Six Life Lessons You Didn’t Learn from your OR Program

Thank you for joining us. We will be starting shortly.

GUROBI OPTIMIZATION

The World’s Fastest Solver

Welcome to the Webinar

Six Life Lessons You Didn’t Learn from your OR Program

GUROBI OPTIMIZATION

The World’s Fastest Solver

Speaker Introduction

Dr. Michael Watson

- CEO at Opex Analytics
- Recognized leader in analytics and supply chain optimization
- Michael was an early employee and officer at LogicTools
- While at IBM, he was the worldwide business leader for network design, inventory and routing solutions
- Co-author of ”Managerial Analytics” and “Supply Chain Network Design”
- Adjunct professor at Northwestern University teaching graduate level courses within the Master in Engineering Management and the Master of Science in Analytics programs

Speaker Introduction

Dr. Pete Cacioppi

- Algorithim Consultant at Opex Analytics
- First employee and Chief Scientist at LogicTools
- Co-founder and Chief Scientist at Opalytics (now part of Accenture)
- Co-author of “Supply Chain Network Design”
- Decades of experience building robust optimization applications with multiple programming languages.

Six Life Lessons You Didn’t Learn from your OR Program

These are our lessons, what we have seen

OR programs teach you OR (as they should)

These lessons are about getting your OR code used

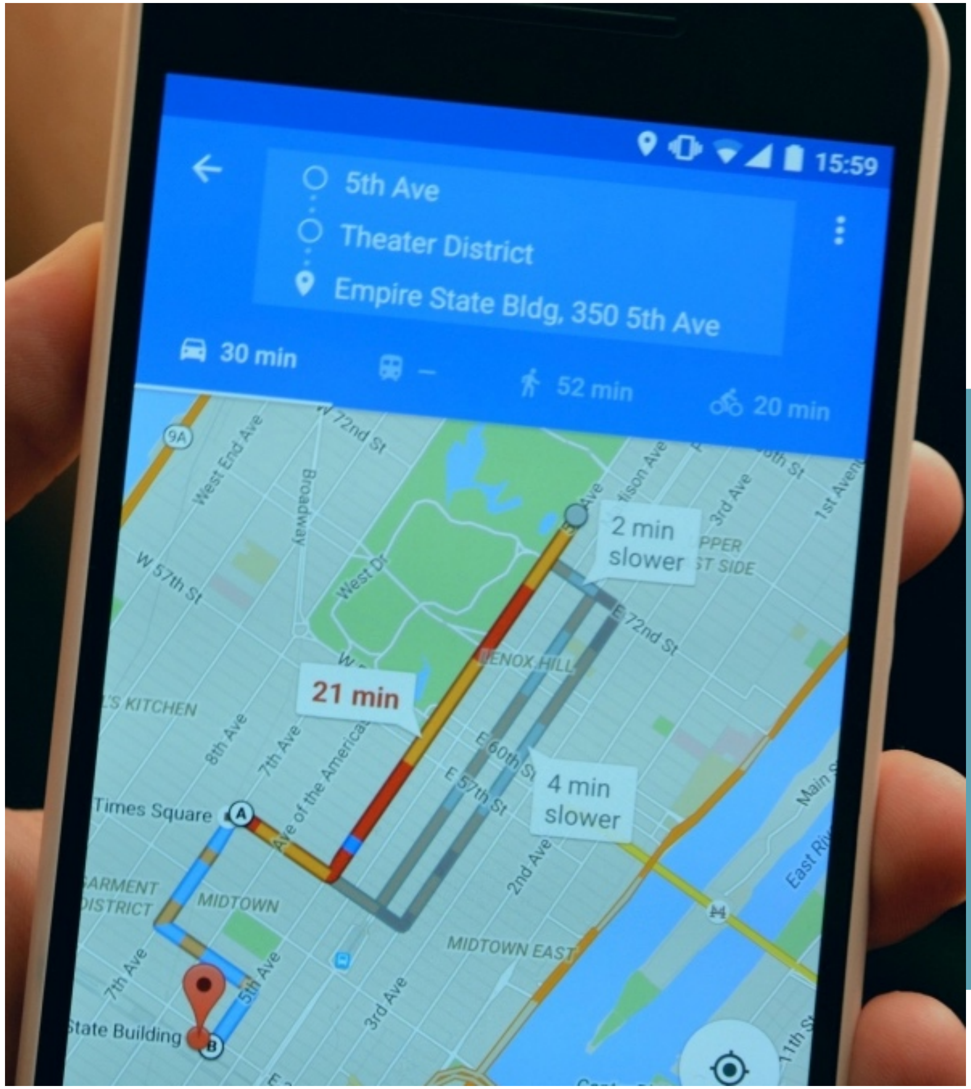
We’ll bring a CS and Business element

Not our first lesson

Users Like Nice Interfaces

We aren’t going to waste one of our six on this

Pay Attention to the End User



5th Ave

Theater District

Empire State Bldg, 350 5th Ave

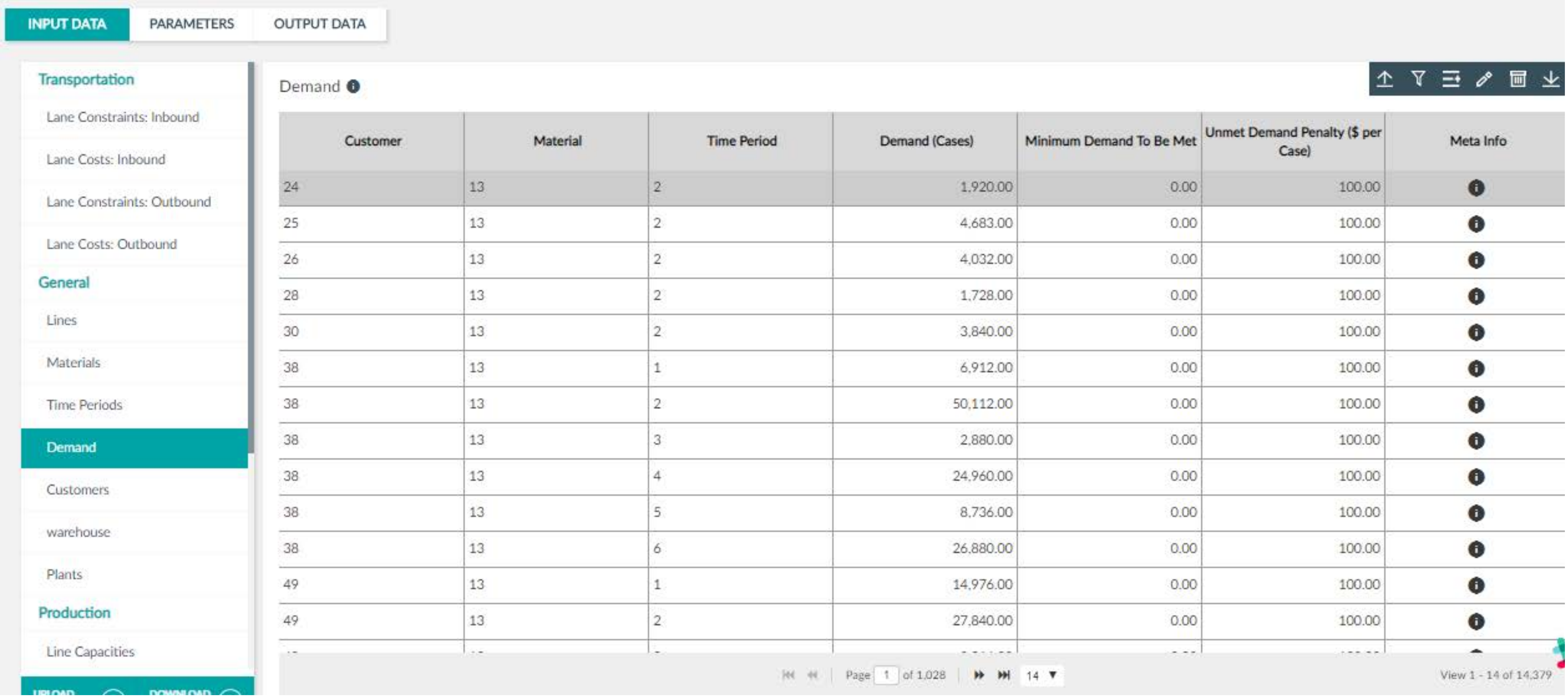
30 min — 52 min 20 min

"If we want users to like our software, we should design it to behave like a likeable person: respectful, generous and helpful."

