Route Machine: UW Medicine Department of Medicine Courier Services

Final Report: Phase 1
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The goal of this report is to survey the current state of practice of UW Medicine Department of Laboratory Medicine Courier Services in order to evaluate potential software(s) that can be implemented to fill information gaps needed to effectively and efficiently make informed decisions. The report describes the high-level goals and decision scope of the route machine, observations of the current state, evaluation criteria and 'route machine' options.

The information in this report can be used to inform:

(1) What data insights (indicators) might be helpful for strategizing courier routing decisions and communicating information to leadership
(2) Potential improvement strategies and what they might look like in implementation
(3) Suitability of various data collection, visualization, and analytical tools, and off-the-shelf packages

This information provides the UW Department of Laboratory Medicine Courier Services the information needed to select tools(s), and general data insights the 'route machine' for implementation.

The rest of this document is organized as follows:

1. Objectives and decision scope of the 'route machine'
2. Observations of the current routes
3. A list of key-performance indicators
4. Potential strategies for improving routes
5. Recommendations
6. Screenshots of Dashboard Prototypes and WorkWaze

1. Objectives and decision scope of the 'route machine'

During the kick-off meeting, on April 1st, at the start of phase 1, objectives of the UW Department of Laboratory Medicine Courier Services were defined. The following objectives acted as the guiding principles of this project:

1. Minimize expected lead time (from the time the specimens are ready for pick up to the time they are delivered to the lab for testing)
2. Minimize costs by reducing Vehicle Miles Traveled and the extent to which couriers work outside of their maximum shift durations

Furthermore, at this time the Urban Freight Lab gathered the following information on the *ideal* capabilities of the tool including:

- Day-to-day (operational) decision making: Given all of the current capacities (i.e., number of vehicles) can routes be improved through changing order of routes or destinations serviced in route?
- Tactical decision making: What modifications to the current capacities (i.e., increasing the number of vehicles) will produce the greatest benefit? How will the optimal routes change if there are modifications to customer requirements?
- Strategic decision making: If UW Medicine Department of Laboratory Medicine expands its operations how will routes and capacities need to change to accommodate the new situation? What should the workforce balance between full-time workers and contractors look like?

Depending on the decisions made at the conclusion of phase 1, the goals of what decisions this 'route machine' framework will inform will be refined.

2. Observations about the current routes

For this project, we conducted ride alongs on April 18th 2019. The first route we observed was Route 4 from clock-in (stop 1) at 11am to drop off at the lab in NW 220 at approximately 2:00 pm (stop 10). After completing the first loop of Route 4, we caught Route 3 starting at the lab in NW 220 around 3:10 pm (stop 13) and completing back at the lab at approximately 5:00 pm (stop 20).

In addition to observations, during the ride alongs, we asked questions to the drivers regarding typical and atypical starting procedures, en-route (on-call pick-ups, unexpected traffic, etc.), and drop offs to the laboratory. Furthermore, we asked generally some of the challenges that the drivers encountered on the job, and how they problem solve those problems.

This section also highlights quantitative observations from preliminary data analysis. We worked with students to quantitatively summarizes stats about the current routes, and potential improvements to the routes and run case-studies. The description regarding how these strategies might be implemented with additional technologies are discussed in this section where they might impact daily observations.

OBSERVATION 1: ROUTE BUFFERS

Google Maps was used to estimate the number time required to complete each route in order to establish a baseline for comparison purposes. We can see from table 1 below that the route times and distance traveled vary extensively from ~7.85 hours and 404 miles (route 7) to ~1.6 hours and 19.7 miles (route 11). Furthermore, we can see the buffer built into each route varies. The buffer is built in to account for traffic, drop off/pick up dwell times, and other unexpected events, but we believe that if these buffers are standardized across each route, which can be done in a route optimization tool, benefits can be realized through less time/mileage waste, and these risks can be mitigated properly. This also indicates the importance of comparing estimated versus actual durations and miles traveled to make sure model assumptions accurately represent the reality so it can 'optimize' appropriately.

