

Transit Network Optimization: A Case Study on Bus Route Planning in Lincoln Parish

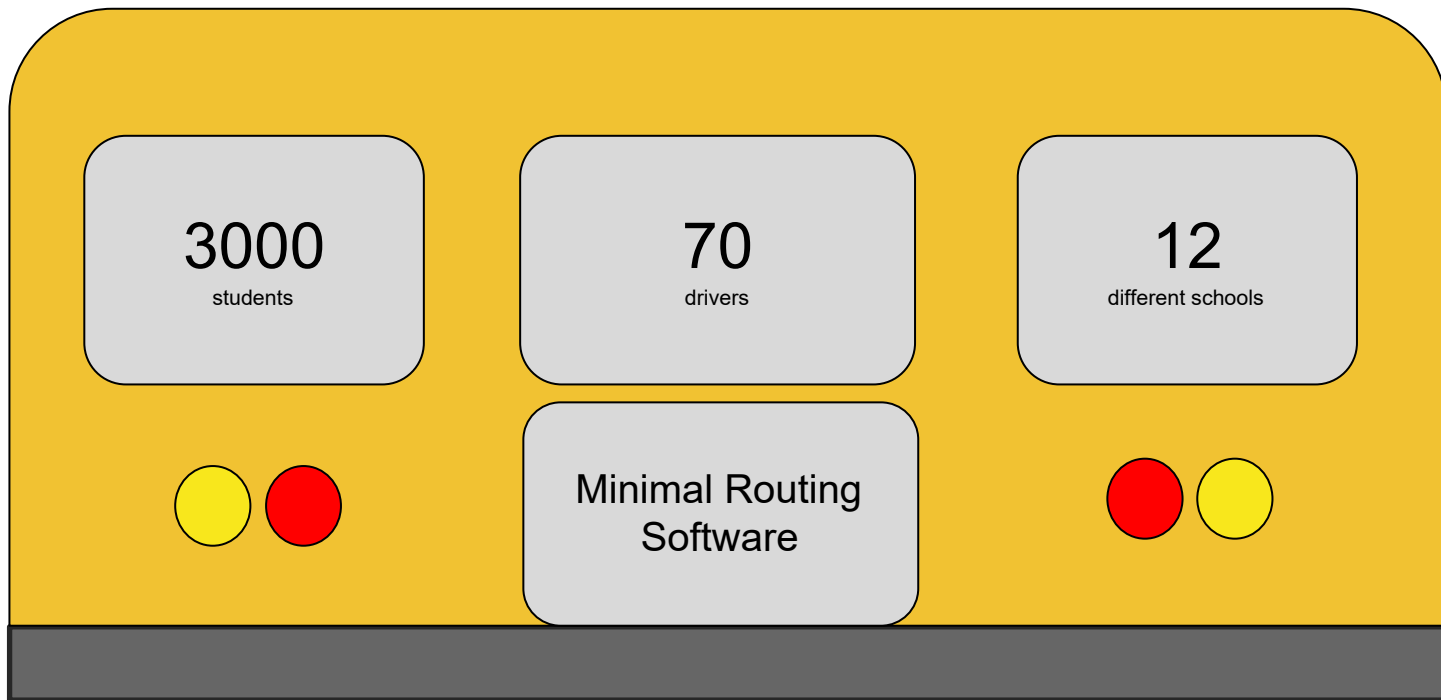
Presented by Ricardo Auerbach

In collaboration with Kosi Anadi,
Wes Brady, and Hayden Scaff

Why KNIME?

- Originally planned to use discrete simulation software, had various limitations
- KNIME was a low/no code alternative with more capabilities
- Open sourced with larger community

Lincoln Parish School Board



Problem Statement

- Routes take longer than 30 minutes
- Buses pick up and drop off students at their homes
- Routes are determined manually by drivers

Improvement Goal

Reduce the number of routes that are over 30 minutes and reduce operating expenses by 10-15%.

Defect = Routes over 30 minutes

Initial Condition

- Drivers stop at each home
- Driver's create their route
- Routes overlap
- Buses are under capacity / at capacity

Collected Data

Driver Sheets

- Data on 33 routes
- Unreliable addresses
- Unknown Destinations
- Missing Times
- Did not contain all requested routes

2021/2022

Bus Route Time Sheet
Please Print

Bus # 5

Schools: Glencreek + Cypress Springs
(Specify when and where school stops are on the list below)

Driver: Becky Browley

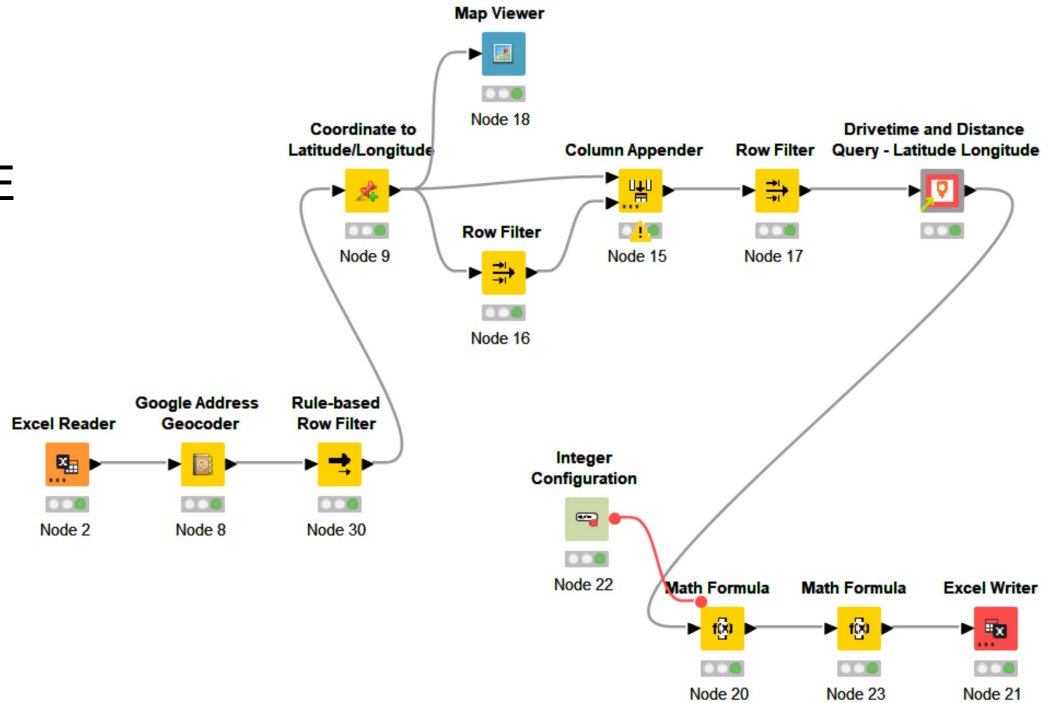
STOP NO.	PICKUP TIME	HOUSE NO.	STREET ADDRESS AND/OR INTERSECTION OF PICKUP	# OF STUDENTS
1	6:18		W. Kentucky + Arabella	1
2	6:18		W. Kentucky + Desiree	1
3	6:22		1406 W. Kentucky	3
4	6:23		1508 Bonaparte	2
5	6:26		924 Pennington	1
6	6:28		1504 W. Kentucky	3
7	6:29		Arcadia + Green	1
8	6:30		1705 Arcadia	1
9	6:31		2616 Kavanaugh	1
10	6:32		2515 Kavanaugh	6
11	6:35		1300 Ashland	1
12	6:36		Alexander + Corley	3
13	6:37		Alexander + Brooks	3
14	6:38		1910 Ashland	3
15	6:39		Ashland + Broadway	2
16	6:39		1612 Bittersweet	2
17			1600 Bittersweet	2