Alan Cooper
Software Designer and Programmer

For the Business User

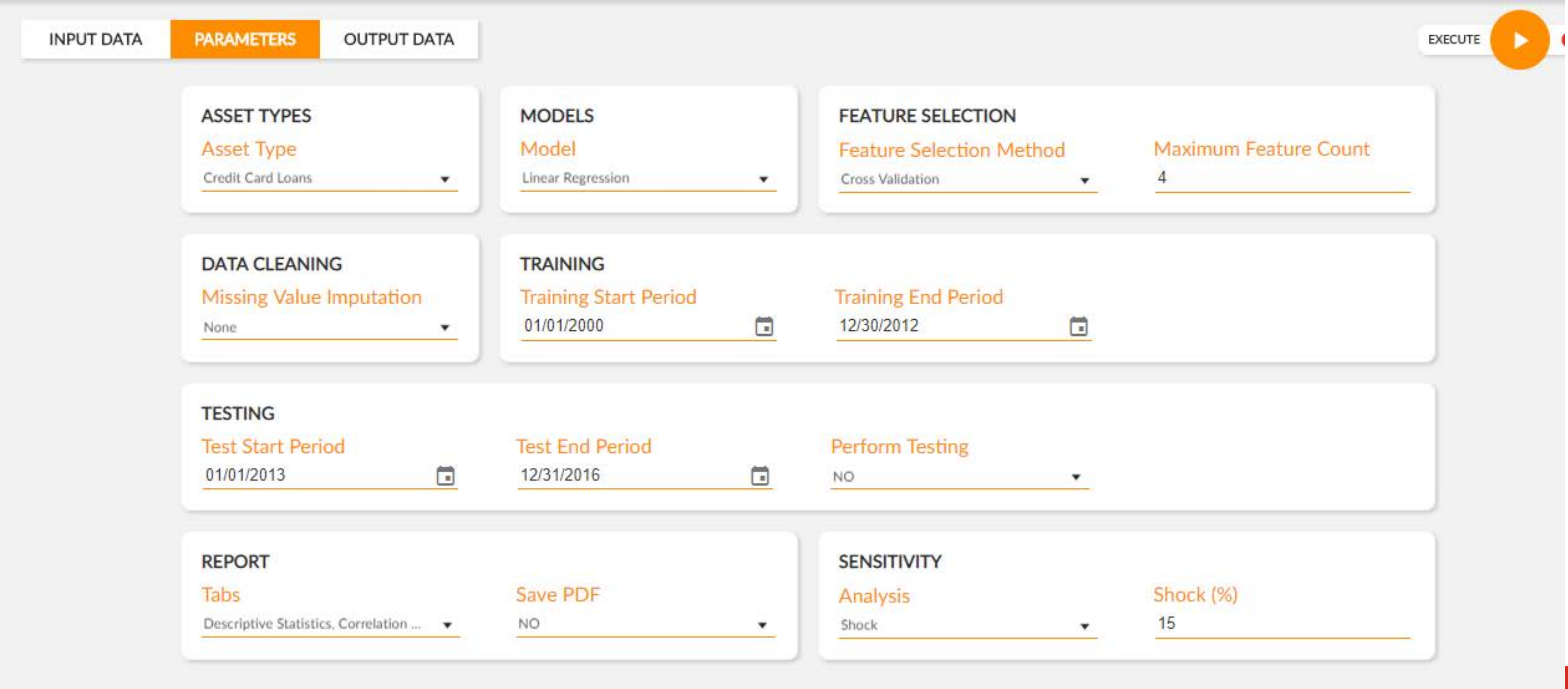
You Need Input (Manual and Automatic)



Customer	Material	Time Period	Demand (Cases)	Minimum Demand To Be Met	Unmet Demand Penalty ($ per Case)	Meta Info
24	13	2	1,920.00	0.00	100.00	ℹ
25	13	2	4,683.00	0.00	100.00	ℹ
26	13	2	4,032.00	0.00	100.00	ℹ
28	13	2	1,728.00	0.00	100.00	ℹ
30	13	2	3,840.00	0.00	100.00	ℹ
38	13	1	6,912.00	0.00	100.00	ℹ
38	13	2	50,112.00	0.00	100.00	ℹ
38	13	3	2,880.00	0.00	100.00	ℹ
38	13	4	24,960.00	0.00	100.00	ℹ
38	13	5	8,736.00	0.00	100.00	ℹ
38	13	6	26,880.00	0.00	100.00	ℹ
49	13	1	14,976.00	0.00	100.00	ℹ
49	13	2	27,840.00	0.00	100.00	ℹ

For the Business User

Users Like to Have Control over Parameters



ASSET TYPES
Asset Type: Credit Card Loans

MODELS
Model: Linear Regression

FEATURE SELECTION
Feature Selection Method: Cross Validation
Maximum Feature Count: 4

DATA CLEANING
Missing Value Imputation: None

TRAINING
Training Start Period: 01/01/2000
Training End Period: 12/30/2012

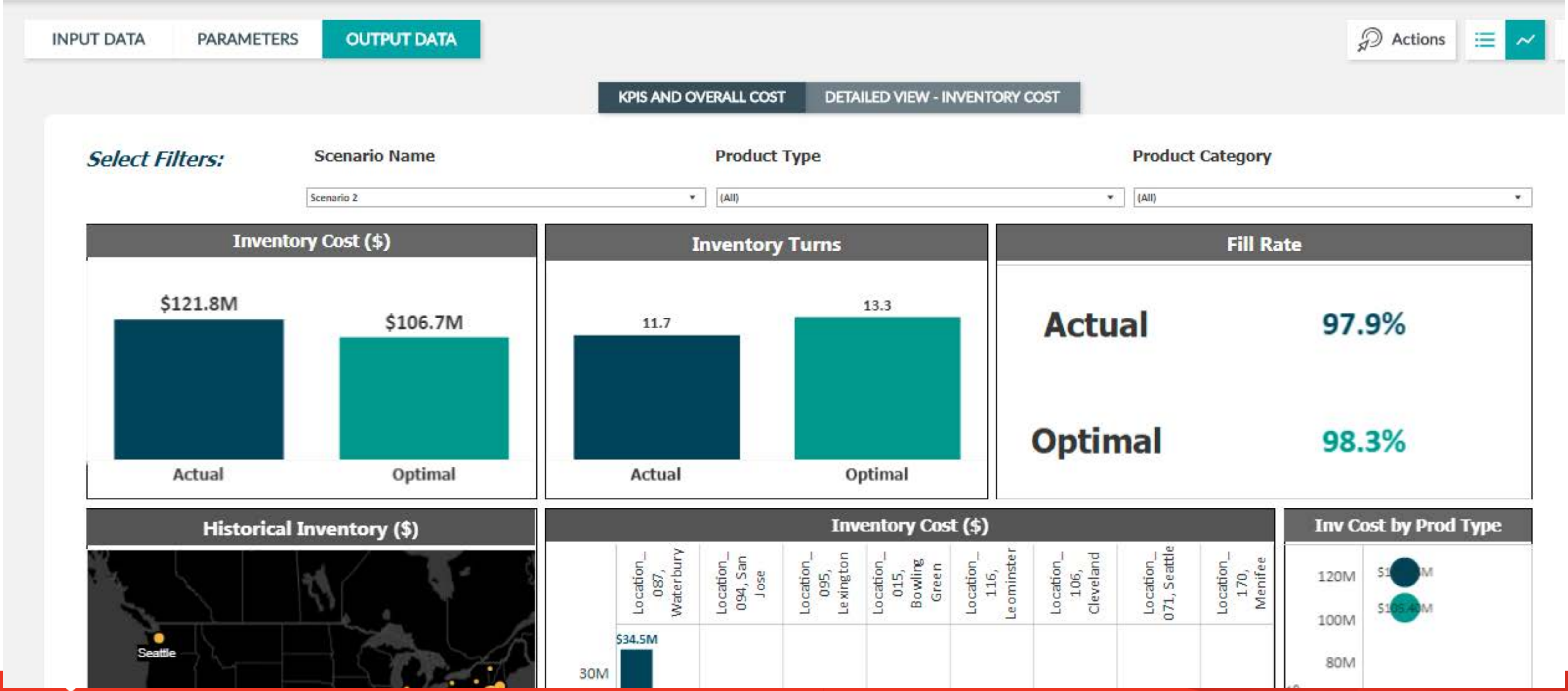
TESTING
Test Start Period: 01/01/2013
Test End Period: 12/31/2016
Perform Testing: NO