Table 1. Estimated Route Duration for Each of the Identified Routes Google Maps vs. From Route Sheet

Route	Start Time	End Time	Estimated Total Duration (hrs)	From route sheet total duration (hrs)	Buffer in route sheet (hrs)	Buffer as % of total time from route sheet
1	645	1940*	7	13	6	43%
3	830	1700	6	9	3	34%
4	1045	1915	7	9	2	20%
5	1400	2230	5	8	3	36%
6	1045	1545	4	5	1	15%
7	1230	2215	8	10	2	20%
8	1600	2430	6	8	2	27%
9	1800	2300	4	5	1	11%
10	1530	2400	4	9	4	49%
11	1145	1415	2	3	1	40%
			Total	**Total**	**Average**	**Average**
			54	**78**	**2**	**30%**

***It was indicated that this end time is a typo**

Observation 2: Splitting up lower traffic days from higher expected traffic days

One of the drivers indicated that the traffic on I-5 on Thursdays and Fridays are worse than the rest of the week. Which indicated to us, that there might be travel time benefit in testing out the routes and allowing Monday through Wednesday Routes to differ from Thursday and Friday routes in the selected route optimization tool.

Observation 3: Combining southern Routes

There are currently 4 routes serving the southern route customers (route 3, route 4, route 6, and route 8). None of the southern route customers are visited more than twice per day. These routes serve three of the worst areas for highway congestion in the state of Washington must be travelled to serve these customers. These sections are HWY 167 between Auburn and Puyallup, I5 in the downtown Tacoma area and I5 travelling through Joint Base Lewis-McChord between Tacoma and Olympia.

This observation indicates that there might be travel time benefits to consolidate routes and/or adjusting pickup windows and starting/ending times to avoid the worst of the daily traffic congestion. Which was one of the strategies suggested One of the strategies suggested (*see strategy: combining southern routes findings documentation*).

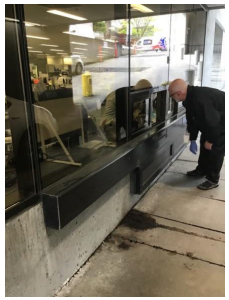
Observation 4: preparation for the day

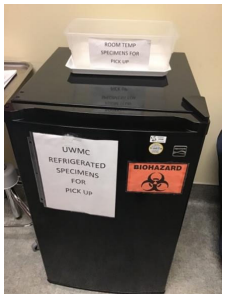
Each day the couriers run the same route, so they tend to know approximately how many frozen and ambient bags they need for the day. The bags are considerably small so there does not seem to be a capacity issue in determining how to pack the cars. The couriers check in to a manual system at their designated starting location.

One of the strategies suggested (*see strategy: realign starting locations findings documentation*) was to realign starting locations to ‘service areas’ closer to the stops that the routes go to. In order to implement this strategy, there would need to be an agreement set up with a service location to store the dry ice. Furthermore, we suggest to set up ‘geo fences’ at these service locations so that couriers can check in from their phones.

Observation 5: Pickups

Pick-ups seem pretty straight forward. There are buckets that specifically say refrigerated, frozen and ambient pickups for UWMC. Often, we observed that when pickups occurred the courier packed the items and simply filled out a paper sheet to record the number of each type of package that was picked up. During the observations, it took approximately 5-10 minutes to finish each pickup. Both of the couriers indicated that very infrequently do the customers ask them to wait to finish packaging of a specimen, but if they do they don't wait more than 10 minutes.





One of the improvements that could be made is to digitalize courier data pickup forms. There is no personably identifiable information (PII) on the forms that the drivers collect and there are many benefits to digitizing the forms. For example, it would allow for collecting of more accurate data, since digitized forms can automatically collect time stamps, locations etc., in real-time. This not only would allow to collect more information to build assumptions into the route machine (with the same time to fill out the form), but it would allow for real-time tracking of items picked up. This is important for unexpected events (car accidents, etc.) to make quick decisions for those events.

