Operational Optimization Model for Hungry Marketplace Using Geographic Information Systems

By

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To Bill and Pam Grant, my Grandparents

Table of Contents

List of Tables

List of Figures

List of Abbreviations

ERD	Entity Relationship Diagram
GIS	Geographic information system
SQL	Structured Query Language
SSI	Spatial Sciences Institute
USC	University of Southern California
VRP	Vehicle Routing Problem

Abstract

The food industry has been completely disrupted over the past 5 years with the onset of platforms like Doordash, Instacart, HelloFresh, and Hungry Marketplace. These platforms, and others like it, offer customers timely, cost-saving, and convenient ways to prepare, consume, and/or experience meals. The explosion in food-industry innovation has changed the dynamic of food services altogether as status quo operations aren't meeting the needs of the innovative operations. More people are opting in to having their meals delivered to more comfortable, familiar, locations as opposed to going to brick-and-mortar restaurants to consume their meals. As a result, the food industry's changing dynamic has led many to reconsider owning expensive restaurant locations in consideration of alternative commercial locations that are much cheaper and allow them to deliver the same quality of service. Given the importance of kitchen and office locations and the critically changing nature of the industry, new methods are needed to determine the optimal locations for companies that are delivering services in this new environment. Using a GIS (Geographic Information System), this thesis uses spatial analysis including site-suitability analysis and network analysis to build an optimization model for Hungry Marketplace, a food-industry start-up. The model utilized the company's current operations in Boston, Massachusetts as a case study. The model identified optimal locations for kitchen and warehouse operations that maximize the market opportunities while keeping the operational expenses low. This thesis provides recommendations to the company for a cost-effective operation going forward. Ultimately, this data-driven and reproducible methodology can be applied by existing and potential companies in the food industry for optimizing their spatial decisions.

Chapter 1 Introduction

Food is not only necessary to sustain human life, but it is also the bedrock of civilization. Throughout history, the act of eating food has extremely important social and cultural significance. Humans have used the act of eating a meal for the most momentous occasions and some of the greatest moments that have redefined history have been made during the act of having a meal, including, the last supper, the first Thanksgiving dinner in America, Churchill and Stalin in 1942, and countless other undocumented dinners that led to revolutionary changes in society. Although civilization has changed dramatically over these time periods, the cultural significance has remained consistent. As the world continues to revolutionize the areas of science and technology, and more social dynamics become digital, it is more important now than ever that the world takes the time to enjoy a fulfilling meal. Although technology may be pushing to remove us from the present moment, it does not mean that we cannot also embrace technology to help build a stronger social and cultural fabric that allows us to reinforce the human connection through food.

Approximately 746 billion U.S. Dollars are spent each year at restaurants in the United States alone (Lock 2018). Restaurant are the location of great meals, however, there is also something to be said about the authenticity and comfort that is experienced when having a meal in your own surroundings. These two situations are ideal, however, there are many factors like time, cost, and convenience that deter people from these restaurant experiences and entice them towards inferior alternatives. Using technology, many companies are looking to solve the problems of time, cost, and convenience to help more people enjoy a meal.

During the past several years, web and mobile technology has allowed companies like Doordash, Hungry Marketplace, Instacart and others to redefine the food industry with innovative approaches to how people consume meals (Oliver 2015). Doordash uses its platform and network of drivers to pick up meals from restaurants around town and deliver them to individual consumers wherever they are in under an hour. Similarly, Instacart uses its platform and network of delivery vehicles, but its service is to pick up groceries from stores around town and deliver them to individual consumers. Hungry Marketplace's platform connects a large group of local chefs that prepare meals and caters the prepared meals including delivery, setup, and teardown. There are many other companies like the above three in the United States and throughout the world that are focused on solving the problems of time, cost, and convenience that people in today's modern society struggle. All of these companies have the shared goal of allowing more people to take the time to have a meal.