REPORT
Tabs: Descriptive Statistics, Correlation ...
Save PDF: NO

SENSITIVITY
Analysis: Shock
Shock (%): 15

For the Business User

And, they like reports to see what happened



Select Filters:

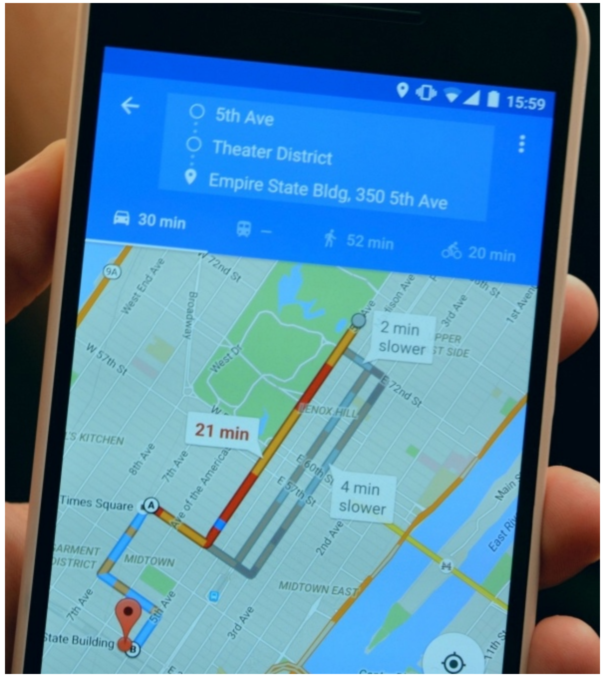
Scenario Name: Scenario 2

Product Type: (All)

Product Category: (All)

For Consumer or Embedded Systems

The interface might not be your problem



15:59

5th Ave

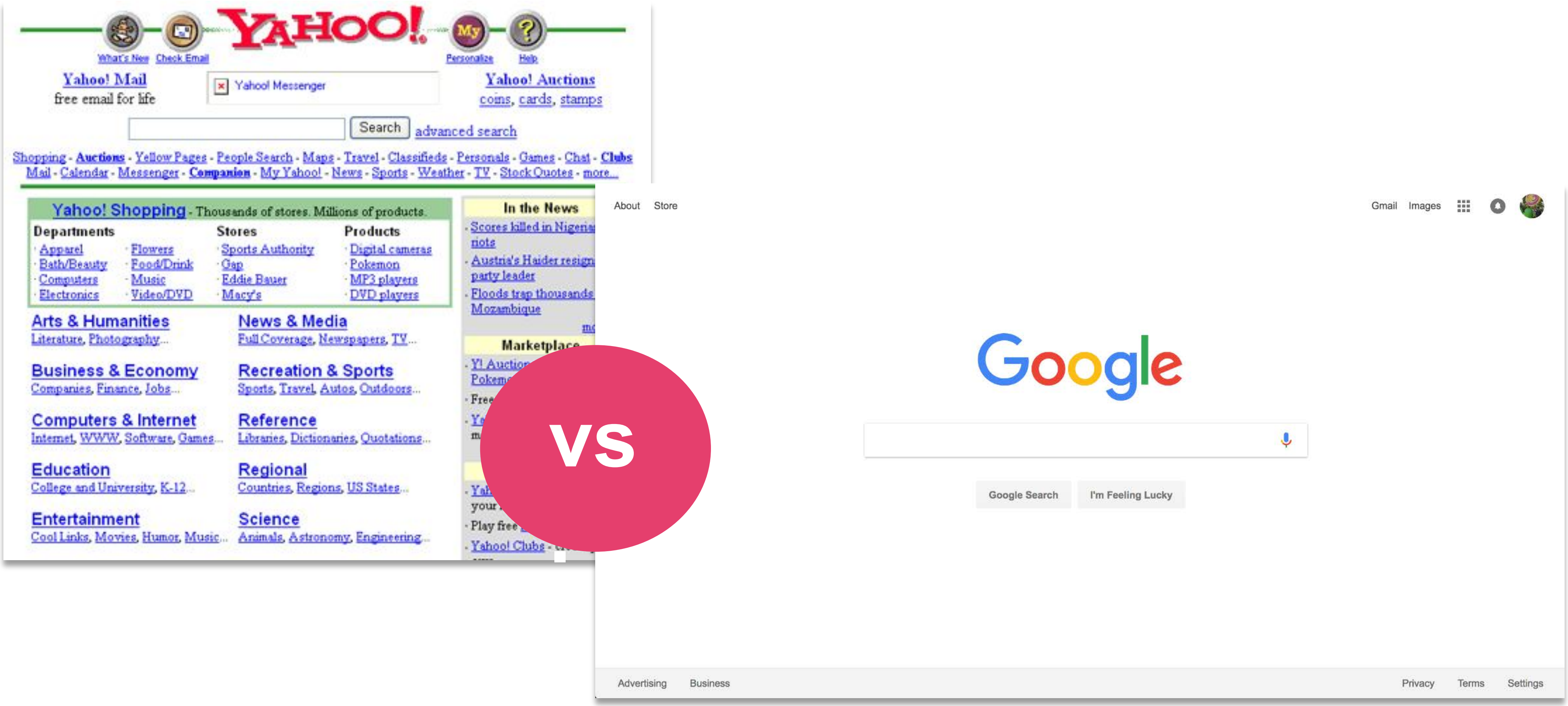
Theater District

Empire State Bldg, 350 5th Ave

30 min — 52 min 20 min

But the principles of “respectful, generous and helpful” still apply (both to the end user and to your fellow engineers).

When Building an OR Interface, Less can be More



Yahoo! Mail
free email for life

Yahoo! Messenger

Yahoo! Auctions
coins, cards, stamps

Search advanced search

Shopping - Auctions - Yellow Pages - People Search - Maps - Travel - Classifieds - Personals - Games - Chat - Clubs
Mail - Calendar - Messenger - Companion - My Yahoo! - News - Sports - Weather - TV - Stock Quotes - more...

Yahoo! Shopping - Thousands of stores. Millions of products.

Departments		Stores	Products
Apparel	Flowers	Sports Authority	Digital cameras
Bath/Beauty	Food/Drink	Gap	Pokemon
Computers	Music	Eddie Bauer	MP3 players
Electronics	Video/DVD	Macy's	DVD players

Arts & Humanities
Literature, Photography...

News & Media
Full Coverage, Newspapers, TV...

Business & Economy
Companies, Finance, Jobs...

Recreation & Sports
Sports, Travel, Autos, Outdoors...

Computers & Internet
Internet, WWW, Software, Games...

Reference
Libraries, Dictionaries, Quotations...

Education
College and University, K-12...

Regional
Countries, Regions, US States...

Entertainment
Cool Links, Movies, Humor, Music...

Science
Animals, Astronomy, Engineering...