A No-Code Solution with KNIME

- Calculate route metrics and validate model using collected data
- Distribute students across available buses
- Generate bus stops for students
- Optimize routes - fastest/shortest order

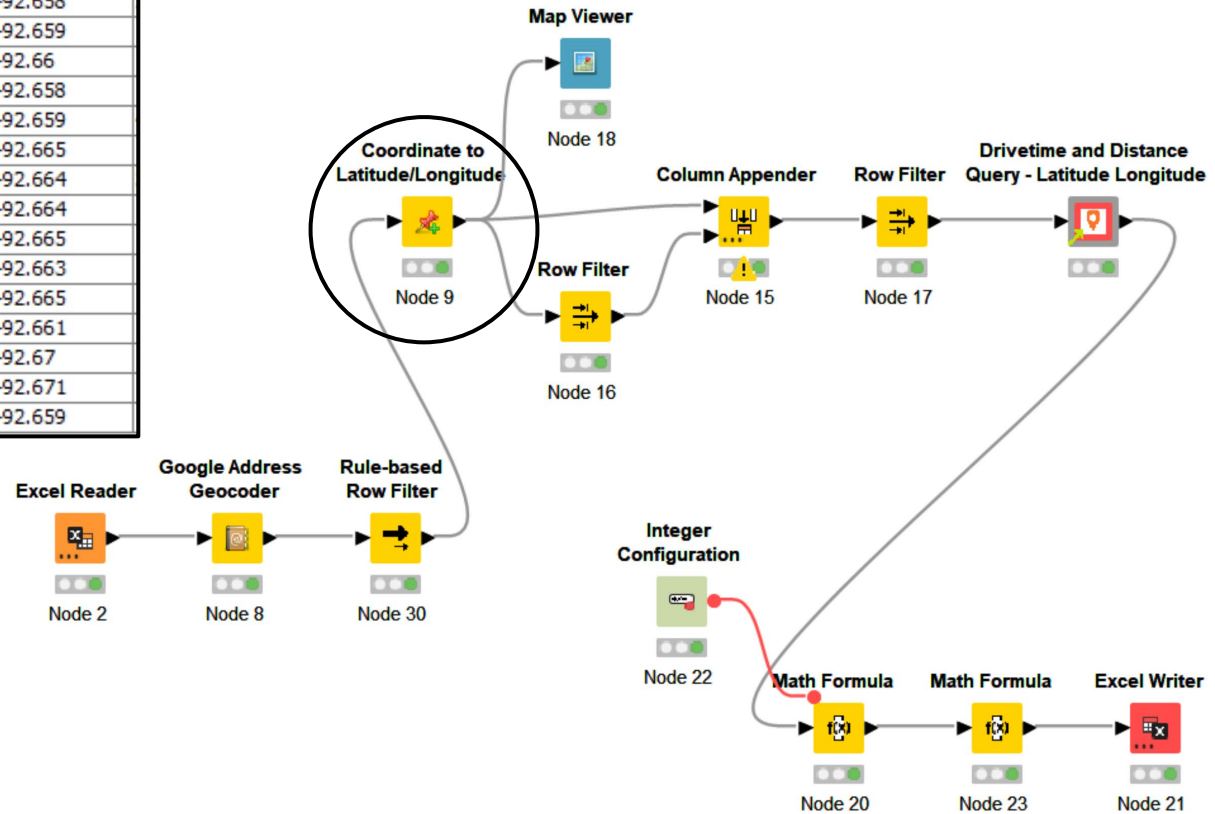
Step 1: Route Modeling

- Reproduce Hand-written route metrics using KNIME
- Determine co-efficient for additional time to load students

