Citibike
Managing Bike Distribution

Derlen Chiu
Tom Laurie
Varun Merchant
Sean Murphy

Decision Models
Fall 2013

Citibike System

- "Pay Per Ride" or "Annual Subscription" basis
- 6,000 bikes
- 330 stations
- 42,000 trips daily
- 5m trips as of November 2013!
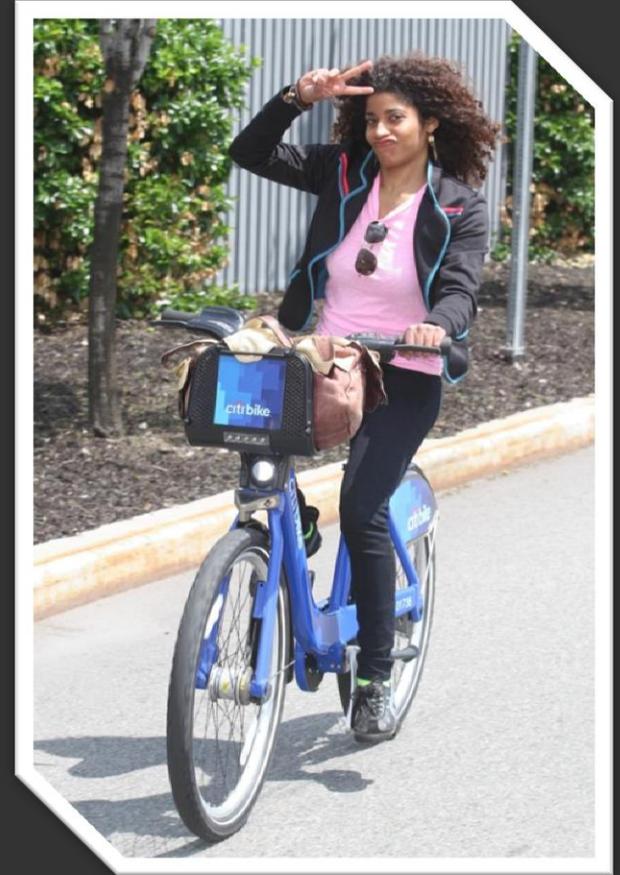
Problem Definition

Inconsistent demand and one-way trips cause a *shortage* of bicycles in popular areas and an *oversupply* in unpopular areas

Why does it matter?

