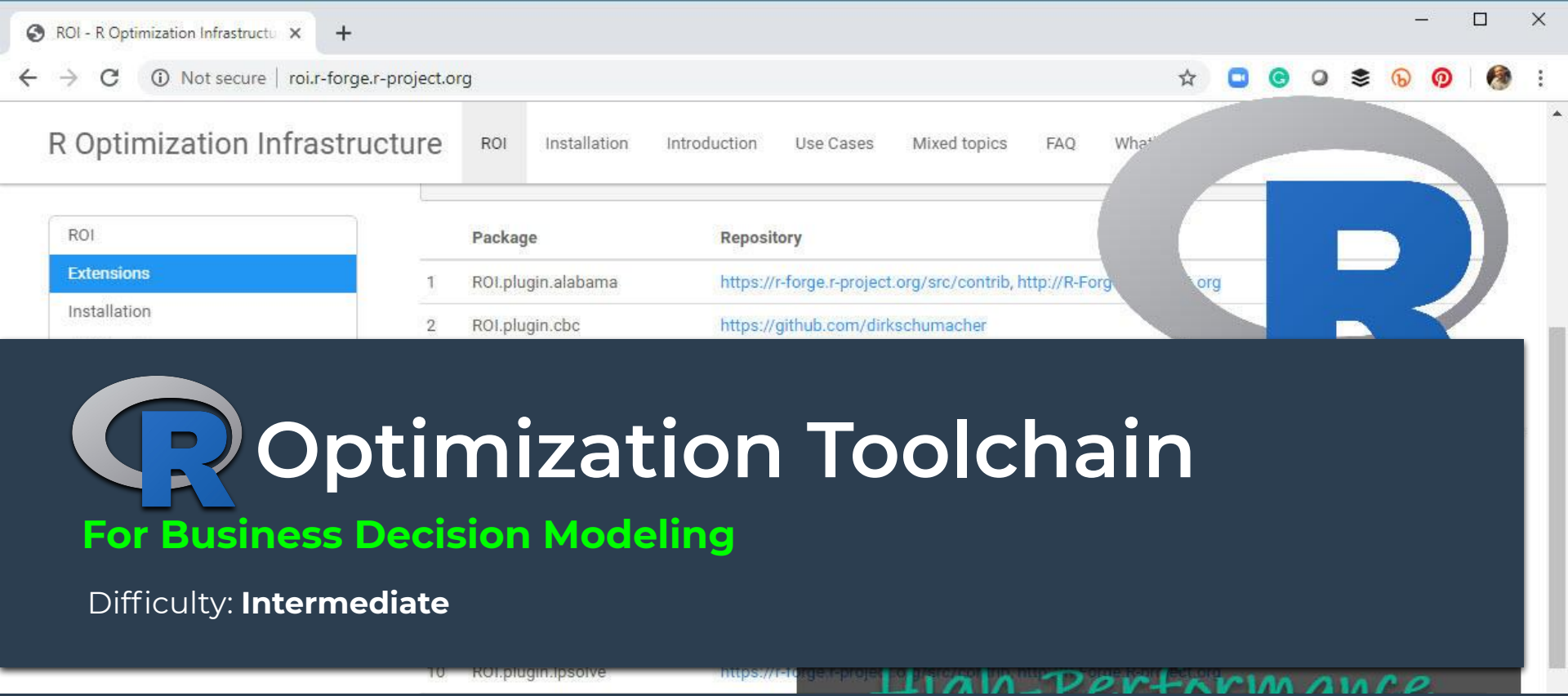


R Optimization Toolchain

For Business Decision Modeling

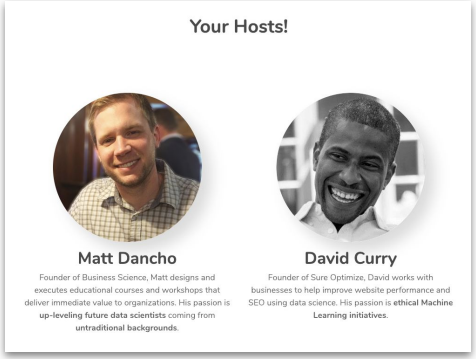
Difficulty: **Intermediate**

Matt Dancho & SPECIAL GUEST: Jonathan Regenstein

Business Science Learning Lab #15

Learning Lab Structure

- **Presentation**
  (20 min)
- **2 Demo's**
  (30 min)
- **Presentation**
  (10 mins)



Reproducible Finance with R

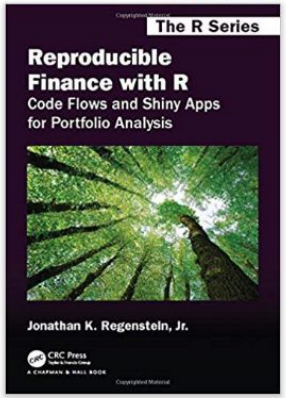
Book Giveaway!

Reproducible Finance with R: Code Flows and Shiny Apps for Portfolio Analysis (Chapman & Hall/CRC The R Series) 1st Edition

by Jonathan K. Regenstein Jr. (Author)

★★★★★ 20 customer reviews

Look inside



ISBN-13: 978-1138484221
ISBN-10: 1138484229
Why is ISBN important?

Have one to sell? Sell on Amazon

Add to List

Kindle	Hardcover	Paperback	Other Sellers
$19.11 - $57.56	$127.57 - $147.42	$48.00 - $71.95	See all 3 versions

Buy used $127.57

Buy new **$147.42**

Only 3 left in stock (more on the way).
Ships from and sold by Amazon.com.
Note: Available at a lower price from other sellers that may not offer free Prime shipping.

