3 Design

Core problem:
Narrow the scope of the problem.
Specific disturbance: Truck breaks and that is it.
Subcases:

1. Find the closest truck that can be re-routed ()
2. Find the set of closest trucks that can take care of the load that the truck has

Set of orders and trucks w/ given capacity. Send the trucks out. Truck 1 can deliver half the load of store A and B, starting at warehouse 1. Somewhere along the route Truck 10 breaks down. Ideally we want to pick up the load from truck 10 and distribute the load amongst other trucks. Need to firstly find the closest truck to the broken down truck. Then I need to see the load of all the closest trucks in a specific set and see what load they can unload from the broken truck.

3.1 Design Context

3.1.1 Broader Context (Joshua Heroldt)

Describe the broader context in which your design problem is situated. What communities are you designing for? What communities are affected by your design? What societal needs does your project address?

The broader context is situated in the domain of transportation and delivery. Specifically, we consider a fleet of delivery trucks, a set of orders for goods from stores with given locations and a set of warehouses where those goods are stored and loaded into the trucks. Given an information about a road network (map) with corresponding distances/travel times and the capacity of load for each truck in the fleet the objective of the work is A. utilize some of the existing techniques for assignments of trucks to destination B. Develop novel solutions to the problem of having one of the trucks break down(re-distributing its load) C. Implement an interactive system that can manage users and assignments.

List relevant considerations related to your project in each of the following areas:

Area	**Description**	**Project Relevance**

Public health, safety, and welfare	How does your project affect the general well-being of various stakeholder groups? These groups may be direct users or may be indirectly affected (e.g., solution is implemented in their communities)	Tries to optimize the efficient delivery of goods(welfare). However, the findings can be indirectly used in public health for routing ambulances. Additionally with efficiently routing trucks we can lessen the probability of trucks coming into contact with pedestrians so public safety will increase.
Global, cultural, and social	How well does your project reflect the values, practices, and aims of the cultural groups it affects? Groups may include but are not limited to specific communities, nations, professions, workplaces, and ethnic cultures.	Our project is not affected by any specific societal context such as nationality, ethnicity and so on. However, it does reflect an impact on the efficiency of transportation and delivery.
Environmental	What environmental impact might your project have? This can include indirect effects, such as deforestation or unsustainable practices related to materials manufacture or procurement.	Minimizing fuel consumption and the emission of a fleet of trucks. This will allow for less greenhouse gases overall to be released companywide for whoever utilizes our product.
Economic	What economic impact might your project have? This can include the financial viability of your product within your team or company, cost to consumers, or broader economic effects on communities, markets, nations, and other groups.	System implementation will be deployable either on standard desktop with minimum installation overhead or on popular mobile devices (e.g., android). This product will allow any company that uses it to optimize costs of delivery and balance it with reassignment of deliveries.

3.1.2 User Needs (Joshua Heroldt)

List each of your user groups. For each user group, list a needs statement in the form of:

User group needs (a way to) do something (i.e., a task to accomplish, a practice to implement, a way to be) because some insight or detail about the user group.

- Each customer needs to be able to access the menu where he/she can place the requested products because they want to get products delivered and restocked as soon as possible.
- Each warehouse needs to be able to summarize all the requests from the customers, check the availability of the products in the local facility, and determine the assignment of trucks to delivery locations so that they can keep track of and be on top of orders that are coming in from customers.
- Each driver needs to be able to log in and see the assigned route and notify the completion of a delivery at a particular time and location(products and quantities) to the warehouse that it was assigned from because they want to be able to work as efficiently and safety as possible.

3.1.3 Prior Work/Solutions (Bernie Fay)

Include relevant background/literature review for the project

The VRP has been written about a lot. Broad nature or specific characteristics of the problem. Previous research includes that done by Nasser A. El-Sherbeny [1], Wang, et. al. [2], and Cappanera, Requejo, and Scuttelà [3].

In his research, El-Sherbeny focused on the various exact methods, heuristics, and metaheuristics that can be used to solve a VRP with time windows (VRPTW). While he investigates a large variety of methods for finding an optimal solution to a VRPTW, the methods are approached from a theoretical perspective rather than a practical one. As a result, the true optimality of the methods presented may not be accurate when transitioned to a real-world application.