In an effort to speed up the process of gathering samples while attempting to reduce the vehicle miles traveled and extending the network of the Lab, one of the strategies suggested was to build in decentralized depots (*see strategy: decentralized depots*

findings documentation), which utilizes existing University of Washington infrastructure in the form of the Neighborhood Clinics. This is done by transforming the neighborhood clinics into individual depots where the drivers will arrive to prepare their vehicles and depart for their and pickups. Once the initial pickups are made, a vehicle will depart from the University of Washington Lab to make a "milk-run" to pick up the samples from every depot. In addition to building in additional infrastructure to store dry ice, if this solution was implemented, it would be imperative to have a real-time dashboard to coordinate milk-runs pickup at a decentralized depot. This would ensure that the courier completing the milk-runs has a full real-time picture of the specimens that need to be picked up to reduce hand-off errors.

Observation 6: On-call pickups

Since these happen so infrequently, it might be beneficial to test routes without these stops built in to evaluate the best routes to add on-call pickups to under different scenarios (heavy traffic, multiple on-call pickups in the same route etc.) Also, it would be helpful to evaluate how frequently each on call pickup occurs. Again, that will allow for better estimation of 'buffers on routes' and allow for greater optimization of the routes.

Observation 7: drop-offs

We observed the couriers going one by one through the courier data collection form to make sure that the lab had a record what items they were receiving. Following completion of route 4, and dropping off the lab specimens, we had to wait for a lab professional to check the courier data collection form and the specimens reconciled. Having the forms digitized, and implementing a barcode system can better align the couriers and lab professionals by informing the lab in real-time the types of and how many items that they can expect coming in, so they can better prepare for the day and make the reconciliation process easier.

3. Key Performance Indicators (KPIs)

As discussed at the kick off meeting on April 1st, the two key objectives for the University of Washington Department of Laboratory Medicine are to provide exceptional customer service, while keeping costs minimal. Based on conversations with University of Washington Department of Laboratory Medicine we learned that the following quantitative metrics could be used to imply costs and exceptional customer service.

Cost indicators

- Total miles traveled (per mile rental car costs)

- Total travel time (salary + overtime)
- Overall costs: Car rental costs + salary + overtime + per mile costs

Customer Service indicators

- Percent of drop offs that arrive to the lab on time
- Percent of pickup within time window specified to customer
- Average lead time
- Max lead time
- Number of customer complaints

As you can see on the strategy dashboard and operational monitoring dashboard, these indicators can be broken down by route, month, and customer to help identify current areas for improvement and strengths, and evaluate different strategies against each other.

4. Potential strategies for improving routes

One of the benefits to a 'route optimization' approach is the mathematical model and input parameters can be easily modified to test tactical and strategic strategies for improving routes. Tactical strategies (the means to meet an objective) can be simulated by modifying any of the input parameters in the base model, which are listed below. Strategic strategies (the overall operational pattern) can be simulated through small modifications to the base model, that represent procedural changes of how the system is set up.

List of potential Strategies: Tactical

- Modify pickup windows
  - Modify all pickup windows to 15, 30, 45-minute ranges around expected pickup time
  - Modify pickup windows range and/or expected arrival time depending on specific characteristics (i.e., specific customers)
- Modify number of vehicles
- Modify allowed route times (a longer allowed route time, is at higher risk for unexpected overtime and longer lead times)
- Add/remove stops from routes
- Modify employee schedules to start earlier or later
- Modify start and end times of routes to avoid traffic
- *Consolidate/break apart routes**
  - *see strategy: combining southern routes findings documentation*

List of potential Strategies: Strategic

- Decentralize depots*
  - *see strategy: decentralized depots findings documentation*
- Realign route start locations*
  - *see strategy: realign starting locations findings documentation*
- Implementing drone delivery*
  - *see strategy: implementing drone deliveries findings documentation**
- Modify Workforce Structure (# of 40-hour vs. 20-hour week positions)

*these strategies were evaluated against key performance indicators. See documentation.

5. Recommendations

Summary of recommended products to develop in phase II

1. **Build Route Machine Optimization Framework:**
   - Generates routes
   - Generate sensitivity analysis indicators (adding a car, adding/removing a stop, modifying time windows etc.)