In the News
- Scores killed in Nigeria riots
- Austria's Haider resign party leader
- Floods trap thousands Mozambique

mo

Marketplace
- Y! Auctio
Pokem
- Free
- Ya
m
- Yah
your
- Play free
- Yahoo! Clubs -

About Store

Gmail Images

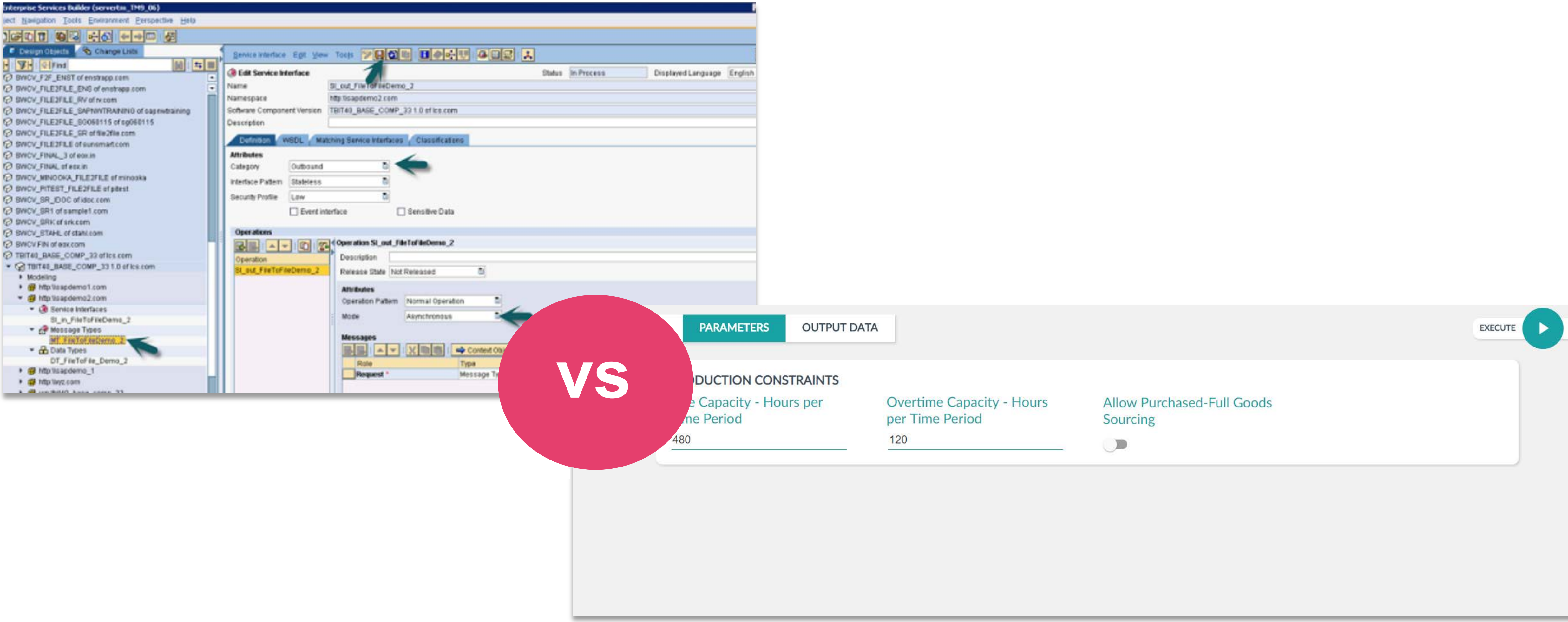
Google

Google Search I'm Feeling Lucky

Advertising Business

Privacy Terms Settings

When Building an OR Interface, Less can be More


Enterprise Services Builder (servertm_TM9_06)
Design Objects
Change Lists
Service Interface Edit View Tools

SWCV_F2F_ENST of enstrapp.com
SWCV_FILE2FILE_ENS of enstrapp.com
SWCV_FILE2FILE_RV of rv.com
SWCV_FILE2FILE_SAPNWTRAINING of sapnwtraining
SWCV_FILE2FILE_SG060115 of sg060115
SWCV_FILE2FILE_SR of file2file.com
SWCV_FILE2FILE of sunsmart.com
SWCV_FINAL_3 of eox.in
SWCV_FINAL of eox.in
SWCV_MINOOKA_FILE2FILE of minooka
SWCV_PITEST_FILE2FILE of pitest
SWCV_SR_IDOC of idoc.com
SWCV_SR1 of sample1.com
SWCV_SRK of srk.com
SWCV_STAHL of stahl.com
SWCV FIN of eox.com
TBIT40_BASE_COMP_33 of lcs.com
TBIT40_BASE_COMP_33 1.0 of lcs.com
Modeling
http://sapdemo1.com
http://sapdemo2.com
Service Interfaces
SI_in_FileToFileDemo_2
Message Types
MT_FileToFileDemo_2
Data Types
DT_FileToFile_Demo_2
http://sapdemo_1
http://xyz.com

Edit Service Interface
Status: In Process
Displayed Language: English
Name: SI_out_FileToFileDemo_2
Namespace: http://sapdemo2.com
Software Component Version: TBIT40_BASE_COMP_33 1.0 of lcs.com
Description:

Definition | WSDL | Matching Service Interfaces | Classifications

Attributes
Category: Outbound
Interface Pattern: Stateless
Security Profile: Low
□ Event interface
□ Sensitive Data

Operations
Operation: SI_out_FileToFileDemo_2
Operation SI_out_FileToFileDemo_2
Description:
Release State: Not Released
Attributes
Operation Pattern: Normal Operation
Mode: Asynchronous
Messages

Role	Type
Request *	Message T

VS

PARAMETERS | OUTPUT DATA | EXECUTE

...DUCTION CONSTRAINTS

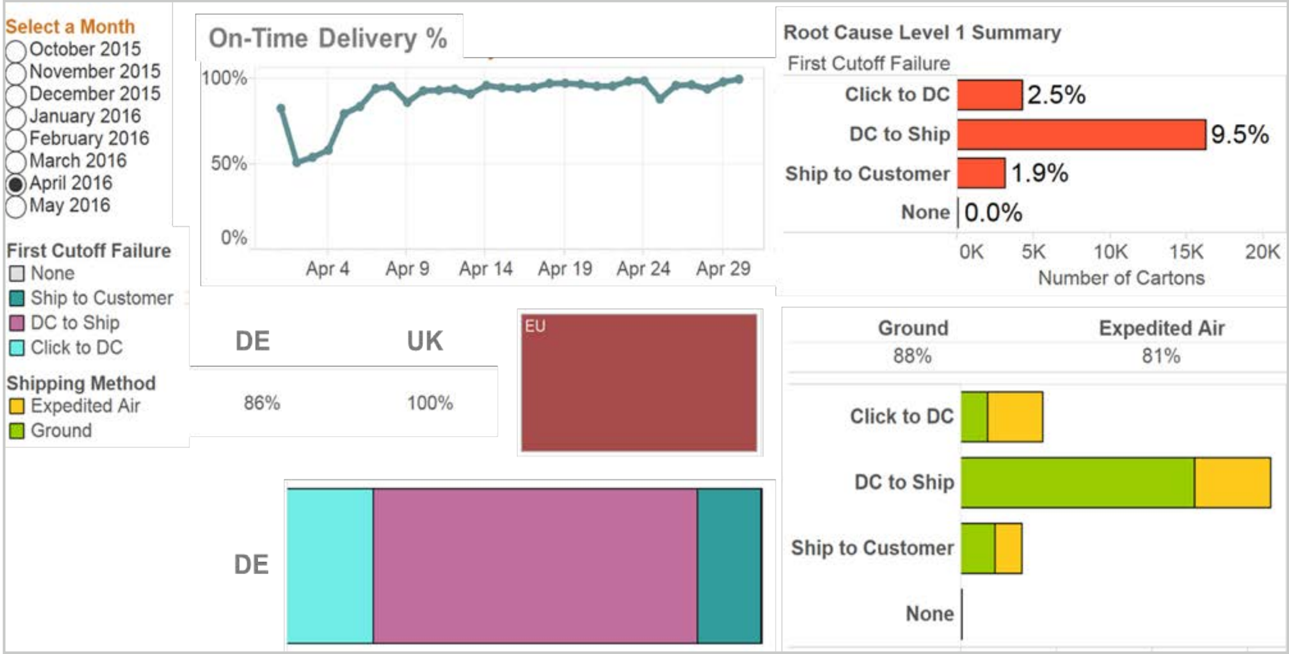
...e Capacity - Hours per ...me Period: 480

