1.1 Problem Statement

Develop a system that will enable different classes of users to participate in route assignments for delivery trucks. The fundamental algorithm question we are trying to solve is how to assign a truck from a given fleet to a new request, or how to re-assign truck(s) to respond to dynamic changes in traffic and requests. The rest of the tasks will involve implementing the algorithmic solutions, the user interface, and integrating map data with request data to generate routes.

1.2 Requirements & Constraints

In the system, there will be a set of trucks and delivery requests that base all of our constraints. Each truck will have an initial location, delivery location, goods being transported, capacity of the truck, and current load. Then, the system must generate the optimal route for each truck. Based on the route, the user must be able to estimate the location of the truck at any time, and know its remaining distance to a delivery location. The route must be able to update to any new pickup location and delivery requests **(constraint).** It also needs to update if any truck breaks down on route at any given time **(constraint).** Based on these two constraints, dynamic updates will be made to reassign the rest of the trucks from a given fleet. These dynamic updates must be made in less than a minute response time **(constraint).** The user interface will consist of a dispatcher web application and a mobile application for the drivers of each truck. Notifications will be sent to both the drivers and dispatchers when given a new route or customer updates for delayed deliveries. The system will also be efficient, and must minimize route time for dynamic updates, idle time of a truck, and initial assignments **(constraint).** This project assumes we have access to road network maps and other traffic information; we will rely on this data and it is necessary to assign trucks **(constraint)**.

- Set of trucks and delivery requests
- For each truck
    - Initial location
    - Delivery location (target)
    - Goods being transported
    - Capacity of the truck (weight of goods that can be carried)
    - Load (amount of goods being carried/transported on the truck)
- Generate route for each truck
- Based on the route: Estimate the location of truck at any given point of time
- Cater to the dynamic updates:
    - New pickup/delivery request
    - Broken truck at any given time
- Reassign the rest of the trucks from the fleet as a result of the dynamic updates
- UI requirements
    - Dispatcher (Desktop) UI
    - Mobile app for drivers of trucks

    - Intuitive for both
- Notifications to both drivers and dispatchers
    - New route
    - Customer updates if a delivery is delayed
- Constraints
    - Response time (Seconds to a minute of response time for dynamic updates)
    - Assuming the availability of road network maps and other traffic distribution data (traffic density) -> Needed for any assignment (both initial and dynamic)
    - Economics:
        - Minimize delivery delay as a result of a dynamic update
        - Minimize idle time of trucks
    - Resource requirements
        - Need a server to be running constantly to host the database and requests as well as running the assignment algorithm
        - Android mobile device
        - Visualization tools/frameworks

1.3 Engineering Standards

What Engineering standards are likely to apply to your project? Some standards might be built into your requirements (Use 802.11 ac wifi standard) and many others might fall out of design. For each standard listed, also provide a brief justification.

For software development:

- Scrum methodology
    - https://scrumguides.org/scrum-guide.html
    - https://www.scrum.org/resources/professional-scrum-developer-glossary
- IEEE 610.12, Standard Glossary of Software Engineering Terminology
- IEEE 1540: Software Risk Management

For software testing:

- IEEE 1012: A standard for Software Verification and Validation.
- IEEE 1061: A methodology for establishing quality requirements
- IEEE 1008: Unit testing standard

For working with coordinate systems:

- GPS Coordinates will use the UTM or WGS84 format for representing geolocated points
- Mercator projection and Map matching have no agreed-upon standards, so we will follow conventional projection formulas

1.4 Intended Users and Uses

Who benefits from the results of your project? Who cares that it exists? How will they use it? Enumerating as many “use cases” as possible also helps you make sure that your requirements are complete (each use case may give rise to its own set of requirements).