2. **Digitize courier data collection forms:**
   - Build forms

3. **Three-tableau dashboard visualizations:**
   - Route optimization real-time monitoring Dashboard
   - Operational Monitoring Dashboard
   - Strategy Dashboard

4. **Data integration:**
   - Create connections from various data sources (data collection forms, route machine, employee schedules, etc.) needed to build out dashboards

5. **White Papers:**
   - Description of how to interpret indicators, underlying assumptions, and explanation of the route machine framework
   - How to modify route machine framework
   - Data integration including data structures, where the data is stored etc.

1. Route Machine Framework Recommendation

A. Off-the-shelf Recommendation: WorkWave

Capabilities

- Built in Dashboard for route optimization (cost) outputs
- Will have built in Dashboard Actual performance compared to estimated (cost and actual time) outputs – although it will be limited (still recommend pulling this information into Tableau)
- You can call them for assistance at any time (they are very easy to reach and answer questions well)
- Can assign 'traffic' speeds to a given area at a given time
- Can assign vehicles to area (for electric cars to not leave area)
- Can create geo-fences that automatically ping when a driver enters/leaves a hospital area (for calculating dwell times)
- Can assign 'importance' to each stop
- Can be programmed to go back to the same area multiple times per day
- Can manually move stops if they need to be in a certain order
- Will have scanner capabilities in the upcoming months (if buy full-app $65)
- Driver app can take notes and pictures at each stop
- Driver can skip stops (for on-calls) and it will still record properly

Limitations

- Does not account for lead times (other than what is specified in time windows)
- Does not provide automatic sensitivity analysis for tactical and strategic decisions – but does provide the information needed to generate the information it just *might* need to be done manually
- Must rerun routes each month, but route specifications can be pre-specified so will only take a few minutes

Cost Range

https://www.workwave.com/route-manager/pricing/

- $69/driver/month otherwise (no setup costs if completed by end of June, otherwise $300)
- $49/driver/month without recording arrival and departure or GPS (no GPS via smartphone)

Other off-the-shelf software evaluated and reasons they were not the off-the shelf recommendation

- Optimo route
  - Clunky interface
  - Does not allow to go back to the same place twice in one day
  - Difficult to pull data (limited API abilities)

- RouteXL
  - Clunky interface
  - Does not support multiple returns to depot
  - Difficult to pull data (limited API abilities)

- OnTime 360
  - Clunky interface
  - Does not support multiple returns to depot

- cxtSoftware:
  - Minimum cost $15,564 per year + $4056 set up costs ($19,620 first year) + additional API costs (to automatically update to Tableau)

- Route4Me
  - Called twice and did not return calls
  - Does not seem to provide much benefit over free solution, I would still need to set up a few things to modify the model accordingly)
  - No additional customer service after set up

- Routific
  - Does not provide much benefit over free solution, I would still need to set up a few things to modify the model accordingly)
  - I found the software 'difficult to work with'
  - No additional customer service after set up

B. Handcrafted recommendation: Build Route Machine in Python (with pre-made vehicle routing scripts from Google ORTools) and use GoogleMaps API to pull traffic and routing data

Capabilities

- Completely customizable specify what goes into the optimization model and automatically generated outputs to automatically generate information into tableau dashboards

- Can account for lead times and provide risk analysis for not getting to depot 'on time'
- Can assign 'traffic' speeds to a given area at a given time
- Can assign vehicles to area (for electric cars to not leave area)
- Can assign 'importance' to each stop
- Can be programmed to go back to the same area multiple times per day
- Can manually move stops if they need to be in a certain order
- Can be programmed to run as frequently as desired

Limitations

- Would require ~ 3 months to build model
- Would need to build all dashboards separately
- OR tools, since it is free open source software does not provide any customer service

Cost Range

- There is no subscription fee for these services

2. Digitalize Courier data collection forms

Recommendation: Zoho Forms

Capabilities

- **Ease of creating and modifying:** It is very intuitive to create and modify the forms
- **Flexibility:** Can integrate barcode & QR scanning if you decide to build in this capability, there is a team that can help you set this up in the future.
- **Display:** The display is very clean and there are many options for building the display to make it as easy as possible for the user. My favorite feature is that you can drag and drop contacts, locations from maps, which will make it very easy for the user to use.
- Forms are **automatically uploaded** to google sheets. This information can be downloaded to excel and through APIs to the server (so it can easily be used to update dashboards) as well provide you information to your phone as desired.
- Can geocode addresses (if you want to have people check in from multiple locations)