Bike unavailability causes dissatisfaction and increases customer attrition rate

Negative economic impact on system

Negative brand impact on sponsors

Solution

- Redistribution
  - Bikes transported between stations
  - Set intervals

- Efficiency?
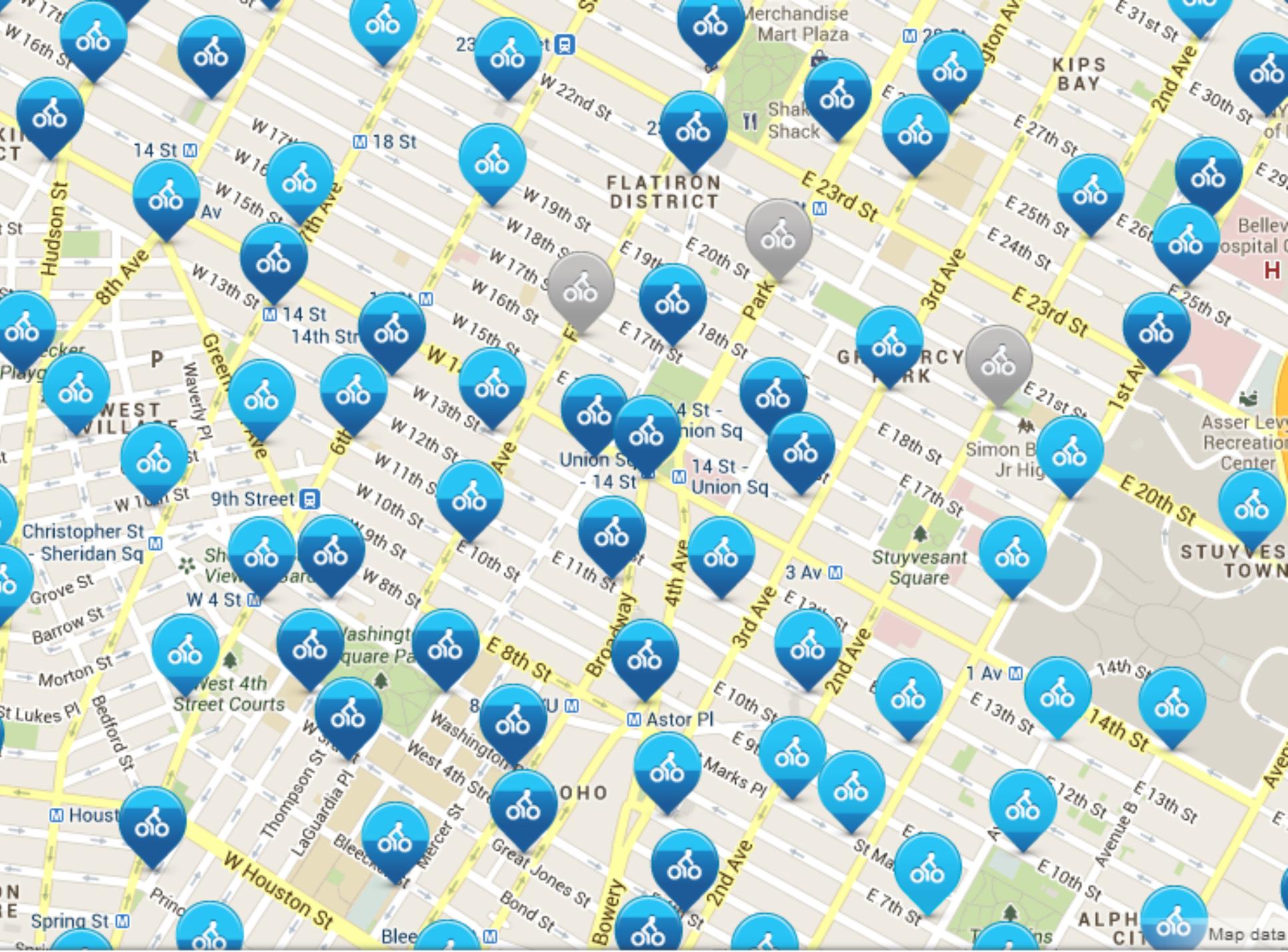
Problem Formulation

- Transport Problem
  - What are the station-to-station loads that need to occur to properly balance the system?