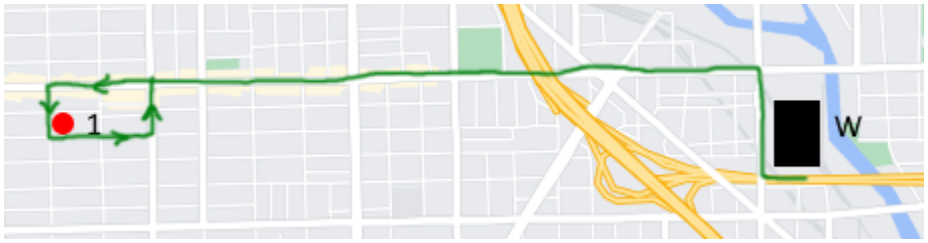
The primary beneficiaries of our project are customers, truck dispatchers, and truck drivers. While not directly used by the customers, the project will have the general impact of ensuring timely deliveries. The project will be more directly used by dispatchers as it will aid them in deciding initial routes for trucks as well as making decisions and adjustments in the case of changing circumstances (traffic, new orders, truck breakdowns, etc.). This will benefit the dispatcher by reducing the stress of unpredictable circumstances and having to make quick decisions. Lastly, the project will be used by truck drivers to receive their assignments and any changes that occur throughout the day due to traffic, new orders, breakdowns, etc. This will benefit truck drivers by reducing the amount of time they spend making deliveries by optimizing routes, reducing waiting times for updated assignments, and minimizing the amount of time spent making deliveries.

POTENTIAL APPLICATION USE CASES

1. BASE USE CASE

   The base use case is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, the order route is between the cargo origin point and a single destination point (in comparison to multiple destination points) and external factors such as traffic, vehicle malfunction are not present.

   A customer's input order is allocated to a dispatcher via the allocation algorithm and the dispatcher then relays the order to a truck driver. Communication between the dispatcher and the truck driver is facilitated by the web and mobile platforms communication/notification system. The truck driver's route from the order origin pick up point to the destination point will be determined by the routing algorithm. Post order delivery to destination, the truck driver notifies the dispatcher, who subsequently notifies the customer that the order has been successfully delivered to the destination point, as per the customer's order input.