Limitations

- Does not track phones in real-time (like Bluetooth)

- Cannot use if there is no data connectivity **I need to double check this

Cost Range

- $40/month if billed annually or $50/month if billed monthly for up to 25 users
- $99/month for up to 100 users

Other forms evaluated and reasons they were not the form recommendation

- Jot Forms
  - $50 per user per month – more expensive with the same capabilities as Zoho Forms, but is HIPPA approved)
- Zoho Creator
  - More than needed
- Google Forms
  - Clunky interface, I don't think the drivers would actually use this
- GoFormz
  - $50 per user per month – more expensive with the same capabilities as Zoho Forms – limited API access so would be difficult to integrate with Tableau or other dashboards)
- CamCode:
  - Limited $10,000 set up per year, is a very robust system and more than you need. Would require additional system set up.

3. Dashboard recommendations

Both deliverable options build in these dashboards

1. **Real-Time Tracking Dashboard:** Depending on the data collection technologies implemented this dashboard might be able to provide limited real-time tracking

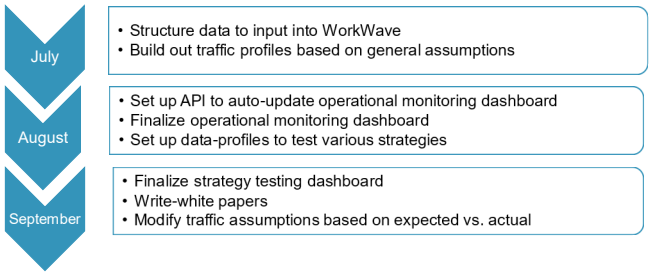
2. **Operational Monitoring Dashboard (see Operational Monitoring Prototype):** This dashboard will compare data collected from the specimen forms filled out by the couriers on their route to the expected outputs from the optimization outputs.

3. **Strategy Dashboard (see Strategy Prototype):** This dashboard present information regarding how various strategic and tactical decisions might improve your indicators. This dashboard will highlight key takeaways from the route optimization, including expected vehicle miles traveled, lead times, and expected travel time per route. It will provide information on the tradeoffs for putting more weight on minimizing costs or on minimizing lead times to allow the decision maker to modify the model as needed. This dashboard will require working to

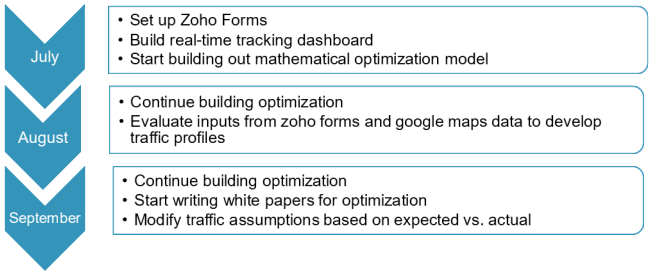
narrow down potential tactical and strategic decisions that the dashboard might inform.

4. Cost and timeline to develop Deliverables

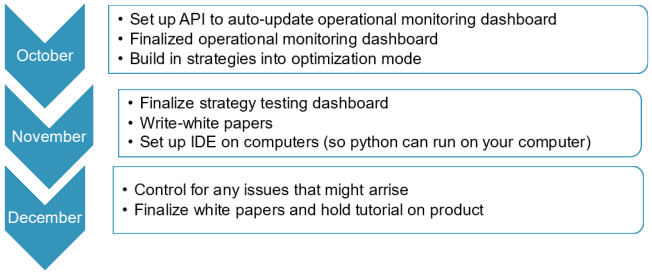
- **Recommendation 1 - Built with off-the-shelf (WorkWaze):** Finish this summer ($30,000) + WorkWaze Product Costs



- **Reccomendation 2 - Build from scratch:** Two quarters ($60,000) + ZohoForms Product Cost