List Price: ~~$189.95~~
Save: $42.53 (22%)
11 New from $144.83
& **FREE Shipping**. Details

Want it Thursday, Aug. 1? Order within **10 hrs 51 mins** and choose **Two-Day Shipping** at checkout. Details

Deliver to State College 16801

Qty: 1

Add to Cart

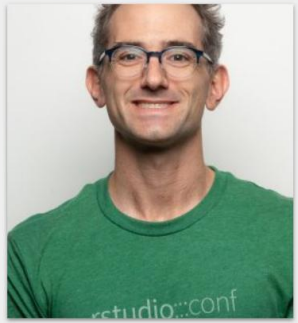
Buy Now

More Buying Choices

11 New from $144.83 | 4 Used from $127.57

15 used & new from $127.57

See All Buying Options



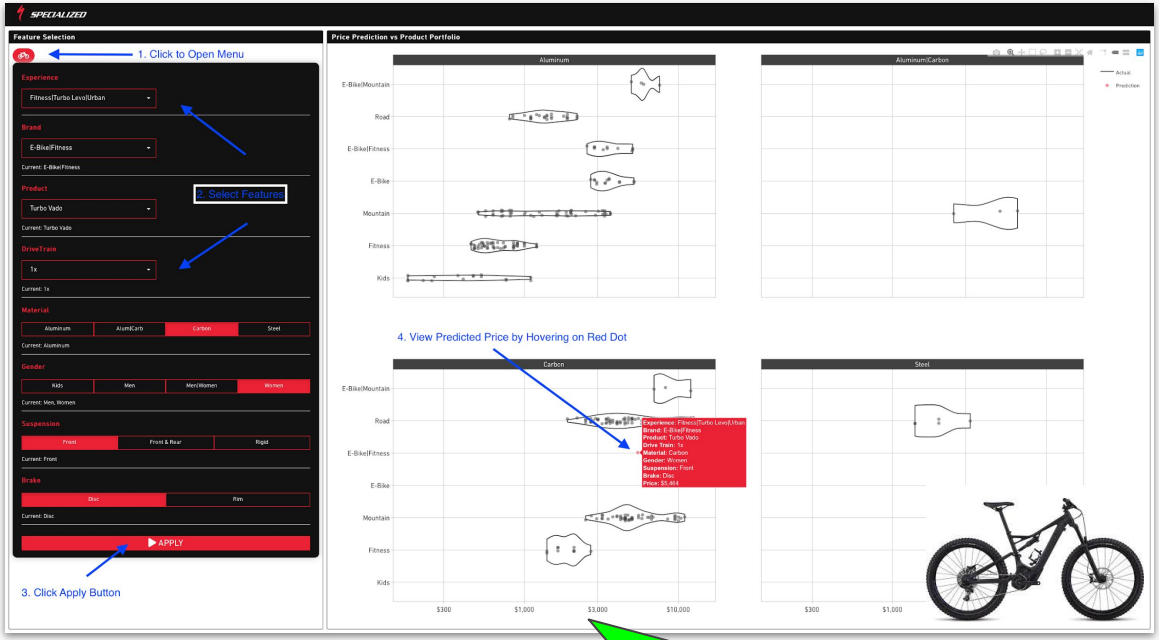
Success Story

Joon Im

- Data Analyst at Instacart
- Watched **Learning Lab #8 - Web Scraping** - Web Scraped Specialized Bikes
- Took **Shiny Apps Course (102)** - Built the Specialized Web App

"Rvest has fundamentally changed the way I understand the Internet"

https://joon.shinyapps.io/specialized_price_prediction/



#BusinessScienceSuccess

Agenda

2 Parts

Part 1 (Today)

Starter Problem

Product Mix Problem

Linear Programming

Excel to R

	A	B	C	D	E	F	G
1	**Exam Grade Optimization**						
2							
3				**Intermediate Calc**	**Constraints**		
4	**Exam**	**Grade**	**Weight**	**Product**	**min**	**max**	
5	***Quiz #1***	50	0.15	7.5			
6	***Midterm***	65	0.25	16.25			
7	***Quiz #2***	70	0.15	10.5			
8	***Final***		0.45		0	100	
9	***Course Grade***	34.25			70	70	
10							

	A	B	C	D	E	F	G	H	I	J
1	**Assembling and Testing Macbooks**									
2										
3	Cost per labor hour assembling	$14								
4	Cost per labor hour testing, line 1	$22								
5	Cost per labor hour testing, line 2	$19								
6										
7	Inputs for assembling and testing a Macbook									
8		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	
9	Labor hours for assembly	4	5	5	5	5.5	5.5	5.5	6	
10	Labor hours for testing, line 1	1.5	2	2	2	2.5	2.5	2.5	3	
11	Labor hours for testing, line 2	2	2.5	2.5	2.5	3	3	3.5	3.5	
12	Cost of component parts	$900	$1,350	$1,350	$1,350	$1,500	$1,500	$1,500	$1,800	
13	Selling price	$2,100	$2,700	$2,760	$2,820	$3,000	$3,150	$3,180	$3,600	
14	Unit margin, tested on line 1	$1,111	$1,236	$1,296	$1,356	$1,368	$1,518	$1,548	$1,650	
15	Unit margin, tested on line 2	$1,106	$1,233	$1,293	$1,353	$1,366	$1,516	$1,537	$1,650	
16										
17	Assembling, testing plan (# of Macbooks)									
18		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	
19	Number tested on line 1	1500	0	0	0	0	100	1000	0	
20	Number tested on line 2	0	0	0	0	0	900	0	500	
21	Total computers produced	1500	0	0	0	0	1000	1000	500	
22		<=	<=	<=	<=	<=	<=	<=	<=	
23	Maximum sales	1500	1250	1250	1250	1000	1000	1000	800	
24										
25	Constraints (hours per month)	Hours used		Hours available						
26	Labor availability for assembling	20000	<=	20000						
27	Labor availability for testing, line 1	5000	<=	5000						
28	Labor availability for testing, line 2	4450	<=	6000						
29										
30	Net profit ($ per month)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Totals
31	Tested on line 1	$1,666,500	$0	$0	$0	$0	$151,800	$1,548,000	$0	$3,366,300
32	Tested on line 2	$0	$0	$0	$0	$0	$1,364,400	$0	$824,750	$2,189,150
33										$5,555,450

Part 2
(Coming Soon)