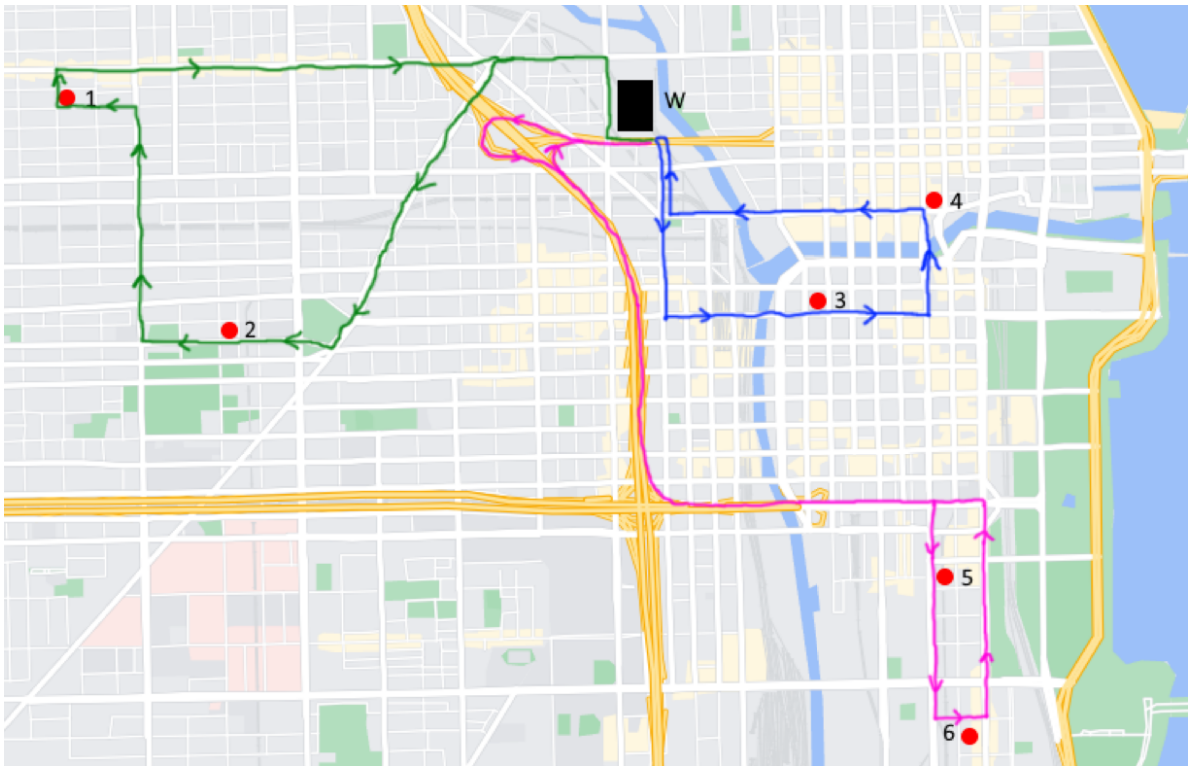


Given warehouse W and order 1, the algorithm will generate the depicted route and present it to the dispatcher. The dispatcher will then inform the truck driver of the order and the route to be taken through the web application. The truck driver will receive this information through the mobile application.

2. MULTIPLE DESTINATION USE CASE

The multiple destination use case is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, the order route is between the cargo origin point and multiple destination points and external factors such as traffic, vehicle malfunction are not present.

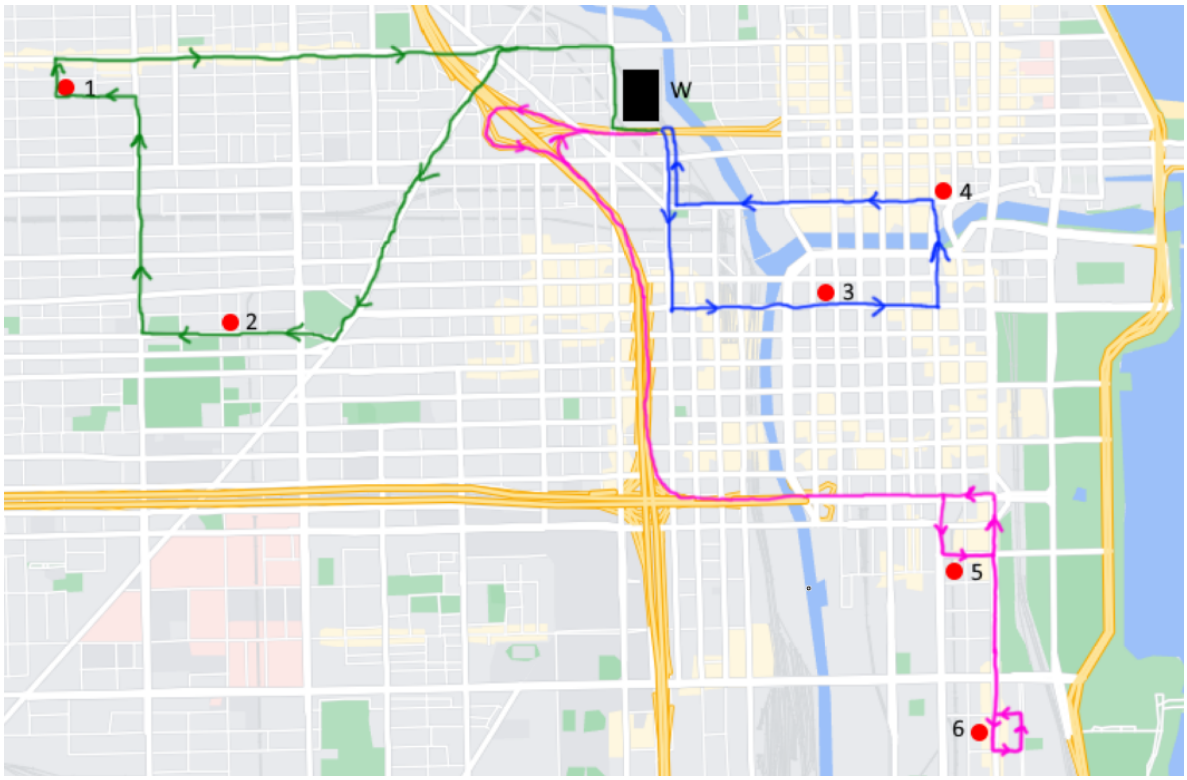
A customer's input order is allocated to a dispatcher via the allocation algorithm and the dispatcher then relays the order to a truck driver. Communication between the dispatcher and the truck driver is facilitated by the web and mobile platforms communication/notification service. The truck driver's route from the warehouse to each of the delivery locations will be determined by the routing algorithm. Post order delivery to the final destination point, the truck driver notifies the dispatcher, which subsequently notifies the customer that the order has been successfully delivered to the destination point, as per the customer's order input.