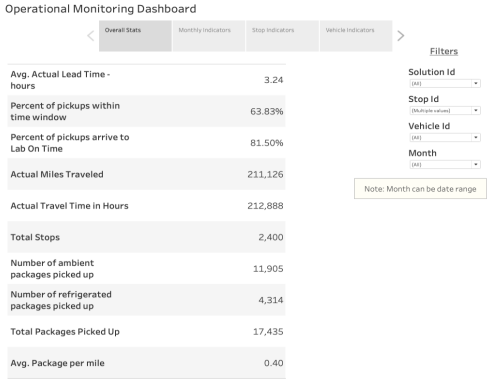
Reccomendation 2 - Build from scratch (continued): Two quarters ($60,000) + ZohoForms Product Cost

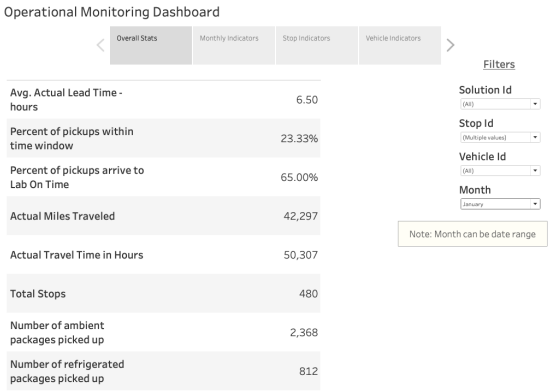


6. Screen Shots of Dashboard Prototypes

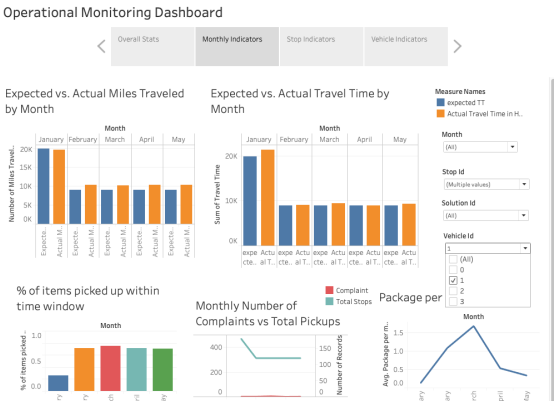
OPERATIONAL MONITORING DASHBOARD

Overall Stats

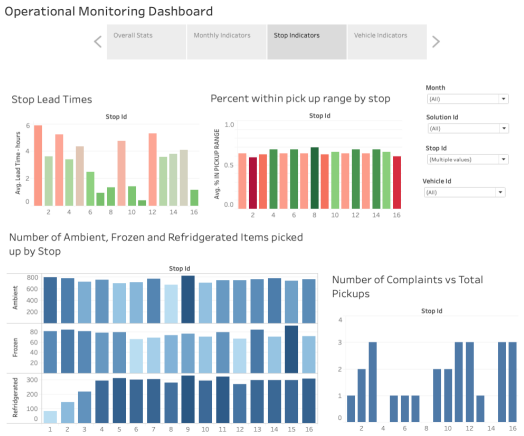




Monthly Indicators



Stop by Stop


Operational Monitoring Dashboard
Overall Stats
Monthly Indicators
Stop Indicators
Vehicle Indicators
Stop Lead Times
Stop Id
Avg. Lead Time - hours
Percent within pick up range by stop
Stop Id
Avg. % IN PICKUP RANGE
Month
(All)
Solution Id
(All)
Stop Id
(Multiple values)
Vehicle Id
(All)
Number of Ambient, Frozen and Refridgerated Items picked up by Stop
Stop Id
Ambient
Frozen
Refridgerated
Number of Complaints vs Total Pickups
Stop Id

