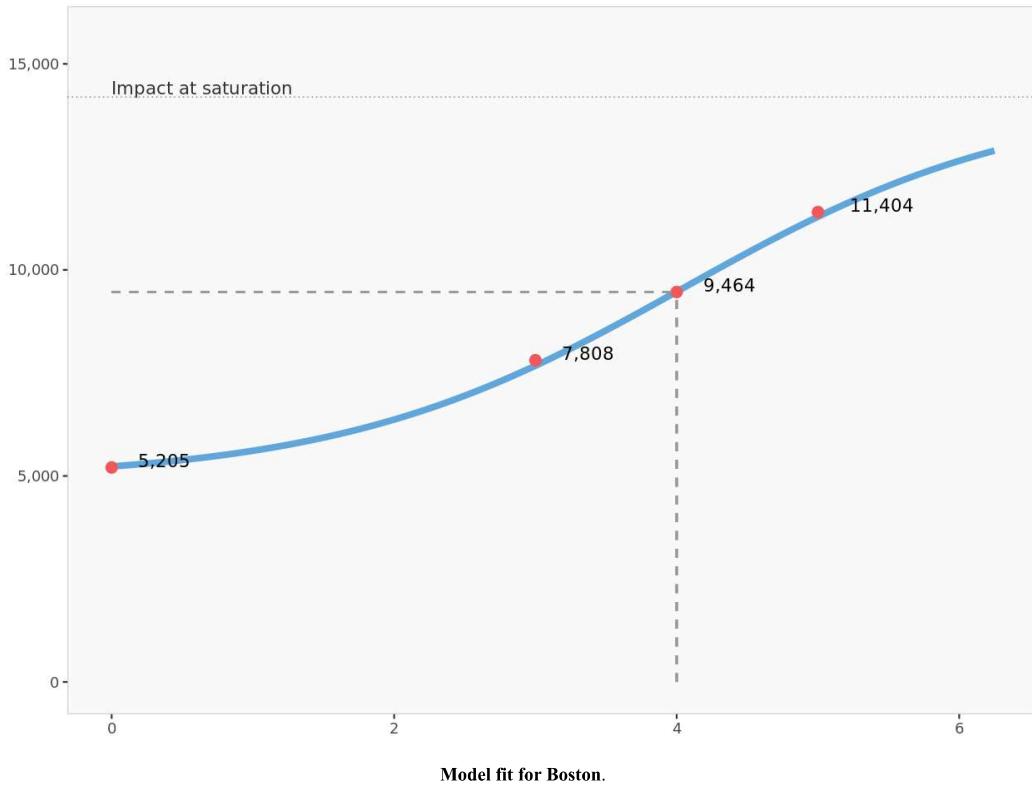
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	14 196	4 906.663	0.822	-3.322

Parameters for Boston.

	Effort	Impact	Fit
None	0.00	5 205	5 230
Low	3.00	7 808	7 675
Base	4.00	9 464	9 471
High	5.00	11 404	11 290
Saturation	Saturation	14 196	14 196

Model fit for Boston.



## Philadelphia

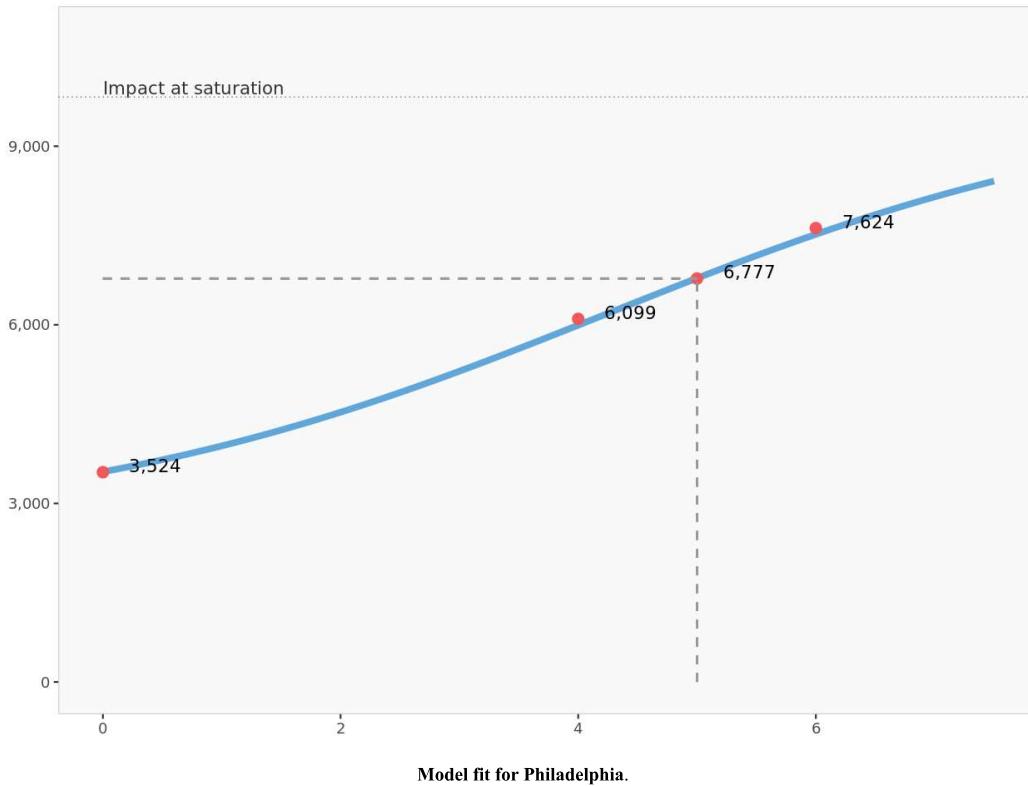
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	9 827	2 547.572	0.437	-1.856

Parameters for Philadelphia.

	Effort	Impact	Fit
None	0.00	3 524	3 531
Low	4.00	6 099	5 993
Base	5.00	6 777	6 783
High	6.00	7 624	7 520
Saturation	Saturation	9 827	9 827

Model fit for Philadelphia.



Model fit for Philadelphia.

## Cleveland

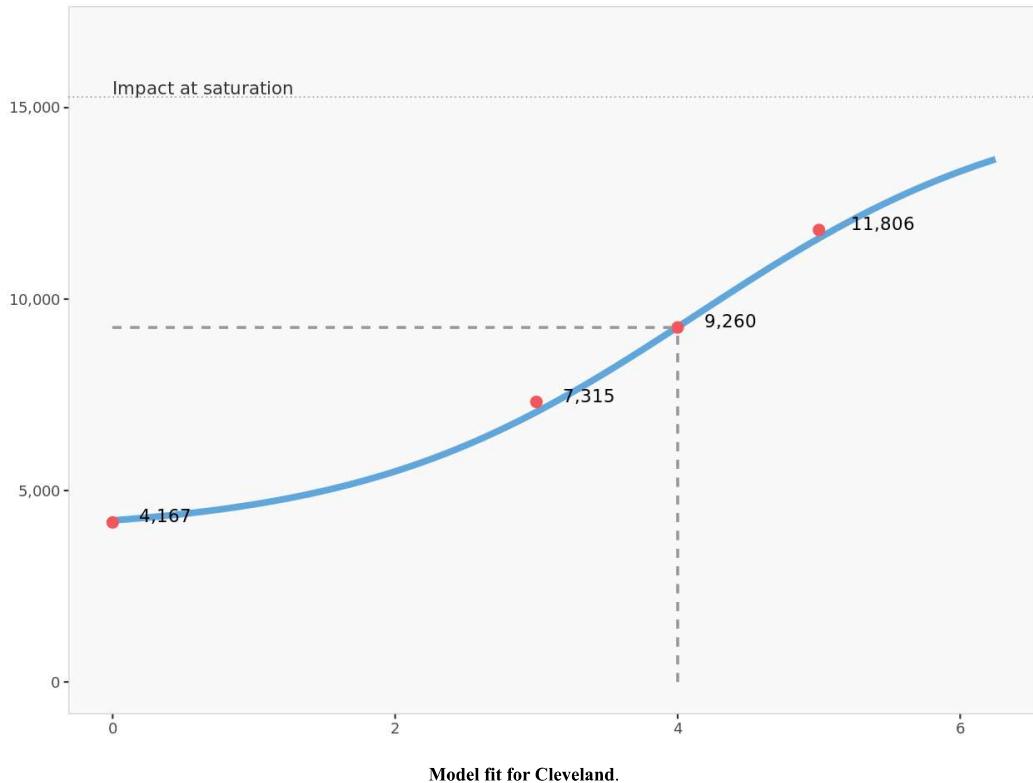
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	15 279	3 881.994	0.845	-3.489

Parameters for Cleveland.

	Effort	Impact	Fit
None	0.00	4 167	4 220
Low	3.00	7 315	7 053
Base	4.00	9 260	9 273
High	5.00	11 807	11 591
Saturation	Saturation	15 279	15 279

Model fit for Cleveland.



## Atlanta

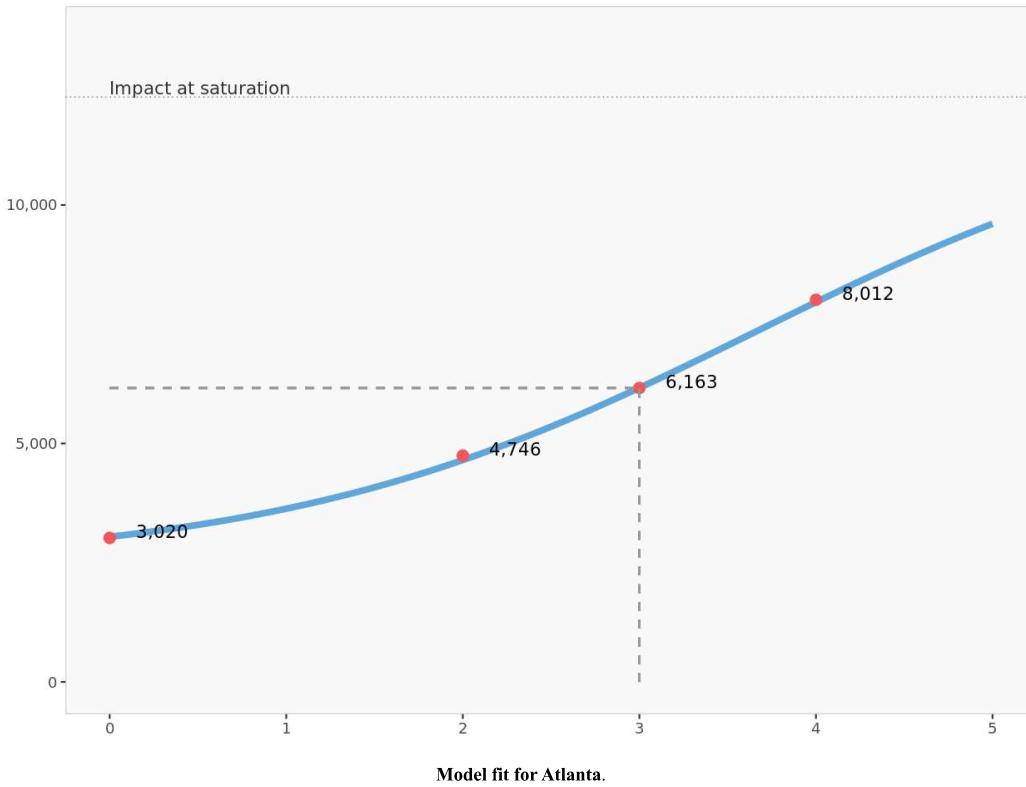
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	12 264	2 434.624	0.742	-2.717

Parameters for Atlanta.

	Effort	Impact	Fit
None	0.00	3 020	3 044
Low	2.00	4 746	4 653
Base	3.00	6 163	6 167
High	4.00	8 012	7 963
Saturation	Saturation	12 264	12 264

Model fit for Atlanta.



Model fit for Atlanta.

## Nashville

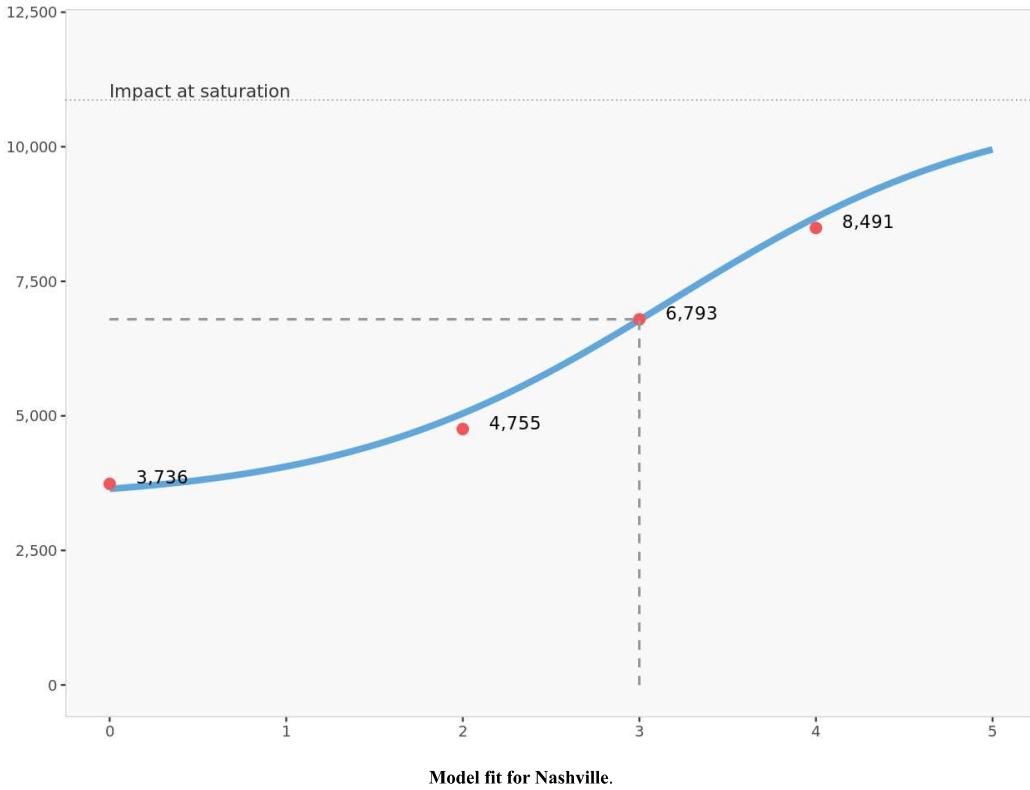
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	10 869	3 408.038	1.077	-3.424

Parameters for Nashville.

	Effort	Impact	Fit
None	0.00	3 736	3 643
Low	2.00	4 755	5 045
Base	3.00	6 793	6 782
High	4.00	8 491	8 690
Saturation	Saturation	10 869	10 869

Model fit for Nashville.



## High Point

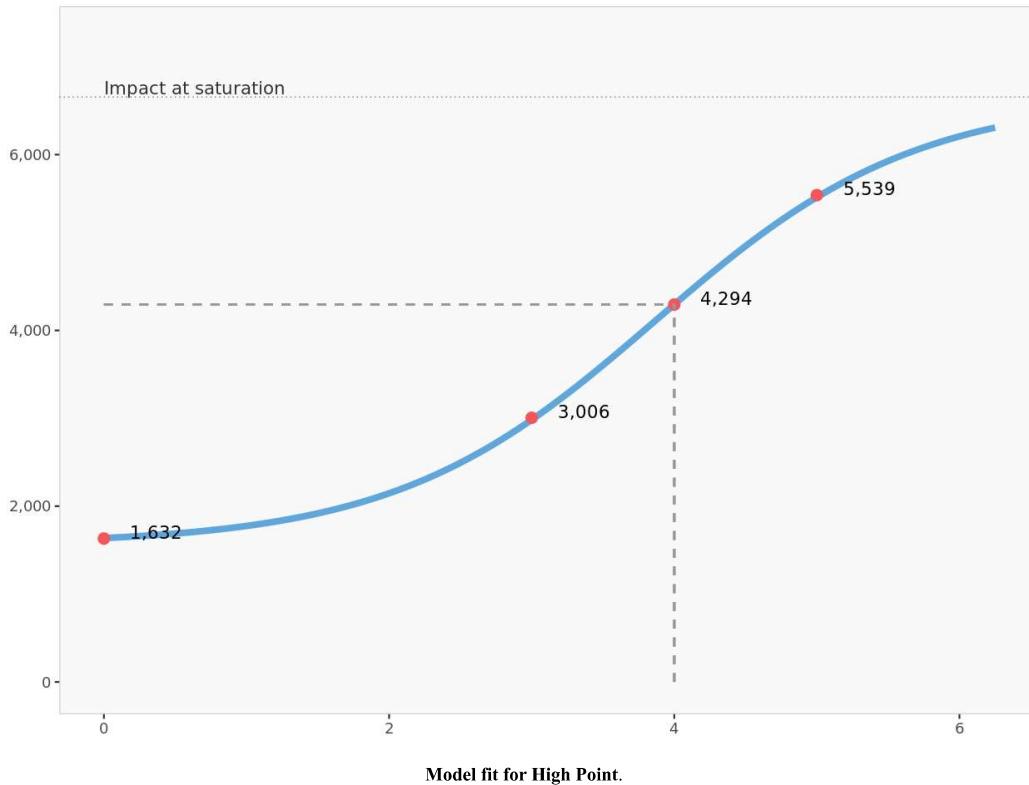
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	6 656	1 564.756	1.097	-4.241

Parameters for High Point.

	Effort	Impact	Fit
<b>None</b>	0.00	1 632	1 637
<b>Low</b>	3.00	3 006	2 983
<b>Base</b>	4.00	4 294	4 295
<b>High</b>	5.00	5 539	5 515
<b>Saturation</b>	Saturation	6 656	6 656

Model fit for High Point.



## Dallas

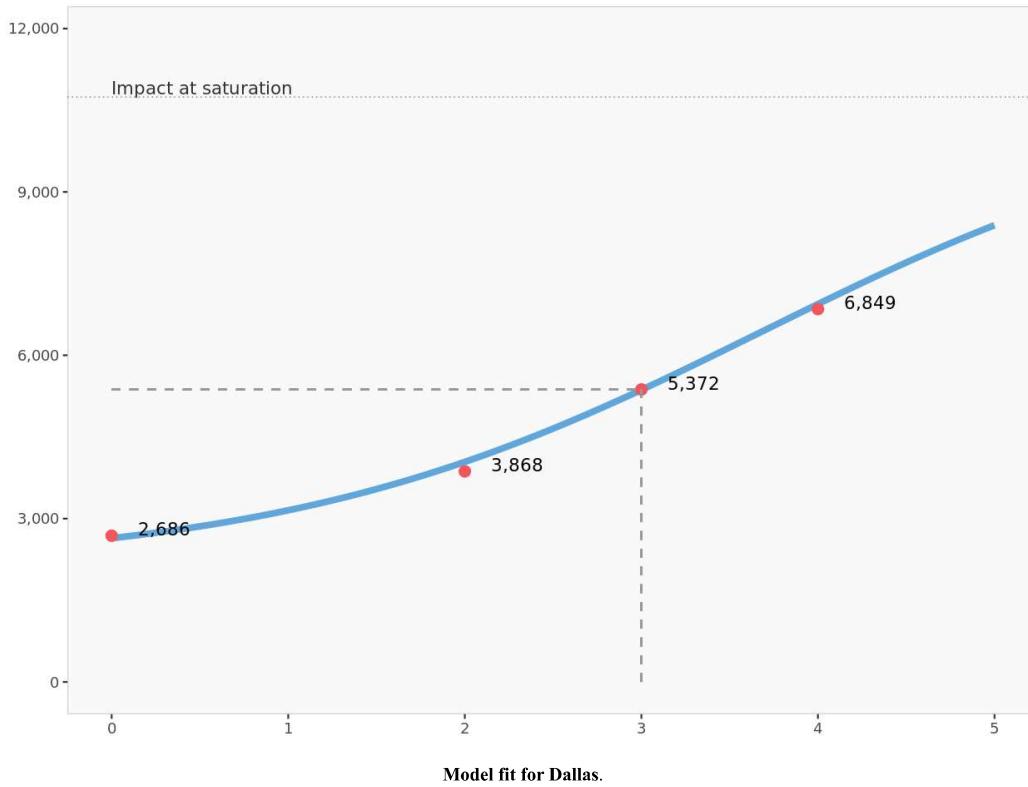
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	10 744	2 110.228	0.741	-2.727

Parameters for Dallas.

	Effort	Impact	Fit
None	0.00	2 686	2 641
Low	2.00	3 868	4 042
Base	3.00	5 372	5 365
High	4.00	6 849	6 941
Saturation	Saturation	10 744	10 744

Model fit for Dallas.