- Travelling Salesman Problem
  - What is the path the truck should travel to hit all required stops but minimize distance?

Test Case

- Starting conditions
  - 13 stations
    - Spread out over the city
    - High variation in usage
  - 1 bike depot
  - 1 replenishment truck
  - End of day bike locations
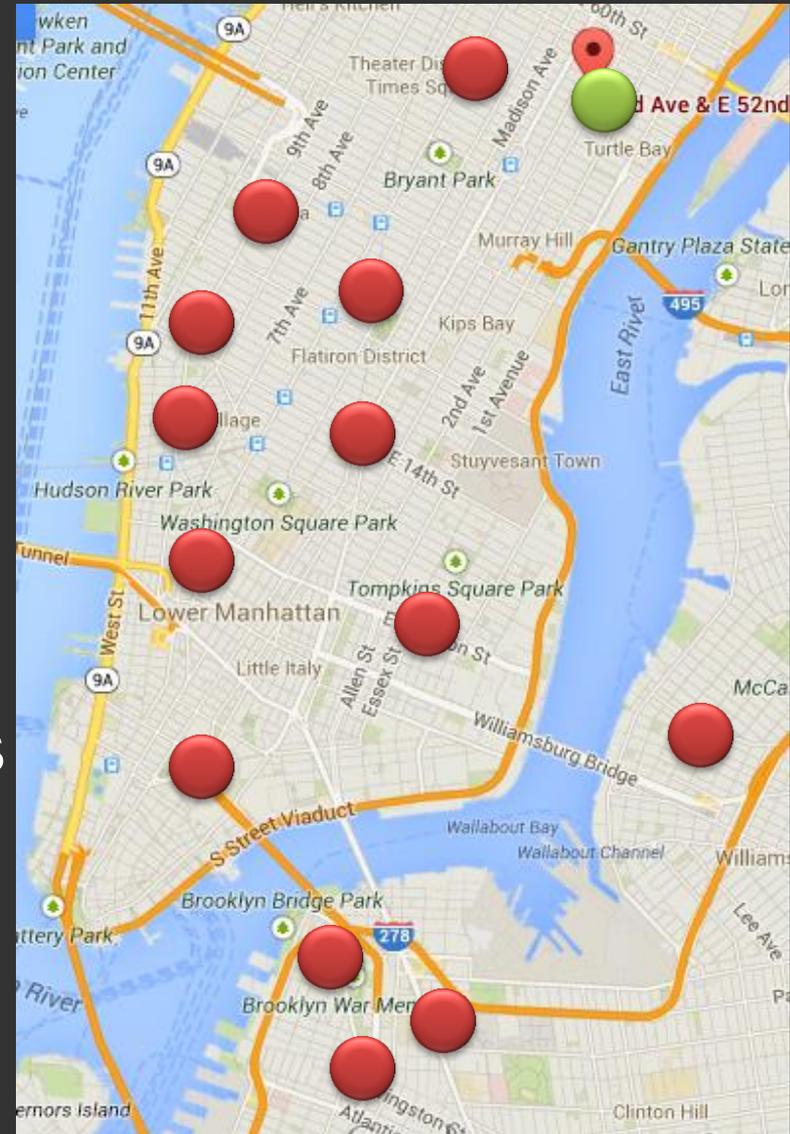
Data