Stock Portfolio Optimization

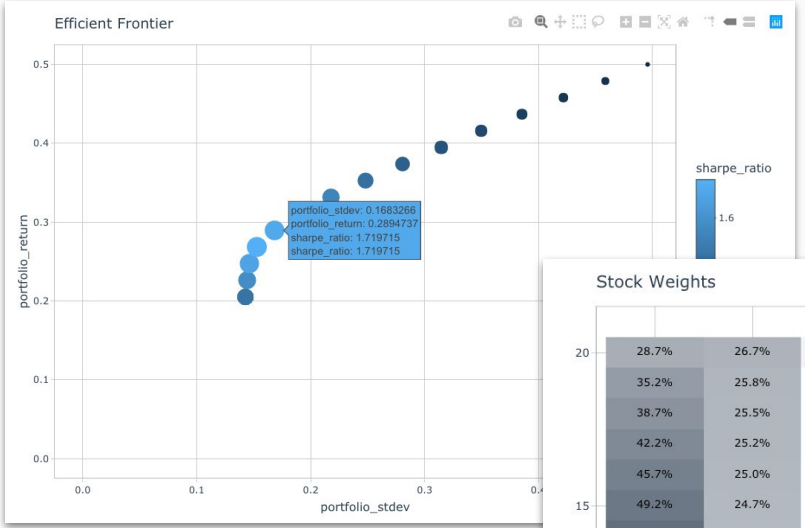
Efficient Frontier

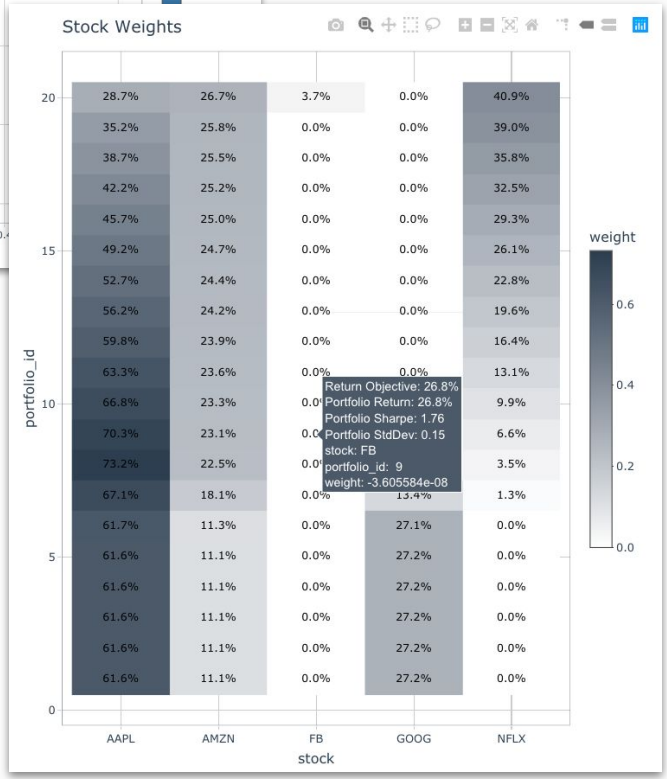
Minimum Variance Portfolio

Nonlinear Programming

Iteration

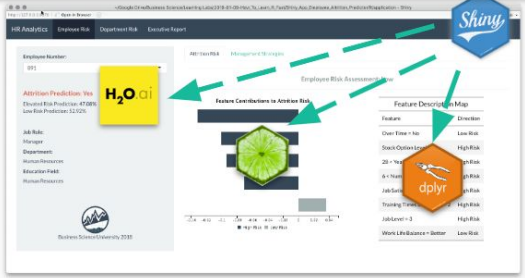
Excel to R



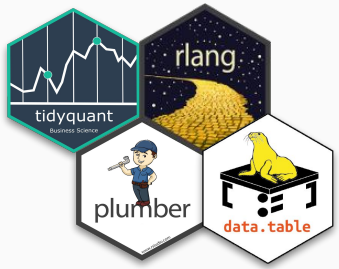


Before We Get Started - SPECIAL OFFER - learninglabs - 15% OFF

Do Business Projects
Climb the Hill



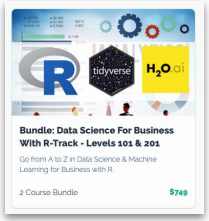
Build Production-Ready
Web Apps



Complete 1-Hour Courses
Continuous Education

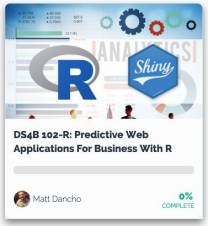
Start

1



Analysis Courses
101 & 201

2



App Development Courses
102

3

Learning Labs PRO

Finish

Everything is **Taken Care of** For You in Our Platform

Learning Labs PRO

Intermediate & Advanced

Every 2 Weeks

Get Code

Recordings

Slack Community

$19/month

university.business-science.io

Lab 14
Churn + Survival Analysis

Lab 13
Wrangling 4.6M Rows w/ data.table

Lab 12
How I built anomalize

Lab 11
Market Basket Analysis w/ recommenderLab

Lab 10
Building API's with plumber & postman

Business Case Study

Manufacturing Company seeks to increase Net Profit with limited resources

Product Mix Optimization

Limited Resources

Apple has limited resources & many decisions:

- Multiple Manufacturing Lines
- Different Labor Costs
- Sales Estimates
- Production Assembly & Test Hours Available

Apple seeks to **maximize profit** in this environment

Optimization

Business Process Model

Labor Costs

Process Attributes

Manufacturing Plan

Sales Estimates

Labor Constraints

Objective

Assembling and Testing Macbooks

Cost per labor hour assembling	$14
Cost per labor hour testing, line 1	$22
Cost per labor hour testing, line 2	$19

Inputs for assembling and testing a Macbook

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Labor hours for assembly	4	5	5	5	5.5	5.5	5.5	6
Labor hours for testing, line 1	1.5	2	2	2	2.5	2.5	2.5	3
Labor hours for testing, line 2	2	2.5	2.5	2.5	3	3	3.5	3.5
Cost of component parts	$900	$1,350	$1,350	$1,350	$1,500	$1,500	$1,500	$1,800
Selling price	$2,100	$2,700	$2,760	$2,820	$3,000	$3,150	$3,180	$3,600
Unit margin, tested on line 1	$1,111	$1,236	$1,296	$1,356	$1,368	$1,518	$1,548	$1,650
Unit margin, tested on line 2	$1,106	$1,233	$1,293	$1,353	$1,366	$1,516	$1,537	$1,650

Assembling, testing plan (# of Macbooks)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Number tested on line 1	1500	0	0	0	0	100	1000	0
Number tested on line 2	0	0	0	0	0	900	0	500
Total computers produced	1500	0	0	0	0	1000	1000	500
	<=	<=	<=	<=	<=	<=	<=	<=
Maximum sales	1500	1250	1250	1250	1000	1000	1000	800

Constraints (hours per month)	Hours used		Hours available
Labor availability for assembling	20000	<=	20000
Labor availability for testing, line 1	5000	<=	5000
Labor availability for testing, line 2	4450	<=	6000

Net profit ($ per month)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Totals
Tested on line 1	$1,666,500	$0	$0	$0	$0	$151,800	$1,548,000	$0	$3,366,300
Tested on line 2	$0	$0	$0	$0	$0	$1,364,400	$0	$824,750	$2,189,150
									$5,555,450

Optimization

80/20 Concepts

Terminology

Objectives

- The goal of the model.
- Always Maximize or Minimize.