In their research, Wang, et. al. expand upon the VRPTW problem by including simultaneous delivery and pickup and optimizing their solution based on a 5 part multiobjective function (MO-VRPSDPTW). The two methods they focus on are local search and a memetic algorithm. While the research comes from a theoretical perspective, they openly acknowledge that the optimality of the two methods may not translate well when implemented in a practical solution.

Lastly, Cappanera, Requejo, and Scuttelà focus on the skill VRP, an extension of the traditional VRP that focuses on delivering human services instead of goods. What makes their research interesting is their specific focus on situations where one individual does not have all of the skills

necessary to complete a job. As a result, multiple “deliveries” must be made to the same customer.

In comparison, what separates this project is the setting that it considers, which is reacting to the breakdown of a truck and properly executing the reassignment of the routes to the rest of the fleet so that

A. the goods from the broken truck(s) will be delivered to their destinations, and
B. It will be done in an optimal manner.

As a result, the focus of the above research on the VRPTW problem does not address the same problem as we seek to address. While many of the aspects are shared between our project and previous research, the end goals diverge greatly when problem constraints are considered. This proves to be an advantage to us as customer-specific time windows for delivery increase the difficulty of finding an optimal solution. Additionally, our focus on the situation where a truck breaks down and routes need to be recalculated part way through is not addressed in any of the above research. This is a shortcoming of the above research and will likely prove to be a disadvantage to us if the solution isn’t immediately obvious.

[1] El-Sherbeny, N. A. (2010). Vehicle routing with time windows: An overview of exact, heuristic and metaheuristic methods. *Journal of King Saud University - Science, 22*(3), 123-131. doi:10.1016/j.jksus.2010.03.002

[2] Wang, J., Zhou, Y., Wang, Y., Zhang, J., Chen, C. L., & Zheng, Z. (2016). Multiobjective Vehicle Routing Problems With Simultaneous Delivery and Pickup and Time Windows: Formulation, Instances, and Algorithms. *IEEE Transactions on Cybernetics, 46*(3), 582-594. doi:10.1109/tcyb.2015.2409837

[3] Cappanera, P., Requejo, C., & Scutellà, M. G. (2020). Temporal constraints and device management for the Skill VRP: Mathematical model and lower bounding techniques. *Computers & Operations Research, 124*, 105054. doi:10.1016/j.cor.2020.105054

3.1.4 Technical Complexity (Nolan Slimp)

Provide evidence that your project is of sufficient technical complexity. Use the following metric or argue for one of your own. Justify your statements (e.g., list the components/subsystems and describe the applicable scientific, mathematical, or engineering principles)

There are two kinds of novelties in this project:

1. Algorithmic: We will solve very specific problem of reassignment of trucks
2. System-wide: We will develop, implement, and deliver a system for managing assignments of trucks to delivery locations which can be accessed and used by all kinds of entity classes that participate in this scenario(customers, warehouses, and drivers).
3. Technical complexity: Defining proper test cases for an “optimal route” and evaluation procedures

1. The design consists of multiple components/subsystems that each utilize distinct scientific, mathematical, or engineering principles –AND–

2. The problem scope contains multiple challenging requirements that match or exceed current solutions or industry standards.

3.2 Design Exploration

3.2.1 Design Decisions (Nolan Slimp)

List key design decisions (at least three) that you have made or will need to make in relation to your proposed solution. These can include, but are not limited to, materials, subsystems, physical components, sensors/chips/devices, physical layout, features, etc.

Use the use cases to see the initial system architecture.

1. Location (Austin Texas, Chicago Illinois, Seattle Washington)
2. Traffic Density and map (A city's department of transportation w/ API ?)
3. Which dbms to use? (MySql vs GravityB)
4. Interface module (Which type of phone?)
5. Front end Framework (React vs Angular)
6. Backend communication (Spring)
7. Database Management System (MySQL Workbench, Postgres, MSMS)

Subject to changes

3.2.2 Ideation (Nolan Slimp)

For one design decision, describe how you ideated or identified potential options (e.g., lotus blossom technique). List at least five options that you considered.

(7) Considered dbms:

1. MySql Workbench
2. Microsoft SQL server management studio
3. PostgreSQL
4. Oracle SQL Developer
5. Toad for SQL Server
6. Neo4j
7. Gravity

3.2.3 Decision-Making and Trade-Off (Joshua Heroldt and Nolan Slimp)

Demonstrate the process you used to identify the pros and cons or trade-offs between each of your ideated options. You may wish you include a weighted decision matrix or other relevant tool. Describe the option you chose and why you chose it.