Given warehouse W, orders 1, 2, 3, 4, 5, and 6 at the locations depicted, and three trucks, the algorithm would output three routes, green, blue, and pink, given the proximity of the orders, expected delivery times, and load balancing. Each of the three trucks would be assigned to one of the routes for the day, starting and ending at the warehouse.

3. ROUTE REALLOCATION USE CASE

The route reallocation use case is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, the order route is between the cargo origin point and destination points and external route blocking or route inefficiency factors such as traffic, road construction, route obstacles are present.



This example is similar to the example presented in the previous use case. However, upon delivering order 5, a backup is reported along the initial planned route to deliver order 6. The route allocation algorithm recalculates the route to ensure timely delivery of the customer's order and reduce the amount of time spent delivering orders for the truck driver. This recalculated route will be given to the dispatcher who will inform the truck driver through the web application and the truck driver will receive the updated route in the mobile app.

4. TRUCK REALLOCATION USE CASE 1

   The truck reallocation use case 1 is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, a route has been allocated between specific cargo origin point and destination points, the truck has already picked up the customers cargo and external truck related inefficiency factors such as vehicle malfunction, flat tire or even driver related factors such as ill-health are present.

   A customer's input order is allocated to a dispatcher via the allocation algorithm and the dispatcher then relays the order to a truck driver. Communication between the dispatcher and the truck driver is facilitated by the web and mobile platforms communication/notification system. The truck driver's route from the warehouse to each of the delivery locations will be determined by the routing algorithm. External factors such as the truck breaking down on a route may occur. The broken down truck driver will communicate to the dispatcher via the application's communication service. The truck allocation algorithm will then assign other truck(s) to the deliveries of the broken down truck. But, the newly allocated trucks' routes' destination point will be the location of the broken down truck. After receiving the cargo from the broken down truck, the newly assigned truck(s) will have the additional customer order destinations included in its new route calculated via the route allocation algorithm. Post order delivery to the final destination point, the truck driver notifies the dispatcher, which subsequently notifies the customer that the order has been successfully delivered to the destination point, as per the customer's order input.

5. TRUCK REALLOCATION USE CASE 2

   The truck reallocation use case 2 is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, a route has been allocated between specific cargo origin points and destination points, the truck has not yet picked up the customers cargo and external truck related inefficiency factors such as vehicle malfunction, flat tire or even driver related factors such as ill-health are present.