Constraints

- Rules for the model
- Restricts the decision variables to boundaries

Decision Variables

- Your problem's frame of reference
- The parameters that your optimization model adjusts

```
model_2 <- MIPModel() %>%

    add_variable(macbooks_tested_line_1[i], i = 1:n_models, type = "integer", lb = 0) %>%
    add_variable(macbooks_tested_line_2[i], i = 1:n_models, type = "integer", lb = 0) %>%

    add_constraint(macbooks_tested_line_1[i] + macbooks_tested_line_2[i] <= max_sales[i], i = 1:n_models) %>%

    add_constraint(sum_expr((macbooks_tested_line_1[i] + macbooks_tested_line_2[i]) * labor_hours_for_assembly[i], i = 1:n_models) <= max_labor[1]) %>%
    add_constraint(sum_expr((macbooks_tested_line_1[i]) * labor_hours_for_testing_line_1[i], i = 1:n_models) <= max_labor[2]) %>%
    add_constraint(sum_expr((macbooks_tested_line_2[i]) * labor_hours_for_testing_line_2[i], i = 1:n_models) <= max_labor[3]) %>%

    set_objective(
        sum_expr(macbooks_tested_line_1[i] * unit_margin_line_1[i] + macbooks_tested_line_2[i] * unit_margin_line_2[i], i = 1:n_models),
        sense = "max") %>%

    solve_model(with_ROI(solver = "glpk"))
```

Types of Optimization Models

Linear

- Fastest solutions
- Easy to conceptualize
- Analysis limited to aggregations, constant multiplications, etc
- Many problems don't fit this mold (e.g. take correlation of something)

Quadratic

- Fast solutions
- Difficult to Conceptualize
- Requires formulation as a quadratic function

Nonlinear

- Easy to conceptualize
- Super Flexible
- Cannot use linear solvers
- Slower solutions
- Tendency to get suboptimal results (local vs global maxima)

Types of Optimization Models

Linear

- Fastest solutions
- **Easy to conceptualize**
- Analysis limited to aggregations, constant multiplications, etc
- Many problems don't fit this mold (e.g. take correlation of something)

Quadratic

- Fast solutions
- **Difficult to Conceptualize**
- Requires formulation as a quadratic function

Nonlinear

- **Easy to conceptualize**
- Super Flexible
- Cannot use linear solvers
- Slower solutions
- Tendency to get suboptimal results (local vs global maxima)

Types of Optimization Models

Linear

- Fastest solutions
- **Easy to conceptualize**
- Analysis limited to aggregations, constant multiplications, etc
- Many problems don't fit this mold (e.g. take correlation of something)

Part 1

Quadratic

- Fast solutions
- **Difficult to Conceptualize**
- Requires formulation as a quadratic function

Nonlinear

- **Easy to conceptualize**
- Super Flexible
- Cannot use linear solvers
- Slower solutions
- Tendency to get suboptimal results (local vs global maxima)

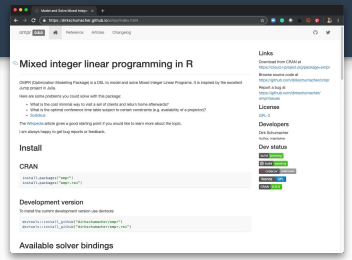
Part 2

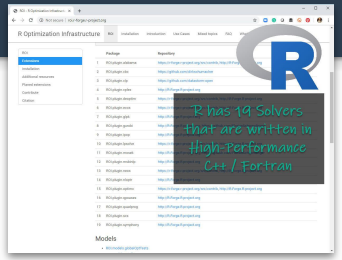
Process & Tools

Churn Modeling & Machine Learning Tools

Business Modeling Process

Step-By-Step





Start

1

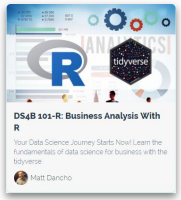
2

3

Finish

dplyr

Format Data



ompr & ROI

Linear Programming

Our focus today!

purrr & ggplot2

Simulation & Sensitivity Analysis

Visualization

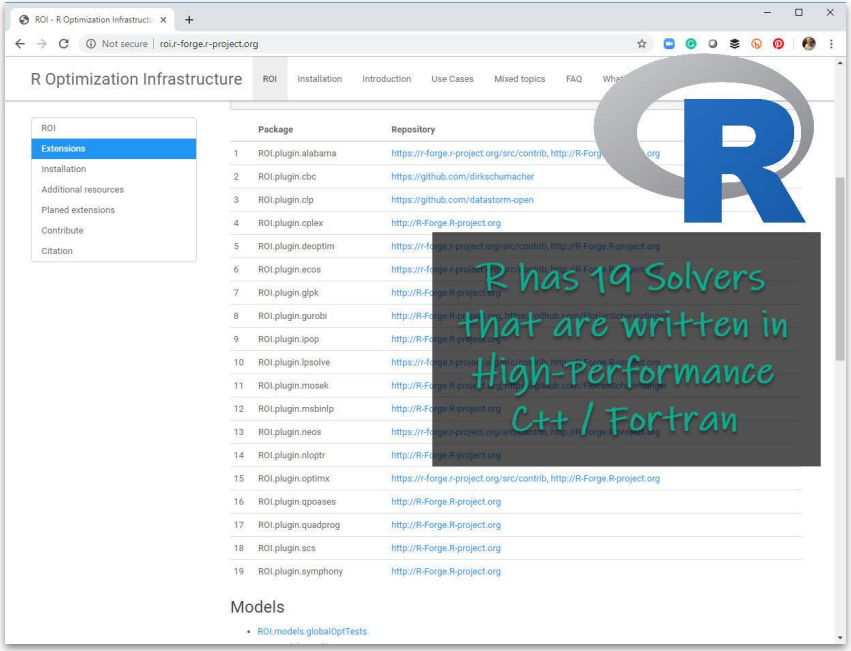
Tools Needed

ROI

- Like parsnip for Optimization Solvers
- 19 Solvers
- Interface requires Matrix Algebra Knowledge

Mixed integer linear programming (MILP)

$$
\begin{aligned}
\text{maximize} \quad & 7x_1 + 3x_2 + 1x_3 \\
\text{subject to} \quad & 6x_1 + 4x_2 + 5x_3 \leq 60 \\
& 8x_1 + x_2 + 2x_3 \leq 80 \\
& 9x_1 + 1x_2 + 7x_3 \leq 70 \\
& x_1, x_3 \in \mathbb{Z}_{\geq 0} \\
& x_2 \geq 0
\end{aligned}
$$



http://roi.r-forge.r-project.org

Matrix Algebra is Conceptually Difficult

At first, it makes my head hurt

Now I love it

Really powerful for Nonlinear Programming!!!