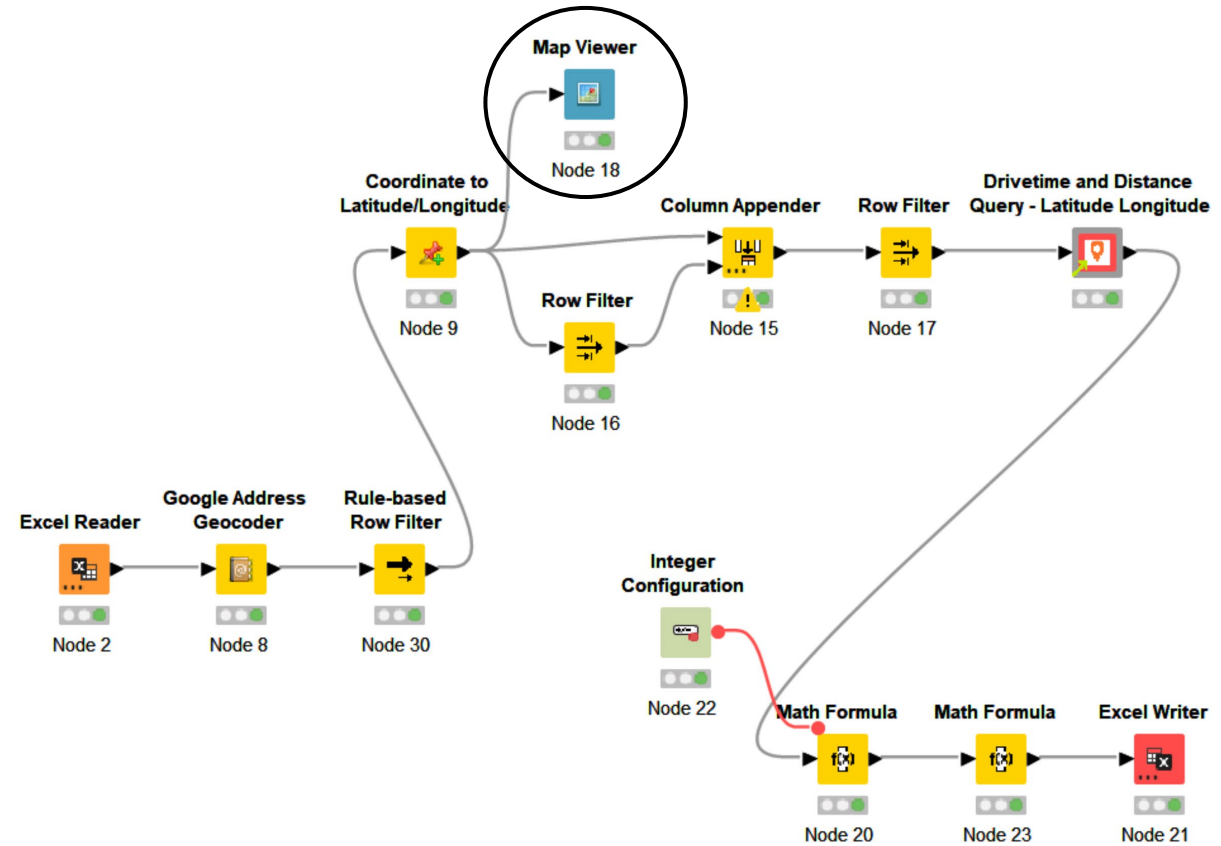
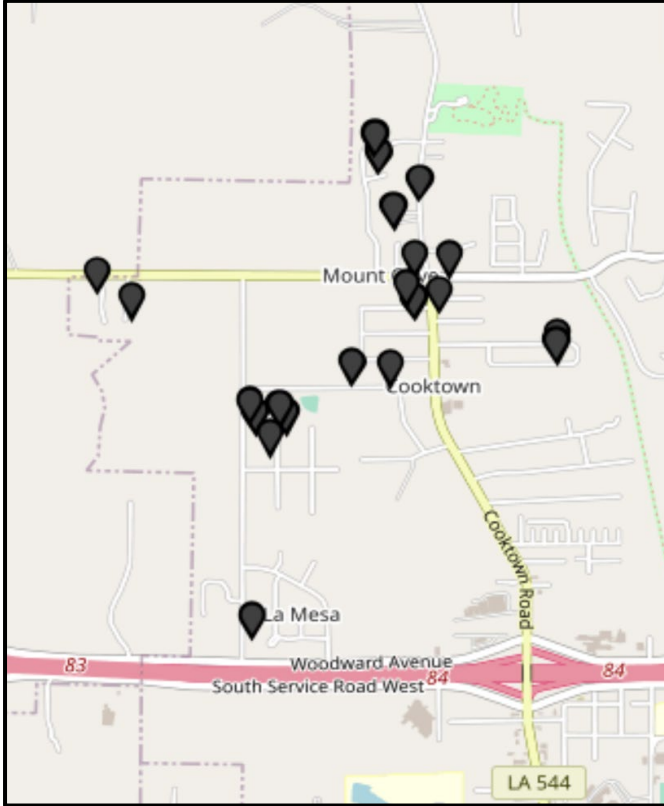


Route Modeling

S R1 Address with State	coordinate	D latitude	D longitude
917 Wedgewood Dr, Ruston, LA, 71270	32.552,-92....	32.552	-92.652
924 Pennington Ln, Ruston, LA, 71270	32.552,-92....	32.552	-92.652
2302 Cooktown Road, Ruston, LA, 71...	32.554,-92....	32.554	-92.657
1508 Bonaparte Dr, Ruston, LA, 71270	32.554,-92....	32.554	-92.658
1503 Bonaparte Dr, Ruston, LA, 71270	32.554,-92....	32.554	-92.658
1406 W Kentucky Ave, Ruston, LA, 7...	32.555,-92....	32.555	-92.656
1504 W Kentucky Ave, Ruston, LA, 7...	32.555,-92....	32.555	-92.658
1703 Greer Dr, Ruston, LA, 71270	32.559,-92....	32.559	-92.659
1705 Arcadia Dr, Ruston, LA, 71270	32.56,-92.66	32.56	-92.66
2616 Kavanaugh Rd, Ruston, LA, 71270	32.558,-92....	32.558	-92.658
2515 Kavanaugh Rd, Ruston, LA, 71270	32.557,-92....	32.557	-92.659
1300 Ashland St, Ruston, LA, 71270	32.542,-92....	32.542	-92.665
1803 Brooks St, Ruston, LA, 71270	32.549,-92....	32.549	-92.664
1712 Broadway Ave, Ruston, LA, 71270	32.55,-92.664	32.55	-92.664
1702 Broadway Ave, Ruston, LA, 71270	32.55,-92.665	32.55	-92.665
1808 Brooks St, Ruston, LA, 71270	32.549,-92....	32.549	-92.663
1910 Ashland St, Ruston, LA, 71270	32.549,-92....	32.549	-92.665
1612 Bittersweet Ave, Ruston, LA, 71...	32.551,-92....	32.551	-92.661
2208 Desiree St, Ruston, LA, 71270	32.554,-92.67	32.554	-92.67
2223 Arabella St, Ruston, LA, 71270	32.555,-92....	32.555	-92.671
1600 Bittersweet Ave, Ruston, LA, 71...	32.551,-92....	32.551	-92.659