One commonality between all these food preparing/servicing/delivery companies is the locational aspect that are necessary for successful operations. At a bare minimum, the companies mentioned above, and other alike, must have a physical location to prepare and produce the food, and another physical location to deliver the food to be consumed. There are additional locations to take into consideration for these companies like office locations, and storage facilities for supplies and vehicles. Generally, each of these companies encounters some transportation and logistics costs given their locations, and if these locations are not optimized, it could destroy a company's bottom line. The companies described above, and others like it, require some sort of spatial decision making in order to begin operations. The quality of these spatial decisions could potentially make or break the viability of their operations, which underscores the importance of a thorough spatial analysis to help optimize location decisions and set the company up for success from the beginning.

This thesis uses Hungry Marketplace, its data, and operational information as a case study to build out the initial model that allows Hungry to make smarter decisions on their kitchen and office locations. This model will allow Hungry Marketplace to identify the most optimal locations and create a framework for its operational guidelines that allows it to operate in an efficient, cost-saving environment. Ultimately, the model uses a data-driven approach to provide a replicable method for which stakeholders can confidently look to verify the decision information and to make strategic business decisions moving forward.

1.1 Meal Delivery

The food-delivery industry is changing rapidly throughout the United States and the world with no signs of stopping. In as little as five years, companies like Doordash, Postmates, Blue Apron, HelloFresh, Instacart, Hungry Marketplace and many others have systematically changed the way the food industry operate by delivering food-related services that save consumers time and money. As these companies continue to grow and others continue to innovate, the changing dynamic is introducing completely new ways of thinking into an industry that has been around in some shape or form since the beginning of time. One of the cornerstones of the food industry has always been and will continue to be a physical location to prepare the food. As these new ways of thinking absorb into the minds of investors, new questions are being considered and the status quo is being challenged. Seeing as location is one of the most important decisions a company in the food industry can make, the location optimization that has been conducted in this thesis will prove to be extremely valuable.

In 2016, a company called Hungry Marketplace launched in Arlington Virginia as an innovative meal-delivery company passionate about supporting local chefs and delivering meals through its online platform. Today, Hungry has expanded its operations to seven different cities throughout the United States and has partnered with hundreds of local chefs to prepare catered food for customers within each market (Mahmoudpour 2020). Customers utilize Hungry's online platform and network of local chefs to order catered meals for events, team outings, or special occasions. Once the order is placed, Hungry uses its team to deliver, set-up, and take-down the meals at the customers desired location. There are at least three locations visited throughout Hungry's meal-delivery operation. First, the Hungry team has an office where their operations are organized, and supplies are stored. Next, the Chef's prepare meals out of commercial kitchens that are located in various spots throughout a city. Finally, the customer choses their desired location where they want the meals to be delivered.

1.2 Study Area

Hungry Marketplace began its operations in Arlington, Virginia in 2016 and, by 2019, had expanded to six other cities in the United States with plans to open numerous other markets throughout 2020 and beyond. Currently, Hungry operates in the D.C Metro Area; New York City Metro Area; Atlanta, Georgia; Austin, Texas; Boston, Massachusetts; Dallas, Texas; and Philadelphia, Pennsylvania.

This study utilizes historical operating data collected from Hungry's operations in Boston, Massachusetts. Hungry began serving the Boston market in June 2019 and continues to serve it today with one office location, 20 full-time employees, and over 40 chefs. This study uses Hungry's order data in the Boston market during a nine-month period ranging from June 1, 2019 to March 31, 2020.

Boston, Massachusetts metro area is the tenth largest in the United States with a population of 4.9 million people, spanning nearly 3,500 square miles, in 2018. The median age is 38 years old and per capita income is roughly $47,000 (Bureau 2018). Boston has played a significant role in the United States and beyond with its powerful academic institutions including Harvard and MIT calling the historic town of Cambridge, home. Kendall Square, a neighborhood in Cambridge, has been called “the most innovative square mile on the planet,” referencing the vast amount of innovation in science and technology that has been born from public, private, and university organizations in this area (WorldAtlas 2019). Given this innovation, Boston boasts a vast network of highly educated business professionals working throughout the metro area. This demographic is ideal for meal delivery as most people work demanding hours at innovative companies and enjoy the convenience offered by meal delivery.