Because of the relational nature of MySQL workbench and its ability to be used easily on backend systems with the use of its specialized drivers we are selecting MySQL workbench for this project. It also has the added benefit of being able to be run and accessed from multiple different systems without having data loss.

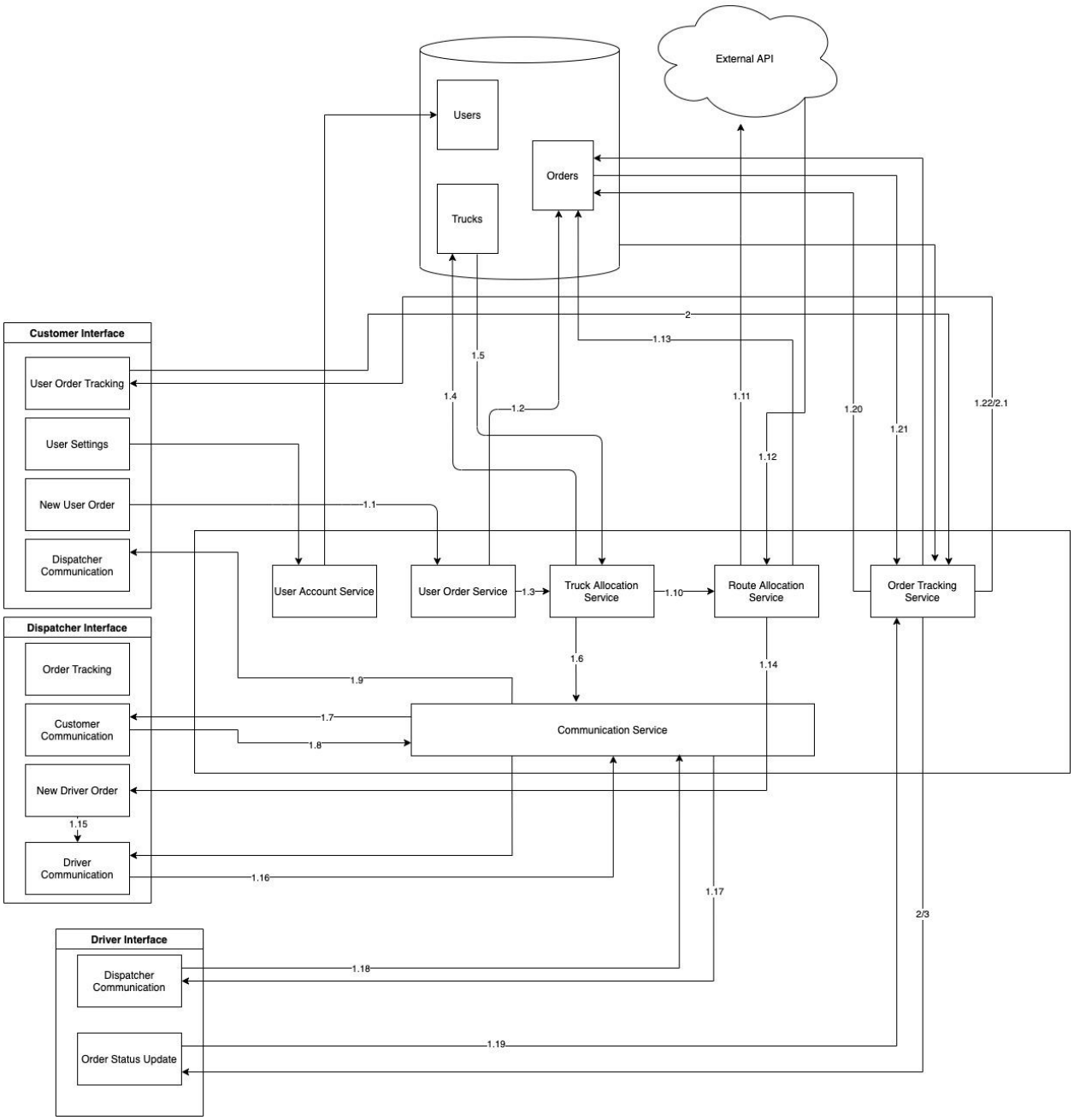
3.3 Proposed Design

Discuss what you have done so far – what have you tried/implemented/tested?