- Citibike Live API
  - Current dock status
  - Dock usage over past 24hrs
  - Dock capacity
  - Station Location
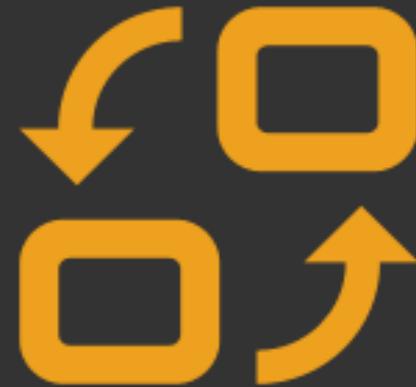
Objective

Keep stations filled to **60%** of capacity, while *minimizing distance* travelled by the replenishment truck

Model Overview
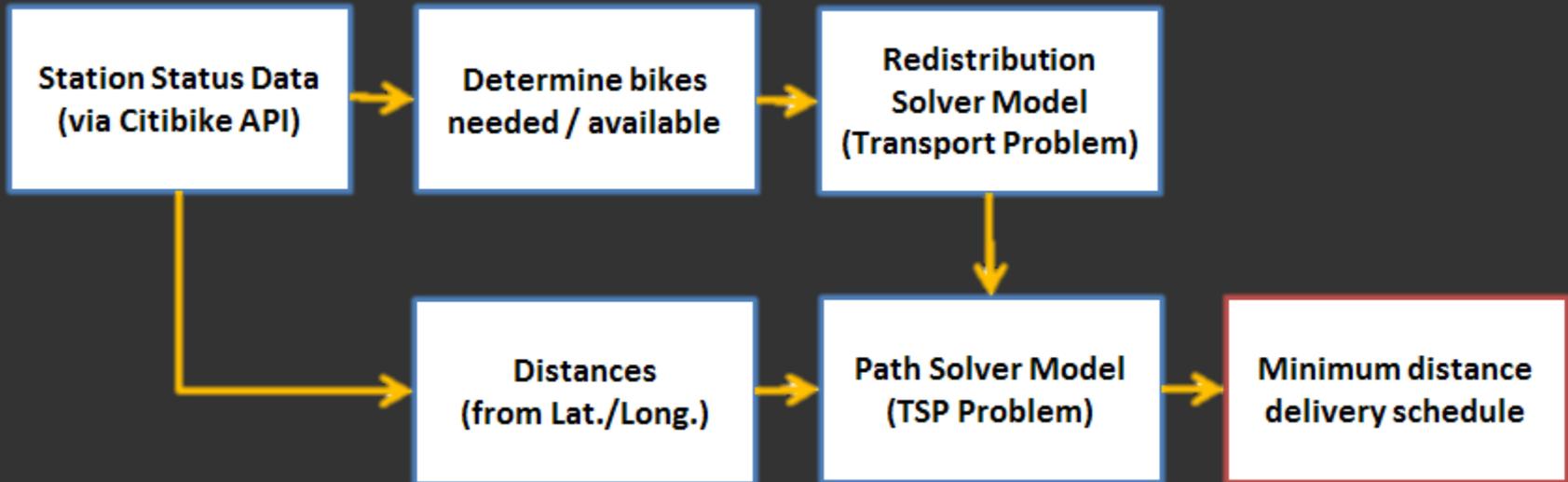
Transport Problem
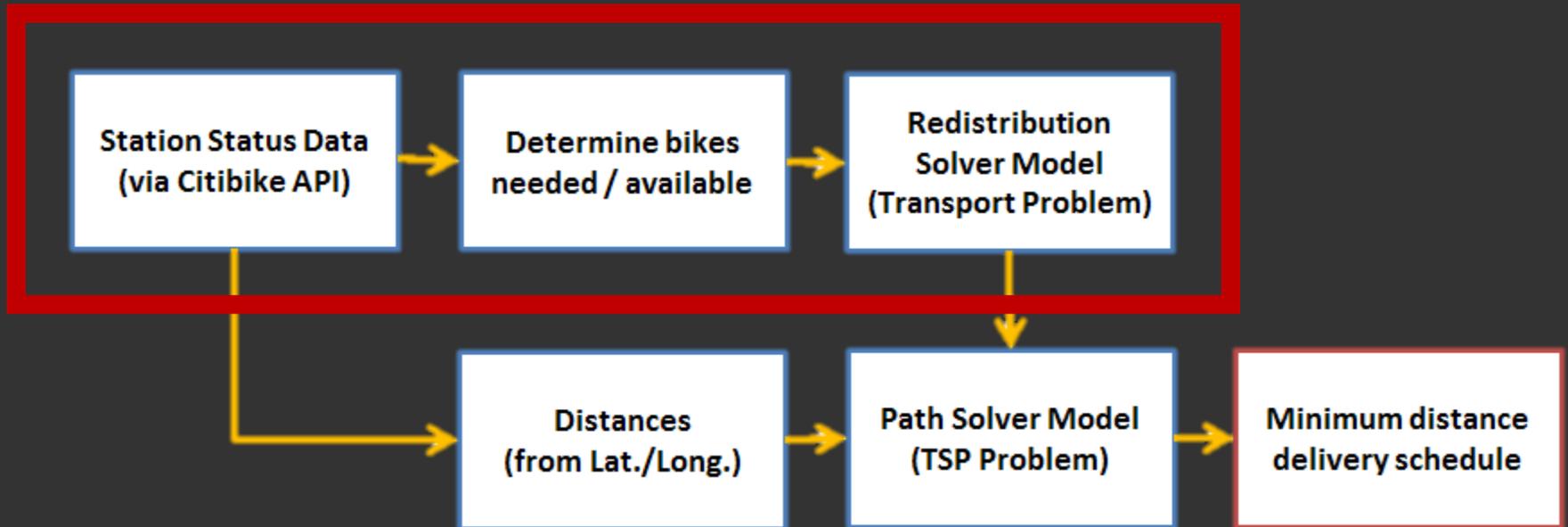
Bikes Available/Needed

Tom Laurie, Derlen Chiu, Sean Murphy, Varun Merchant

INPUTS

Target Min. Fill   **60%**

> **Bikes available at Depot.** Needs to be at least enough to fill orders beyond bikes to be redistributed from other stations

Station ID	stationName	totalDocks	availableBikes	Fill%	Min Deliv.	Max Deliv.	Avail. for redistrib
Depot							500
261	Johnson St & Gold St	27	3	11%	14	24	0
217	Old Fulton St	39	15	38%	9	24	0
539	Metropolitan Ave & Bedford Ave	31	13	42%	6	18	0
444	Broadway & W 24 St	52	0	0%	32	52	0
346	Bank St & Hudson St	27	2	7%	15	25	0
512	W 29 St & 9 Ave	27	0	0%	17	27	0
510	W 51 St & 6 Ave	51	33	65%	0	18	2
387	Centre St & Chambers St	39	25	64%	0	14	1
301	E 2 St & Avenue B	37	2	5%	21	35	0
285	Broadway & E 14 St	47	11	23%	18	36	0
128	MacDougal St & Prince St	30	25	83%	0	5	7
212	W 16 St & The High Line	28	9	32%	8	19	0
233	Joralemon St & Adams St	39	28	72%	0	11	4
		474	166	34%	140	308	14