Mixed integer linear programming (MILP)

$$
\begin{aligned}
\text{maximize} \quad & 7x_1 + 3x_2 + 1x_3 \\
\text{subject to} \quad & 6x_1 + 4x_2 + 5x_3 \leq 60 \\
& 8x_1 + x_2 + 2x_3 \leq 80 \\
& 9x_1 + 1x_2 + 7x_3 \leq 70 \\
& x_1, x_3 \in \mathbb{Z}_{\geq 0} \\
& x_2 \geq 0
\end{aligned}
$$

```
A <- rbind(c(6, 4, 5), c(8, 0, 2), c(9, 1, 7))
milp <- OP(objective = L_objective(c(7, 1, 3), c("x", "y", "z")),
           constraints = L_constraint(L = rbind(c(6, 4, 5), c(8, 0, 2), c(9, 1, 7)),
                                      dir = c("<=", "<=", "<="),
                                      rhs = c(60, 80, 70)),
           types = c("I", "C", "I"),
           maximum = TRUE)
(sol <- ROI_solve(milp))
```

```
## Optimal solution found.
## The objective value is: 5.350000e+01
```

```
solution(sol)
```

```
##   x   y   z
## 7.0 4.5 0.0
```

http://roi.r-forge.r-project.org

Tools Needed

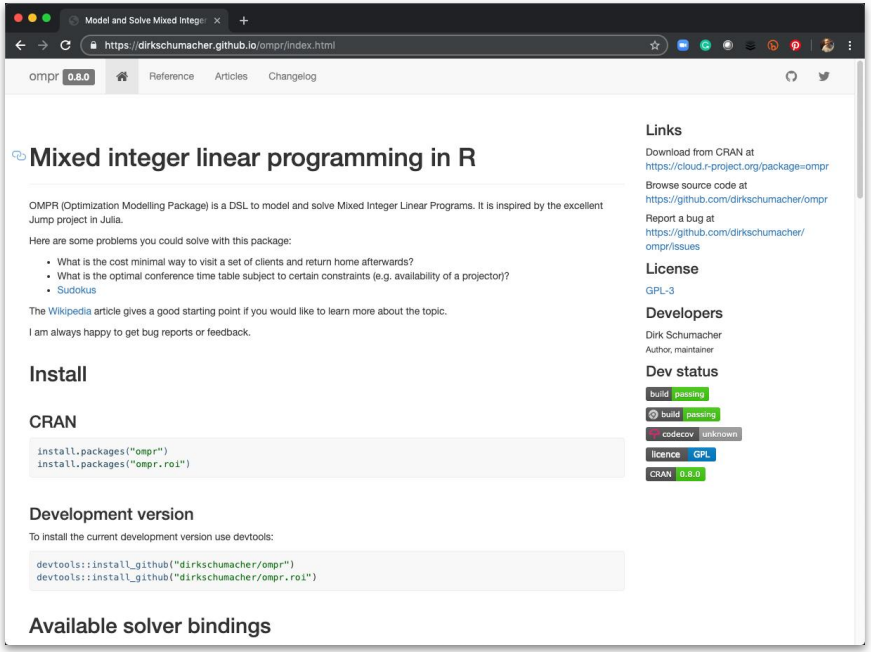
ompr

Pros:

- Tidyverse-style pipes
- More understandable equations
- Makes going from Excel to R easier

Cons

- Cannot be used for Nonlinear Programming



https://dirkschumacher.github.io/ompr/index.html

ompr

Uses pipes!

Faster **to make** business models than Excel

Faster **to change** business models than Excel

Fast **to solve** business models than Excel

A simple example:

```
library(dplyr)
library(ROI)
library(ROI.plugin.glpk)
library(ompr)
library(ompr.roi)

result <- MIPModel() %>%
  add_variable(x, type = "integer") %>%
  add_variable(y, type = "continuous", lb = 0) %>%
  set_bounds(x, lb = 0) %>%
  set_objective(x + y, "max") %>%
  add_constraint(x + y <= 11.25) %>%
  solve_model(with_ROI(solver = "glpk"))
get_solution(result, x)
get_solution(result, y)
```

http://roi.r-forge.r-project.org

30 Min Demo

Super Basic Example

	A	B	C	D	E	F	G
1	**Exam Grade Optimization**						
2							
3				**Intermediate Calc**	**Constraints**		
4	**Exam**	**Grade**	**Weight**	**Product**	**min**	**max**	
5	***Quiz #1***	50	0.15	7.5			
6	***Midterm***	65	0.25	16.25			
7	***Quiz #2***	70	0.15	10.5			
8	***Final***		0.45		0	100	
9	***Course Grade***	34.25			70	70	
10							