Route Modeling



Options | Flow Variables | Memory Policy

Please enter your Tom Tom developer API key

Select your starting latitude column

Select your starting longitude column

Select your ending latitude column

Select your ending longitude column

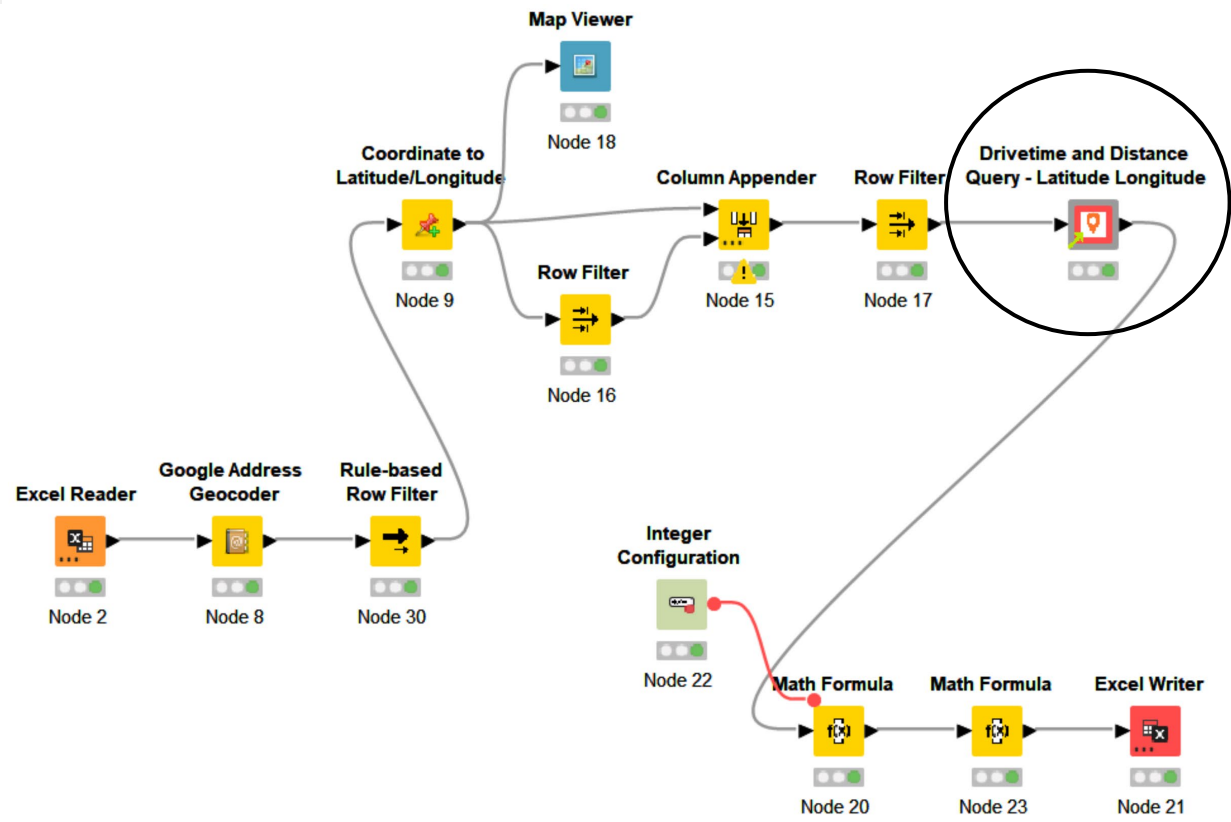
Select your travel Mode

- car
- car
- truck
- taxi
- bus
- van
- motorcycle
- bicycle
- pedestrian

filter out rows with missing GPS information?

OK Apply Cancel ?

Route Modeling



Statistical Information

The regression equation is

$$\text{Time on Bus (min)} = 19.66 + 1.050 \text{ Stops}$$

Descriptive Statistics

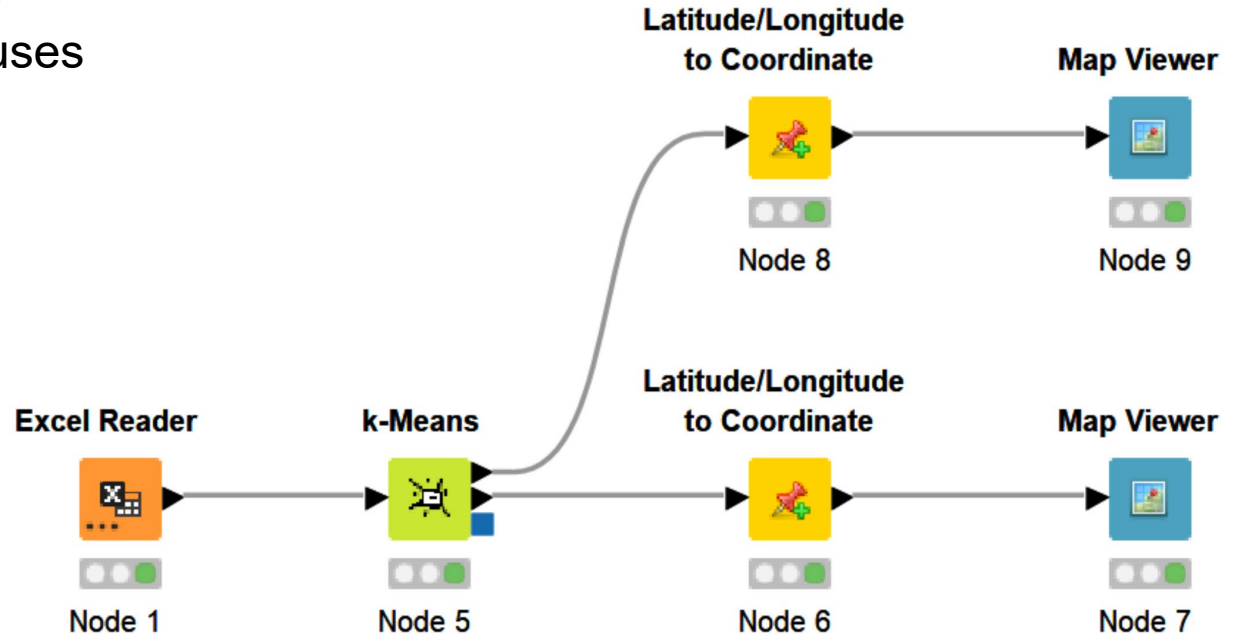
				95% Lower Bound
N	Mean	StDev	SE Mean	for μ
24	45.92	40.69	8.31	31.69

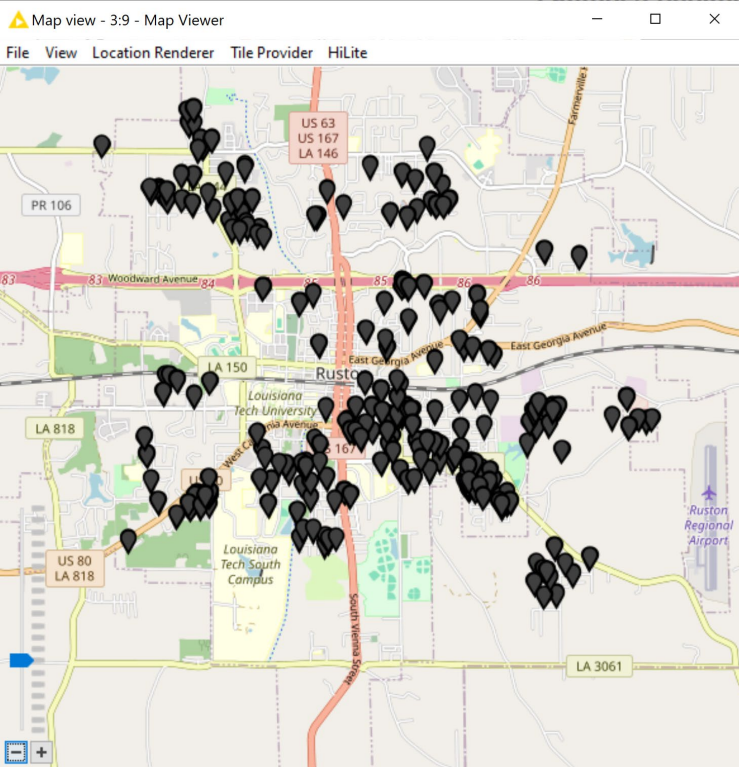
μ : population mean of Current Times

Defect: Route time over 30 minutes	
Based on driver sheets	Based on KNIME Routes
17 defects for 32 routes collected	16 defects for 24 routes collected