## Chicago

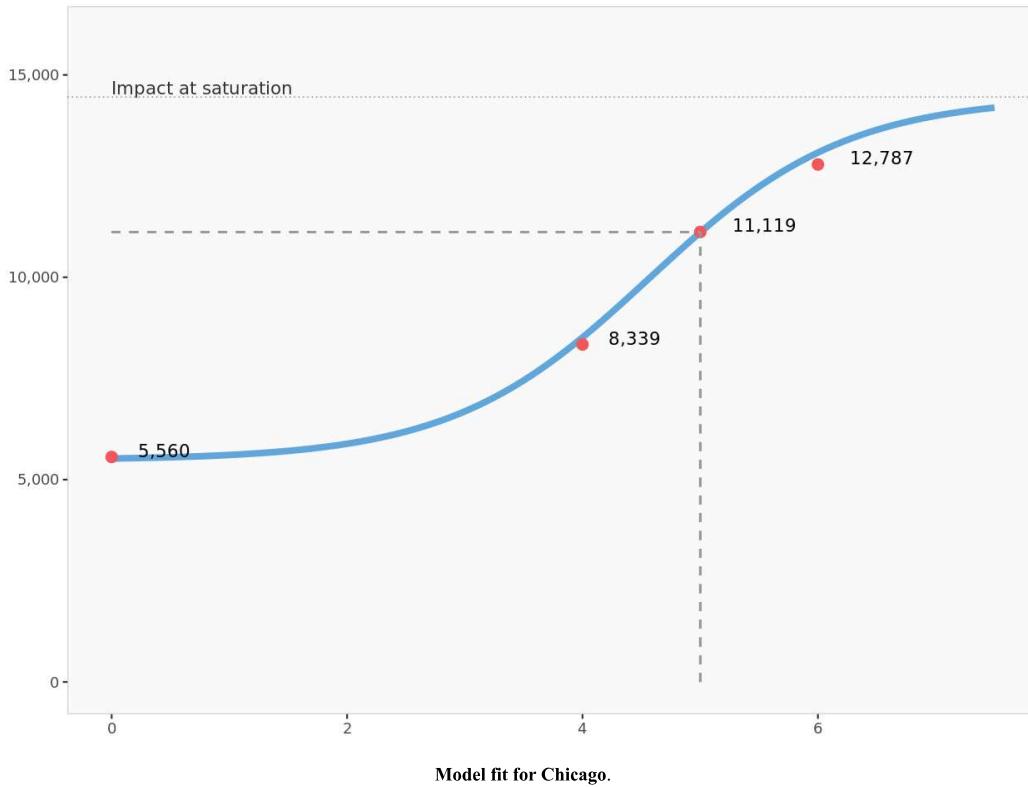
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	14 455	5 482.849	1.192	-5.442

Parameters for Chicago.

	Effort	Impact	Fit
None	0.00	5 560	5 522
Low	4.00	8 339	8 514
Base	5.00	11 119	11 108
High	6.00	12 787	13 083
Saturation	Saturation	14 455	14 455

Model fit for Chicago.



## Cincinnati

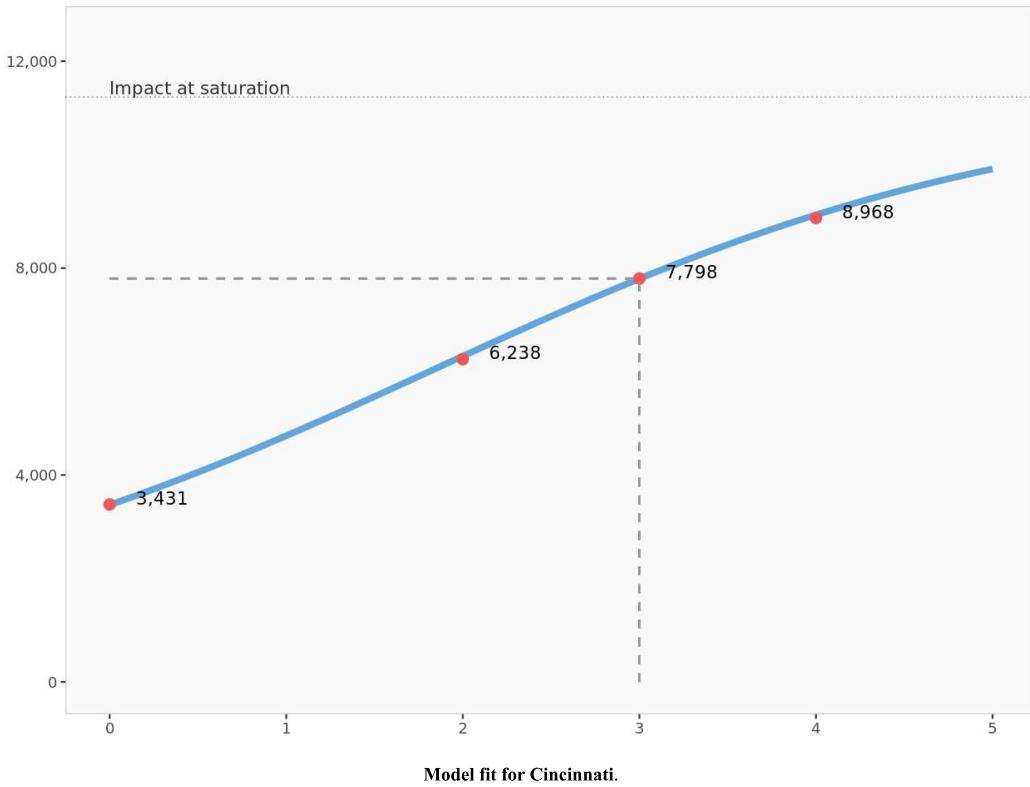
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	11,307	784,025	0.595	-1,094

Parameters for Cincinnati.

	Effort	Impact	Fit
None	0.00	3,431	3,423
Low	2.00	6,238	6,298
Base	3.00	7,798	7,795
High	4.00	8,968	9,029
Saturation	Saturation	11,307	11,307

Model fit for Cincinnati.



### St. Louis

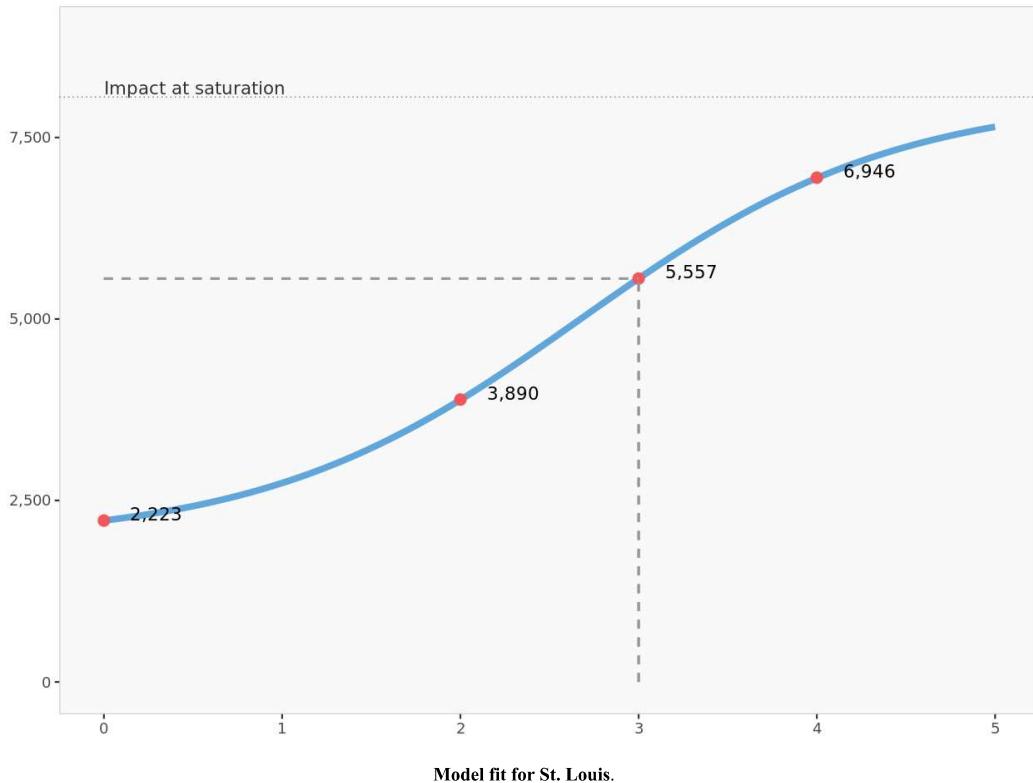
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	8 058	1 940.104	1.131	-3.025

Parameters for St. Louis.

	Effort	Impact	Fit
None	0.00	2 223	2 223
Low	2.00	3 890	3 886
Base	3.00	5 557	5 557
High	4.00	6 946	6 942
Saturation	Saturation	8 058	8 058

Model fit for St. Louis.



## Twin Cities

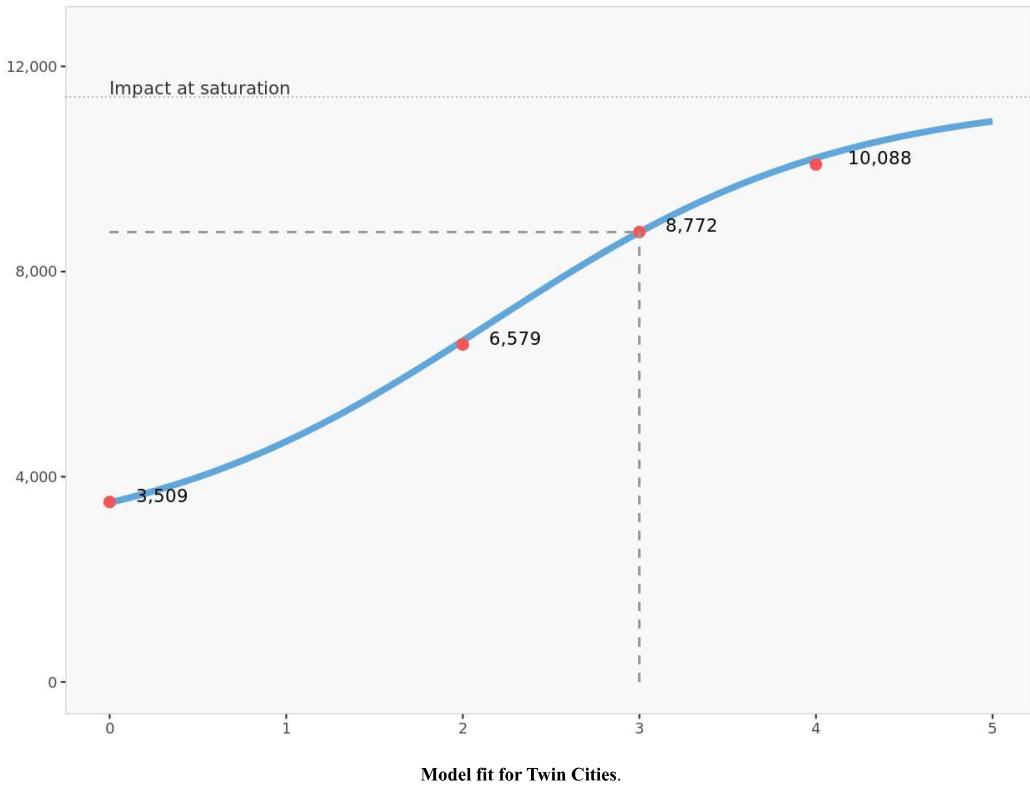
Model used: logistic

	Ceiling	Floor	Slope	Intercept
Parameters	11 404	2 597.138	1.008	-2.174

Parameters for Twin Cities.

	Effort	Impact	Fit
None	0.00	3 509	3 496
Low	2.00	6 579	6 653
Base	3.00	8 772	8 767
High	4.00	10 088	10 216
Saturation	Saturation	11 404	11 404

Model fit for Twin Cities.



## Base scenario

---

	Current number of reps	Current sales (\$000)	Cost per sales rep (\$000)	Margin	Cost of effort	Gross margin	Net margin
<b>Los Angeles</b>	5.00	8 250	147.00	0.35	735	2 888	2 153
<b>San Francisco</b>	4.00	5 598	147.00	0.35	588	1 959	1 371
<b>Seattle</b>	3.00	8 703	147.00	0.35	441	3 046	2 605
<b>Boston</b>	4.00	9 464	147.00	0.35	588	3 312	2 724
<b>Philadelphia</b>	5.00	6 777	147.00	0.35	735	2 372	1 637
<b>Cleveland</b>	4.00	9 260	147.00	0.35	588	3 241	2 653
<b>Atlanta</b>	3.00	6 163	147.00	0.35	441	2 157	1 716
<b>Nashville</b>	3.00	6 793	147.00	0.35	441	2 378	1 937
<b>High Point</b>	4.00	4 294	147.00	0.35	588	1 503	915
<b>Dallas</b>	3.00	5 372	147.00	0.35	441	1 880	1 439
<b>Chicago</b>	5.00	11 119	147.00	0.35	735	3 892	3 157
<b>Cincinnati</b>	3.00	7 798	147.00	0.35	441	2 729	2 288
<b>St. Louis</b>	3.00	5 557	147.00	0.35	441	1 945	1 504
<b>Twin Cities</b>	3.00	8 772	147.00	0.35	441	3 070	2 629
<b>Total</b>	52.00	103 920			7 644	36 372	28 728

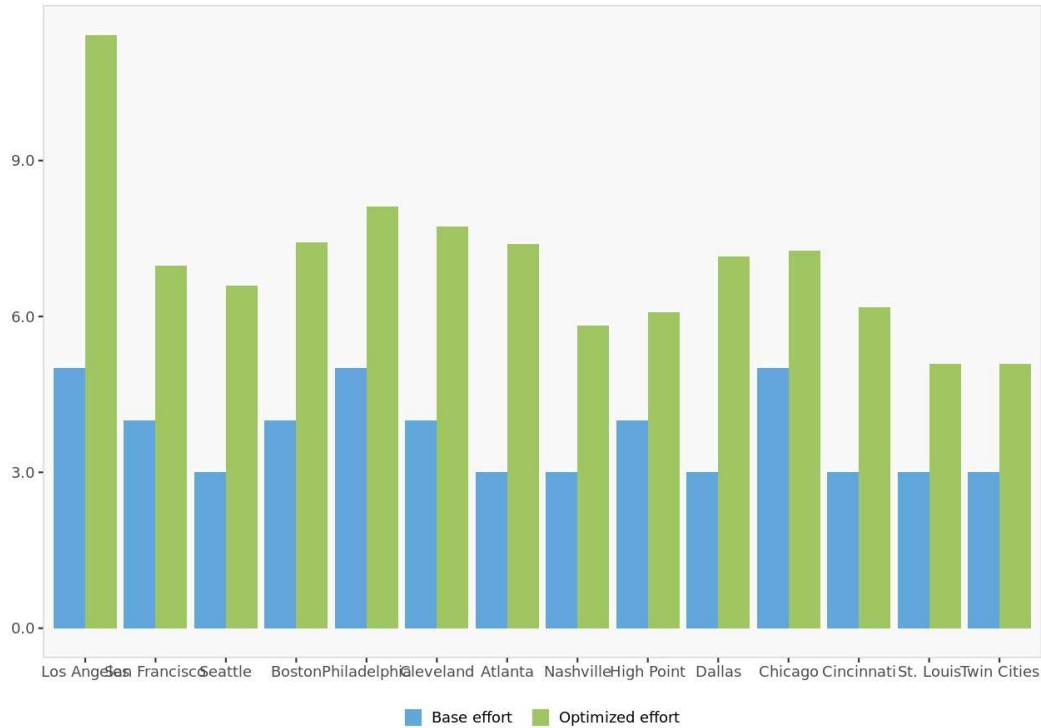
Base scenario table.

## Unconstrained optimization

### Effort

	Base effort	Optimized effort	% change in effort
<b>Los Angeles</b>	5.00	11.42	128.3%
<b>San Francisco</b>	4.00	6.99	74.6%
<b>Seattle</b>	3.00	6.59	119.7%
<b>Boston</b>	4.00	7.42	85.6%
<b>Philadelphia</b>	5.00	8.12	62.4%
<b>Cleveland</b>	4.00	7.73	93.2%
<b>Atlanta</b>	3.00	7.39	146.5%
<b>Nashville</b>	3.00	5.82	93.9%
<b>High Point</b>	4.00	6.07	51.8%
<b>Dallas</b>	3.00	7.16	138.5%
<b>Chicago</b>	5.00	7.27	45.5%
<b>Cincinnati</b>	3.00	6.18	106.1%
<b>St. Louis</b>	3.00	5.09	69.7%
<b>Twin Cities</b>	3.00	5.09	69.7%
<b>Total</b>	52.00	98.34	89.1%

Comparison of effort in unconstrained optimization.



Comparison of effort in unconstrained optimization.

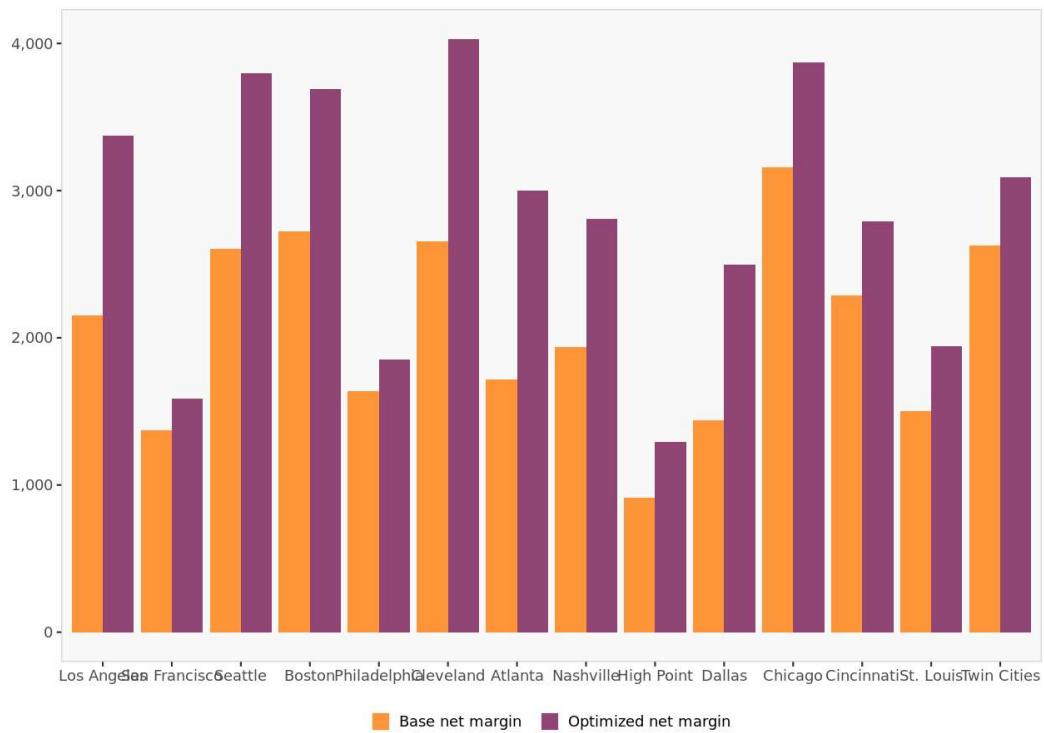
### Net margin

	Base net margin	Optimized net margin	% change in margin
<b>Los Angeles</b>	2 153	3 376	56.8%
<b>San Francisco</b>	1 371	1 588	15.8%
<b>Seattle</b>	2 605	3 796	45.7%
<b>Boston</b>	2 724	3 687	35.3%
<b>Philadelphia</b>	1 637	1 851	13.1%
<b>Cleveland</b>	2 653	4 030	51.9%
<b>Atlanta</b>	1 716	3 003	75.0%
<b>Nashville</b>	1 937	2 805	44.9%
<b>High Point</b>	915	1 291	41.1%
<b>Dallas</b>	1 439	2 495	73.4%

## Resource Allocation

<b>Chicago</b>	3 157	3 870	22.6%
<b>Cincinnati</b>	2 288	2 790	21.9%
<b>St. Louis</b>	1 504	1 941	29.1%
<b>Twin Cities</b>	2 629	3 091	17.6%
<b>Total</b>	28 728	39 616	37.9%

Comparison of net margin in unconstrained optimization.



Comparison of net margin in unconstrained optimization.

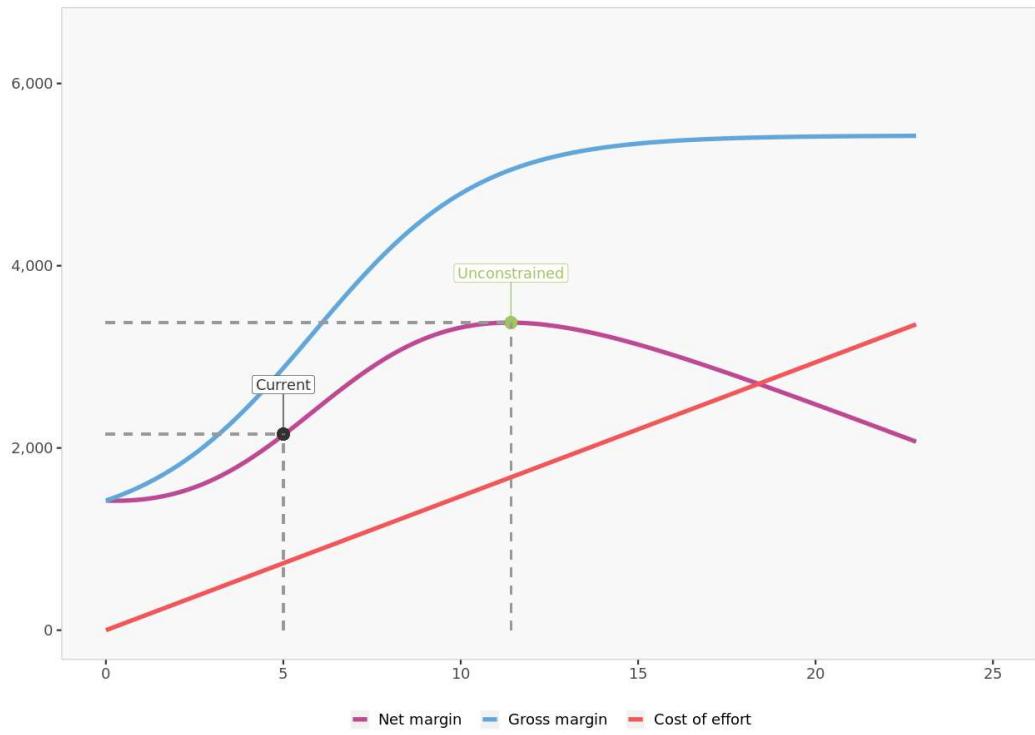
## Constrained optimization

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The unconstrained solution does not violate any of the user-specified constraints. Therefore, imposing constraints would not change the recommended solution, and is not required.