As with most large metro areas in the United States, Boston suffers from transportation congestion. In 2018, a study from INRIX found that Boston had the worst rush-hour traffic in the United States with each driver, on average, wasting over 164 hours commuting each year (INRIX 2020).Given the congestion in Boston, companies relying on transportation to offer their service must take these concerns into account to find optimal locations that allow them to maximize their time and not waste precious dollars sitting in traffic.

Hungry Marketplace has capitalized on the enticing business innovation and dense population of wealthy companies in Boston by offering quick, efficient, and tasty catered meals directly to company offices. This not only saves employees precious time, but it also allows companies to offer benefits to their employees, enticing them to work harder and longer at the office. Although Hungry has capitalized on the healthy market demand for corporate meal catering, Hungry’s operations rely heavily on transportation throughout the city. Transportation costs have not been thoroughly considered throughout Hungry's current operations in Boston. Transportation costs could be severely impacting Hungry's business, considerations that are analyzed further in this study.

1.3 Document Structure

The remaining sections of this study include the background, methodology, results and conclusion. Chapter 2 discusses Hungry Marketplace's operational intricacies. Additionally, this chapter discusses literature concerning site suitability and location optimization. Chapter 3 dives deep into the methods used to conduct this study. Chapter 4 presents the results that were found after conducting the methodology. Finally, Chapter 5 discusses the study's limitations, future work and ultimately concludes with recommendations for Hungry Marketplace's operations in Boston.

Chapter 2 first discusses how Hungry Marketplace operates. It details exactly what Hungry Marketplace is and then presents Hungry's operational flow which is the foundation for all meal orders that are placed on its platform. Once Hungry's operational groundwork is understood, more detail is given into operations specific to the Boston market including current operating locations and historical order data. The chapter then moves onto a literature review to provide background and justification for the methodology proposed in the next chapter.

Chapter 3 presents the methodology used to guide the analysis in this study. The chapter begins with a broad overview of the methodology, with subsequent sections diving much deeper into the specific steps taken to achieve the desired analytical insights. Subsequent sections detail considerations taken during data collection and processing, network analysis, database creation, and operational analysis. The insights gathered from these sections fuel the results that are presented in the next chapter.

Chapter 4 discusses the results obtained from the methodology described in the previous chapter. The results include detailed operational costs for Hungry's current operations, which is based on order data from June 2019 to March 2020. The results chapter also presents potential cost savings if Hungry took steps to optimize its transportation costs through more efficient location decisions.

Finally, Chapter 5 brings the study home by reflecting on its assumptions and limitations. The chapter goes further into discussing how future work could build from this study to include additional inputs that would make the insights gathered in Chapter 4 more robust. The chapter then concludes the entire Thesis by summarizing its objectives, analysis, and results. This study's aim is to build a model that can definitively recommend operational improvements for Hungry Marketplace's delivery operations in Boston Massachusetts.

Chapter 2 Background

To provide context for this study, this section presents a detailed description of Hungry's current operations and a literature review to justify the study's subsequent methodology. First, Hungry's operations are described by identifying its operational flow, operating locations, and historical order data. Next, a literature review is conducted, outlining other site-suitability and location optimization studies that have been performed.

2.1 Hungry's Current Operations

Hungry has created an online meal ordering platform for its clients. Hungry presents specific meal choices on its platform where clients can then order meals by specifying order details including date and time, meal quantities, and more. Once a meal is ordered from the online platform, Hungry uses its network of employees, vehicles, offices, and kitchens to prepare and deliver the meals to the client. Hungry has provided data on its operations from June 1, 2019 to March 31, 2020. Using this data, the following sections present Hungry's specific operational flow, operating locations, and order history in the Boston market.