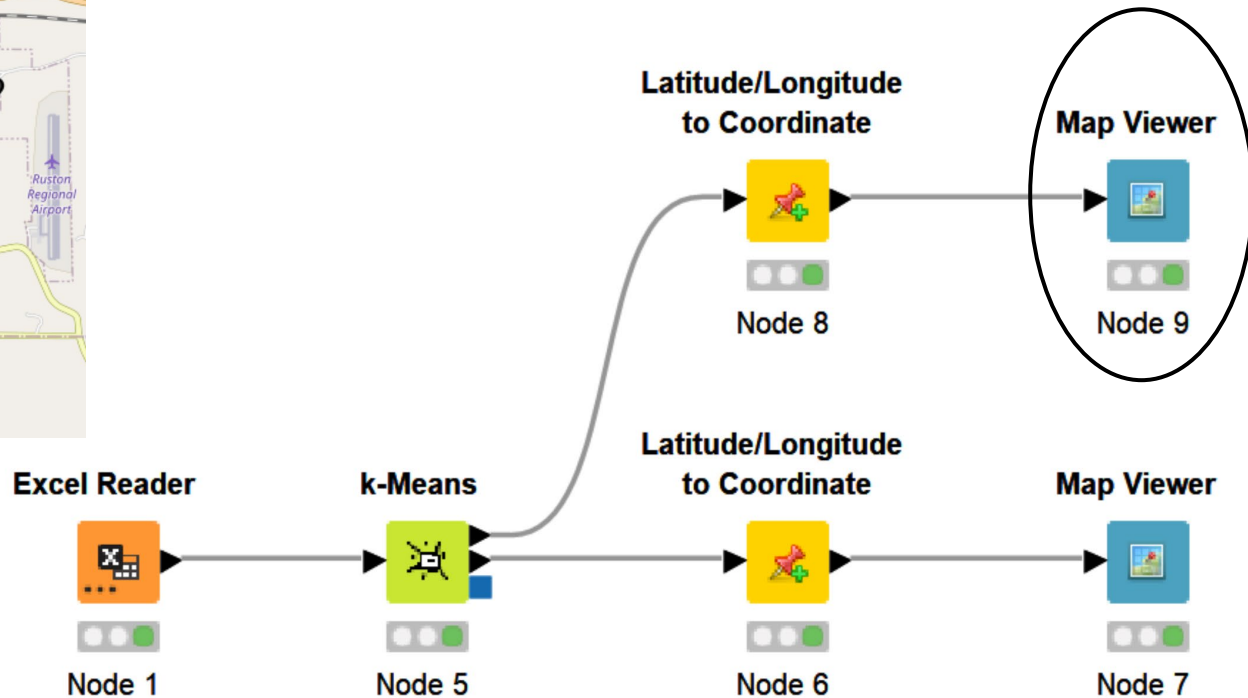
Step 2: Assign Students to Buses

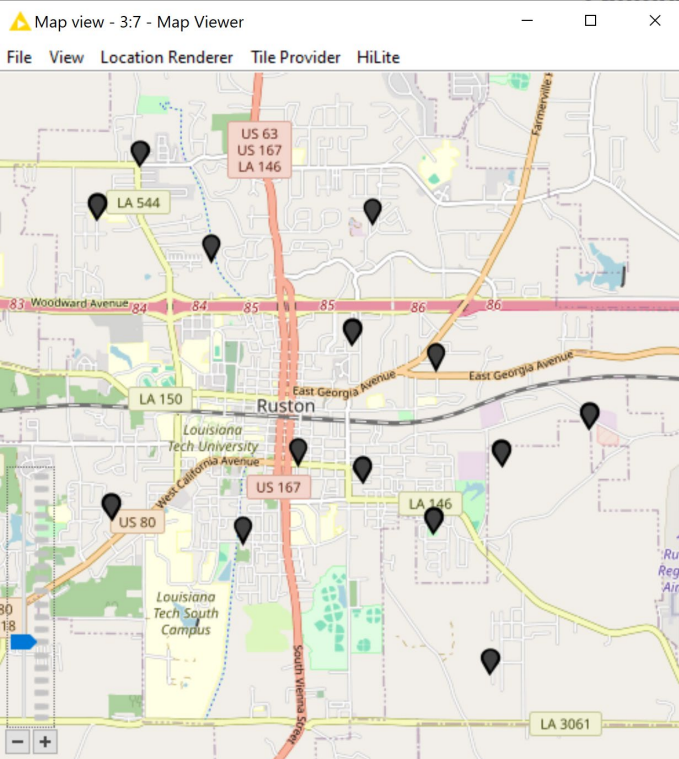
Use K-means to assign students to available buses without exceeding seat capacity