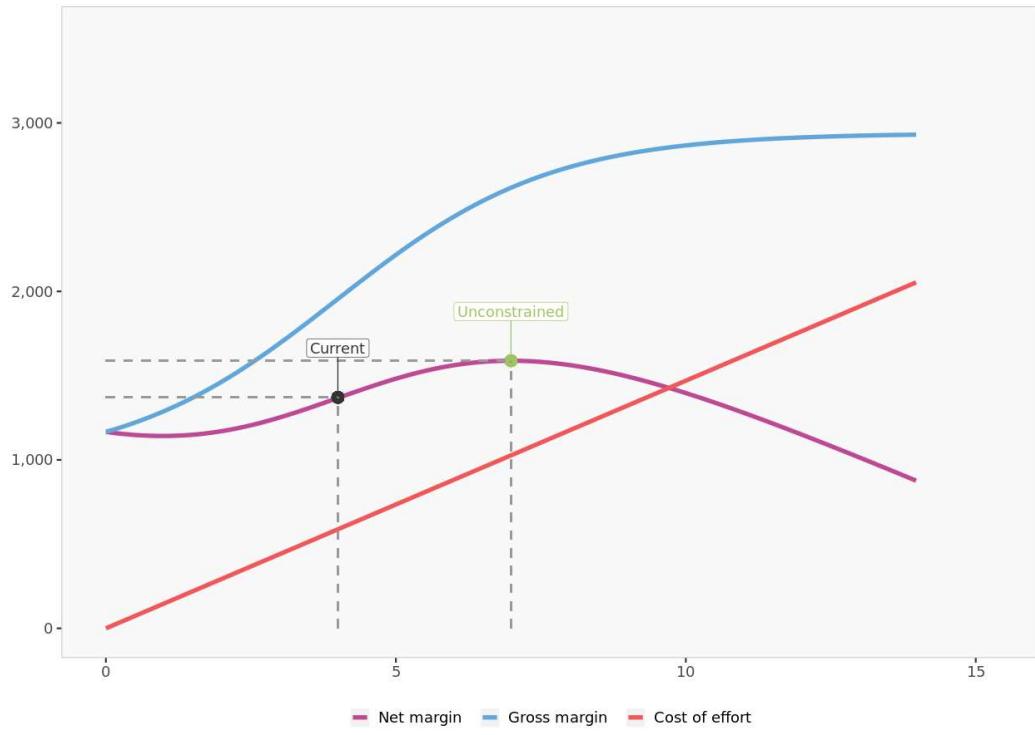
## Comparison of scenarios

### Los Angeles: scenarios



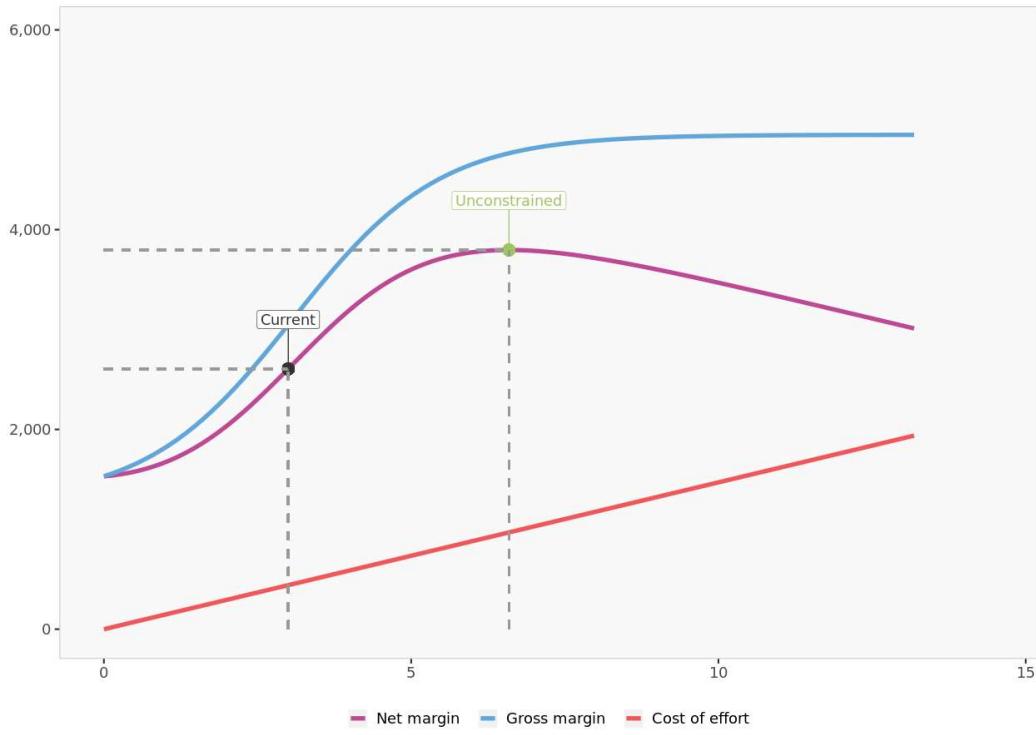
Los Angeles: scenarios.

### San Francisco: scenarios

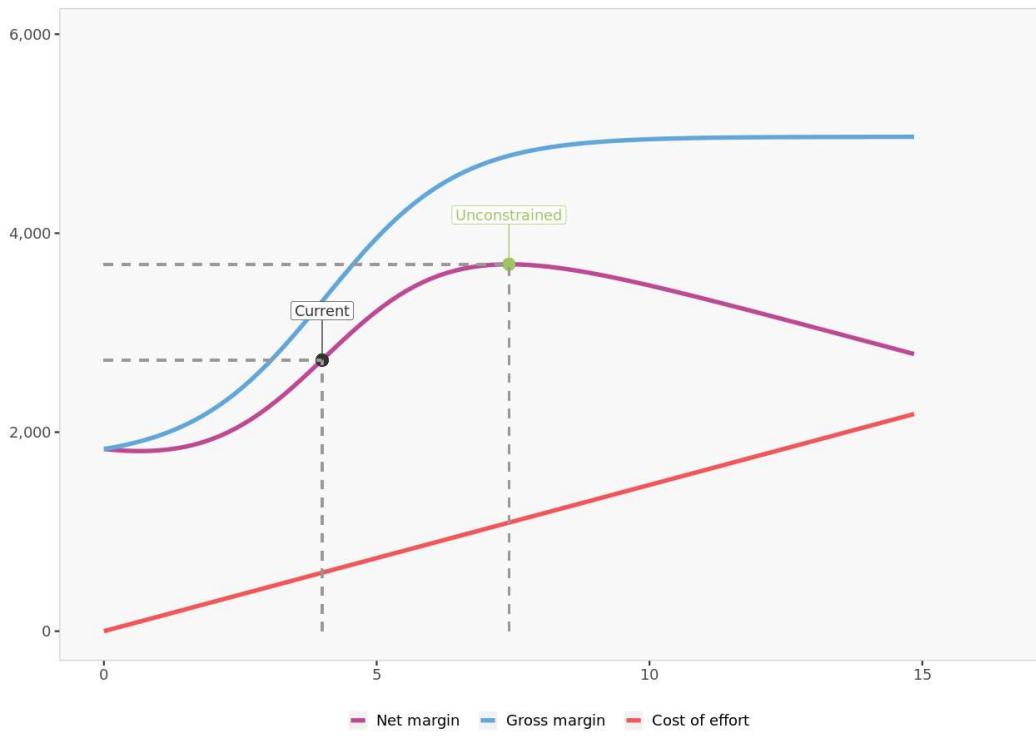


San Francisco: scenarios.

### Seattle: scenarios

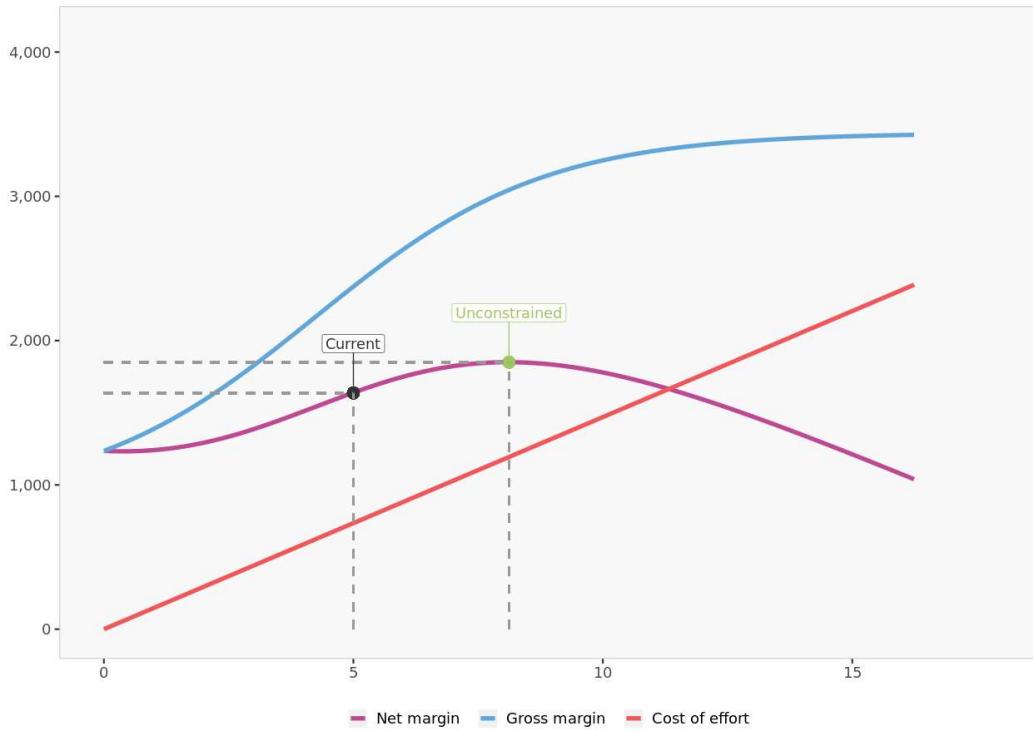


Seattle: scenarios.

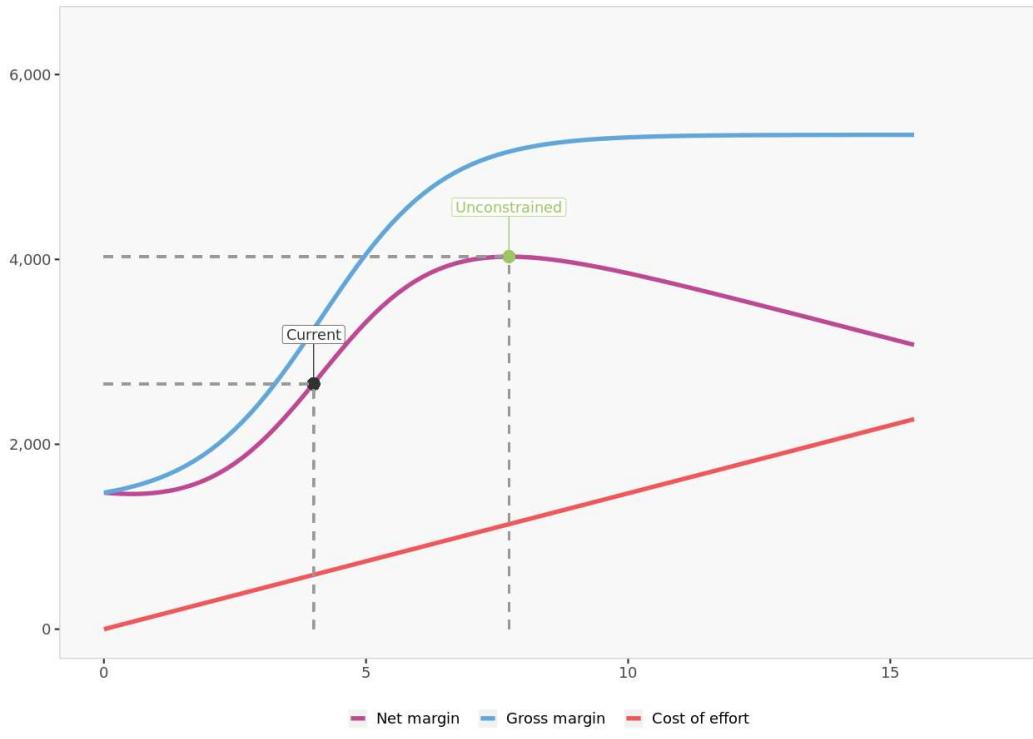
**Boston: scenarios**

Boston: scenarios.

**Philadelphia: scenarios**

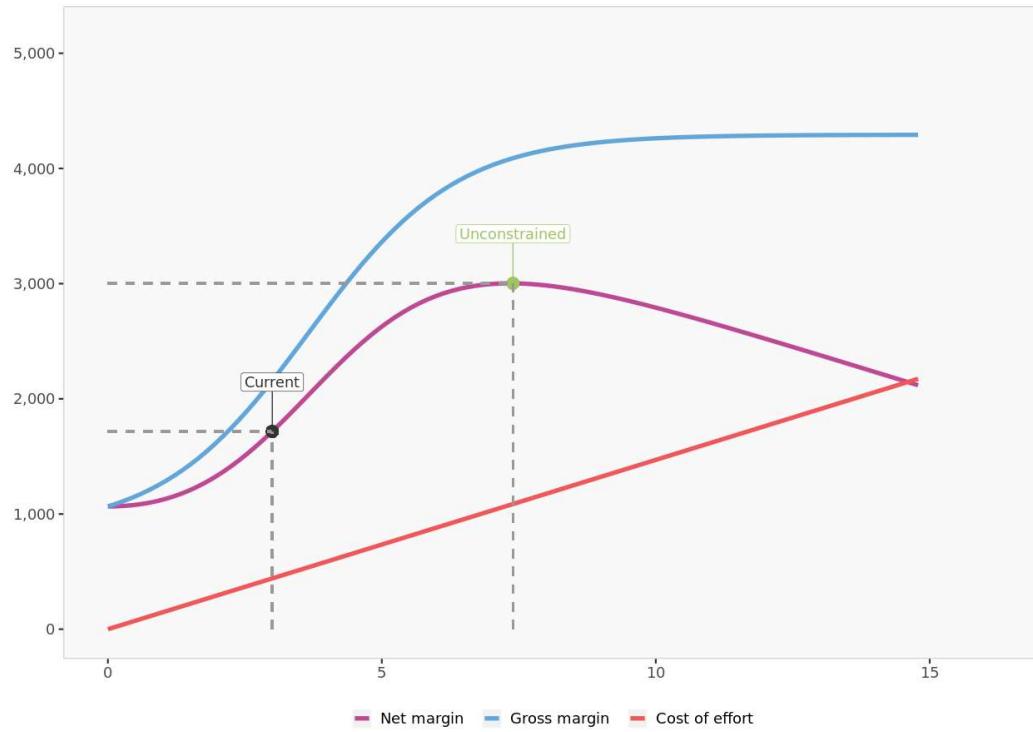


Philadelphia: scenarios.

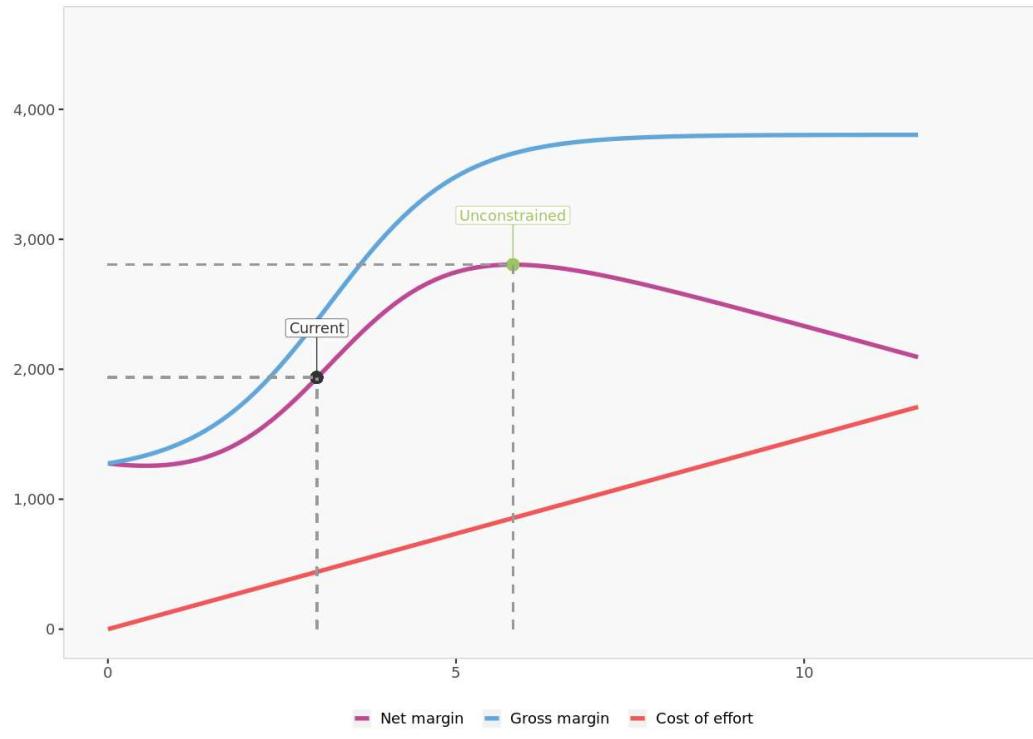
**Cleveland: scenarios**

Cleveland: scenarios.

**Atlanta: scenarios**

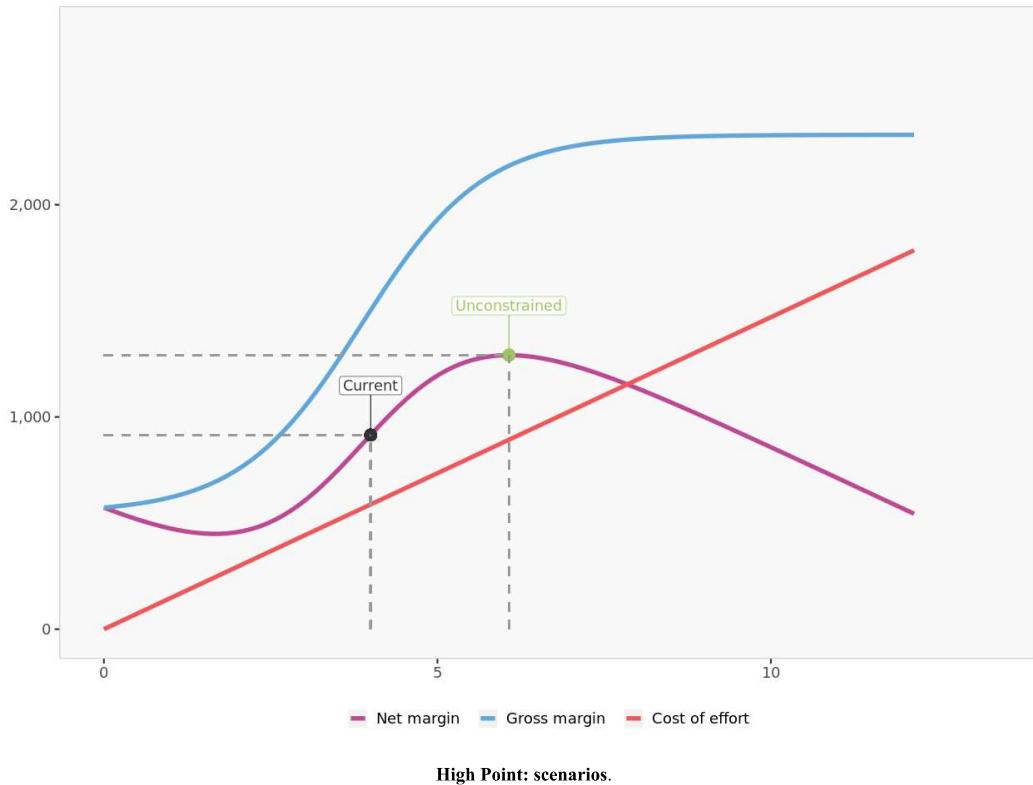


Atlanta: scenarios.

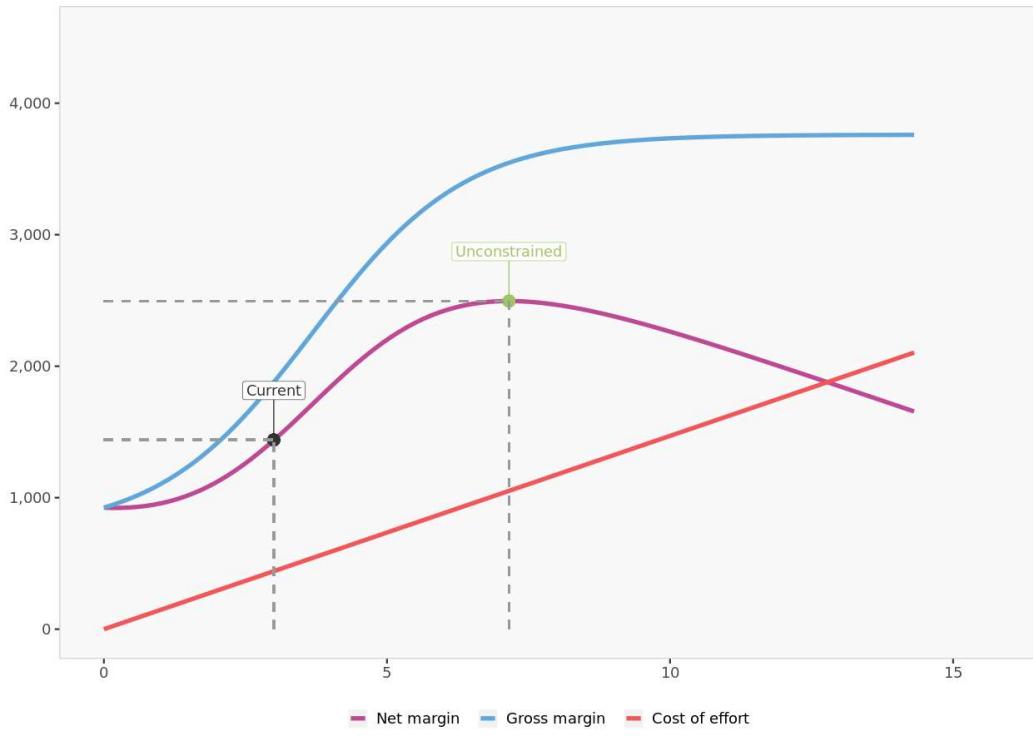
**Nashville: scenarios**

Nashville: scenarios.