Redistribution

Part 1 - Transport problem

Variabl No. *Bikes*

From / To	Depot	261	217	539	444	346	512	510	387	301	285	128	212	233	Collected from		Available	
Depot			9	6	32	15	17			21	18		8		126.00	<=	500	✅
261															0	<=	0	✅
217															0	<=	0	✅
539															0	<=	0	✅
444															0	<=	0	✅
346															0	<=	0	✅
512															0	<=	0	✅
510		2													2	<=	2	✅
387		1													1	<=	1	✅
301															0	<=	0	✅
285															0	<=	0	✅
128		7													7	<=	7	✅
212															0	<=	0	✅
233		4													4	<=	4	✅
Delivered to ...	0	14	9	6	32	15	17	0	0	21	18	0	8	0				
MIN	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=			(4)	
to be delivered	0	14	9	6	32	15	17	0	0	21	18	0	8	0				
	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅				
MAX	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=				
to be delivered	0	24	24	18	52	25	27	18	14	35	36	5	19	11				
	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅				

Constraints

1) Can't transport more bikes than are available at a station

Collected from		Available	
126	<=	500	✓
0	<=	0	✓
0	<=	0	✓
0	<=	0	✓
0	<=	0	✓
0	<=	0	✓
0	<=	0	✓
2	<=	2	✓
1	<=	1	✓
0	<=	0	✓
0	<=	0	✓
7	<=	7	✓
0	<=	0	✓
4	<=	4	✓

Constraints

233		4							
Delivered to ...	0	14	9	6	32	15	17	0	0
MIN	>=	>=	>=	>=	>=	>=	>=	>=	>=
to be delivered	0	14	9	6	32	15	17	0	0
	✓	✓	✓	✓	✓	✓	✓	✓	✓
MAX	<=	<=	<=	<=	<=	<=	<=	<=	<=
to be delivered	0	24	24	18	52	25	27	18	14
	✓	✓	✓	✓	✓	✓	✓	✓	✓

2) Must deliver the minimum number of bikes

3) Cannot exceed the maximum number of docks

Model Details

Model Details

Variabl·No. *Bikes*

From / To	Depot	261	217	539	444	346	512	510	387	301	285	128	212	233	Collected from		Available	
Depot			9	6	32	15	17			21	18		8		126.00	<=	500	✓
261															0	<=	0	✓
217															0	<=	0	✓
539															0	<=	0	✓
444															0	<=	0	✓
346															0	<=	0	✓
512															0	<=	0	✓
510		2													2	<=	2	✓
387		1													1	<=	1	✓
301															0	<=	0	✓
285															0	<=	0	✓
128		7													7	<=	7	✓
212															0	<=	0	✓
233		4													4	<=	4	✓
Delivered to …	0	14	9	6	32	15	17	0	0	21	18	0	8	0				
MIN	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=			(4)	
to be delivered	0	14	9	6	32	15	17	0	0	21	18	0	8	0				
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				
MAX	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=	<=				
to be delivered	0	24	24	18	52	25	27	18	14	35	36	5	19	11				
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓				

Travelling Salesman
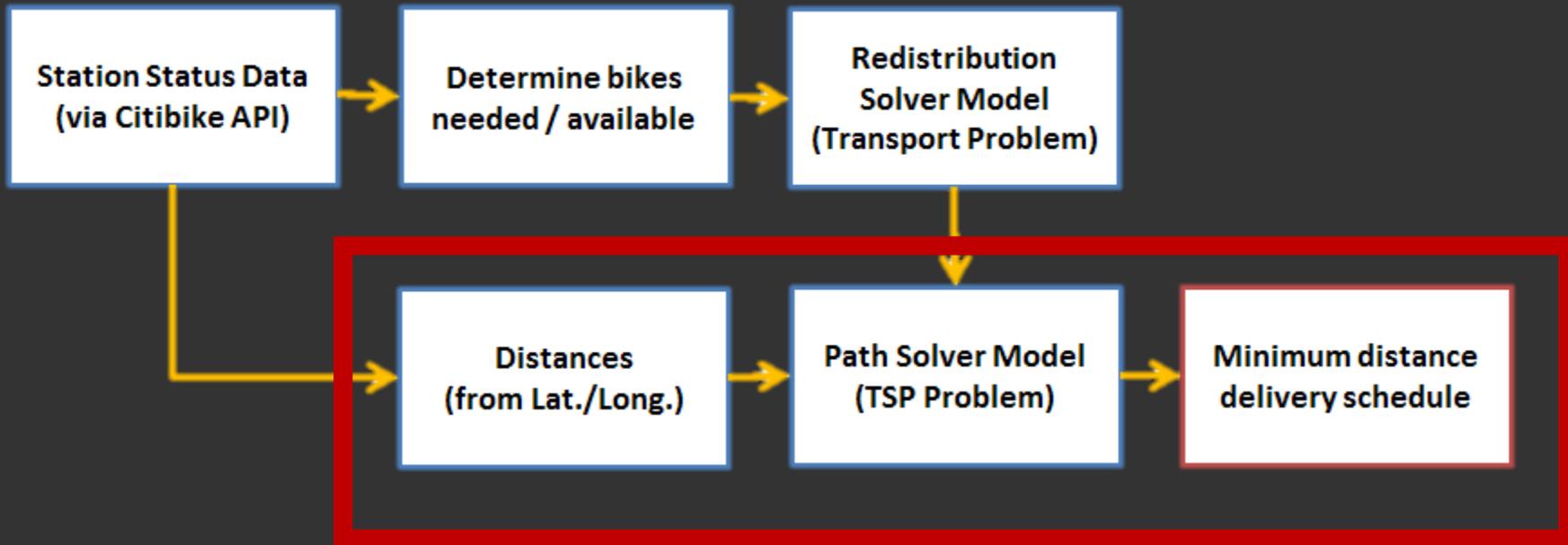
Calculating Station Distance