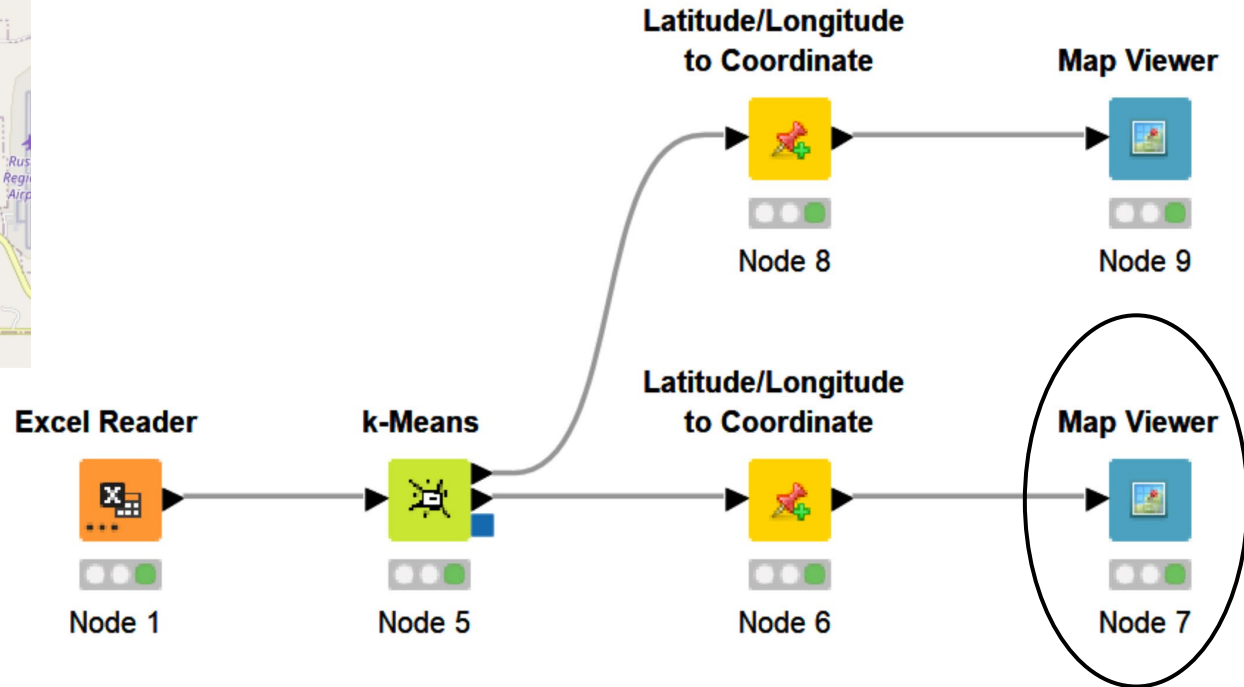


Assign Students to Buses



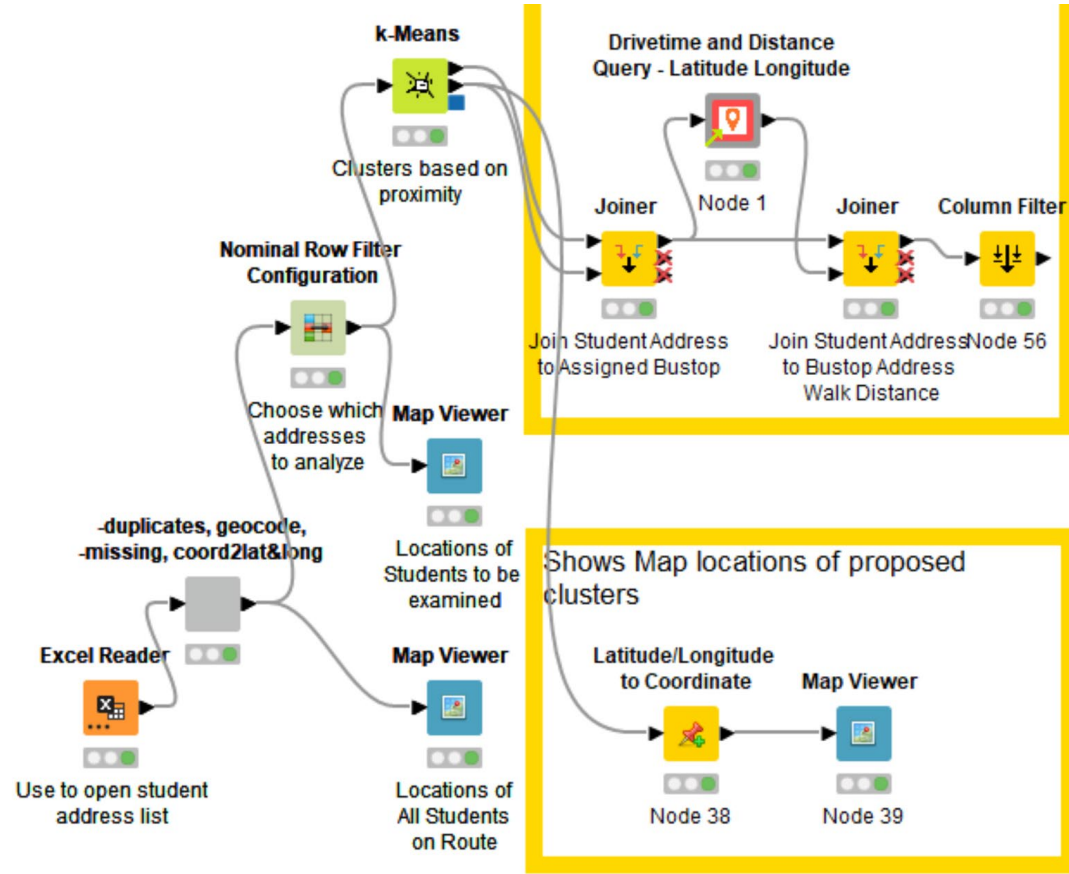


Assign Students to Buses

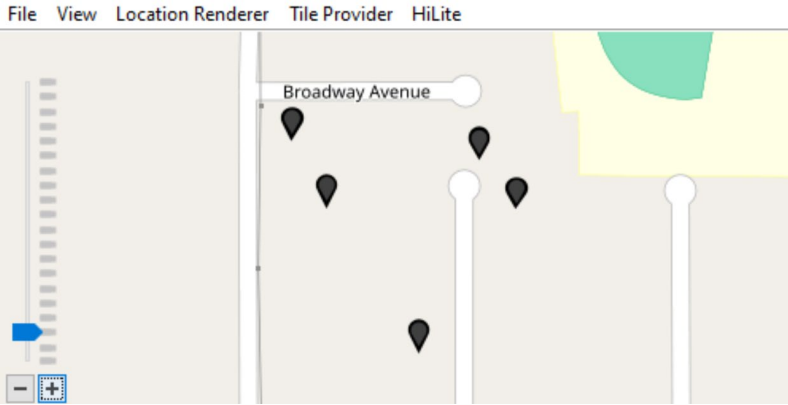


Step 3: Generate Bus Stops

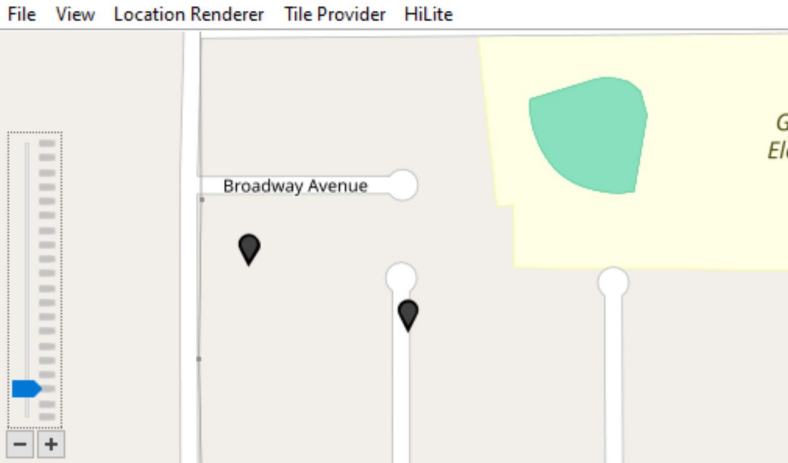
- Use K-means to assign bus stops to students
- Cannot walk more than 200 meters
- Locations verified using satellite imaging
- Cannot crossing highways