Vehicle Indicators

Vehicle Data

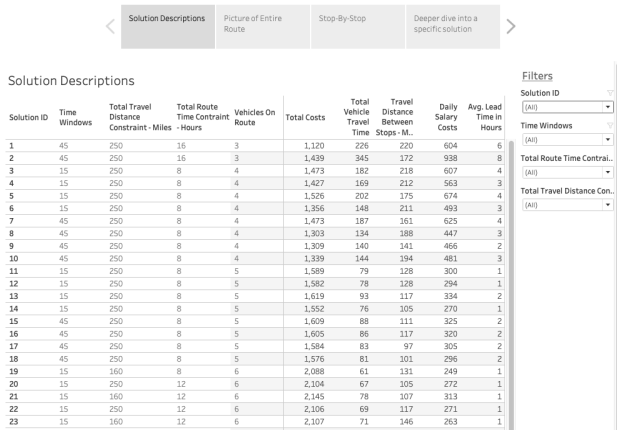
Vehicle Id	Pickups within window	Total Stops	Percent of pickups within time window	Avg. Actual Lead Time - hours	Actual Miles Traveled	Actual Travel Time in Hours
0	389	630	62%	3	58,425	62,439
1	393	660	60%	4	60,673	58,022
2	386	630	61%	3	51,662	53,695
3	364	480	76%	2	40,365	38,732

Operational Monitoring Dashboard

STRATEGY DASHBOARD

Solution Descriptions and High-Level Stats

Tactical Decisions - What happens to solution outputs when you modify:
- Time windows?
- Number of vehicles?
- Total distance each vehicle is allowed to travel?
- Total time each route is allowed to travel?



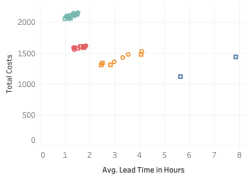
Solutions Compared by Indicators

Tactical Decisions - What happens to solution outputs when you modify:
- Time windows?
- Number of vehicles?
- Total distance each vehicle is allowed to travel?
- Total time each route is allowed to travel?

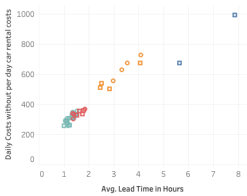
Assumptions:
Per Vehicle Rental Costs Per Day = $25
Per Mile Costs = .3
Courier Salary = $20/hour

Solution Descriptions | Solutions Compared by Indicators | Stop-By-Stop | Deeper dive into a specific solution

Avg Lead Time vs. Total Fixed and Variable Daily Cost (per vehicle rental and milage costs + courier salary)



Avg Lead Time vs. Variable Daily Cost (milage costs + courier salary)



Time Windows
15
45

Vehicles On Route
3
4
5
6

Filters

Solution ID
All

Number of Vehicles On Ro..
All

Time Windows
All

Total Route Time Contrai..
All

Total Travel Distance Con..
All

All Solution Indicators

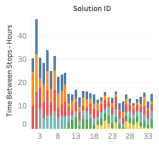
Solution ID	Avg. Lead Time in Hours	Max. Route Travel Time	Total Costs	Travel Distance Between Stops - Miles
1	6	15	1,120	220
2	8	16	1,439	172
3	4	9	1,473	218
4	3	9	1,427	212
5	4	11	1,526	175
6	3	8	1,356	211
7	4	9	1,473	161
8	3	7	1,303	188
9	2	7	1,309	141
10	3	8	1,339	194
11	1	4	1,589	128
12	1	4	1,582	128
13	2	5	1,619	117

Stop by Stop Outputs

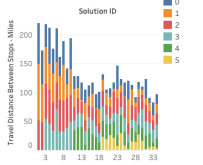
Tactical Decisions - What happens to solution outputs when you modify:
- Time windows?
- Number of vehicles?
- Total distance each vehicle is allowed to travel?
- Total time each route is allowed to travel?