Overtime Capacity - Hours per Time Period: 120

Allow Purchased-Full Goods Sourcing: ○

Don’t Be Hard On Yourself

Your first version won’t be that good



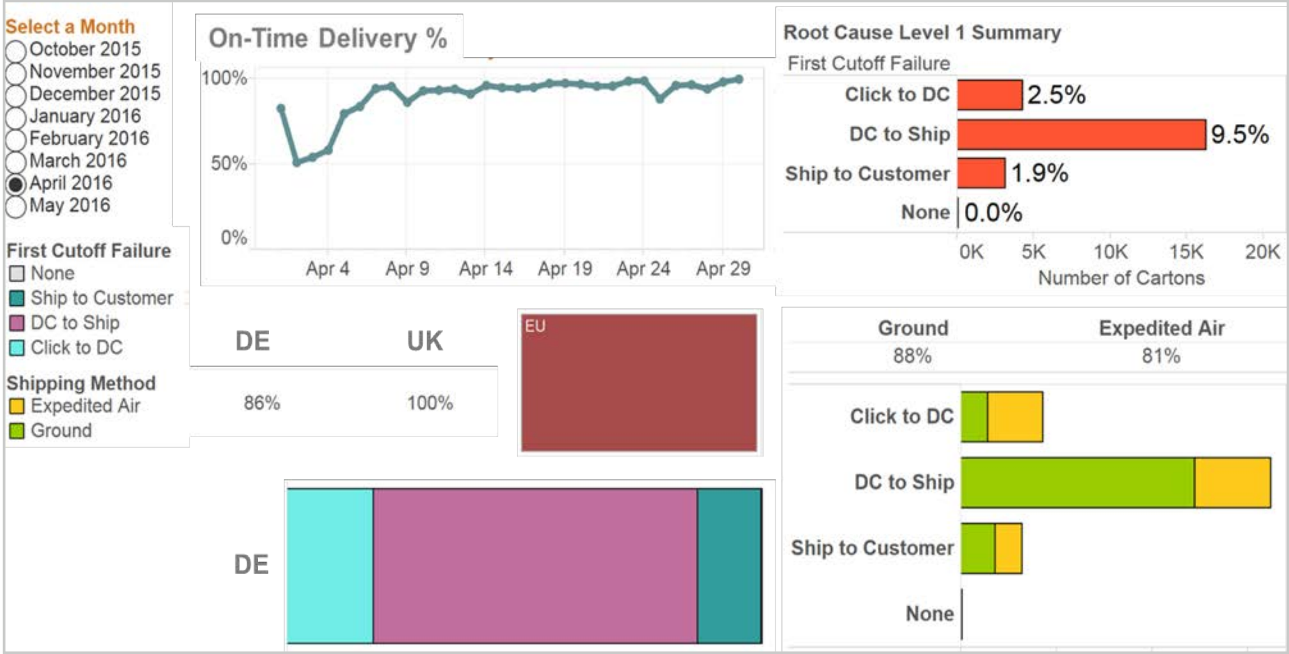
Select a Month
○ October 2015
○ November 2015
○ December 2015
○ January 2016
○ February 2016
○ March 2016
● April 2016
○ May 2016

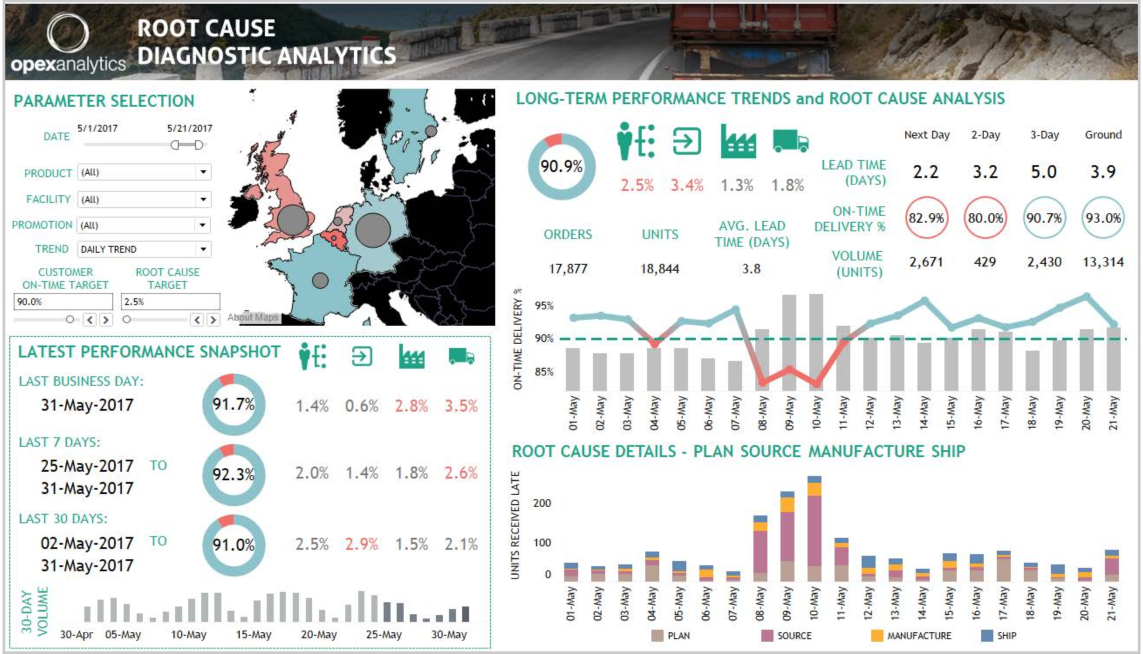
First Cutoff Failure
□ None
■ Ship to Customer
■ DC to Ship
■ Click to DC

Shipping Method
■ Expedited Air
■ Ground

Don’t Be Hard On Yourself

Your first version won’t be that good





Proof of new analytics concept

2 countries

5-10 users

Monthly

4 major releases

20+ sprints

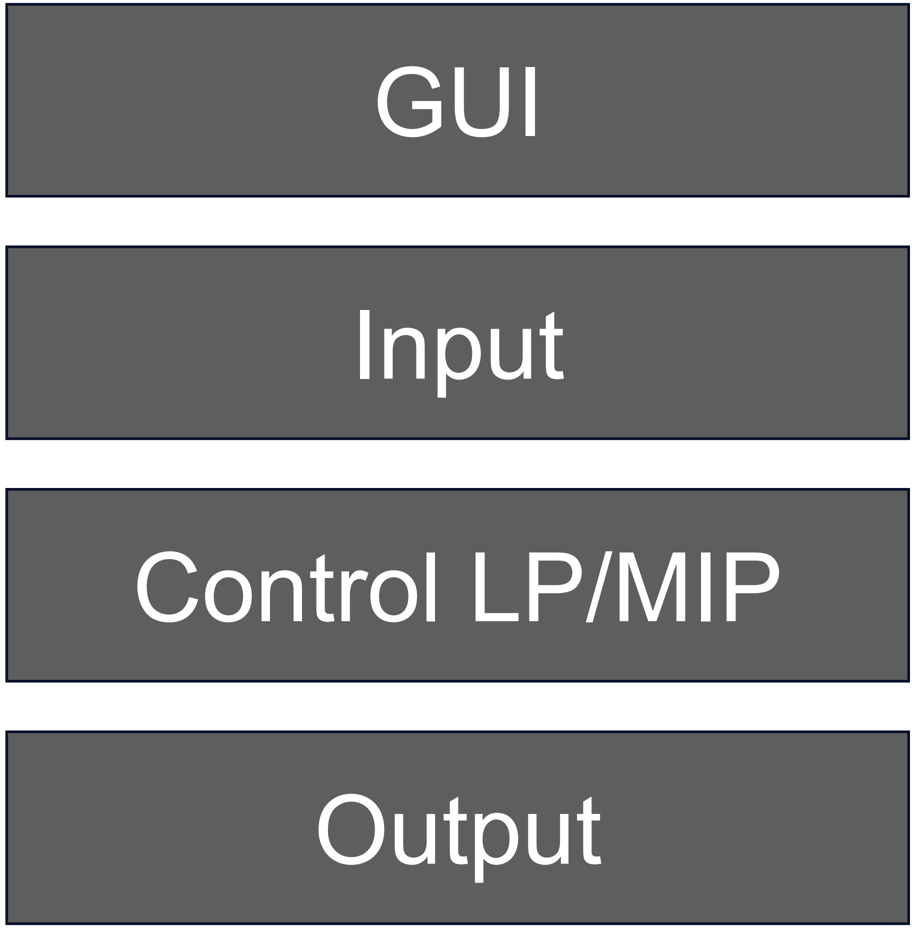
Production-level system

49 countries

200-300 users

Twice-daily

When We Talk Interface, we mean…



GUI

Input

Control LP/MIP

Output

Lesson #1
Don’t Let Users Get Themselves In Trouble

Their trouble becomes your trouble

Story Told by Dr. Jeffrey Karrenbauer

(as a Guest Lecturer at Northwestern in the mid 1990's)

Story Told by Dr. Jeffrey Karrenbauer

(as a Guest Lecturer at Northwestern in the mid 1990's)

Parameter X (1-9 are valid) 9

He designed a system for a client that had a parameter limited to a single digit.