**High Point: scenarios**

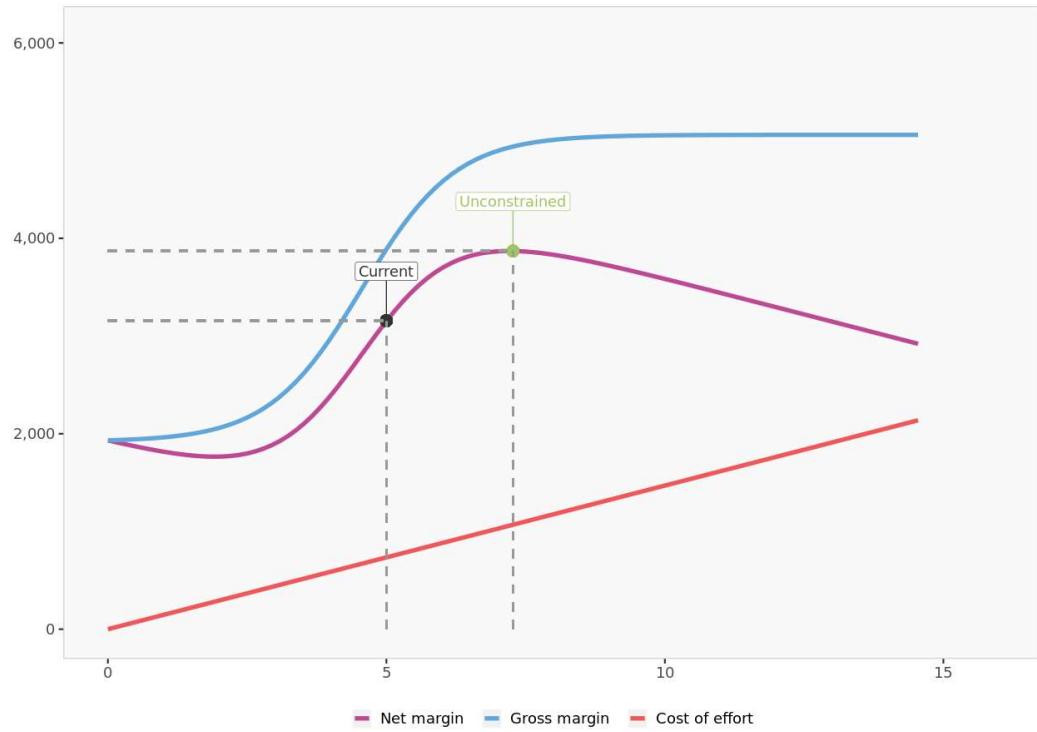


High Point: scenarios.

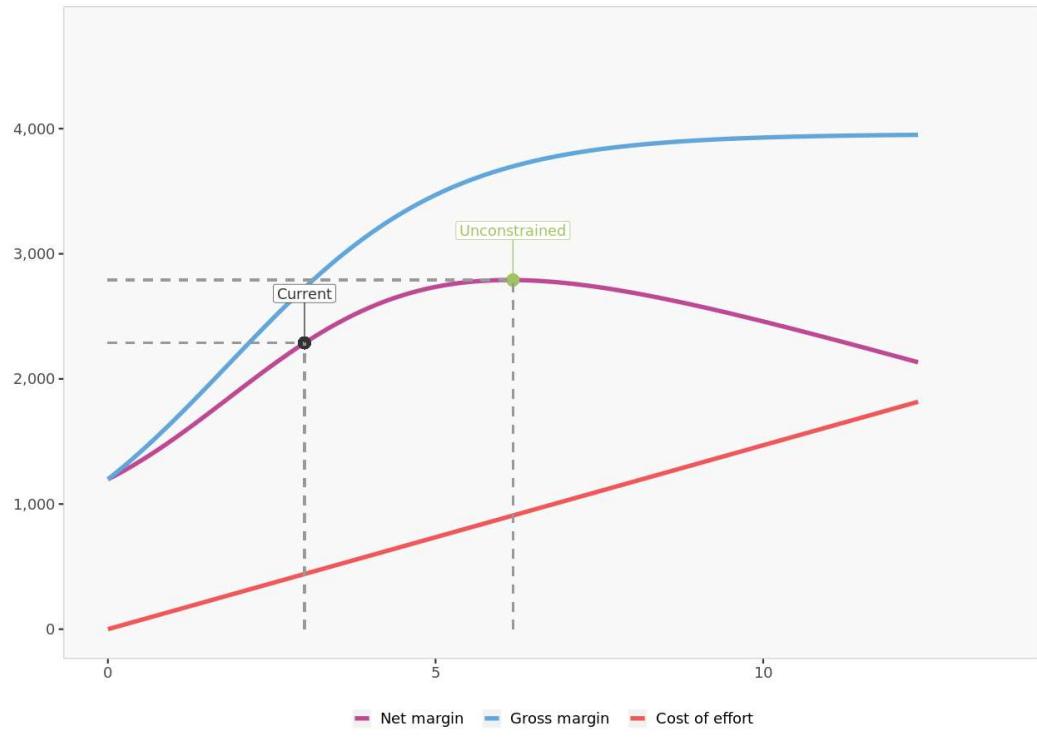
**Dallas: scenarios**

Dallas: scenarios.

**Chicago: scenarios**

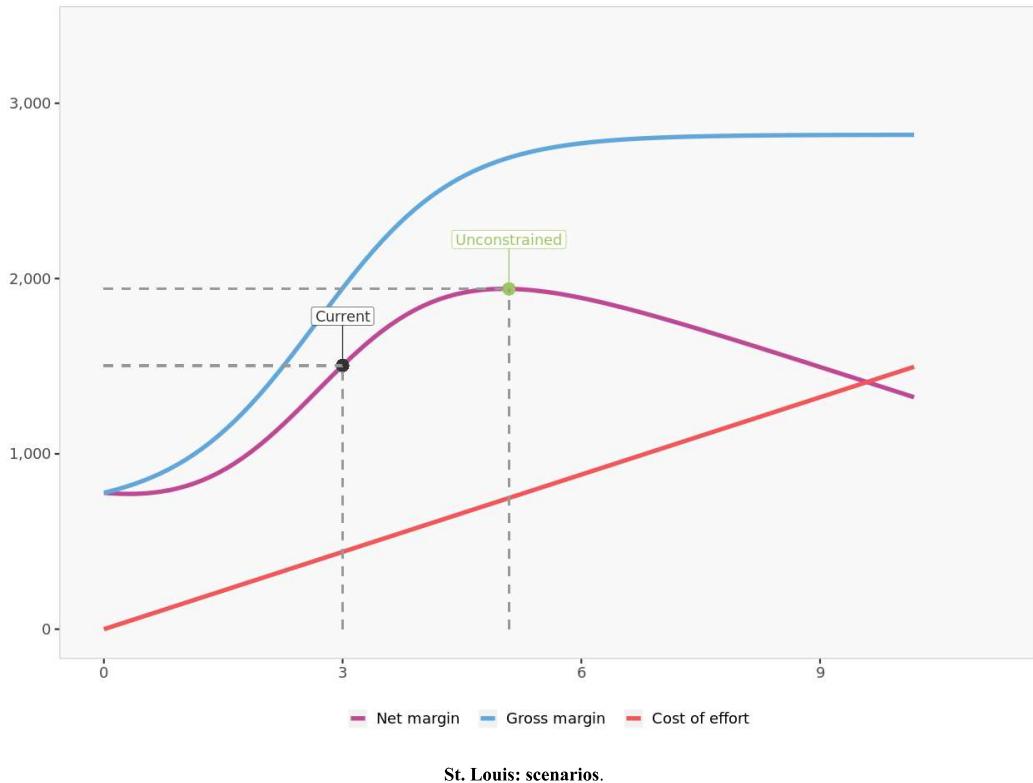


Chicago: scenarios.

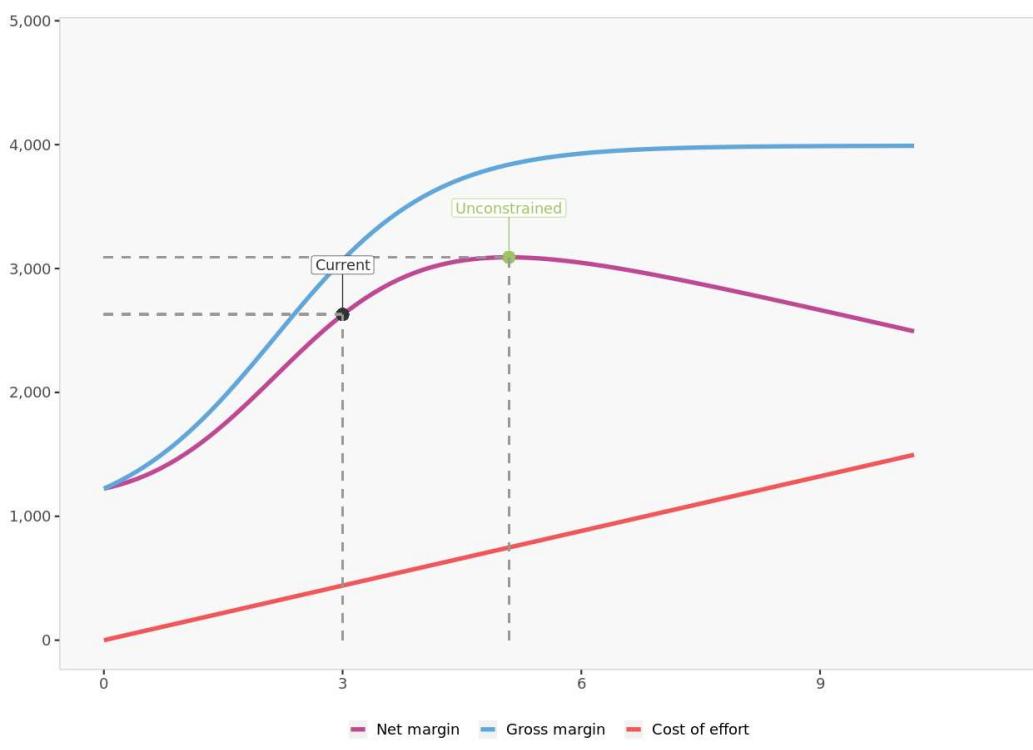
**Cincinnati: scenarios**

Cincinnati: scenarios.

**St. Louis: scenarios**



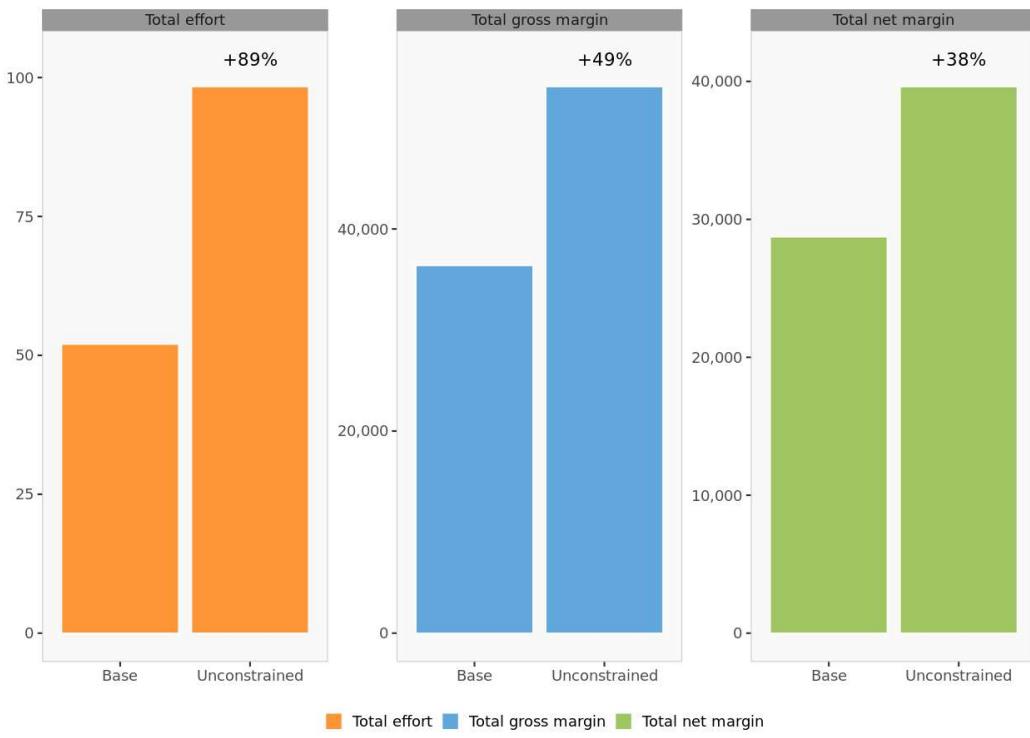
St. Louis: scenarios.

**Twin Cities: scenarios**

Twin Cities: scenarios.

**Comparison of scenarios**

## Resource Allocation

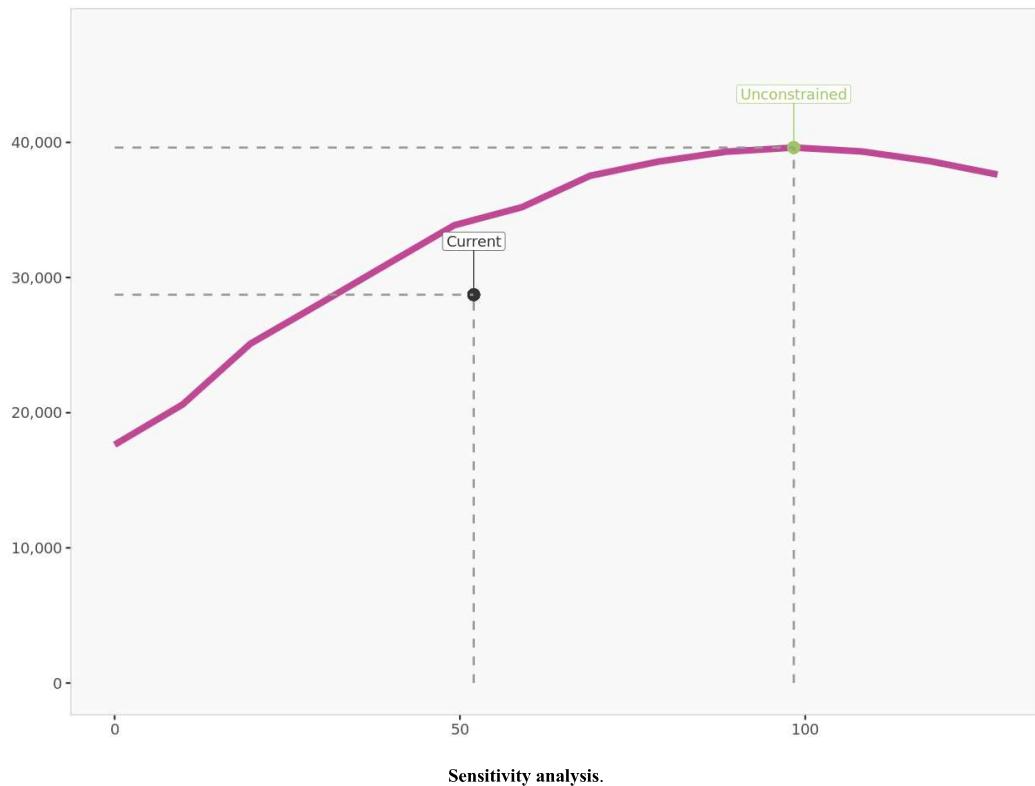


Comparison of scenarios.

## Sensitivity analysis

	Total effort	Net margin
No effort	0.00	17 632
-90% effort	9.83	20 604
-80% effort	19.67	25 108
-70% effort	29.50	28 006
-60% effort	39.34	30 945
-50% effort	49.17	33 866
-40% effort	59.01	35 209
-30% effort	68.84	37 528
-20% effort	78.67	38 573
-10% effort	88.51	39 306
Recommended	98.34	39 616
+10% effort	108.18	39 326
+20% effort	118.01	38 612
+30% effort	127.85	37 618

Sensitivity analysis.



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# Enginius

# Resource Allocation

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## Response function calibration

### Los Angeles

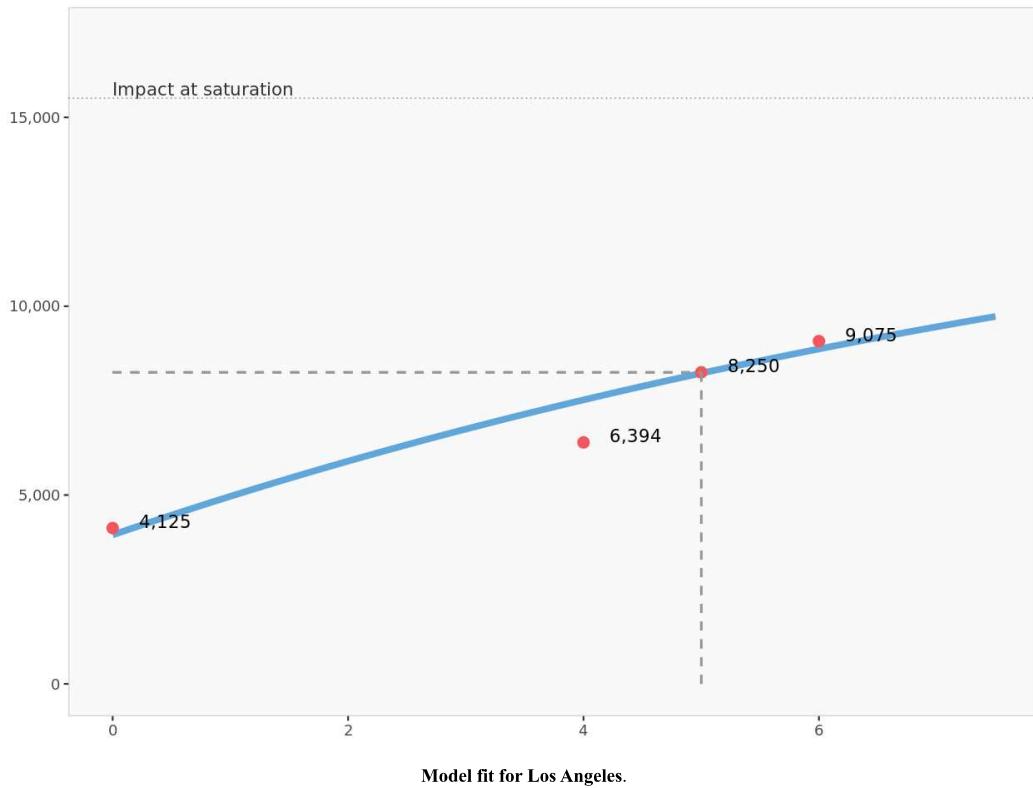
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	15 510	1 412.173	0.092	2.143

Parameters for Los Angeles.

	Effort	Impact	Fit
None	0.00	4 125	3 945
Low	4.00	6 394	7 520
Base	5.00	8 250	8 225
High	6.00	9 075	8 869
Saturation	Saturation	15 510	15 510

Model fit for Los Angeles.



### San Francisco

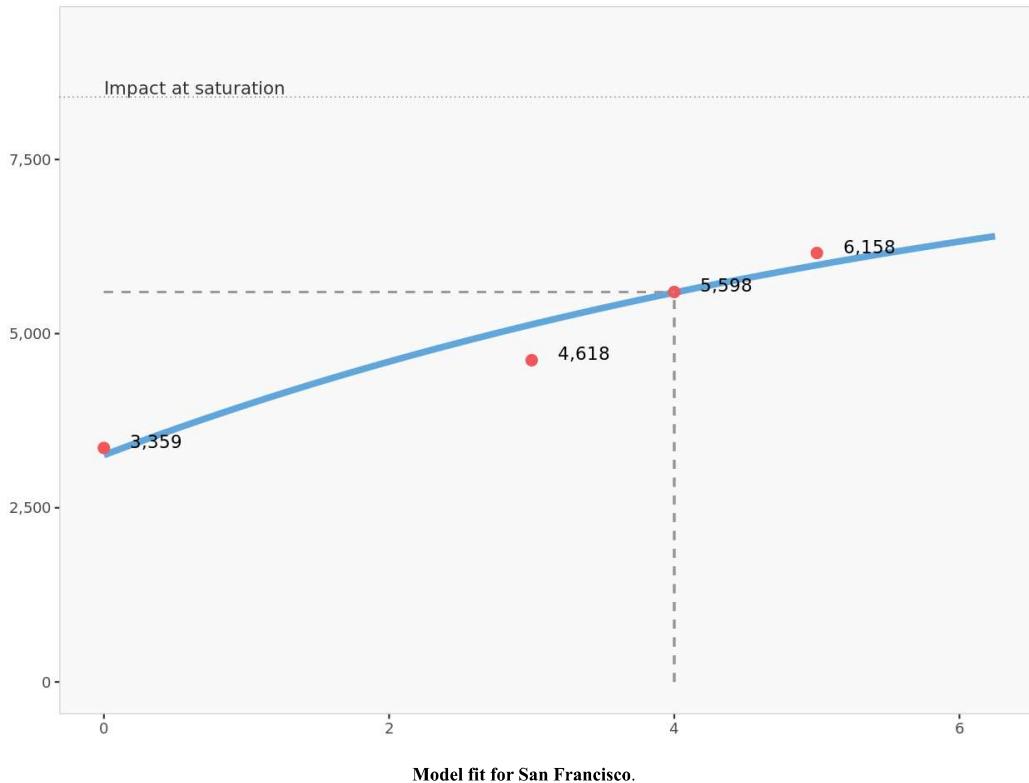
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	8 397	2 236.063	0.151	1.198

Parameters for San Francisco.