DISTANCES *(see 'Long.Lat Calc' tab)* Unit = Miles

From/To	Depot	261	217	539	444	346	512	510	387	301	285	128	212	233
Depot	0.0	4.4	4.0	2.9	1.4	2.4	1.6	0.6	3.6	2.5	1.9	2.7	2.2	4.6
261	4.4	0.0	0.8	1.9	3.3	3.1	3.9	4.6	1.7	1.9	2.8	2.5	3.6	0.4
217	4.0	0.8	0.0	2.0	2.7	2.4	3.3	4.1	0.9	1.4	2.2	1.7	2.9	0.7
539	2.9	1.9	2.0	0.0	2.4	2.8	3.1	3.3	2.3	1.3	2.1	2.4	3.1	2.2
444	1.4	3.3	2.7	2.4	0.0	1.0	0.7	1.3	2.2	1.4	0.5	1.3	0.9	3.4
346	2.4	3.1	2.4	2.8	1.0	0.0	1.0	2.1	1.6	1.5	0.8	0.7	0.5	3.2
512	1.6	3.9	3.3	3.1	0.7	1.0	0.0	1.2	2.6	2.1	1.1	1.6	0.6	4.0
510	0.6	4.6	4.1	3.3	1.3	2.1	1.2	0.0	3.5	2.7	1.9	2.6	1.8	4.7
387	3.6	1.7	0.9	2.3	2.2	1.6	2.6	3.5	0.0	1.3	1.7	1.0	2.1	1.6
301	2.5	1.9	1.4	1.3	1.4	1.5	2.1	2.7	1.3	0.0	0.9	1.1	1.9	2.1
285	1.9	2.8	2.2	2.1	0.5	0.8	1.1	1.9	1.7	0.9	0.0	0.8	1.0	2.9
128	2.7	2.5	1.7	2.4	1.3	0.7	1.6	2.6	1.0	1.1	0.8	0.0	1.1	2.5
212	2.2	3.6	2.9	3.1	0.9	0.5	0.6	1.8	2.1	1.9	1.0	1.1	0.0	3.6
233	4.6	0.4	0.7	2.2	3.4	3.2	4.0	4.7	1.6	2.1	2.9	2.5	3.6	0.0

Model Details

Part 2 - Travelling Salesman problem

PATH

Variable =   Binary

From / To	Depot	261	217	539	444	346	512	510	387	301	285	128	212	233				
Depot					1										1	>=	1	✅
261														1	1	>=	0	✅
217							1								1	>=	0	✅
539		1													1	>=	0	✅
444												1			1	>=	0	✅
346													1		1	>=	0	✅
512								1							1	>=	0	✅
510	1														1	>=	1	✅
387												1			1	>=	1	✅
301				1											1	>=	0	✅
285										1					1	>=	0	✅
128						1									1	>=	1	✅
212							1								1	>=	0	✅
233			1												1	>=	1	✅
	1	1	1	1	1	1	1	1	1	1	1	1	1	1				

(4) If need to collect then must arr

(1) If need to deliver then must arrive_

	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=
	0	1	1	1	1	1	1	0	0	1	1	0	1	0
	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅

(2) If depart from a station then need to have arrived at station

SUMDIFFERENCE --->	0	0	0	0	0	0	-	0	0	0	0	0	0	0
+ve = No. arrivals > departures	=	=	=	=	=	=	=	=	=	=	=	=	=	=
-ve = departures > arrivals	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅	✅

(3) Must move between different points   -   =   0   ✅

Total distance (miles)   12.68   *Minimize*

Eliminating Subtours between

	Depot	510
Depot	512	512
217	261	387
	261	233
	387	217
	301	539

Constraints

1) If a fill is needed, truck must arrive
2) No teleportation
3) No self-deliveries

Constraints

4) If a pickup is needed, truck must arrive

Subtours

Eliminating Subtours between...