I don't remember what this parameter controlled, but it had something to do with a limit on some very hard variables

Story Told by Dr. Jeffrey Karrenbauer

(as a Guest Lecturer at Northwestern in the mid 1990's)

Parameter X (1-9 are valid) 9

The client had filled in a value of 9.

But, the client begged them to release the limit just so they put in a value of 10 or 11, **maybe 12 at the most**

Story Told by Dr. Jeffrey Karrenbauer

(as a Guest Lecturer at Northwestern in the mid 1990's)

Parameter X (1-9 are valid) **11**

So, they did, they gave them a 2-digit entry here…..

… and soon the client was calling because the model failed.

… they spent a lot of time trying to figure it out…. Finally they looked at this parameter

Story Told by Dr. Jeffrey Karrenbauer

(as a Guest Lecturer at Northwestern in the mid 1990's)

Parameter X (1-9 are valid) 99

Story Told by Dr. Jeffrey Karrenbauer

(as a Guest Lecturer at Northwestern in the mid 1990’s)

Parameter X (1-9 are valid) 99

The client had taken this parameter to 99.

Of course, it was limited to 9 for a reason.

Story holds today, just in different forms

If you are using a Set Covering approach

(For vehicle routing or cutting stock)

Story holds today, just in different forms

If you are using a Set Covering approach

(For vehicle routing or cutting stock)

It is easy to imagine that some average cases have a tractable number of feasible inputs (say limits of 5 stops, or limits of 3 cuts in 5 inch increments).

Story holds today, just in different forms

If you are using a Set Covering approach

(For vehicle routing or cutting stock)

It is easy to imagine that some average cases have a tractable number of feasible inputs (say limits of 5 stops, or limits of 3 cuts in 5 inch increments).

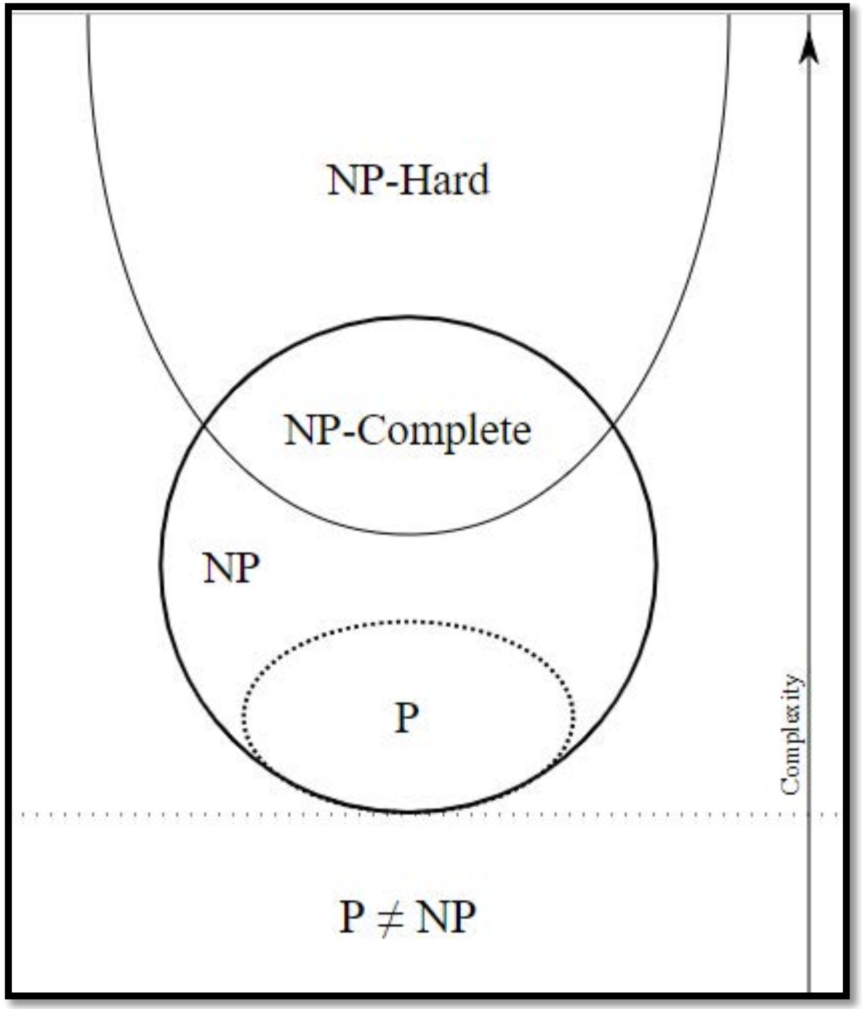
It is also easy to imagine giving your users some control of the parameters and then accidently unlocking choices with combinations that would take weeks (or longer) to generate.

Today Gurobi's MIP Solver is Awesome

It can solve large problems

It can model almost anything

Today Gurobi's MIP Solver is Awesome



It can solve large problems

It can model almost anything

But, still, P ≠ NP

Gurobi Power and Flexibility + P ≠ NP:

Shows up in design….

“Can I model all my products?”

- ‘Yes, Gurobi can handle large models’

Gurobi Power and Flexibility + P ≠ NP:

Shows up in design….

“Can I model 52 time periods?”

- ‘Yes, multiple time periods are quite common

Gurobi Power and Flexibility + P ≠ NP:

Shows up in design….

“Can I do open/close (use/not use) decision at lots of locations?”

- ‘Yes, MIPs are always getting faster

Gurobi Power and Flexibility + P ≠ NP:

Shows up in design….

“Can I model fixed set up and switching?”

- ‘Yes, there are ways to do this

Gurobi Power and Flexibility + P ≠ NP:

Shows up in design….

“Can I ….”

- Probably, yes….

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- ‘Yes, MIPs are always getting faster

“Can I model fixed set up and switching?”

- ‘Yes, there are ways to do this

“Can I ….”

- Probably, yes….

Each one of these is perfectly reasonable and we’ve seen models that do them…

Gurobi Power and Flexibility + P ≠ NP:

Shows up in design….

“Can I model all my products?”

- ‘Yes, Gurobi can handle large models’

“Can I model 52 time periods?”

- ‘Yes, multiple time periods are quite common’

“Can I do open/close (use/not use) decision at lots of locations?”

- ‘Yes, MIPs are always getting faster

“Can I model fixed set up and switching?”

- ‘Yes, there are ways to do this

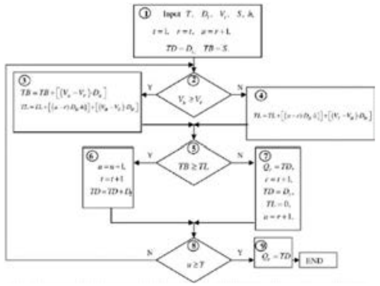
“Can I ….”

- Probably, yes….

But, you know when you put them together, it is just not going to work….

What do you need to do about all of this?

1. **Set up guardrails:** Don’t let users automatically kick off near-infinite loops of input or create a large set of integer variables that will certainly fail



2. **Build Heuristics:** guardrails might not work. Build a heuristic that builds and solves a smaller problem

3. **Educate:** teach your users good modeling so they build good models that solve and answer the question

What do you need to do about all of this?

My least favorite one (because I always lost)…

vs

What do you need to do about all of this?

My least favorite one (because I always lost)…

vs

We were responsible for strategic facility location tool

Me: Users really wanted to model each truck or at least step sizes on lane

Pete: Even if we gave them the feature, they wouldn't actually be able to use it!!

What do you need to do about all of this?