	Effort	Impact	Fit
None	0.00	3 359	3 257
Low	3.00	4 618	5 131
Base	4.00	5 598	5 590
High	5.00	6 158	5 984
Saturation	Saturation	8 397	8 397

Model fit for San Francisco.



Model fit for San Francisco.

**Seattle**

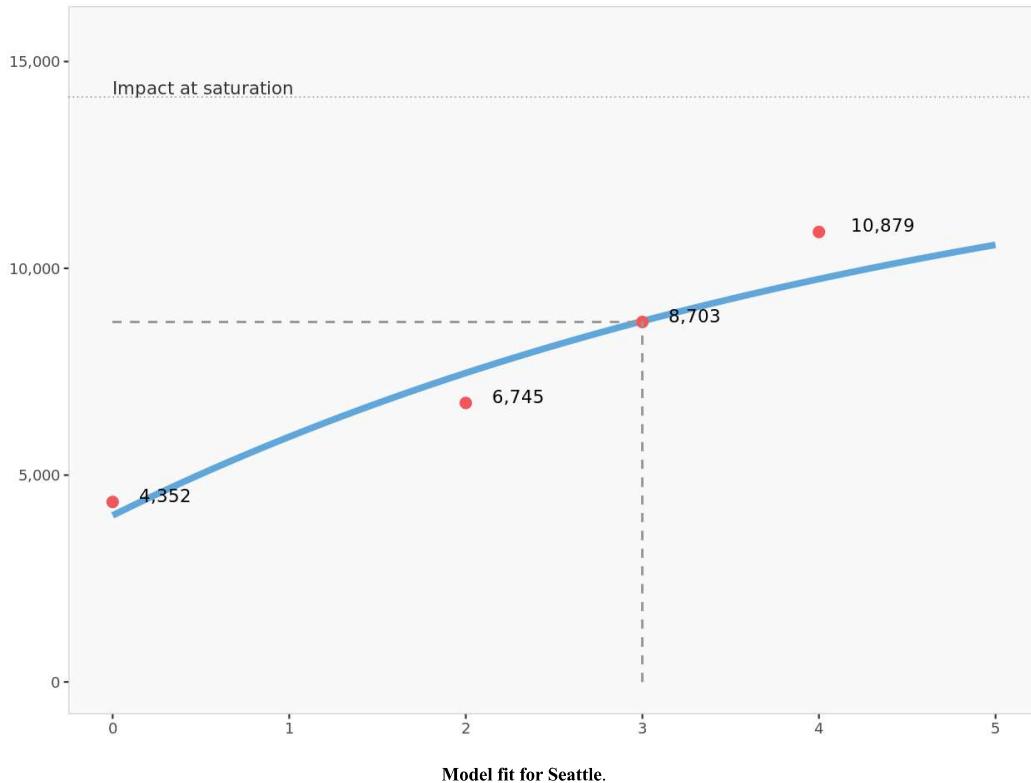
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	14 142	2 643.014	0.208	0.616

Parameters for Seattle.

	Effort	Impact	Fit
None	0.00	4 352	4 027
Low	2.00	6 745	7 470
Base	3.00	8 703	8 724
High	4.00	10 879	9 741
Saturation	Saturation	14 142	14 142

Model fit for Seattle.



Model fit for Seattle.

**Boston**

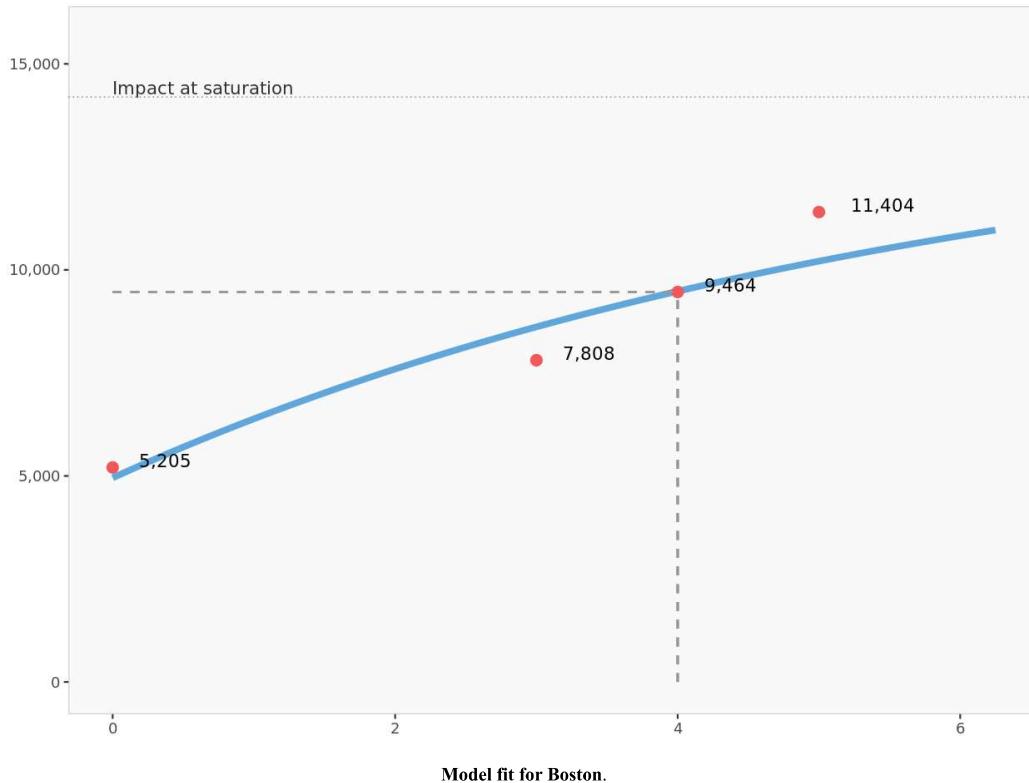
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	14 196	3 274.261	0.168	0.993

Parameters for Boston.

	Effort	Impact	Fit
None	0.00	5 205	4 954
Low	3.00	7 808	8 618
Base	4.00	9 464	9 481
High	5.00	11 404	10 212
Saturation	Saturation	14 196	14 196

Model fit for Boston.



## Philadelphia

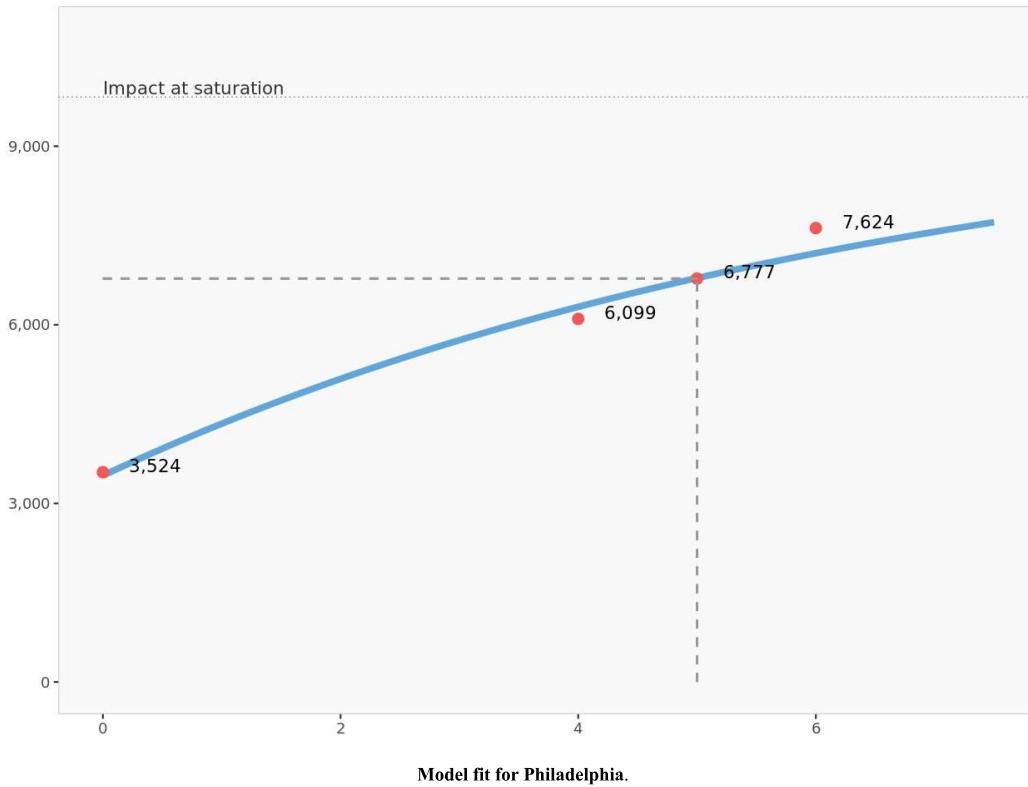
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	9 827	2 098.843	0.148	1.321

Parameters for Philadelphia.

	Effort	Impact	Fit
None	0.00	3 524	3 467
Low	4.00	6 099	6 302
Base	5.00	6 777	6 785
High	6.00	7 624	7 202
Saturation	Saturation	9 827	9 827

Model fit for Philadelphia.



## Cleveland

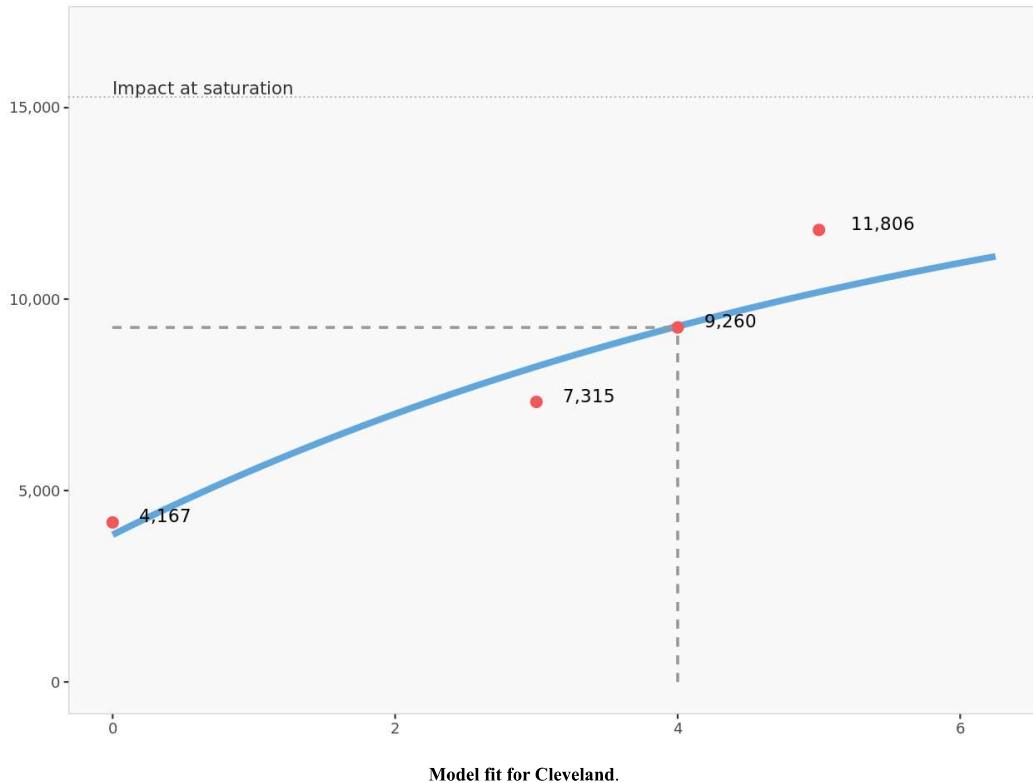
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	15 279	2 415.459	0.162	0.728

Parameters for Cleveland.

	Effort	Impact	Fit
None	0.00	4 167	3 844
Low	3.00	7 315	8 238
Base	4.00	9 260	9 289
High	5.00	11 807	10 183
Saturation	Saturation	15 279	15 279

Model fit for Cleveland.



## Atlanta

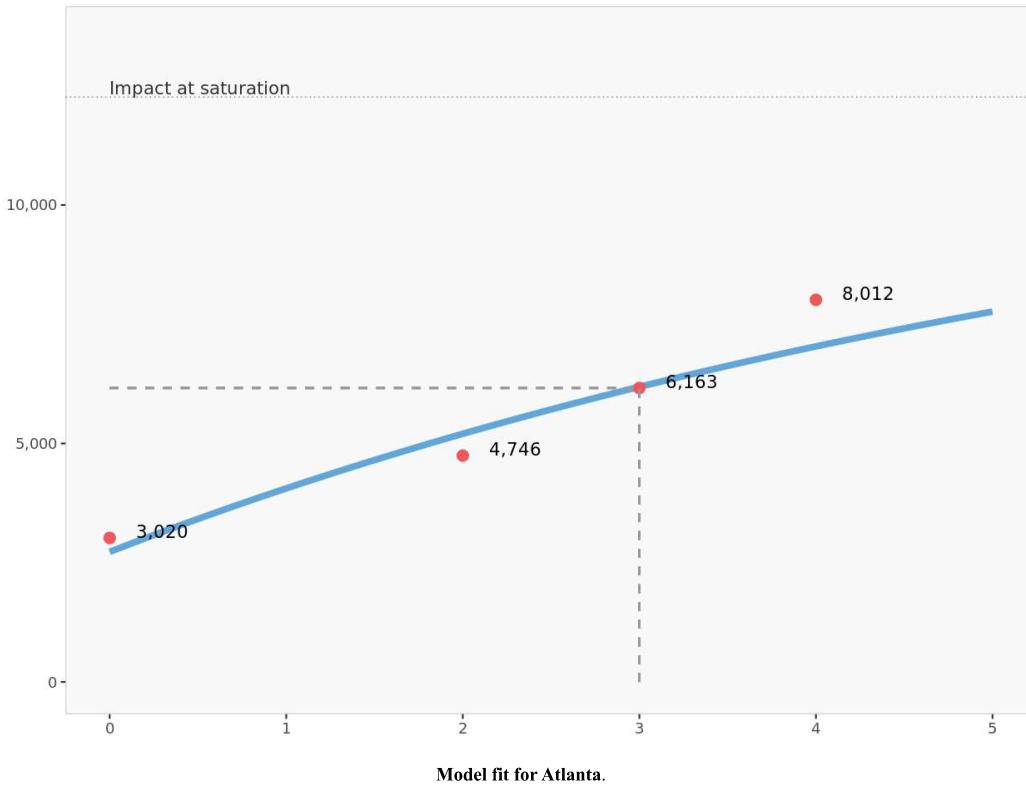
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	12 264	1 473.907	0.150	0.823

Parameters for Atlanta.

	Effort	Impact	Fit
None	0.00	3 020	2 728
Low	2.00	4 746	5 203
Base	3.00	6 163	6 188
High	4.00	8 012	7 035
Saturation	Saturation	12 264	12 264

Model fit for Atlanta.



## Nashville

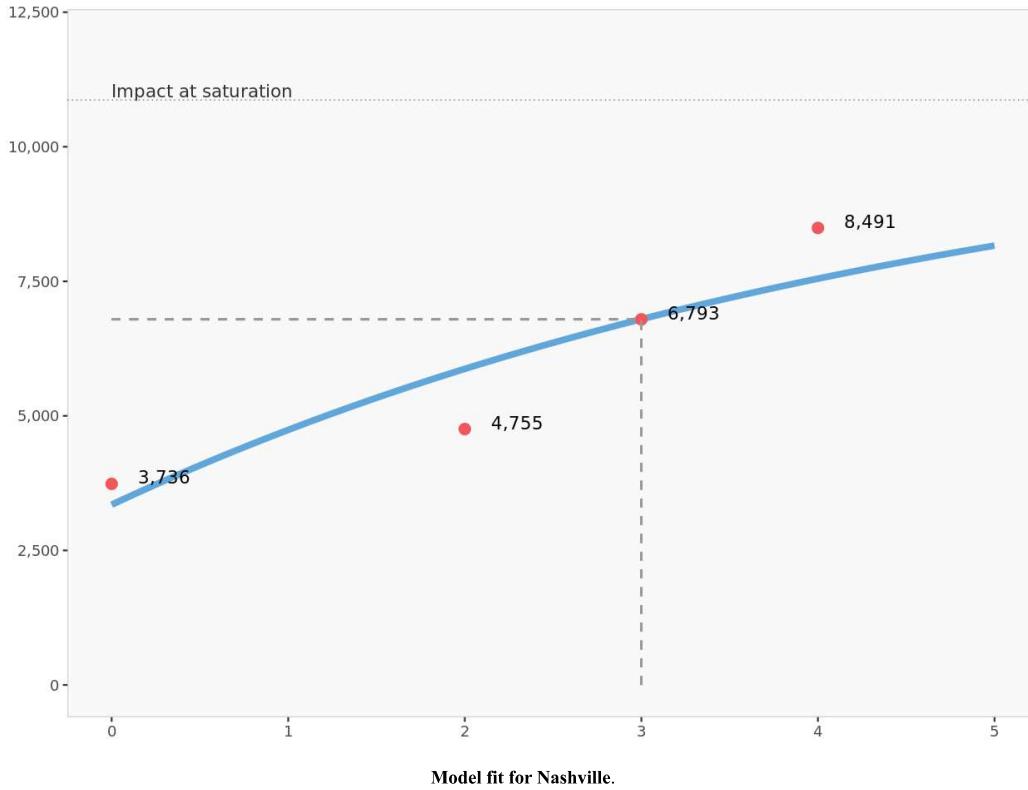
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	10 869	2 314.301	0.204	0.631

Parameters for Nashville.

	Effort	Impact	Fit
None	0.00	3 736	3 349
Low	2.00	4 755	5 873
Base	3.00	6 793	6 797
High	4.00	8 491	7 549
Saturation	Saturation	10 869	10 869

Model fit for Nashville.



## High Point

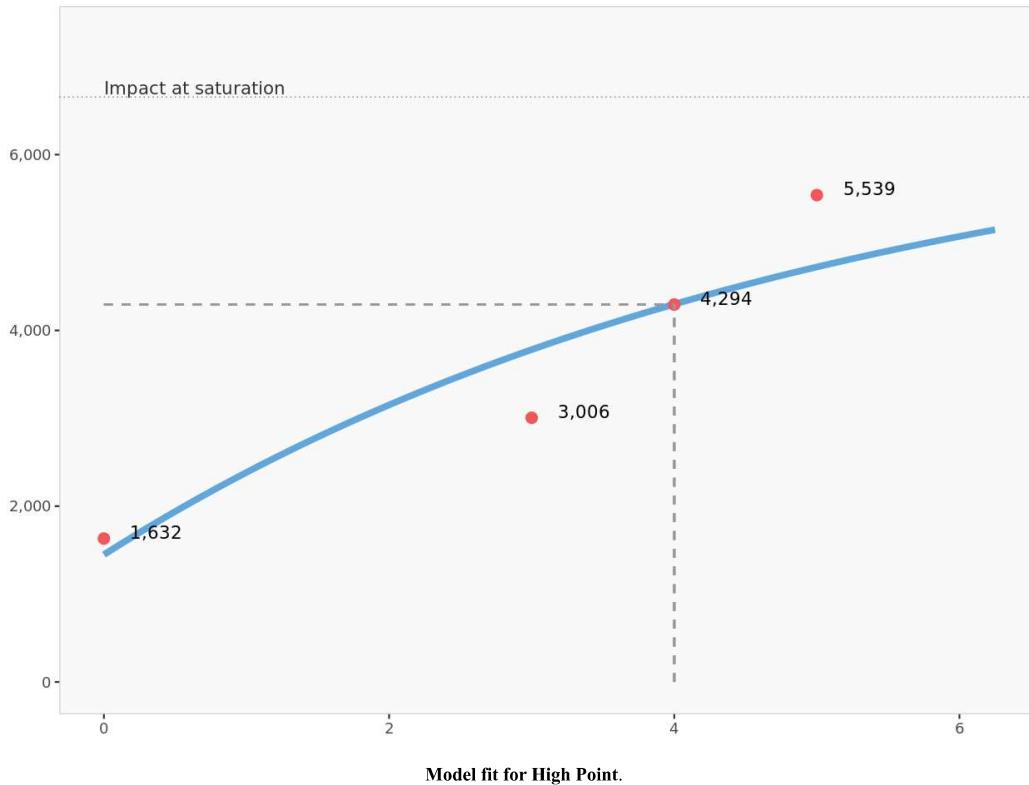
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	6 656	813.662	0.198	0.581

Parameters for High Point.

	Effort	Impact	Fit
<b>None</b>	0.00	1 632	1 449
<b>Low</b>	3.00	3 006	3 782
<b>Base</b>	4.00	4 294	4 298
<b>High</b>	5.00	5 539	4 722
<b>Saturation</b>	Saturation	6 656	6 656

Model fit for High Point.