	Depot	510
Depot	512	512
217	261	387
	261	233
	387	217
	301	539

1 <= 1 ✓
2 <= 2 ✓
1 <= 2 ✓
1 <= 1 ✓
1 <= 1 ✓
1 <= 1 ✓

0   0
0   0
0   0

Solver Parameters

Model Details

Part 2 - Travelling Salesman problem

PATH — Variable = Binary

(4) If need to collect then must arrive...

From / To	Depot	261	217	539	444	346	512	510	387	301	285	128	212	233				
Depot					1										1	>=	1	✓
261														1	1	>=	0	✓
217								1							1	>=	0	✓
539		1													1	>=	0	✓
444											1				1	>=	0	✓
346													1		1	>=	0	✓
512								1							1	>=	0	✓
510	1														1	>=	1	✓
387												1			1	>=	1	✓
301			1												1	>=	0	✓
285												1			1	>=	0	✓
128							1								1	>=	1	✓
212									1						1	>=	0	✓
233			1												1	>=	1	✓
	1	1	1	1	1	1	1	1	1	1	1	1	1	1				

(1) If need to deliver then must arrive...

	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=	>=
	0	1	1	1	1	1	1	0	0	1	1	0	1	0
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

(2) If depart from a station then need to have arrived at station

SUMDIFFERENCE --->	0	0	0	0	0	0	-	0	0	0	0	0	0	0
+ve = No. arrivals > departures	=	=	=	=	=	=	=	=	=	=	=	=	=	=
-ve = departures > arrivals	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

(3) Must move between different points — - = 0 ✓

Total distance (miles) 12.68 *Minimize*

Eliminating Subtours between...

	Depot	510	1
Depot	512	512	2
217	261	387	1
	261	233	1
	387	217	1
	301	539	1
			0
			0
			0

Results

PATH & DELIVERY TRACKING							
		No. Bikes on Truck					
From	To	@start	Change	@end		Station	Visited?
Depot	444	126	(32.00)	94		Depot	✓
444	285	94	(18.00)	76		261	✓
285	301	76	(21.00)	55		217	✓
301	539	55	(6.00)	49		539	✓
539	261	49	(14.00)	35		444	✓
261	233	35	4.00	39		346	✓
233	217	39	(9.00)	30		512	✓
217	387	30	1.00	31		510	✓
387	128	31	7.00	38		387	✓
128	346	38	(15.00)	23		301	✓
346	212	23	(8.00)	15		285	✓
212	512	15	(17.00)	-2		128	✓
512	510	-2	2.00	0		212	✓
510	Depot	0	-	0		233	✓

Total distance (miles)	12.68	*Minimize*

Optimal Path

Future Applications

- Different Objectives
  - Minimize time by accounting for traffic
  - Minimize loading and unloading of bikes
  - Maximize bike lifetime (indiv. bike usage tracking)

- System expansion
  - Multiple trucks and multiple depots
  - More stations (+~100), More bikes (+4,000) by 2014

- Cross-System Coordination
  - Coordination with MTA buses, subways
  - [Will Citi Bike Launch In Greenpoint Before The G Train Shuts Down?](#) (Gothamist)

Questions

?

New York Nerds Sift Citi Bike Data to Solve Availability

By Priya Anand - Nov 6, 2013 12:01 AM ET

Each morning, New York commuters who use the nation's largest cycle-sharing system face a question that decides whether the workday begins in disappointment or with a smooth glide: Will any Citi Bikes be available?

A cadre of data vigilantes, including as many as 80 software engineers, analysts and urban planners, work in their free time to make the answer yes. Without help from the city Transportation Department, they crunch numbers at meetings held by the nonprofit Code for America, analyzing patterns of ridership for the cobalt two-wheelers sponsored by Citigroup Inc. Their tables are lined with laptops — and sometimes beer.