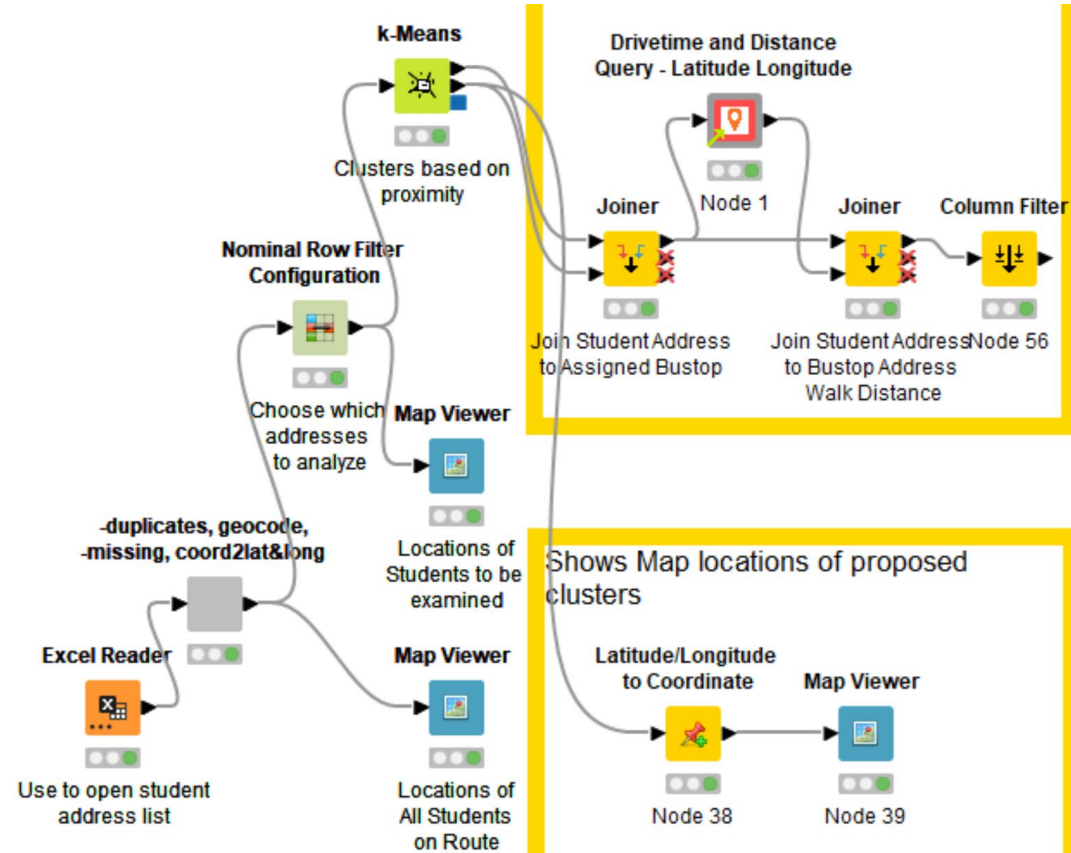
Map view - 9:55 - Map Viewer (Locations of)



Map view - 9:39 - Map Viewer



Generate Bus Stops

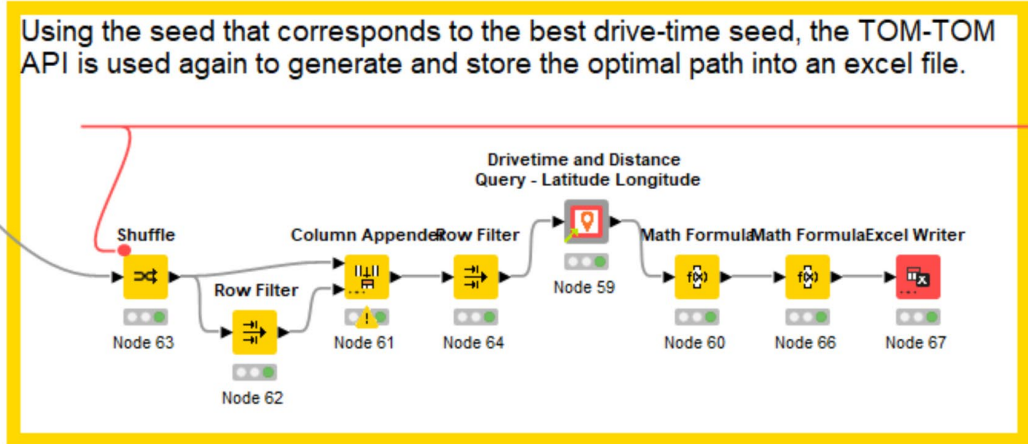
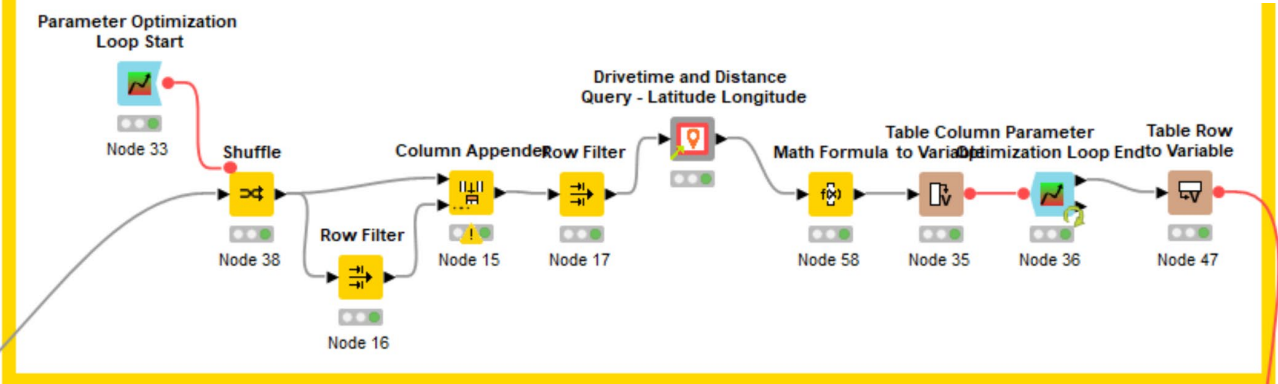
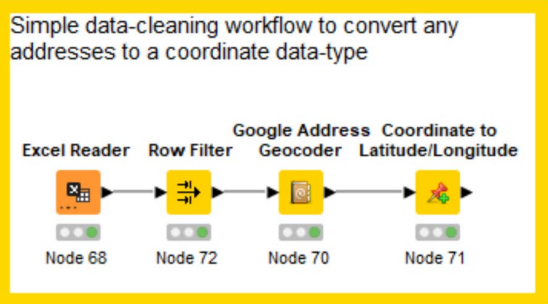
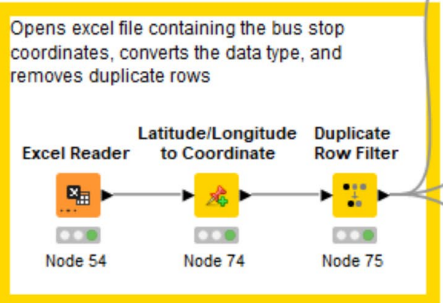
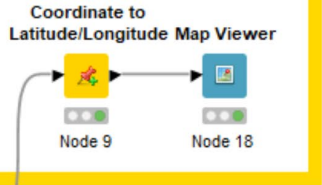