Filters

Total Time Per Day per Vehicle



Total Distance Per Route



Vehicle ID
0
1
2
3
4
5

Solution ID
All

Time Windows
All

Vehicles On Route
All

Total Travel Distance Constraint - Miles
All

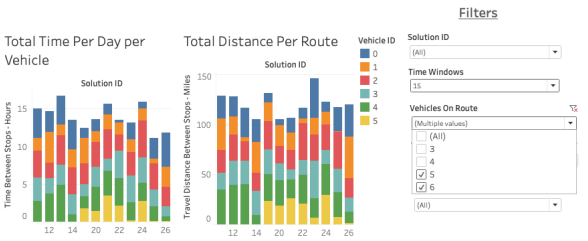
Total Route Time Contraint - Hours
All

Route outputs

Solution ID	Vehicle ID	Stop On Route	Center Name	Pick up range: start	Pick up range: end	
1	0	0	NW 220	08:00	08:00	5.80
		1	BloodWorks NW	08:28	09:13	4.96
		2	Billing Group	09:30	10:15	3.92
		3	Arlington MFM Clinic	09:40	10:25	3.75
		4	Blue Pearl Vet Partners R..	12:12	12:57	1.21
		5	Capital Medical Center	12:14	12:59	0.19
		6	NW 220	12:25	13:10	0.00
	1	0	NW 220	08:00	08:00	14.52
		1	Blue Pearl Vet Partners S..	08:55	09:40	13.21
		2	CHMC	09:19	10:04	12.82
		3	Cellnetix Labs	11:26	12:11	10.71
		4	Digestive Health	15:11	15:56	6.95
		5	Dynacare	16:07	16:52	6.01
		6	Drs Kent Ta/Dr Dadda	18:40	19:25	3.46

- Total time each route is allowed to travel

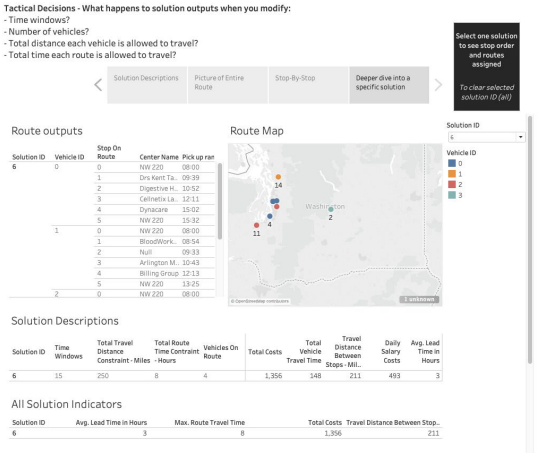
Solution Descriptions | Picture of Entire Route | Stop-By-Stop | Deeper dive into a specific solution



Route outputs

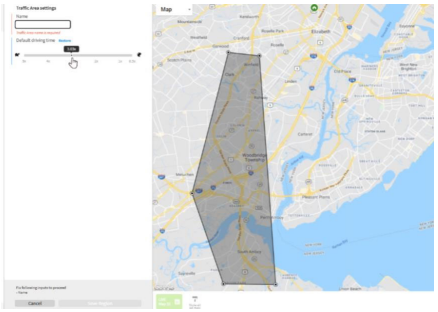
Solution ID	Vehicle ID	Stop On Route	Canter Name	Pick up range: start	Pick up range: end	
11	0	0	NW 220	08:00	08:00	3.914
		1	Drs Kent Ta/Dr Dadda	09:21	09:36	2.423

Deeper Dive into a Specific Solution

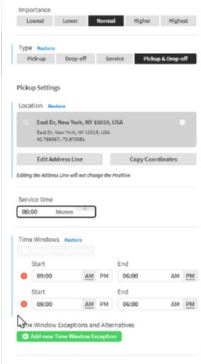


WorkWave demo Screen shots

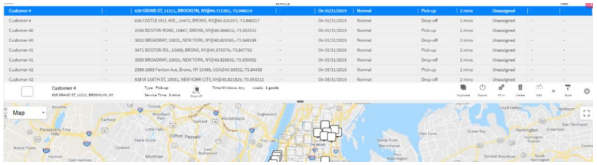
Adjusting traffic settings



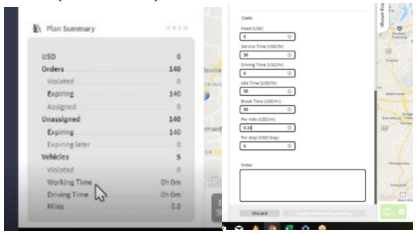
Adjusting stop settings (can do from sheet)



Stops that don't fit into routes



Cost inputs and outputs



Route Outputs