Product Mix Example - Manufacturing Macbook Pros

	A	B	C	D	E	F	G	H	I	J
1	**Assembling and Testing Macbooks**									
2										
3	Cost per labor hour assembling	$14								
4	Cost per labor hour testing, line 1	$22								
5	Cost per labor hour testing, line 2	$19								
6										
7	Inputs for assembling and testing a Macbook									
8		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	
9	Labor hours for assembly	4	5	5	5	5.5	5.5	5.5	6	
10	Labor hours for testing, line 1	1.5	2	2	2	2.5	2.5	2.5	3	
11	Labor hours for testing, line 2	2	2.5	2.5	2.5	3	3	3.5	3.5	
12	Cost of component parts	$900	$1,350	$1,350	$1,350	$1,500	$1,500	$1,500	$1,800	
13	Selling price	$2,100	$2,700	$2,760	$2,820	$3,000	$3,150	$3,180	$3,600	
14	Unit margin, tested on line 1	$1,111	$1,236	$1,296	$1,356	$1,368	$1,518	$1,548	$1,650	
15	Unit margin, tested on line 2	$1,106	$1,233	$1,293	$1,353	$1,366	$1,516	$1,537	$1,650	
16										
17	Assembling, testing plan (# of Macbooks)									
18		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	
19	Number tested on line 1	1500	0	0	0	0	100	1000	0	
20	Number tested on line 2	0	0	0	0	0	900	0	500	
21	Total computers produced	1500	0	0	0	0	1000	1000	500	
22		<=	<=	<=	<=	<=	<=	<=	<=	
23	Maximum sales	1500	1250	1250	1250	1000	1000	1000	800	
24										
25	Constraints (hours per month)	Hours used		Hours available						
26	Labor availability for assembling	20000	<=	20000						
27	Labor availability for testing, line 1	5000	<=	5000						
28	Labor availability for testing, line 2	4450	<=	6000						
29										
30	Net profit ($ per month)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Totals
31	Tested on line 1	$1,666,500	$0	$0	$0	$0	$151,800	$1,548,000	$0	$3,366,300
32	Tested on line 2	$0	$0	$0	$0	$0	$1,364,400	$0	$824,750	$2,189,150
33										$5,555,450

Recap & Learning Plan

2 Optimization Problems

	A	B	C	D	E	F	G
1	**Exam Grade Optimization**						
2							
3				**Intermediate Calc**	**Constraints**		
4	**Exam**	**Grade**	**Weight**	**Product**	**min**	**max**	
5	***Quiz #1***	50	0.15	7.5			
6	***Midterm***	65	0.25	16.25			
7	***Quiz #2***	70	0.15	10.5			
8	***Final***		0.45		0	100	
9	***Course Grade***	34.25			70	70	
10							

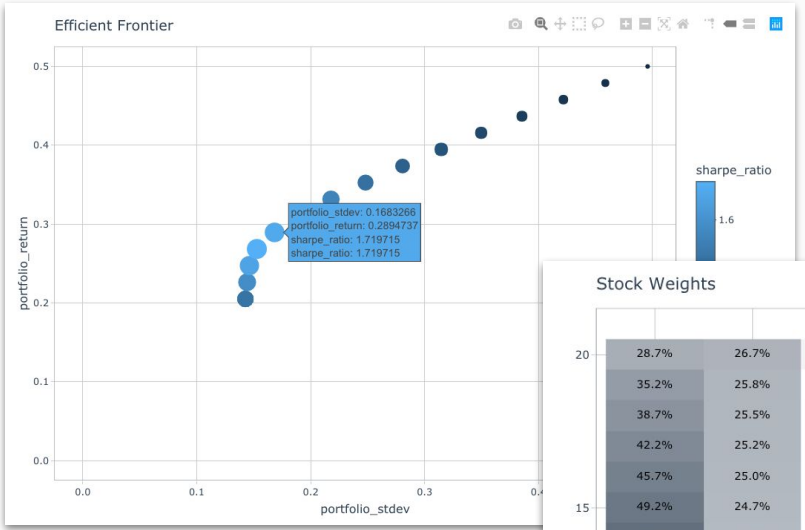
	A	B	C	D	E	F	G	H	I	J
1	**Assembling and Testing Macbooks**									
2										
3	Cost per labor hour assembling	$14								
4	Cost per labor hour testing, line 1	$22								
5	Cost per labor hour testing, line 2	$19								
6										
7	Inputs for assembling and testing a Macbook									
8		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	
9	Labor hours for assembly	4	5	5	5	5.5	5.5	5.5	6	
10	Labor hours for testing, line 1	1.5	2	2	2	2.5	2.5	2.5	3	
11	Labor hours for testing, line 2	2	2.5	2.5	2.5	3	3	3.5	3.5	
12	Cost of component parts	$900	$1,350	$1,350	$1,350	$1,500	$1,500	$1,500	$1,800	
13	Selling price	$2,100	$2,700	$2,760	$2,820	$3,000	$3,150	$3,180	$3,600	
14	Unit margin, tested on line 1	$1,111	$1,236	$1,296	$1,356	$1,368	$1,518	$1,548	$1,650	
15	Unit margin, tested on line 2	$1,106	$1,233	$1,293	$1,353	$1,366	$1,516	$1,537	$1,650	
16										
17	Assembling, testing plan (# of Macbooks)									
18		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	
19	Number tested on line 1	1500	0	0	0	0	100	1000	0	
20	Number tested on line 2	0	0	0	0	0	900	0	500	
21	Total computers produced	1500	0	0	0	0	1000	1000	500	
22		<=	<=	<=	<=	<=	<=	<=	<=	
23	Maximum sales	1500	1250	1250	1250	1000	1000	1000	800	
24										
25	Constraints (hours per month)	Hours used		Hours available						
26	Labor availability for assembling	20000	<=	20000						
27	Labor availability for testing, line 1	5000	<=	5000						
28	Labor availability for testing, line 2	4450	<=	6000						
29										
30	Net profit ($ per month)	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Totals
31	Tested on line 1	$1,666,500	$0	$0	$0	$0	$151,800	$1,548,000	$0	$3,366,300
32	Tested on line 2	$0	$0	$0	$0	$0	$1,364,400	$0	$824,750	$2,189,150
33										$5,555,450