3.3.1 Design Visual and Description (Asma, Matthew, Indrajeet, and Siddharth)

Include a visual depiction of your current design. Different visual types may be relevant to different types of projects. You may include: a block diagram of individual components or subsystems and their interconnections, a circuit diagram, a sketch of physical components and their operation, etc.

Reference 3.2 listing components of the architecture(Or do it here).



Components

- Customer/dispatcher/driver interfaces
- DB (User, Truck and Order tables)
- API (Account service, order service, order tracking/update service, route allocation service, truck allocation service, communication service)
- External API service

1.1 A customer can place a new order via the new user order component of the interface which will be handled by the user order service.

1.2 The user order service will perform CRUD operations with the db, to persist the order information for later use.

1.3 The order information is passed to the truck allocation service from the user order service.

1.4/1.5 The truck allocation service fetches truck information from the db on the basis of the new order param inputs and allocates a truck to the order.

1.6/1.7/1.8/1.9 Communication service establishes and handles communication between the assigned truck dispatcher and customer.

1.10 Order updated with truck information now passed to route allocation service, which will determine the most efficient route for the truck.

1.11/1.12 Truck Allocation service calls external API (Google Maps, Department of transportation) for information which will be consumed by the route allocation algorithm to determine the most efficient route.

1.13 Route allocation service performs CRUD operation to update route parameters of the order in the db.

1.14 Order with truck and route information is passed to the dispatcher.

1.15/1.16/1.17/1.18 Communication service establishes and handles communication between the assigned truck dispatcher and assigned truck driver. Dispatcher passes route information to the driver.

1.19 Post order complemention, via Order status update component of the driver UI, the driver notifies the customer which is handled by the order tracking service.

1.20/1.21/1.22 The order tracking service performs CRUD operations to update the order status in the db. The updated order status is forwarded to the customer.

2/2.1 A customer can track the status of their order or cancel their order via the User order tracking component of the UI. The requests will be handled by the order tracking service, which will fetch the order from the db and relay it to the user. If the order is cancelled, the driver will be notified via the order status component of the driver UI.

3. User account settings can be accessed via the user settings component of the customer UI. The requests will be handled by the user account service, which will perform CRUD operations with the users table in the db.

Describe your current design, referencing the visual. This design description should be in sufficient detail that another team of engineers can look through it and implement it.

3.3.2 Functionality (Asma, Matthew, Indrajeet, and Siddharth)

Describe how your design is intended to operate in its user and/or real-world context. This description can be supplemented by a visual, such as a timeline, storyboard, or sketch.

How well does the current design satisfy functional and non-functional requirements?

Functional requirements:

1. Truck drivers should pick-up locations.
2. Truck drivers should be able to deliver to the picked location.
3. Find the nearest truck in case of any breaks.
4. Find the set of closest trucks that can take care of the load that the truck has Set of orders and trucks w/ given capacity.

Non-functional requirements:

1. App should have access to all truck drivers databases.
2. App should have enough information about all warehouses locations, type of loads and capacity.

Our design functions by taking the orders in the system and the associated delivery locations (red dots in the below figures) and generating an optimal set of routes (denoted by green, pink, orange, and blue lines in the below figures) based on the available number of trucks and warehouse locations(denoted by grey boxes in the below figures). Routes will start and end at the same warehouse and trucks will only deliver goods from a single warehouse. The result of this step is shown in Figure 1. Once the routes have been decided and assigned, the truck drivers will be notified via the UI system of their route for that day. In our specific case, we are addressing the instance in which a truck breaks down. Suppose the pink truck breaks down at the location depicted in Figure 2. The UI system will be used to notify the central system that the pink truck has broken down Based on the locations of the other trucks, their load capacity and the remaining delivery locations, two trucks are assigned to take over the remaining deliveries for the pink truck and their routes are recalculated. In this instance, the blue and orange trucks are identified as the optimal choices and new routes for these two trucks are generated as depicted in Figure 3. The orange and blue truck drivers are then notified of their updated routes via the UI system. This system meets all of the listed functional and non-functional requirements sufficiently.