Generate Bus Stops

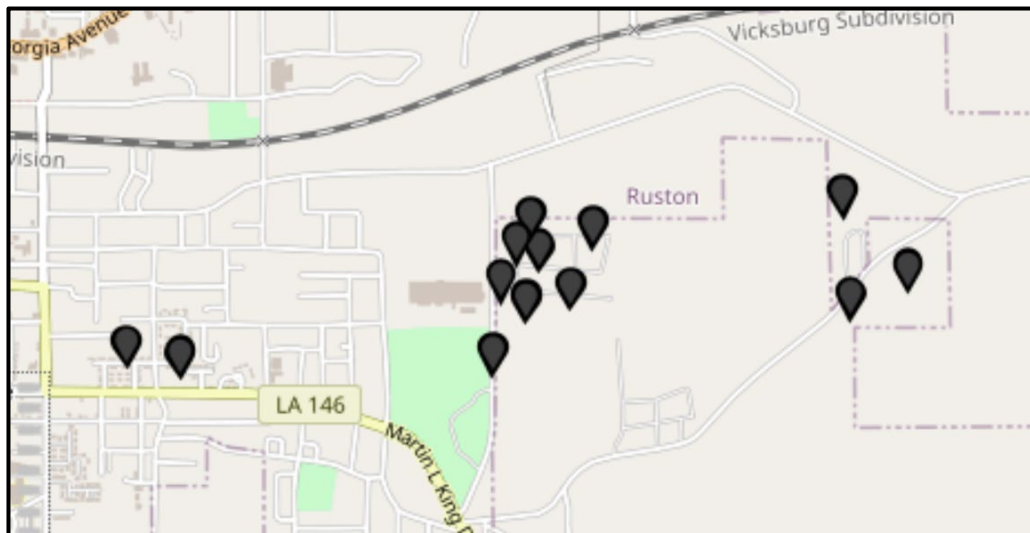
K-Means Clusters are incremented until students walk less than 200 meters to their bustop

S R1 Address ...	D latitude	D longitude	S ▲ Cluster	D latitude (right)	D longitude (right)	I ▲ Distance (Meters)
917 Wedgewood ...	32.552	-92.652	cluster_0	32.552	-92.652	0
924 Pennington L...	32.552	-92.652	cluster_1	32.552	-92.652	0
2302 Cooktown R...	32.554	-92.657	cluster_2	32.554	-92.657	65
1504 W Kentucky...	32.555	-92.658	cluster_2	32.554	-92.657	121
1503 Bonaparte ...	32.554	-92.658	cluster_2	32.554	-92.657	138
1406 W Kentucky...	32.555	-92.656	cluster_2	32.554	-92.657	145
1508 Bonaparte ...	32.554	-92.658	cluster_2	32.554	-92.657	168
1705 Arcadia Dr, ...	32.56	-92.66	cluster_3	32.559	-92.659	2

Step 4: Optimize Routes



Parameter Optimization Route



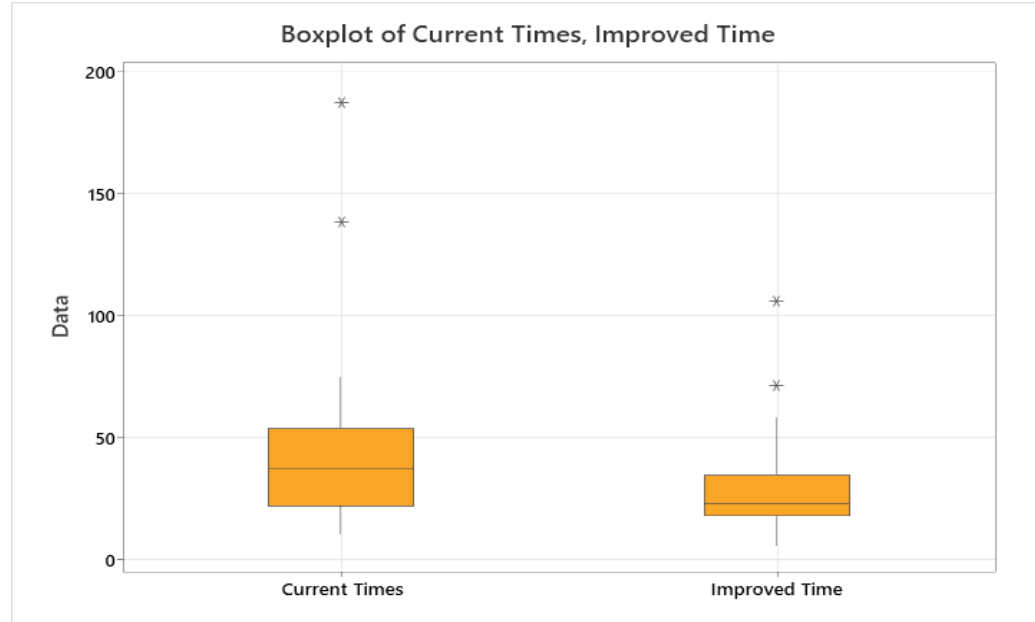
Row ID	I Rando...	D Objecti...
Best parameters	8	35.3

1	49.05
2	38.15
3	38.817
4	35.333
5	40.867
6	42.633
7	42.2
8	35.3
9	36.45
10	45.25
11	44.667
12	41.767
13	41.9
14	44.017
15	40.033
16	36.567
17	39.033
18	39.017
19	38.067
20	45.3

Improved Statistics

Current Mean = 45.9 min.

Improved Mean = 29.6 min.



Statistical Results

Defect: Route time over 30 minutes	
Original Route Model	Optimized Route Model
16 defects for 24 routes	8 defects for 24 routes

Financial Estimate

State	Cost of Diesel per gallon (Source: AAA.com as of 11/1/22)	Total Distance for select routes (mi)	Miles per gallon (Source: U.S. Department of Energy)	Total number of days in a school year	Routes are driven twice a day (drop-off/pick-up)	Total Cost of select routes
Current	4.881	431.0973912	6.2	180	2	\$122,178.56
Improved	4.881	210.86	6.2	180	2	\$59,760.44
					Theoretical Savings	\$62,418.12

How KNIME Impacted My Journey

- Learned to harness a new tool
- Prepared me for my current role at Benteler Steel/Tube as a Process Engineer

How I Use KNIME Now

- Invaluable in our automated, state-of-the-art, seamless pipe steel mill
- Perform rapid ad-hoc data analysis
- Ability to harness large quantities of data from various sources: SQL, PLCs, IMS Gauges, etc

Acknowledgements

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Lincoln Parish School Board

All Bus Barn Employees

Instructor: Dr. Beth Hegab, PhD