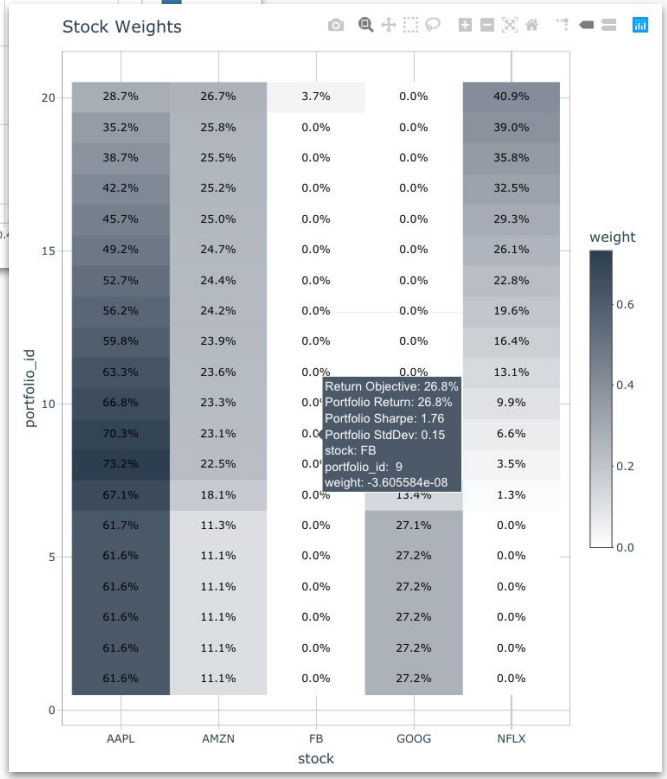
Part 2

Portfolio Optimization

Nonlinear Programming

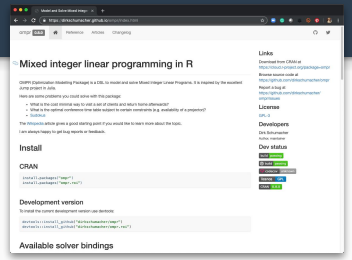
Simulation

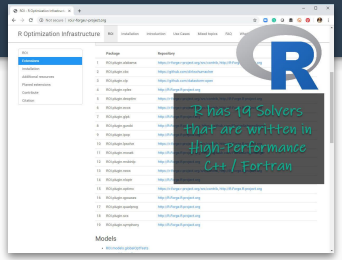




Business Modeling Process

Step-By-Step





Start

1

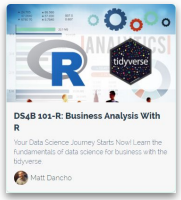
2

3

Finish

dplyr

Format Data



ompr & ROI

Linear Programming

Our focus today!

purrr & ggplot2

Simulation & Sensitivity Analysis

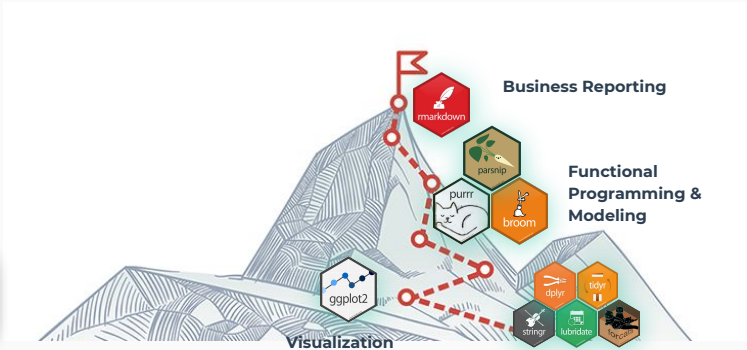
Visualization

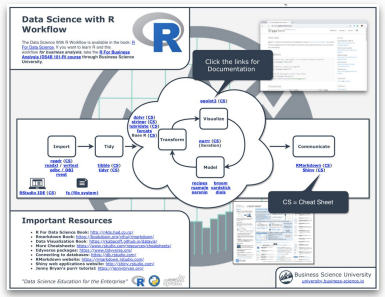
Step 1 - Learn the Foundations

Data Science Foundations

35 Hours of Video Lessons

- Machine Learning (parsnip)
- **Data Manipulation (dplyr)**
- **Visualization (ggplot2)**
- Reporting (rmarkdown)
- R Workflow Framework



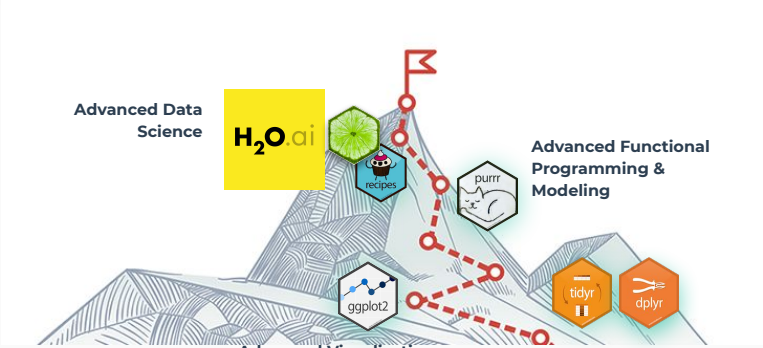


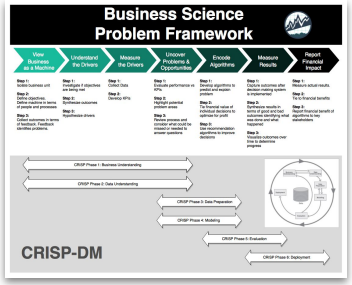
Step 2 - Learn Advanced ML

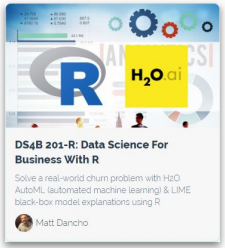
Advanced ML + Business Consulting

End-to-End Churn Project

- Churn Prediction w/ Machine Learning (H2O)
- Churn Explanation (lime)
- Repeatable Framework for Business Problems
- **ROI Analysis for Project Benefit**
- **Sensitivity Analysis with purrr**
- **Classifier Threshold Optimization with purrr**

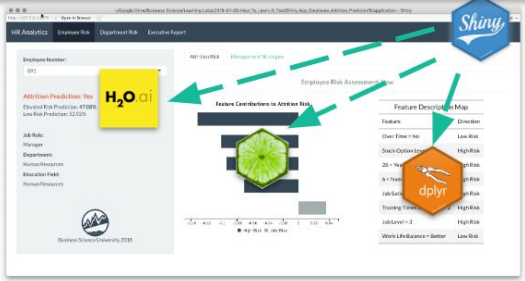




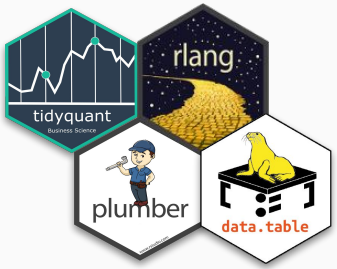


-Track Curriculum

Do Business Projects
Climb the Hill

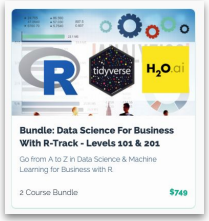


Build Production-Ready
Web Apps

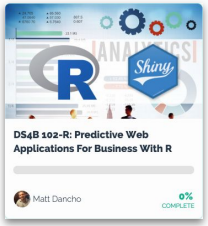


Complete 1-Hour Courses
Continuous Education

Start → 1 → 2 → 3 → **Finish**



Analysis Courses



App Development
Courses

Learning Labs PRO

Everything is **Taken Care of** For You in Our Platform

3-Course R-Track System

Business Analysis with R
(DS4B 101-R)