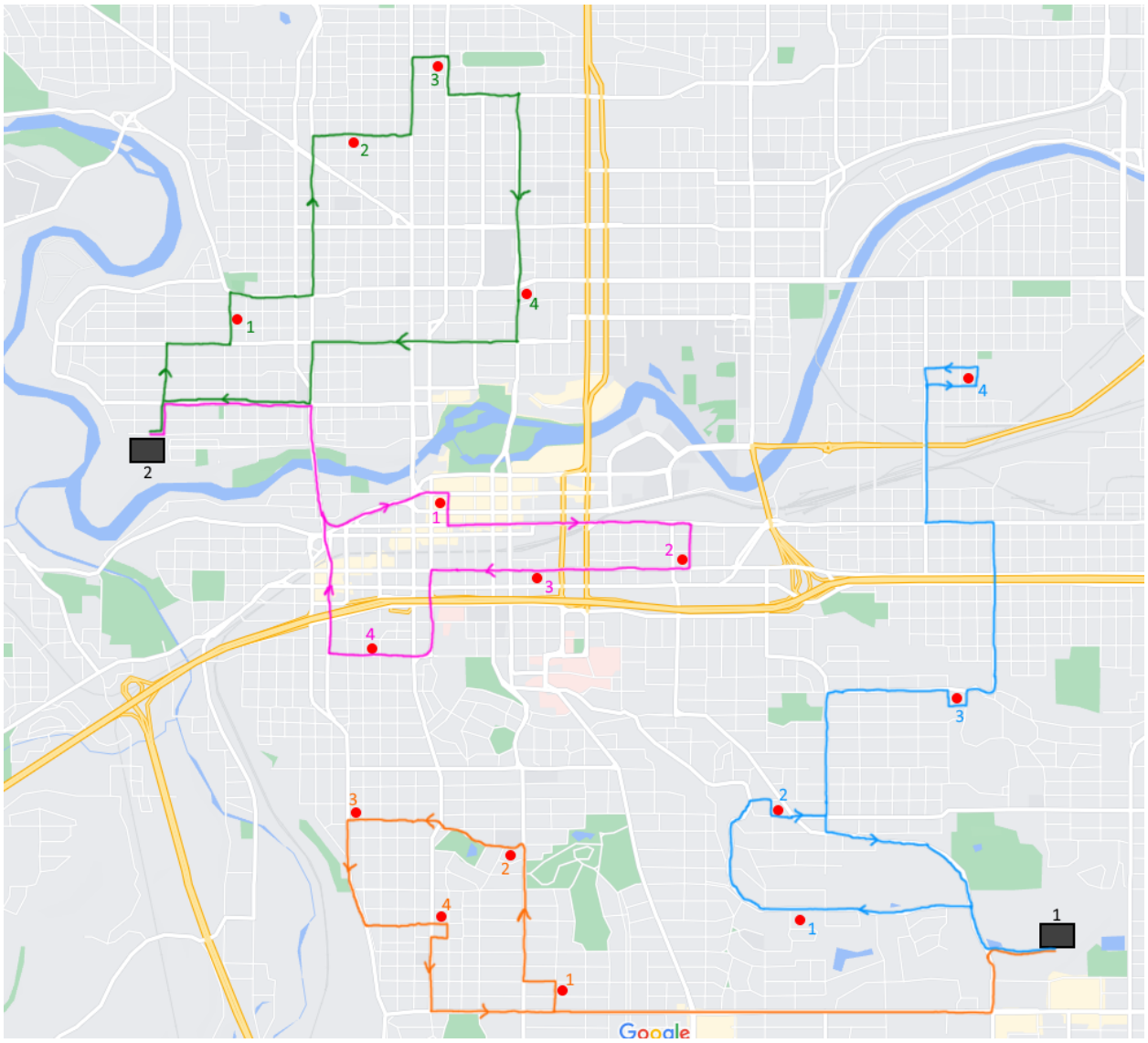


Figure 1. Initial routes calculated by algorithm.