My least favorite one (because I always lost)…

vs

Lesson #2, #3 and #4

THE 3 P'S

Be Prepared. Be Proactive. Be Paranoid

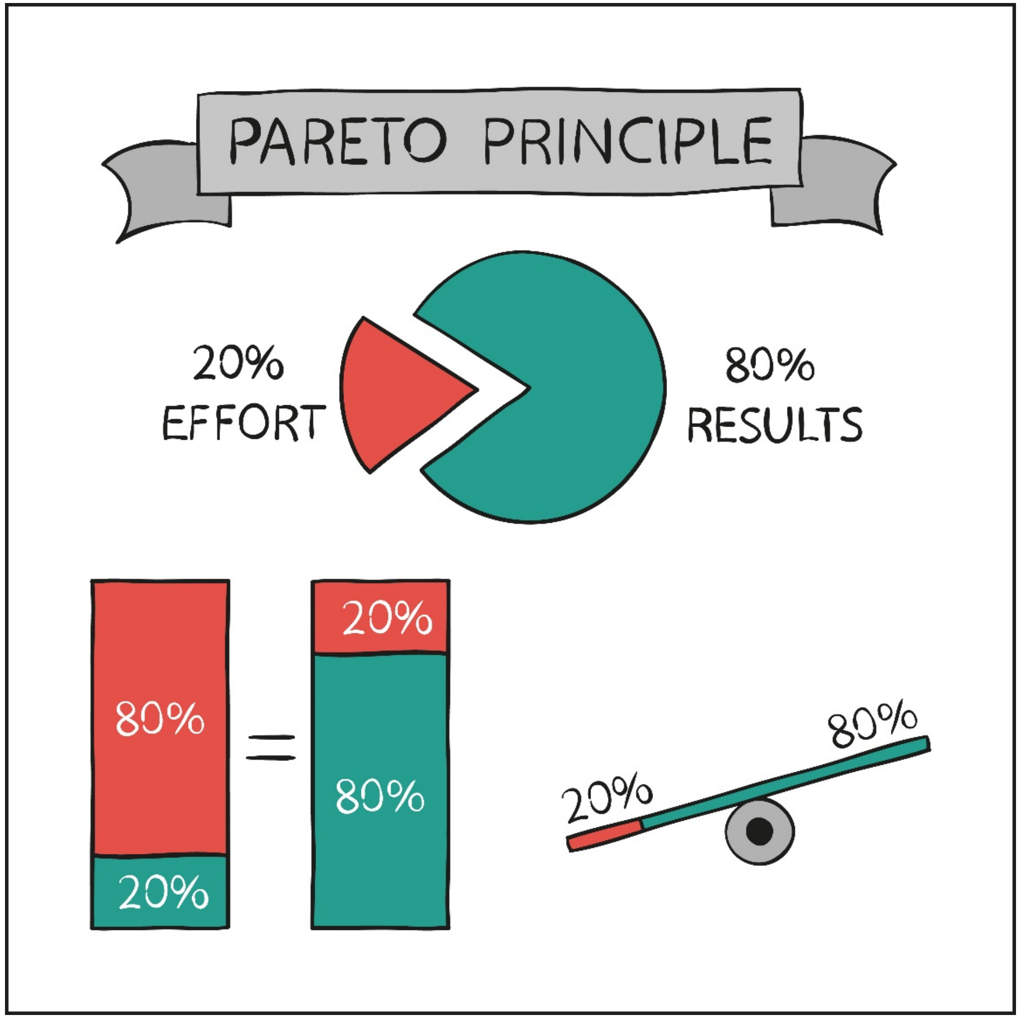
Lesson #2

Be Prepared (Not Proactive) to Become Fast

Speed is less important (and less controllable) than you think.

Classic Trope of Computer Science:

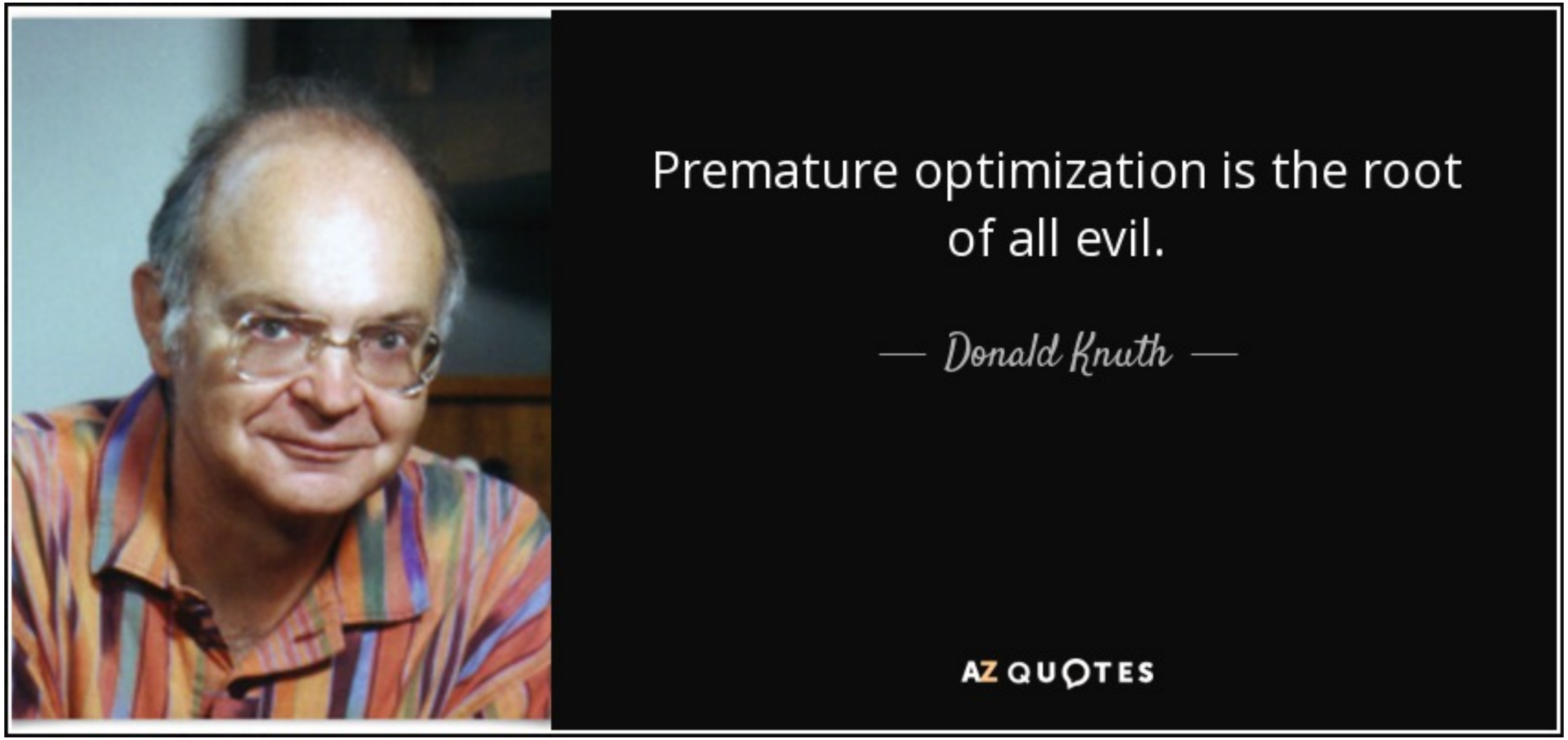
90/10 (or 80/20) profile for slow programs



Wait for real data

You can’t predict the bottleneck

Don’t Slow Down For Speed



Premature optimization is the root of all evil.

— Donald Knuth —

AZ QUOTES

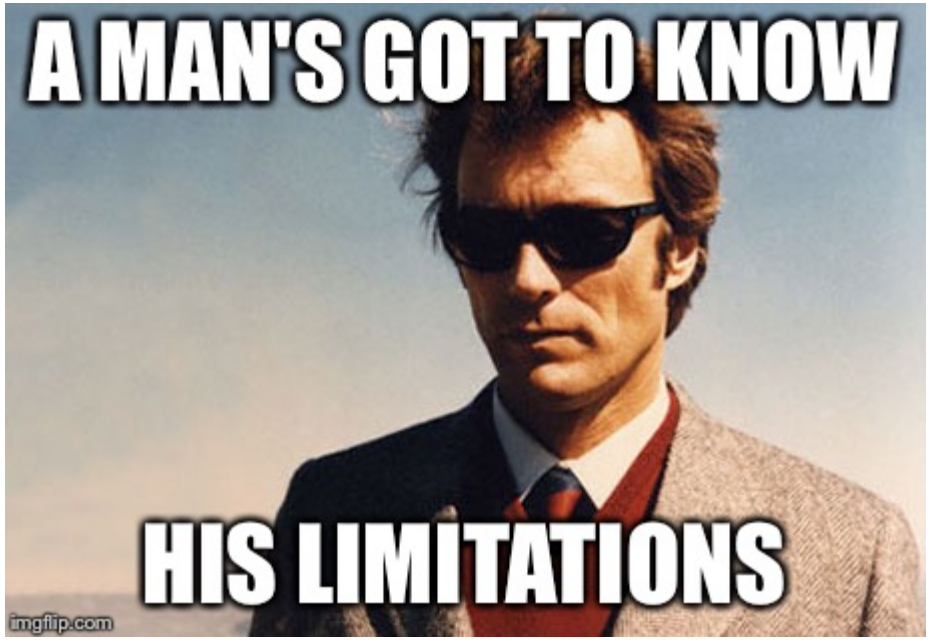
Optimization = Fast Code (in this case)