**Dallas**

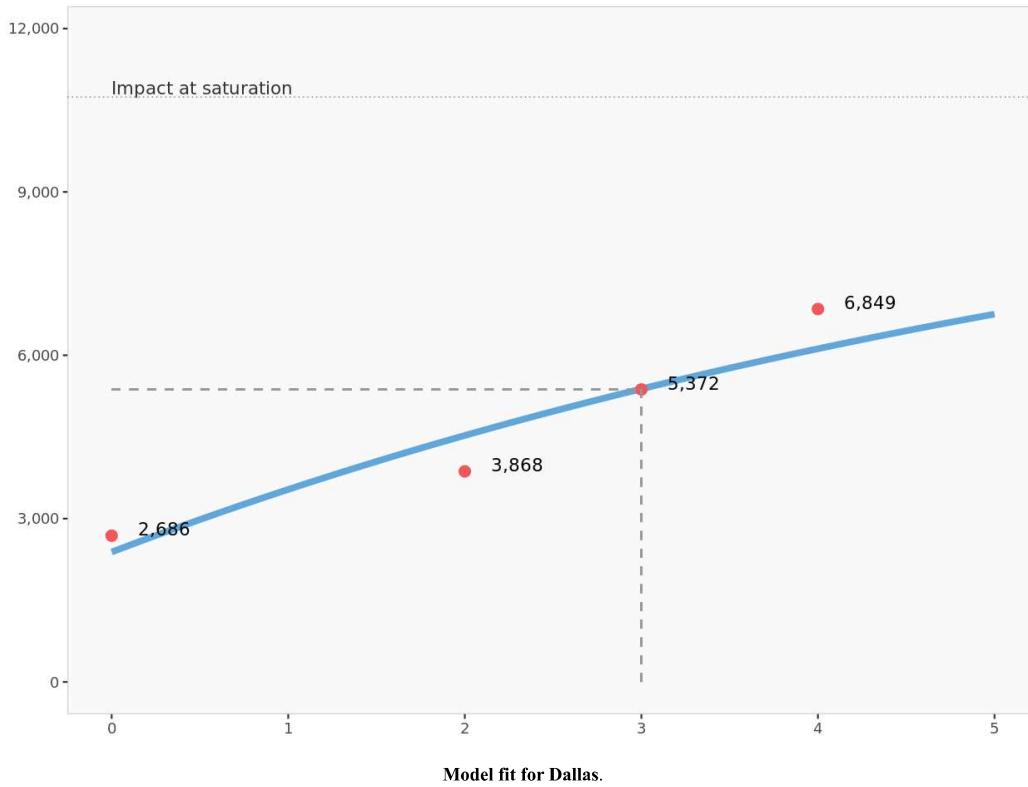
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	10 744	1 004.494	0.148	1.034

Parameters for Dallas.

	Effort	Impact	Fit
None	0.00	2 686	2 386
Low	2.00	3 868	4 528
Base	3.00	5 372	5 383
High	4.00	6 849	6 120
Saturation	Saturation	10 744	10 744

Model fit for Dallas.



## Chicago

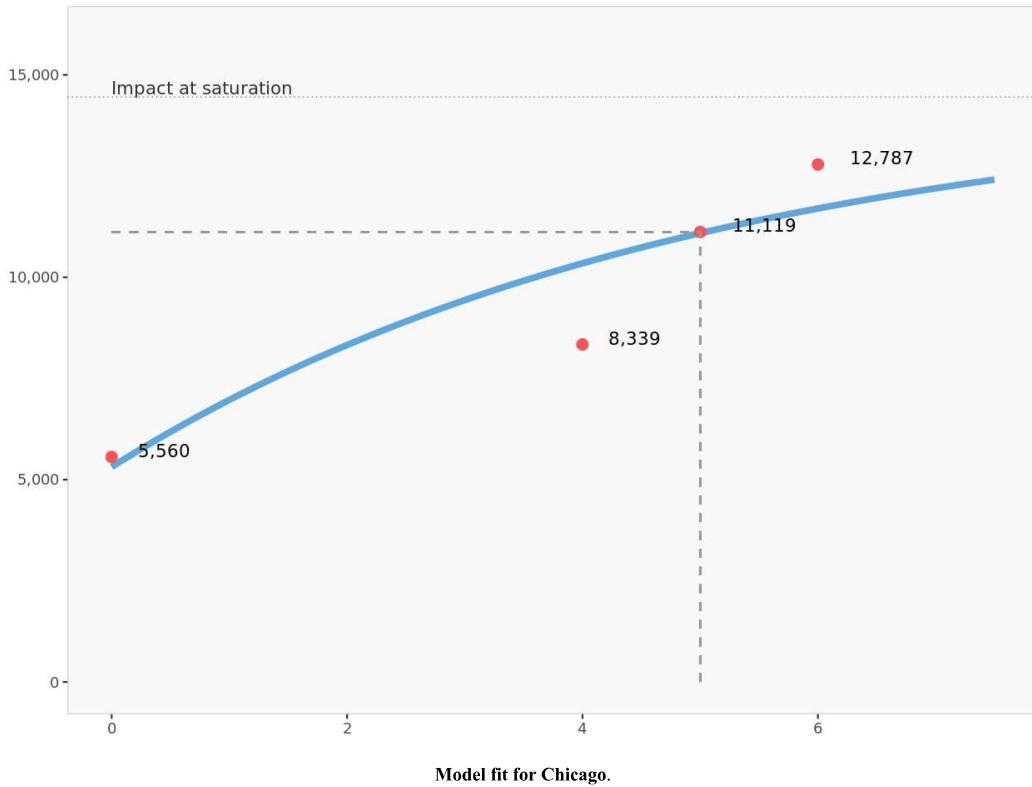
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	14 455	2 864.798	0.200	1.187

Parameters for Chicago.

	Effort	Impact	Fit
None	0.00	5 560	5 314
Low	4.00	8 339	10 346
Base	5.00	11 119	11 090
High	6.00	12 787	11 700
Saturation	Saturation	14 455	14 455

Model fit for Chicago.



## Cincinnati

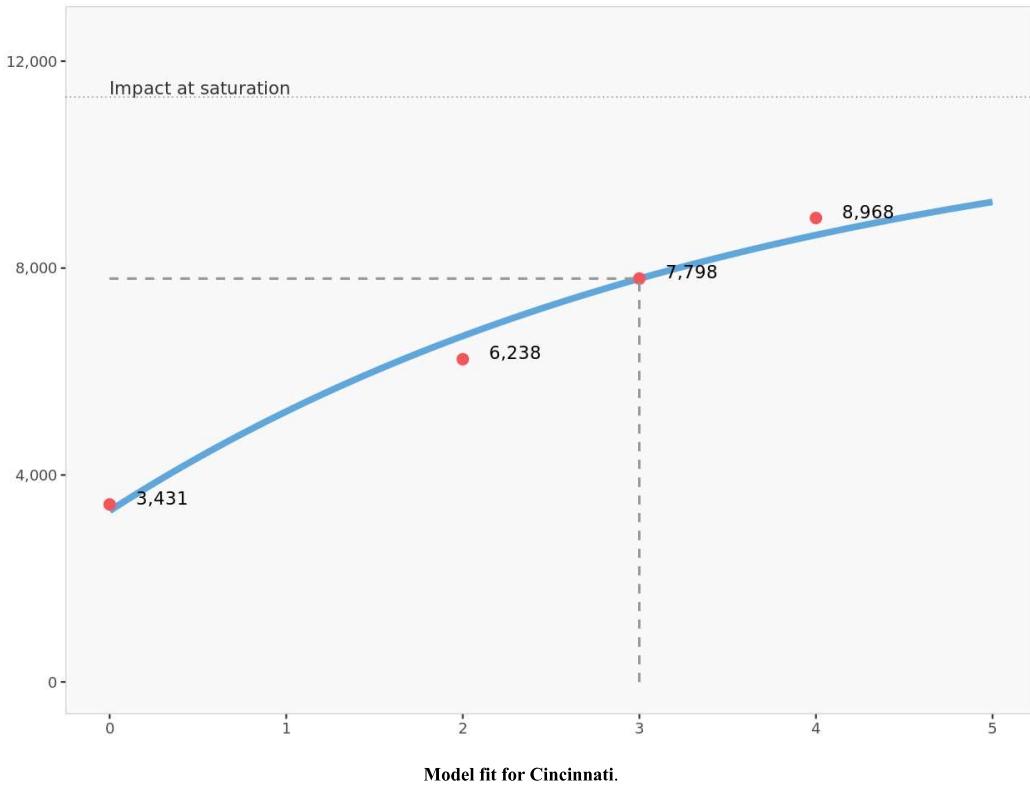
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	11 307	1 820.024	0.274	0.622

Parameters for Cincinnati.

	Effort	Impact	Fit
None	0.00	3 431	3 308
Low	2.00	6 238	6 687
Base	3.00	7 798	7 796
High	4.00	8 968	8 639
Saturation	Saturation	11 307	11 307

Model fit for Cincinnati.



### St. Louis

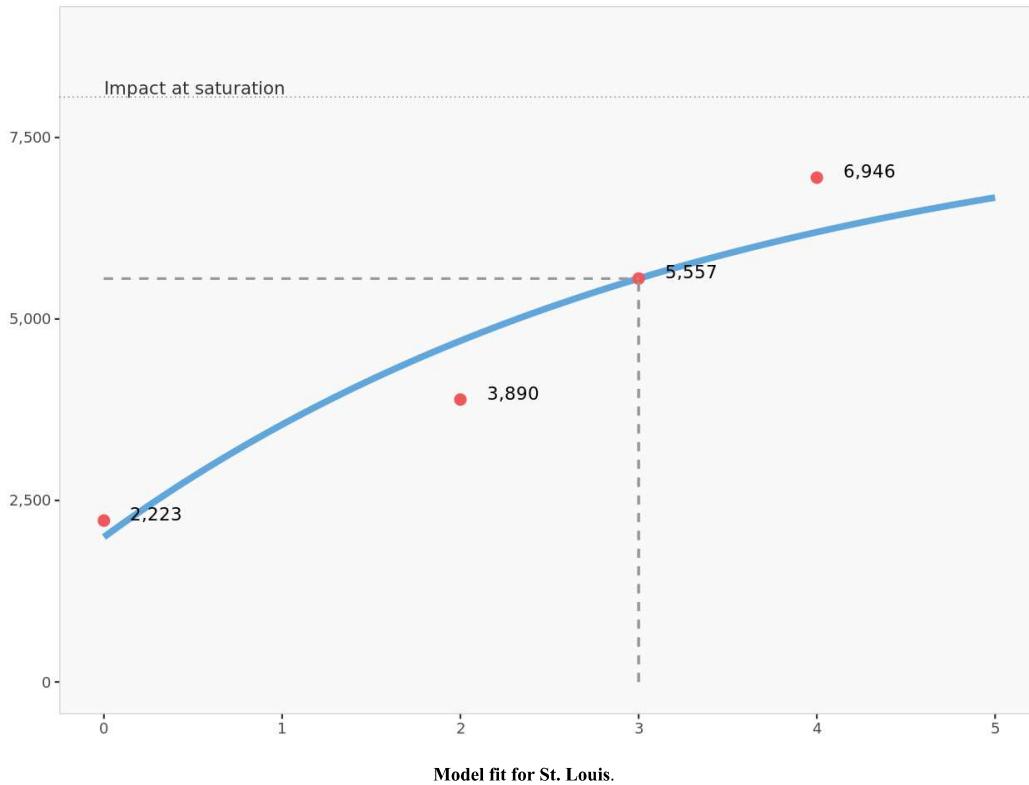
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	8 058	1 066.856	0.295	0.483

Parameters for St. Louis.

	Effort	Impact	Fit
None	0.00	2 223	1 996
Low	2.00	3 890	4 699
Base	3.00	5 557	5 558
High	4.00	6 946	6 197
Saturation	Saturation	8 058	8 058

Model fit for St. Louis.



## Twin Cities

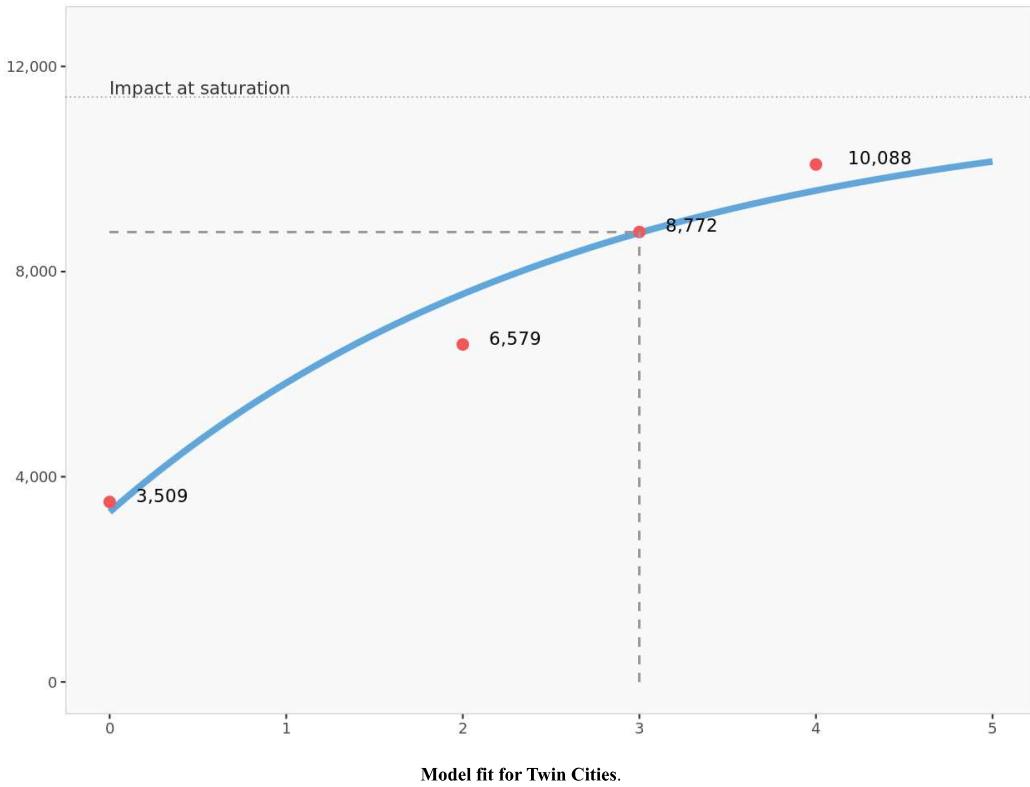
Model used: exponential

	Ceiling	Floor	Exponent	Intercept
Parameters	11 404	1 551.732	0.372	0.530

Parameters for Twin Cities.

	Effort	Impact	Fit
None	0.00	3 509	3 315
Low	2.00	6 579	7 562
Base	3.00	8 772	8 756
High	4.00	10 088	9 579
Saturation	Saturation	11 404	11 404

Model fit for Twin Cities.



## Base scenario

---

	Current number of reps	Current sales (\$000)	Cost per sales rep (\$000)	Margin	Cost of effort	Gross margin	Net margin
<b>Los Angeles</b>	5.00	8 250	147.00	0.35	735	2 888	2 153
<b>San Francisco</b>	4.00	5 598	147.00	0.35	588	1 959	1 371
<b>Seattle</b>	3.00	8 703	147.00	0.35	441	3 046	2 605
<b>Boston</b>	4.00	9 464	147.00	0.35	588	3 312	2 724
<b>Philadelphia</b>	5.00	6 777	147.00	0.35	735	2 372	1 637
<b>Cleveland</b>	4.00	9 260	147.00	0.35	588	3 241	2 653
<b>Atlanta</b>	3.00	6 163	147.00	0.35	441	2 157	1 716
<b>Nashville</b>	3.00	6 793	147.00	0.35	441	2 378	1 937
<b>High Point</b>	4.00	4 294	147.00	0.35	588	1 503	915
<b>Dallas</b>	3.00	5 372	147.00	0.35	441	1 880	1 439
<b>Chicago</b>	5.00	11 119	147.00	0.35	735	3 892	3 157
<b>Cincinnati</b>	3.00	7 798	147.00	0.35	441	2 729	2 288
<b>St. Louis</b>	3.00	5 557	147.00	0.35	441	1 945	1 504
<b>Twin Cities</b>	3.00	8 772	147.00	0.35	441	3 070	2 629
<b>Total</b>	52.00	103 920			7 644	36 372	28 728

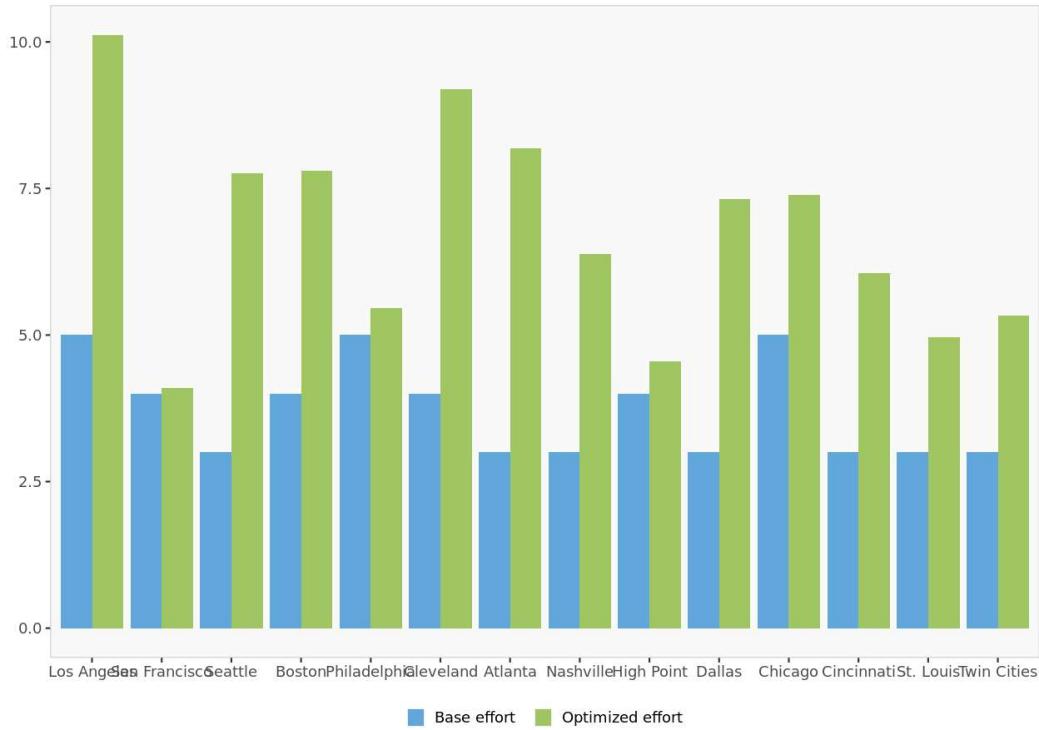
Base scenario table.

## Unconstrained optimization

### Effort

	Base effort	Optimized effort	% change in effort
<b>Los Angeles</b>	5.00	10.12	102.4%
<b>San Francisco</b>	4.00	4.09	2.3%
<b>Seattle</b>	3.00	7.76	158.6%
<b>Boston</b>	4.00	7.80	95.1%
<b>Philadelphia</b>	5.00	5.45	9.1%
<b>Cleveland</b>	4.00	9.19	129.7%
<b>Atlanta</b>	3.00	8.19	172.9%
<b>Nashville</b>	3.00	6.38	112.6%
<b>High Point</b>	4.00	4.55	13.6%
<b>Dallas</b>	3.00	7.32	143.9%
<b>Chicago</b>	5.00	7.39	47.7%
<b>Cincinnati</b>	3.00	6.06	102.0%
<b>St. Louis</b>	3.00	4.96	65.3%
<b>Twin Cities</b>	3.00	5.33	77.8%
<b>Total</b>	52.00	94.58	81.9%

Comparison of effort in unconstrained optimization.



Comparison of effort in unconstrained optimization.