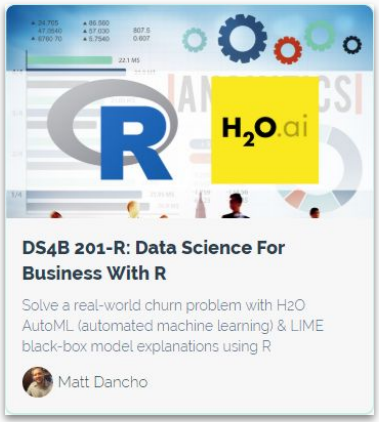
Data Science For Business with R
(DS4B 201-R)

R Shiny Web Apps For Business
(DS4B 102-R)

Project-Based Courses with Business Application

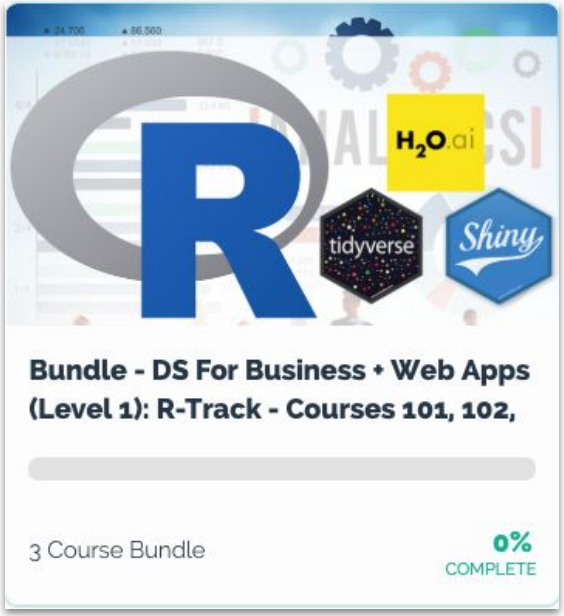
Data Science Foundations
7 Weeks

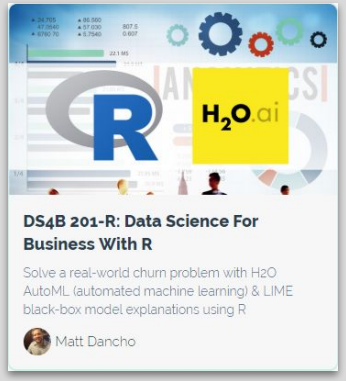
Machine Learning & Business Consulting
10 Weeks

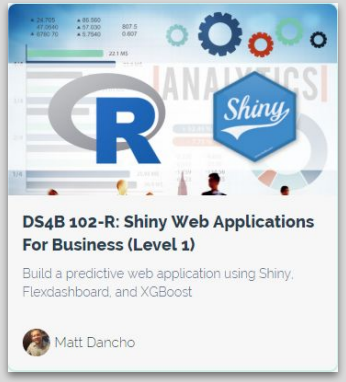


Web Application Development
4 Weeks

PROMO Code: learninglabs







R-TRACK BUNDLE

NEW PAYMENT OPTION

12 Low Monthly Payments

$125/mo

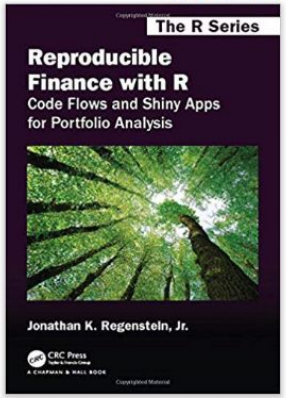
Reproducible Finance with R
Book Giveaway

Reproducible Finance with R: Code Flows and Shiny Apps for Portfolio Analysis (Chapman & Hall/CRC The R Series) 1st Edition

by Jonathan K. Regenstein Jr. (Author)

★★★★★ 20 customer reviews

Look inside



ISBN-13: 978-1138484221
ISBN-10: 1138484229
Why is ISBN important?

Have one to sell? Sell on Amazon

Add to List

Kindle	Hardcover	Paperback	Other Sellers
$19.11 - $57.56	$127.57 - $147.42	$48.00 - $71.95	See all 3 versions

Buy used $127.57

Buy new **$147.42**

Only 3 left in stock (more on the way).
Ships from and sold by Amazon.com.
Note: Available at a lower price from other sellers that may not offer free Prime shipping.

List Price: ~~$189.95~~
Save: $42.53 (22%)
11 New from $144.83
& **FREE Shipping**. Details

Want it Thursday, Aug. 1? Order within **10 hrs 51 mins** and choose **Two-Day Shipping** at checkout. Details

Deliver to State College 16801

Qty: 1

Add to Cart

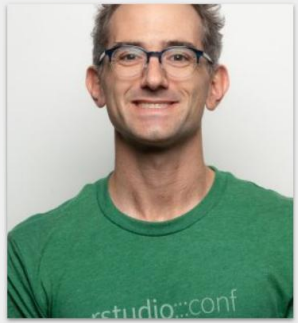
Buy Now

More Buying Choices

11 New from $144.83 | 4 Used from $127.57

15 used & new from $127.57

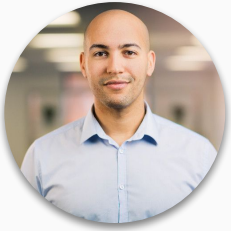
See All Buying Options



Results

*“Your program allowed me to cut down to **50% of the time** to deliver solutions to my clients.”*

-Rodrigo Prado, Managing Partner Big Data Analytics & Strategy at Genesis Partners



*“I can already **apply** a lot of the early gains from the course to current working projects.”*

-Adam Mitchell, Data Analyst with Eurostar

*“My work became **10X easier**. I can spend quality time asking questions rather than wasting time trying to figure out syntax.”*

-Mohana Chittor, Data Scientist with Kabbage, Inc

Achieve **Results** that Matter to the **Business**

Begin Learning Today

university.business-science.io