For Speed, Be Prepared

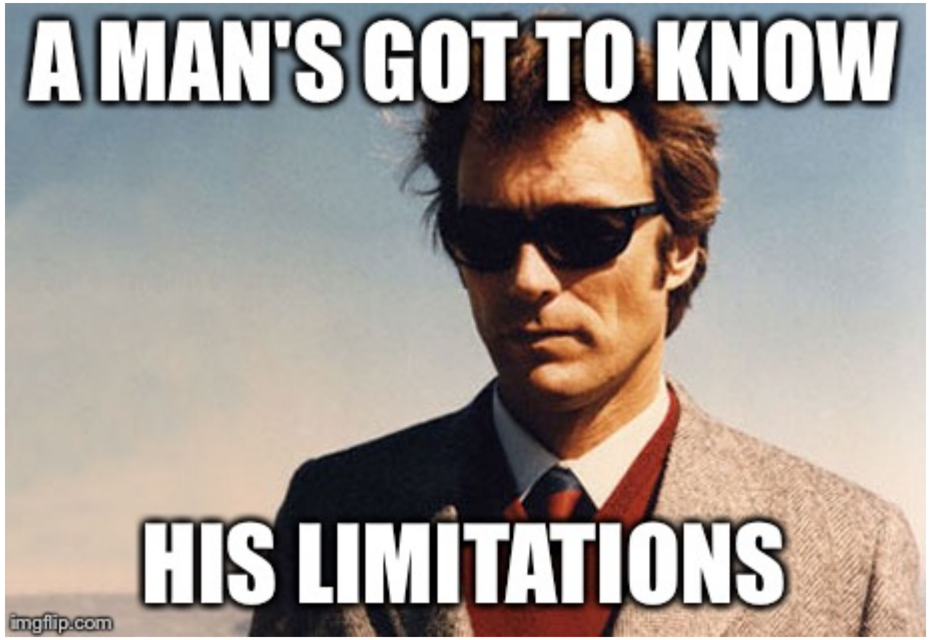
1. Know how to profile your engine with reality based performance complaints (cProfile works well with Python)

2. Know how to “slice” with whatever language you’re using (tuplelist with Python)

At some point, you will have addressed the bottlenecks



At some point, you will be removed obvious bottlenecks



	Case1	Other Cases
Creating Input	33%	90%
Running Solver	33%	90%
Creating Output	33%	90%
	Likely Removed it	If you've worked, you may be stuck

don't let
PERFECT
be the enemy
of the
GOOD.

Lesson #3
Be Proactive with Bugs

Strive for Zero Defect Software

Do Slow Down to Catch Bugs or Go Slow to Go Fast

Bugs not only erode credibility, they waste time.

Don’t release untested software.

Any released bugs should be post-mortem-ed for lessons learned. Rhinoceros become Jedis.

Do Slow Down to Catch Bugs

Put the O-Rings in ice water

You’re going to write fewer math modeling bugs than you expect, but they can be incredibly insidious.

Do Slow Down to Catch Bugs

Write code to test code.

- Don’t let testing be “tears in rain”.
- Unit test and Jenkins are perfect fits for Gurobi engines…. Why aren’t more people doing this?

Do Slow Down to Catch Bugs

False Bugs (users that want magic) aren't counted in "zero defect" scoring.

Some clients don't know what they want and correct code will still ”feel wrong” to them. This is to be expected, and zero defect development is even more important for such engagements.

Lesson #4

Be Paranoid About Solver Failures

Users hate infeasibility but they appreciate insights

Paranoid Means Be Proactive and Be Prepared

A solve that fails with a cryptic message is always unwelcome. A good engine always has something helpful to say.

Two types of solve failures

1. Dirty data
2. Infeasible models

Dirty Data Should be Handled Proactively

Protect your fragile math model with rich integrity checks

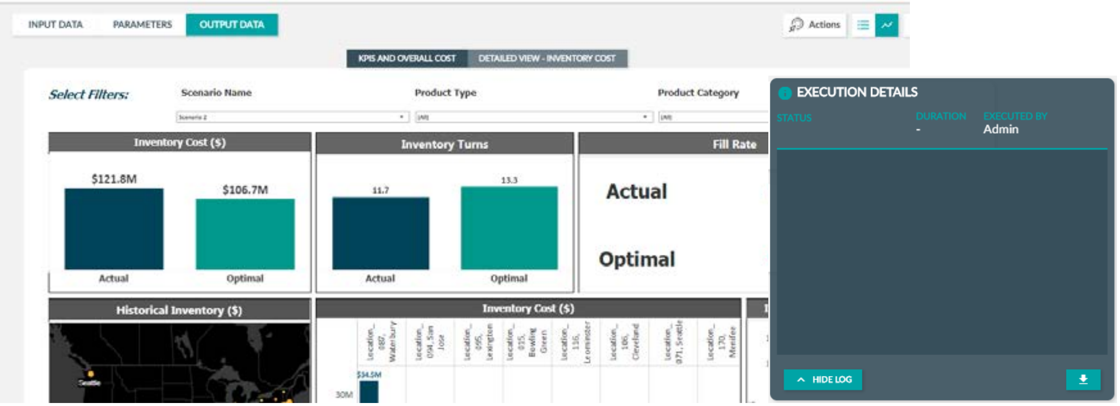
Build the GUI to prevent dirty data from entering (user cleans it outside)

Build the GUI to allow the user to clean the data in the GUI (but not run yet)

(Bad Choice): Just assume that clean data is obvious and let it go

Infeasible model support is a blend of proactive and prepared

- Slack variables (with penalties) can be useful, but only if the user understands the results
- “This-might-create-an-infeasibility” data checks are best added in response to real world complaints. You should be prepared on how to generate these supplemental reports without drowning out solution reports



Add to a knowledge base over time of errors and problems

Lesson #5

You Will Be Swimming in Data

Don’t forget the data in data science

Data is the first word in data science

You will spend more time working with data than with math.

- The MIP engine is really just one more tool that generates insight about data.
- Need to have expertise with tools that let you study data quickly and efficiently

Prefers “Raw Python”
Gets pandas, SQL

Old school Excel,
Consider Alteryx, or
a visualization tool

Data is the first word in data science

Part of swimming in data is about making it easier to read that data

Following two tricks can drastically simplify .ilp files for infeasible model support

- ‘Obfusimplify` trick for simpler .lp/.ilp files - makes infeasible models even easier.
- Model shrinking with cascading deletes - also makes infeasible models easier.

Don’t Let Design and Build Get Ahead of Data

Don’t! Don’t let this happen:

You want to build a model with really detailed features

(like details at the workstati within a line, or down to the worke

You build such a model

You are never able to get the data to feed the model

(you can’t get workstation data, you can’t get worker skills)

Lesson #6

Take advantage of modern tools and don’t be afraid to migrate to new ones

Not easy, but we did it many times and will do so again

Switching Technology is Painful…

We’ve done it many times since 1997:

- MapInfo to VB and Access to … to .Net to Cloud Based….

It was painful every time– no new features, just new platform

It almost always seemed to pay off!

The Tools Matter

Long Time Ago (~2003)

“Consultants”

- Used Excel and Access
- Did “pivot tables” and “cross tab queries”

“Developers”

- Used low level code in compiled languages
- Worried about memory management

Both use Python (or R)

- Share info, share code
- Do it yourself coding, developers can take notebooks from consultants

The Tools Matter

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Python has momentum

- Big and growing ecosystem
- Still need to worry about questions like “has Library Y made Library X obsolete?”
- And, still need to watch out for the next generation of tools
- Don’t stay stagnant!

Thank You – Questions?

GUROBI OPTIMIZATION

The World's Fastest Solver

Your Next Steps

- If you haven't already done so, please register for an account at http://www.gurobi.com
- For questions about Gurobi pricing contact sales@gurobi.com or sales@gurobi.de
- A recording of this webinar, including the slides, will be available in roughly one week
- Please access https://support.gurobi.com with any technical questions