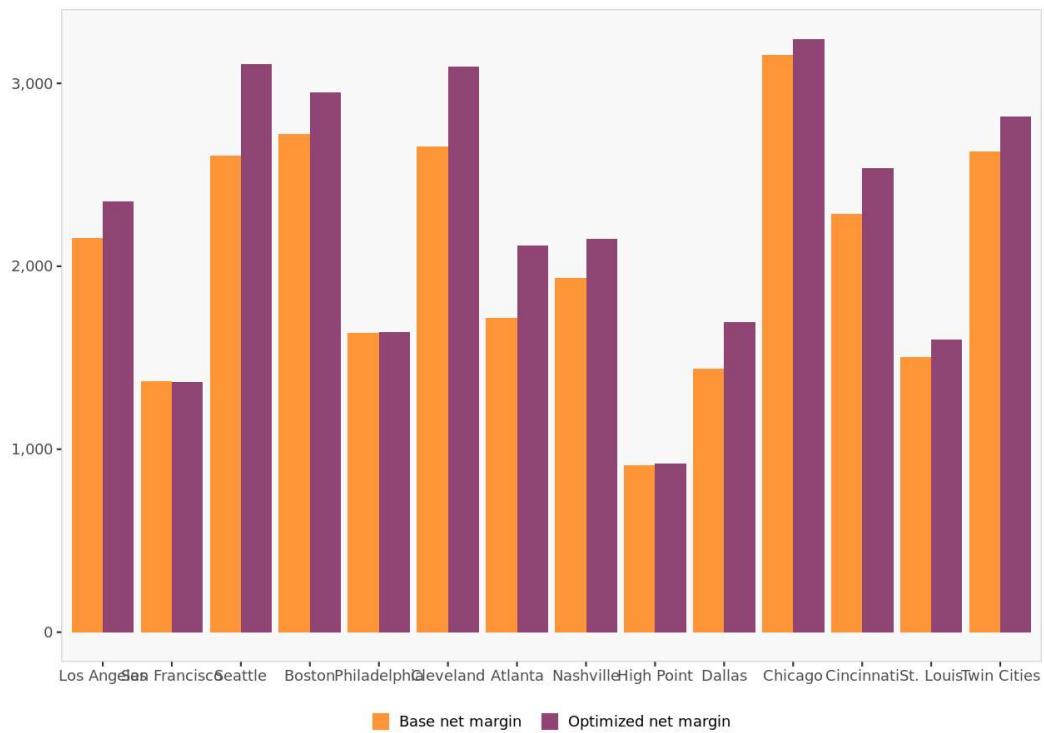
### Net margin

	Base net margin	Optimized net margin	% change in margin
<b>Los Angeles</b>	2 153	2 353	9.3%
<b>San Francisco</b>	1 371	1 368	-0.2%
<b>Seattle</b>	2 605	3 105	19.2%
<b>Boston</b>	2 724	2 951	8.3%
<b>Philadelphia</b>	1 637	1 642	0.3%
<b>Cleveland</b>	2 653	3 091	16.5%
<b>Atlanta</b>	1 716	2 113	23.1%
<b>Nashville</b>	1 937	2 152	11.1%
<b>High Point</b>	915	921	0.6%
<b>Dallas</b>	1 439	1 694	17.7%

## Resource Allocation

<b>Chicago</b>	3 157	3 243	2.7%
<b>Cincinnati</b>	2 288	2 536	10.8%
<b>St. Louis</b>	1 504	1 600	6.4%
<b>Twin Cities</b>	2 629	2 819	7.2%
<b>Total</b>	28 728	31 588	10.0%

Comparison of net margin in unconstrained optimization.



Comparison of net margin in unconstrained optimization.

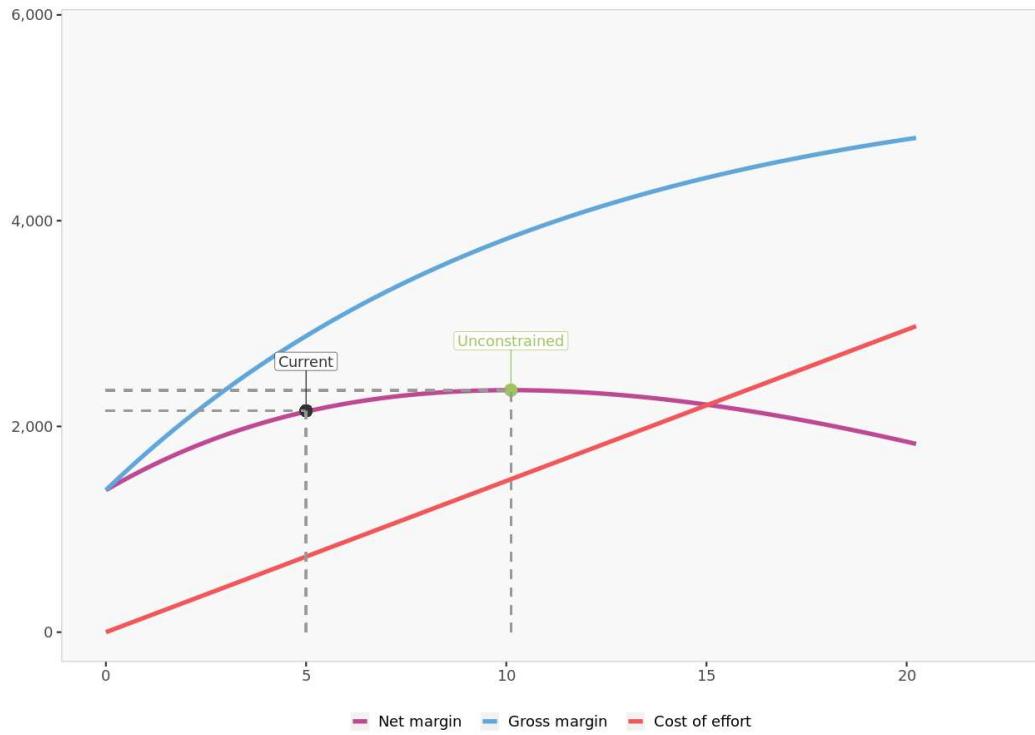
## Constrained optimization

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The unconstrained solution does not violate any of the user-specified constraints. Therefore, imposing constraints would not change the recommended solution, and is not required.

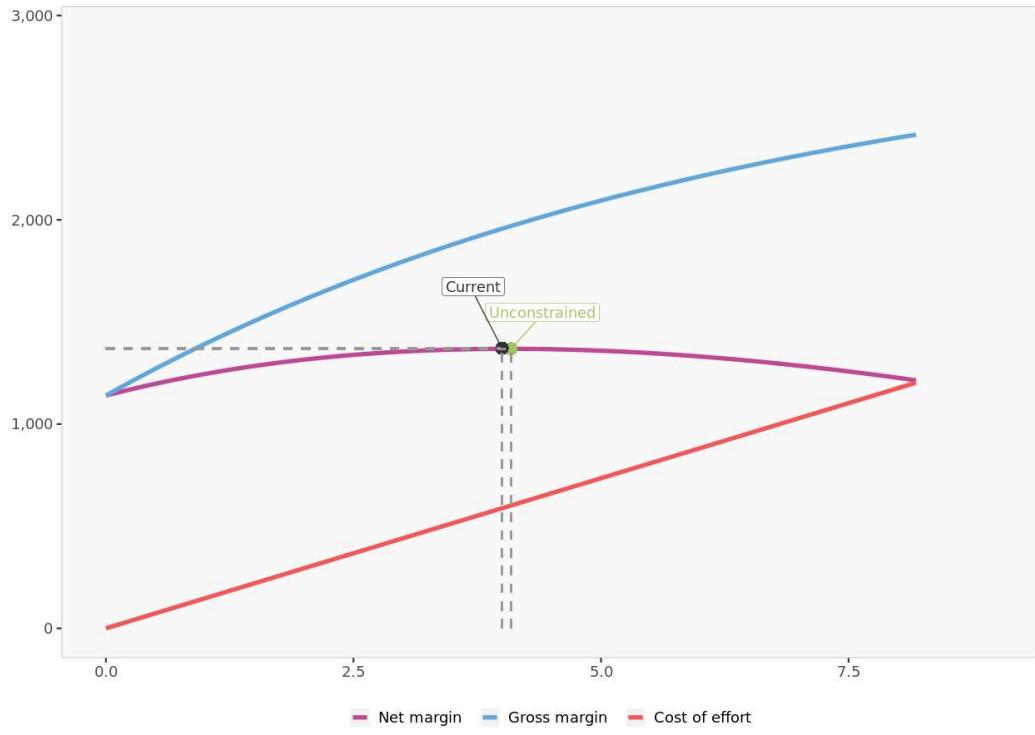
## Comparison of scenarios

### Los Angeles: scenarios



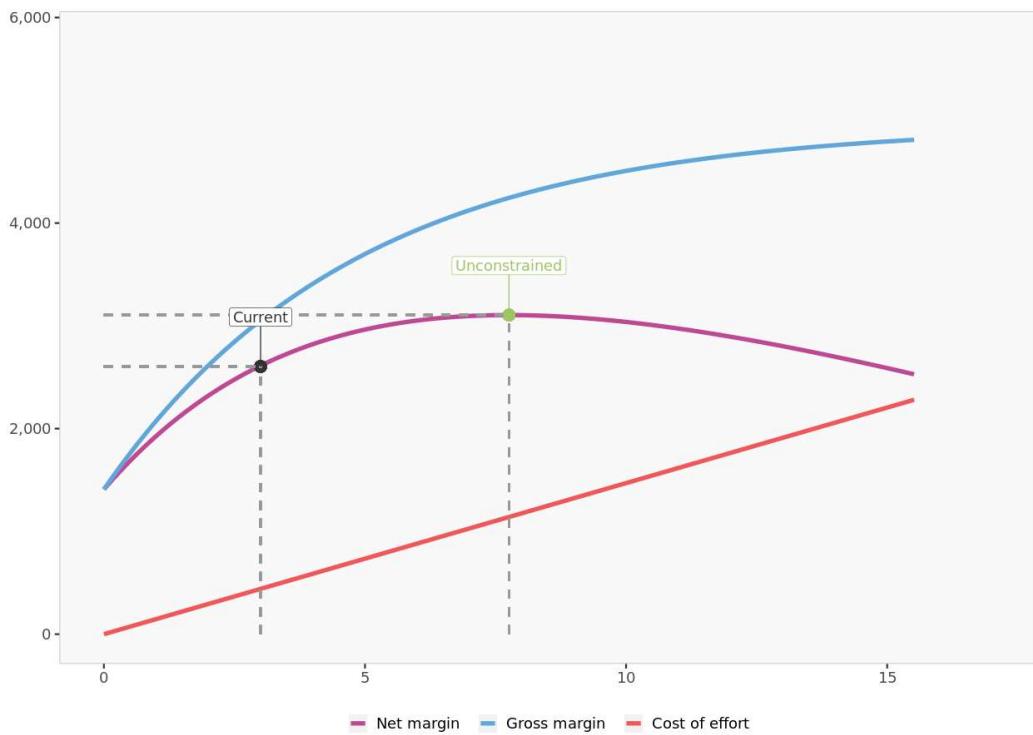
Los Angeles: scenarios.

### San Francisco: scenarios

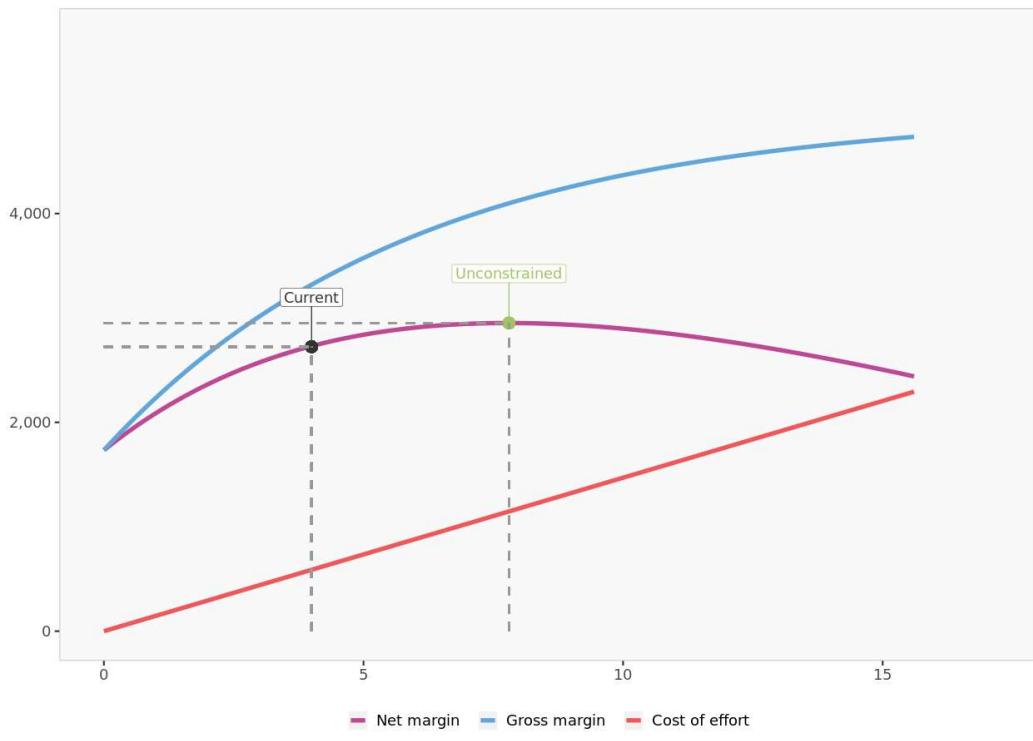


San Francisco: scenarios.

### Seattle: scenarios

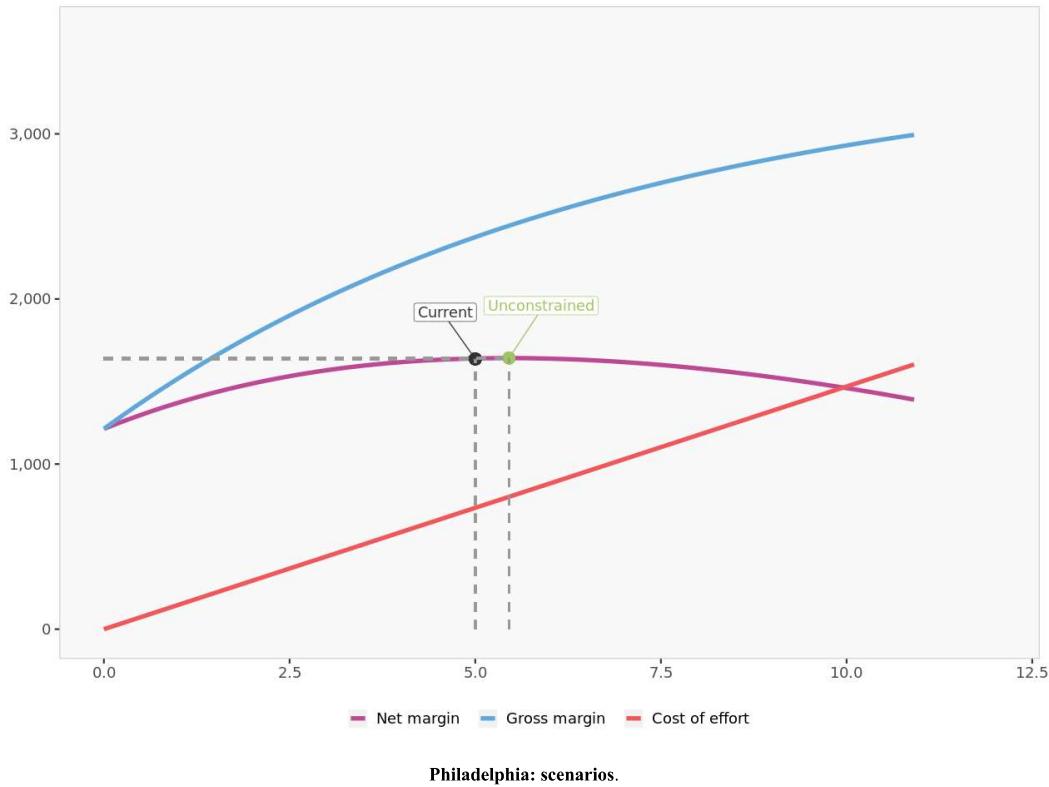
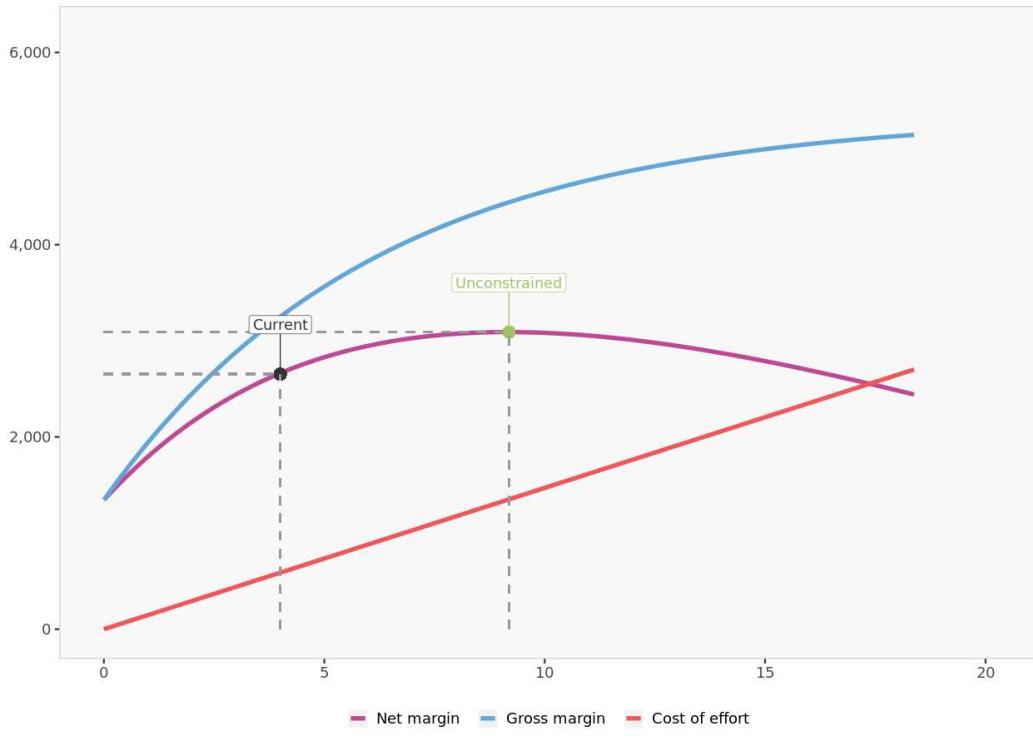


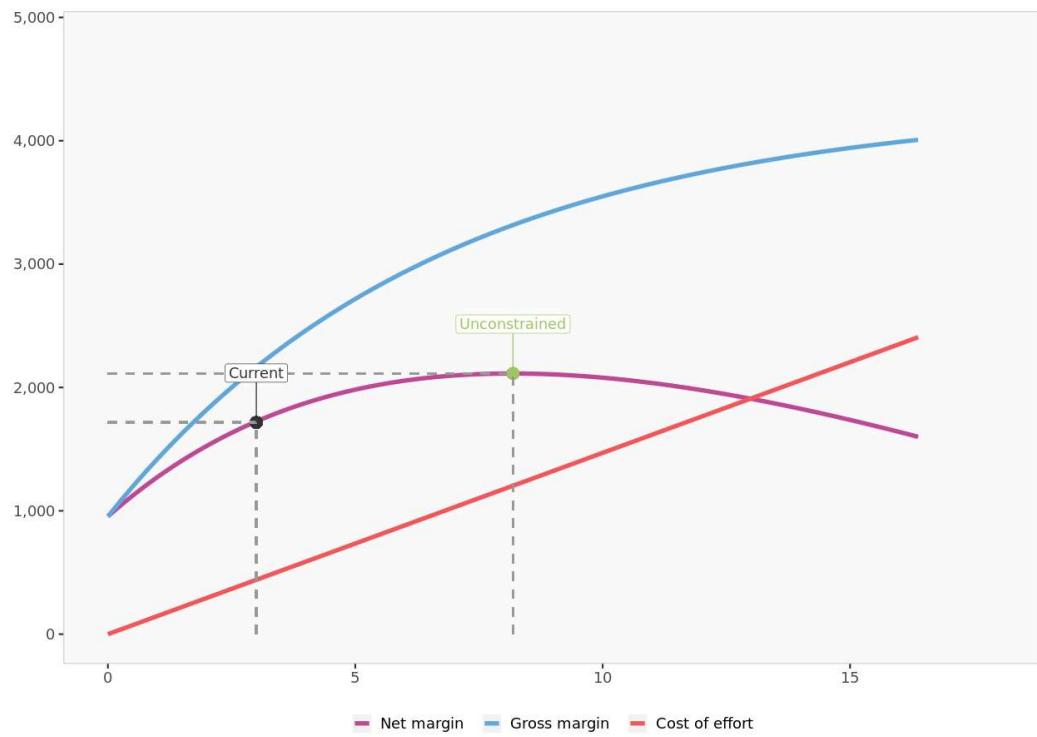
Seattle: scenarios.

**Boston: scenarios**

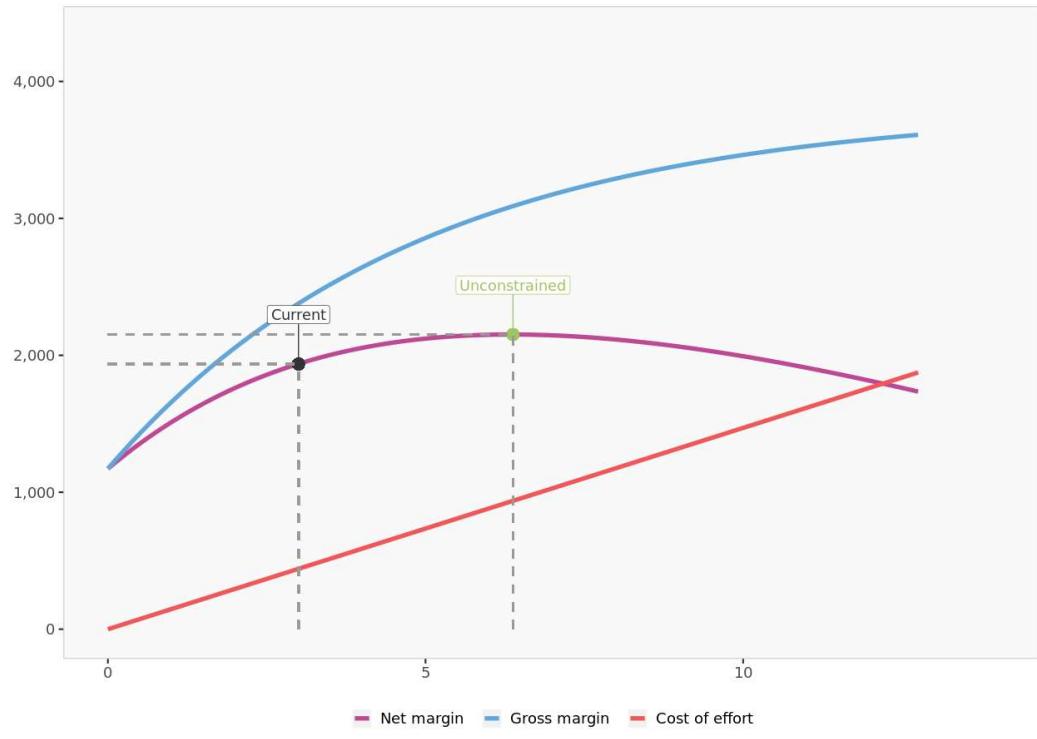
Boston: scenarios.