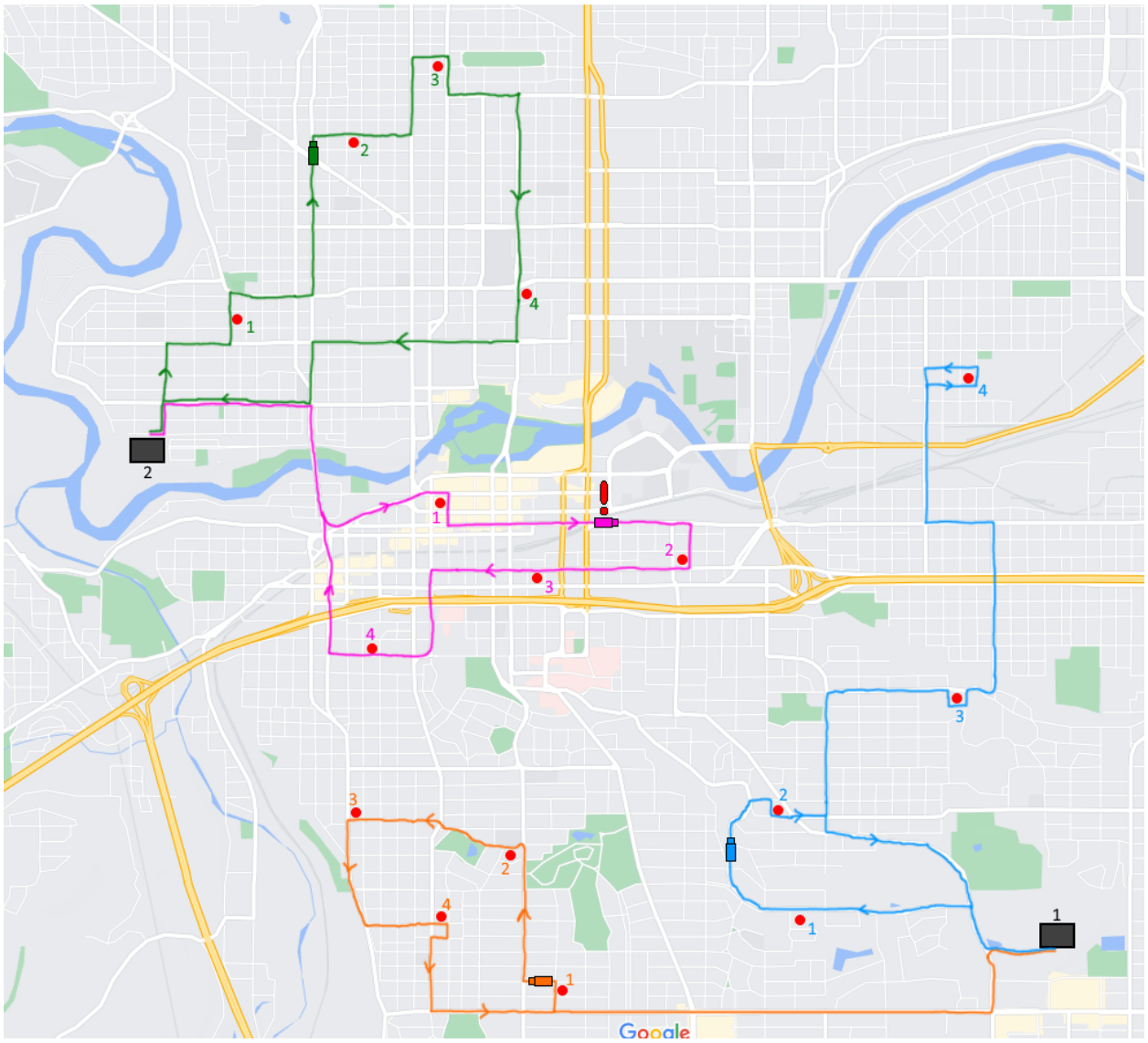


Figure 2. Truck P breaks down

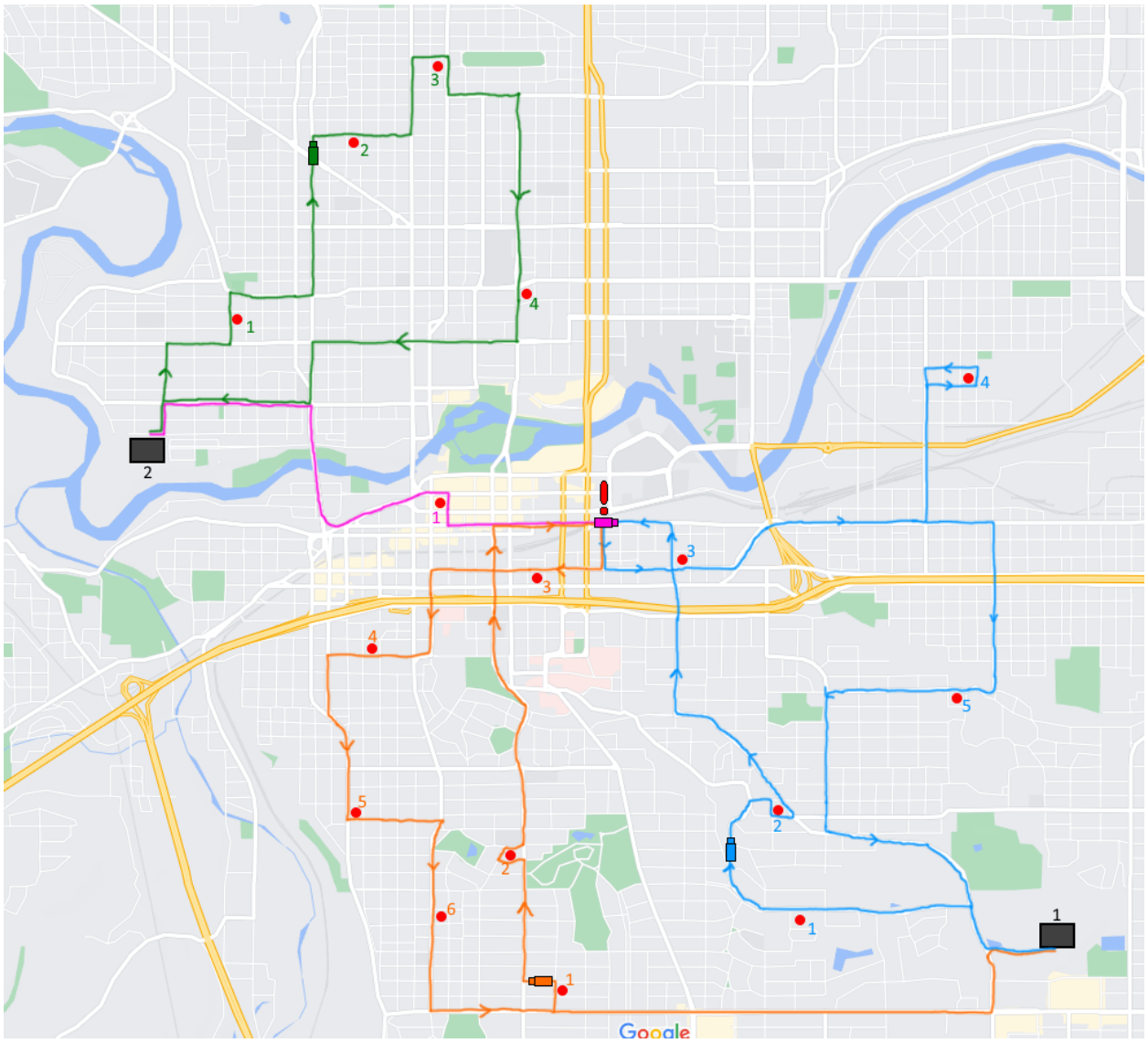


Figure 3. Load is divided between trucks B and O. Routes are recalculated accordingly.

3.3.3 Areas of Concern and Development (Asma, Matthew, Indrajeet, and Siddharth)

Based on your current design, what are your primary concerns for delivering a product/system that addresses requirements and meets user and client needs?

1. For our current design, we have a better sense of how we want to structure our backend services as opposed to our frontend UIs. This lack of description in the UI design can raise a possible concern because it can leave multiple interpretations to team members, making the project structure less organized. In the upcoming week, this issue will be addressed by the team.

2. Another possible concern is the usage of Google Maps/Department of Transportation external API. Although necessary for the application, the learning curve for this could potentially be pretty high.

What are your immediate plans for developing the solution to address those concerns? What questions do you have for clients, TAs, and faculty advisers?

1. Developing the solution for redistribution and incorporating it into the system
2. Scalability: Up to which point does the system react efficiently.
3. List other functional requirements. List how the concerns are met with the current system. Map them to how different components interact with each other to meet the requirements.

NOTE: The following sections will be included in your final design document but do not need to be completed for the current assignment. They are included for your reference. If you have ideas for these sections, they can also be discussed with your TA and/or faculty adviser.

3.4 Technology Considerations

Highlight the strengths, weakness, and trade-offs made in technology available.

Discuss possible solutions and design alternatives

3.5 Design Analysis

– Did your proposed design from 3.3 work? Why or why not?

– What are your observations, thoughts, and ideas to modify or iterate over the design?

3.6 Design Plan

Describe a design plan with respect to use-cases within the context of requirements, modules in your design (dependency/concurrency of modules through a module diagram, interfaces, architectural overview), module constraints tied to requirements.