   A customer's input order is allocated to a dispatcher via the allocation algorithm and the dispatcher then relays the order to a truck driver. Communication between the dispatcher and the truck driver is facilitated by the web and mobile platforms communication/notification service. The truck driver's route from the warehouse to each of the delivery locations will be determined by the routing algorithm. External factors such as the truck breaking down prior to leaving the warehouse may occur. The broken down truck driver will communicate to the dispatcher via the application's communication service. The truck allocation algorithm will then assign other truck(s) to the deliveries of the broken down truck. As the broken down truck has not picked up the customer's order cargo yet, the newly allocated truck will directly be assigned the route to the customer order pick up point, instead of the broken down truck location. However, if all trucks are currently in use, the deliveries for the broken down truck will be reassigned and spread

amongst the functional trucks. Post order delivery to the final destination point, the truck driver notifies the dispatcher, which subsequently notifies the customer that the order has been successfully delivered to the destination point, as per the customer's order input.

6. NEW ORDER USE CASE

   The new order use case is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, there are no operational trucks sitting idle at the warehouse and external truck related inefficiency factors such as vehicle malfunction, flat tire or even driver related factors such as ill-health are present.

   A customer's input order is allocated to a dispatcher via the allocation algorithm and the dispatcher then relays the order to a truck driver. Communication between the dispatcher and the truck driver is facilitated by the web and mobile platforms communication/notification system. A customer places a new order after all trucks have left the warehouse and needs the order delivered today. The algorithm will analyze truck locations, traffic, estimated delivery times, and re-routing cost among other factors to determine which truck to allocate the new order to. Once the order has been allocated to a truck and at what point the truck should pick up the new order from the warehouse, the dispatcher will communicate the updated route information with the selected truck driver through the application. The truck driver will follow the updated route and pick up and deliver the new order at the specified points on the new route. Post order delivery to the final destination point, the truck driver notifies the dispatcher, which subsequently notifies the customer that the order has been successfully delivered to the destination point, as per the customer's order input.

7. CUSTOMER ORDER CANCELLATION USE CASE 1

   The customer order cancellation use case 1 is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, there are operational and active trucks available for delivery services, the customer places multiple orders and cancels an order from a set of orders before the order cargo has left the cargo origin point. External factors such as traffic, vehicle malfunction are not present.

   A customer places multiple orders, which are allocated to different dispatchers via the truck allocation algorithm, and the dispatchers then relay the order to truck drivers. Communication between a dispatcher and a truck driver is facilitated by the web and mobile platforms communication/notification system. A customer cancels an order from a set of multiple orders. If the truck is at the cargo origin point, but has not picked up the cargo before order cancellation, the truck driver is free to leave the cargo pickup point as the order has been cancelled. The customer’s order cancellation notification will be forwarded to the dispatcher, who will then relay the cancelation information to the truck

driver. As the truck is now available, it will be put back into the allocation pool, and be assigned to a new cargo order via the truck allocation algorithm.

8. CUSTOMER ORDER CANCELLATION USE CASE 2

The new order use case is formulated on the assumptions that all 3 actors (Truck drivers, Truck dispatchers and customers) are involved, there are operational and active trucks available for delivery services, the customer places multiple orders and cancels an order from a set of orders after the order cargo has been picked up at the cargo origin point. External factors such as traffic, vehicle malfunction are not present.

A customer places multiple orders, which are allocated to different dispatchers via the truck allocation algorithm, and the dispatchers then relay the order to truck drivers. Communication between a dispatcher and a truck driver is facilitated by the web and mobile platforms communication/notification system. A customer cancels an order from a set of multiple orders. If the truck has already picked up the order cargo from the cargo origin point and is actively following the route to the destination point, the driver is notified via the communication service by the dispatcher of order cancellation. The truck is to be put back into the allocation pool, and be assigned to a new cargo order via the truck allocation algorithm. The cancelled order’s cargo is returned via the backlog service, wherein the cancelled orders details including routing and customer information are persisted, so the routing algorithm can calculate a path to the cancelled order’s cargo origin point, for the cancelled orders cargo to be returned. Post order delivery to the cargo origin point, the truck driver notifies the dispatcher, which subsequently notifies the customer that the order has been successfully delivered to the cargo origin point, as per the customer's order input.