**Philadelphia: scenarios**

**Cleveland: scenarios****Atlanta: scenarios**

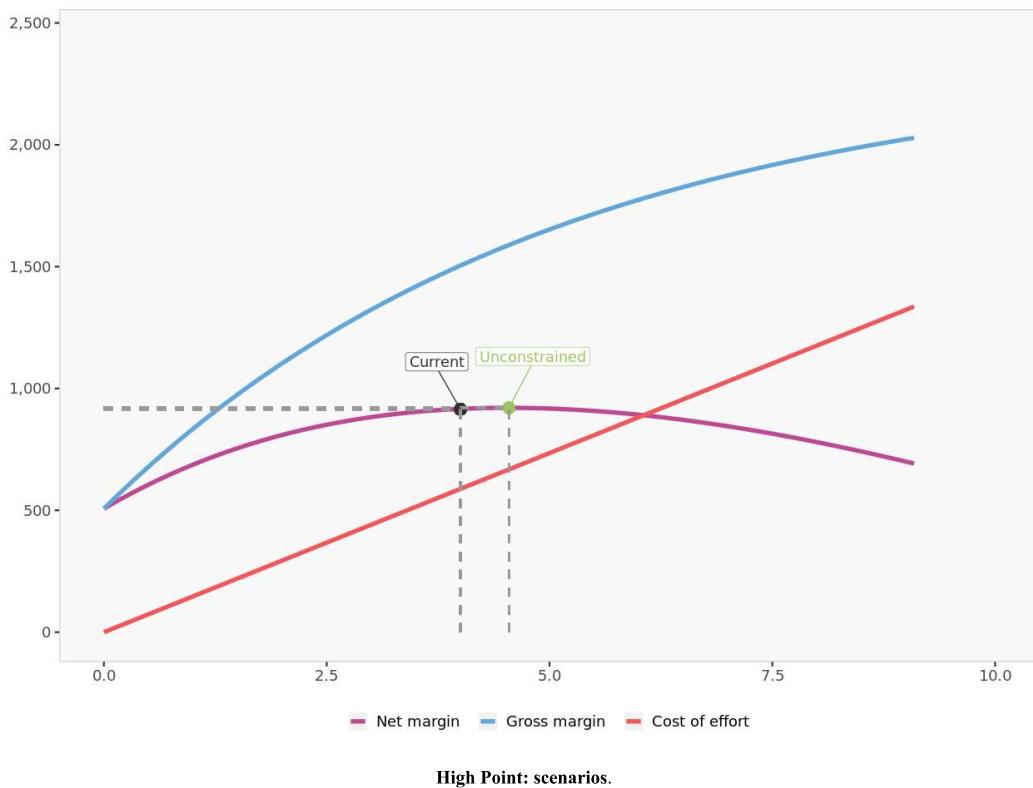


Atlanta: scenarios.

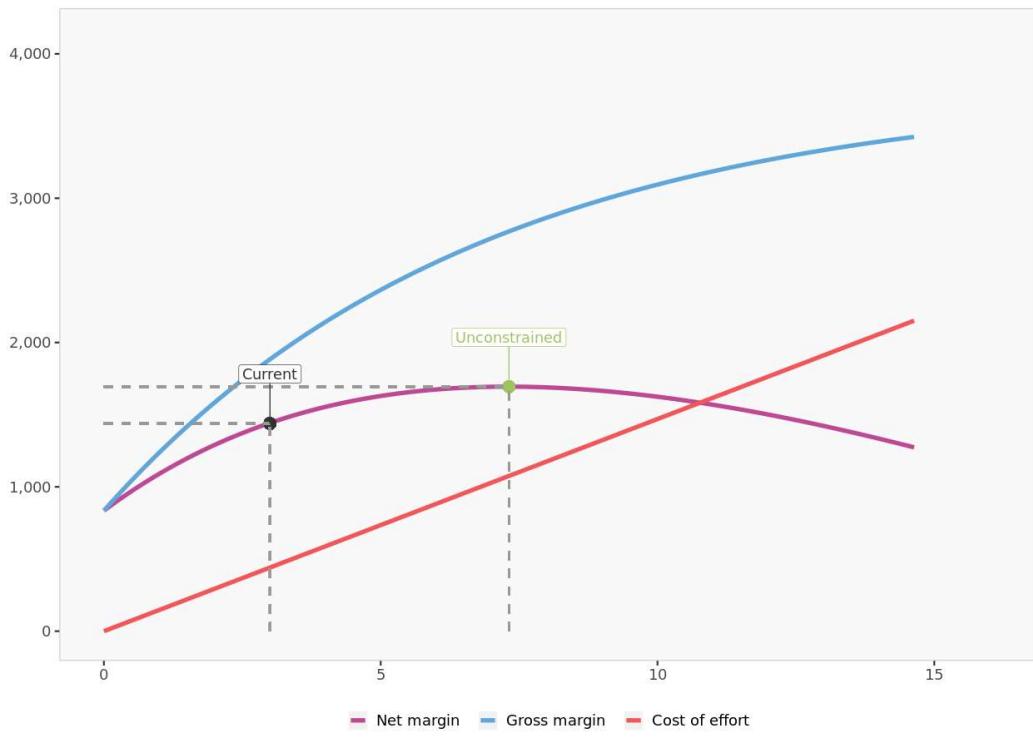
**Nashville: scenarios**

Nashville: scenarios.

**High Point: scenarios**

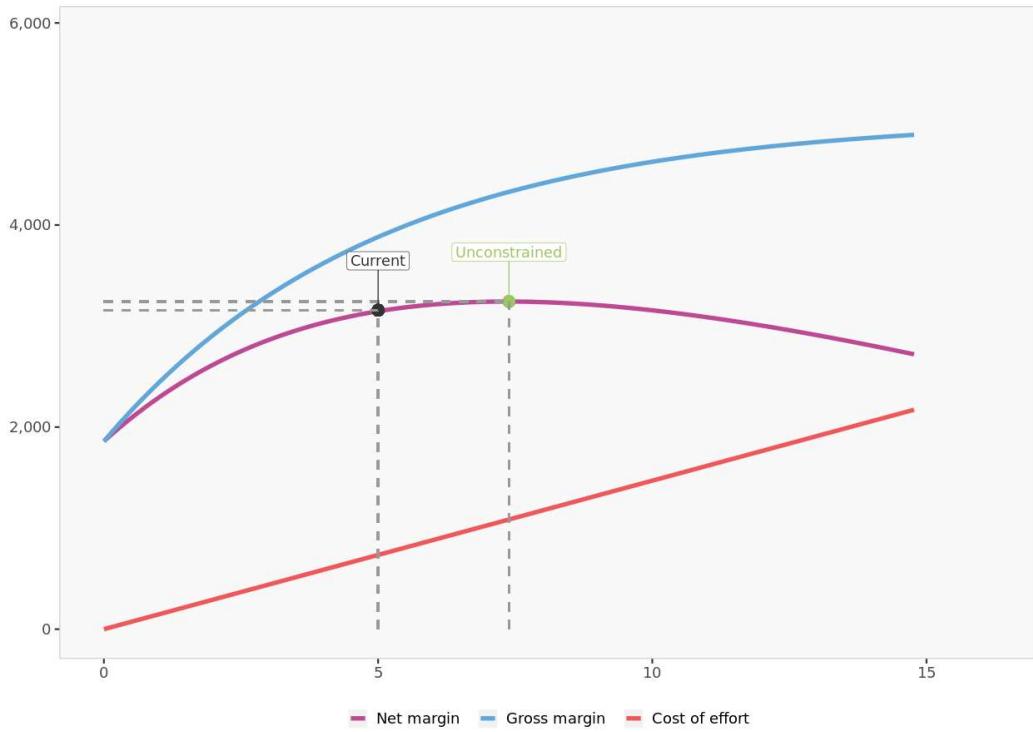
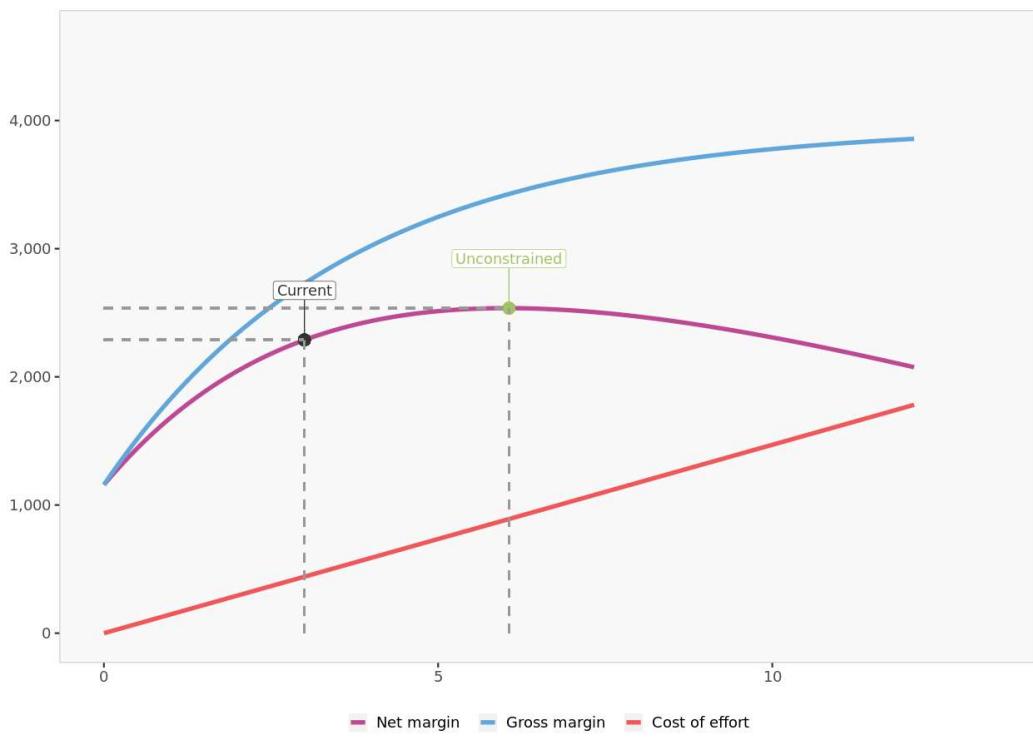


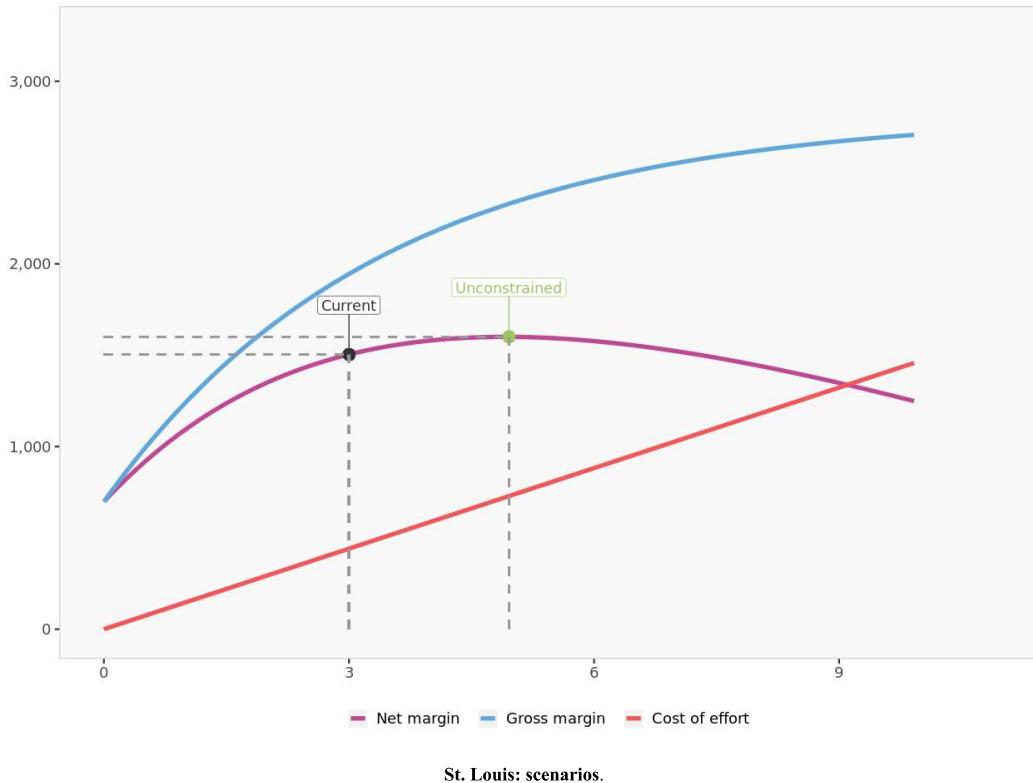
High Point: scenarios.

**Dallas: scenarios**

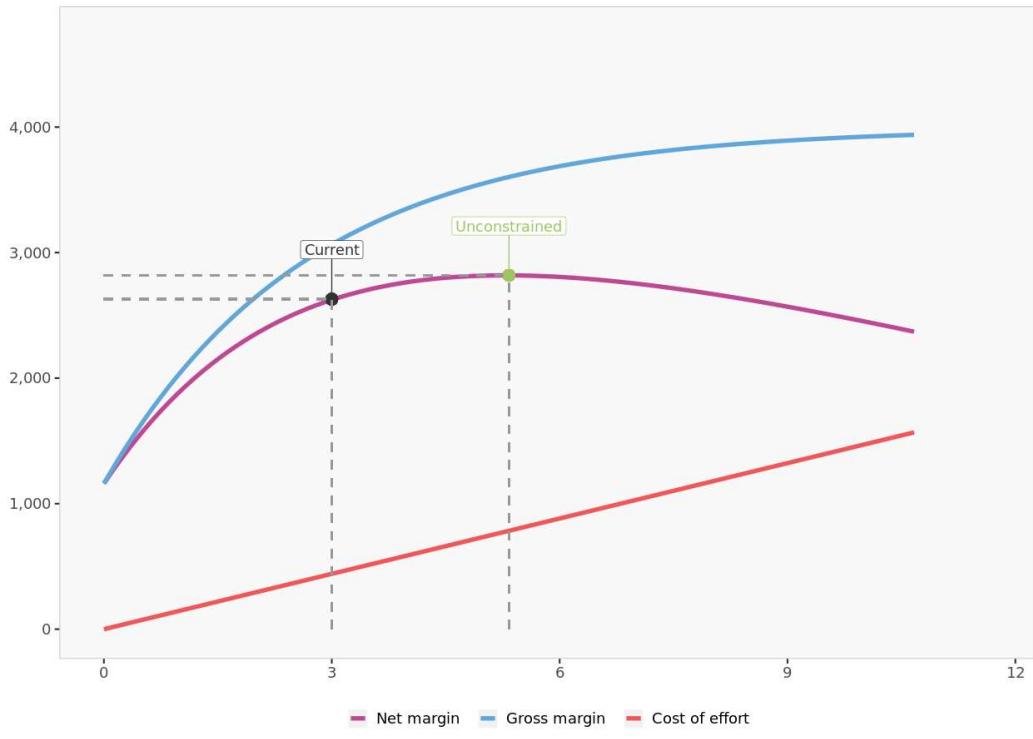
Dallas: scenarios.

**Chicago: scenarios**

**Cincinnati: scenarios****St. Louis: scenarios**

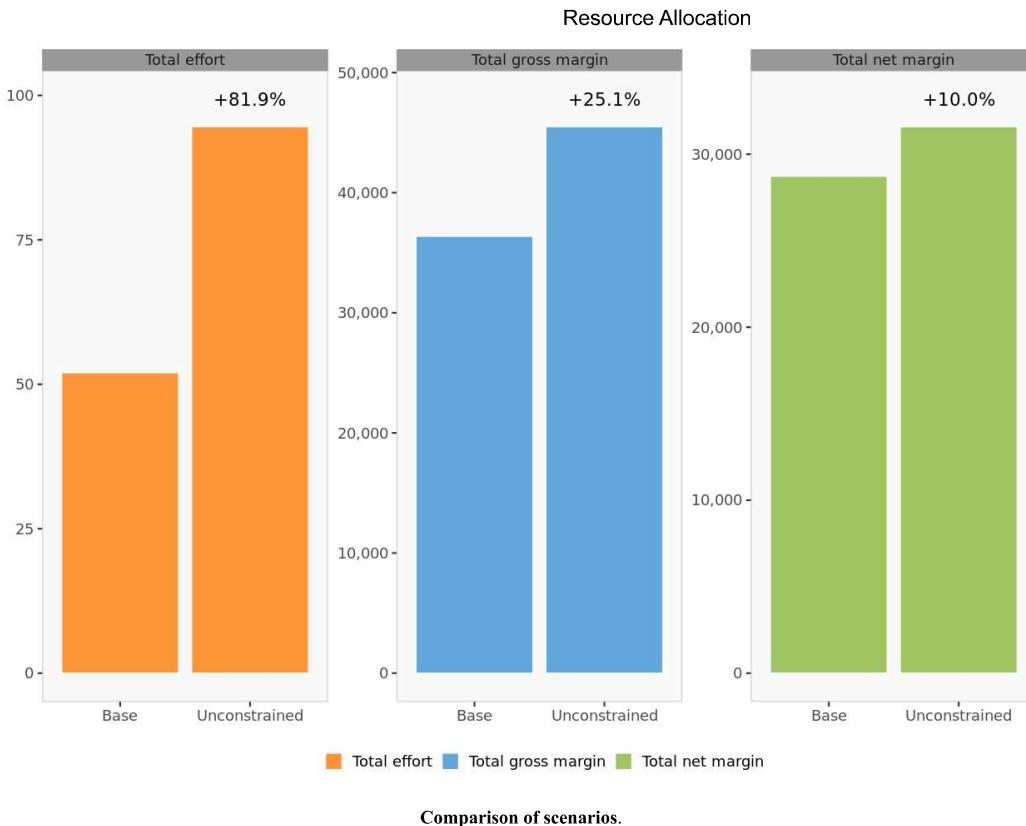


St. Louis: scenarios.

**Twin Cities: scenarios**

Twin Cities: scenarios.

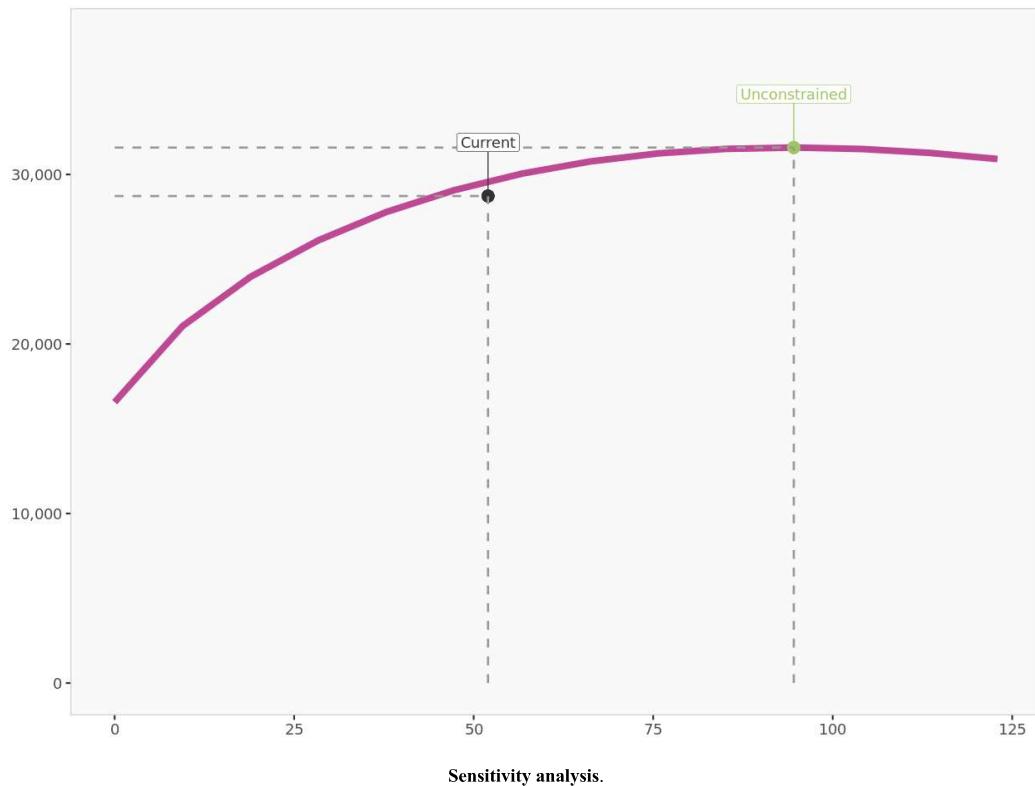
**Comparison of scenarios**



## Sensitivity analysis

	Total effort	Net margin
No effort	0.00	16 569
-90% effort	9.46	21 056
-80% effort	18.92	23 960
-70% effort	28.37	26 116
-60% effort	37.83	27 785
-50% effort	47.29	29 073
-40% effort	56.75	30 052
-30% effort	66.21	30 767
-20% effort	75.66	31 242
-10% effort	85.12	31 508
Recommended	94.58	31 588
+10% effort	104.04	31 503
+20% effort	113.50	31 272
+30% effort	122.95	30 912

Sensitivity analysis.



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