2.1.1 Operational Flow

Figure 1 shows Hungry's basic transportation flow. A typical Hungry order begins at Hungry's office location where employees called "Captains" pick up the catering supplies needed to set up the meals. Once the supplies have been obtained at Hungry's office, Captains travel by car from the office to one of the dozens of potential commercial kitchens where the meals could be cooked from. Once the meals are picked up, Captains deliver the meals to the client's location.

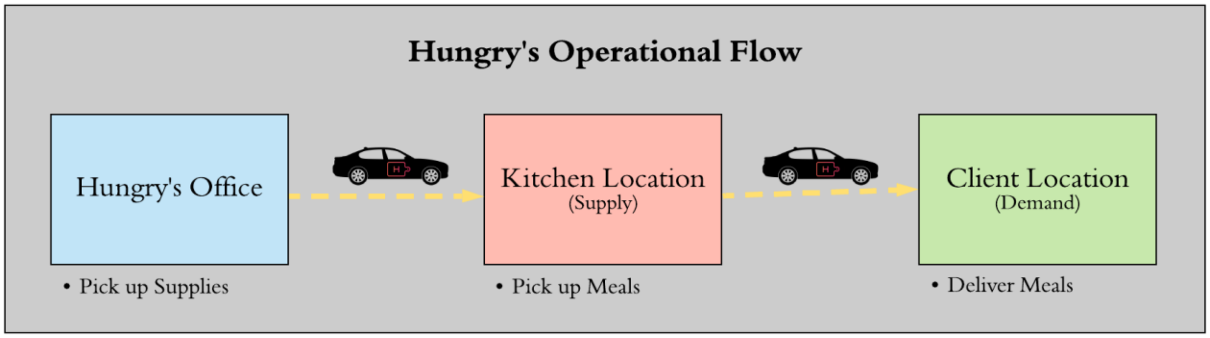

Figure 1 Hungry's Operational Flow

In Hungry's current operating model, chefs are not employees but rather contractors that are expected to maintain their own commercial kitchen. Most chef's rent space from larger commercial kitchens that offer monthly occupancy rates and are located throughout the metro area. This results in each chef being locked into their kitchen location per their specified rental agreement. In this typical situation, each chef is responsible for their own lease, kitchen equipment, and supplies. Hungry is only responsible for paying the chef per order that is placed through the online platform. Each chef has their own unique cuisine and style of meals that they cook from their location. There is no standardization across the kitchen locations, therefore when a client orders a meal, it will always be prepared by that particular chef in that particular location. Each chef is unique to exactly one kitchen location, and Hungry simply presents their network of chefs and meals to each client. The client is then able to choose whatever meal they would like to order on Hungry's online platform.

Once the client chooses a meal, the chef is notified with order details including date and time the meals need to be ready, quantity of meals to be prepared, and any other requirements the client has requested. Once the chef prepares the meals, Hungry's Captain travels from the office to pick up the prepared meals. Once the meal has been picked up, the Captain transports the meal to the Client's specified location. Finally, Captains arrive at the client's location where they setup the meals, serve the meals, then tear down the meal set up and bring the supplies back to the Hungry Office.

2.1.2 Operating Locations

Hungry currently operates out of one office in Downtown Boston, which can be seen in Figure 2 below. The location was chosen in the early 2019 based on pre-launch partnerships, as well as other considerations such as initial employee housing locations, and general business suitability. Given the pre-launch status of the company, the decision to locate Hungry's office in Downtown Boston was not based on operational insights. Moving forward, the current office location lease agreement expires in August 2020, and Hungry leadership is interested in relocating to another area that makes sense from an operational cost perspective.

Hungry has partnered with 37 chefs across the region. Some chefs operate out of the same commercial kitchen location because the commercial kitchen companies offer multiple spaces for individual chefs to lease. Given this, Hungry has delivered meals from 33 distinct kitchen locations across the region, which can also be seen in Figure 2 below.

Since Hungry's launch in Boston in 2019, the company has delivered 788 orders to over 100 clients throughout the region. Client locations can be seen in Figure 2 below.

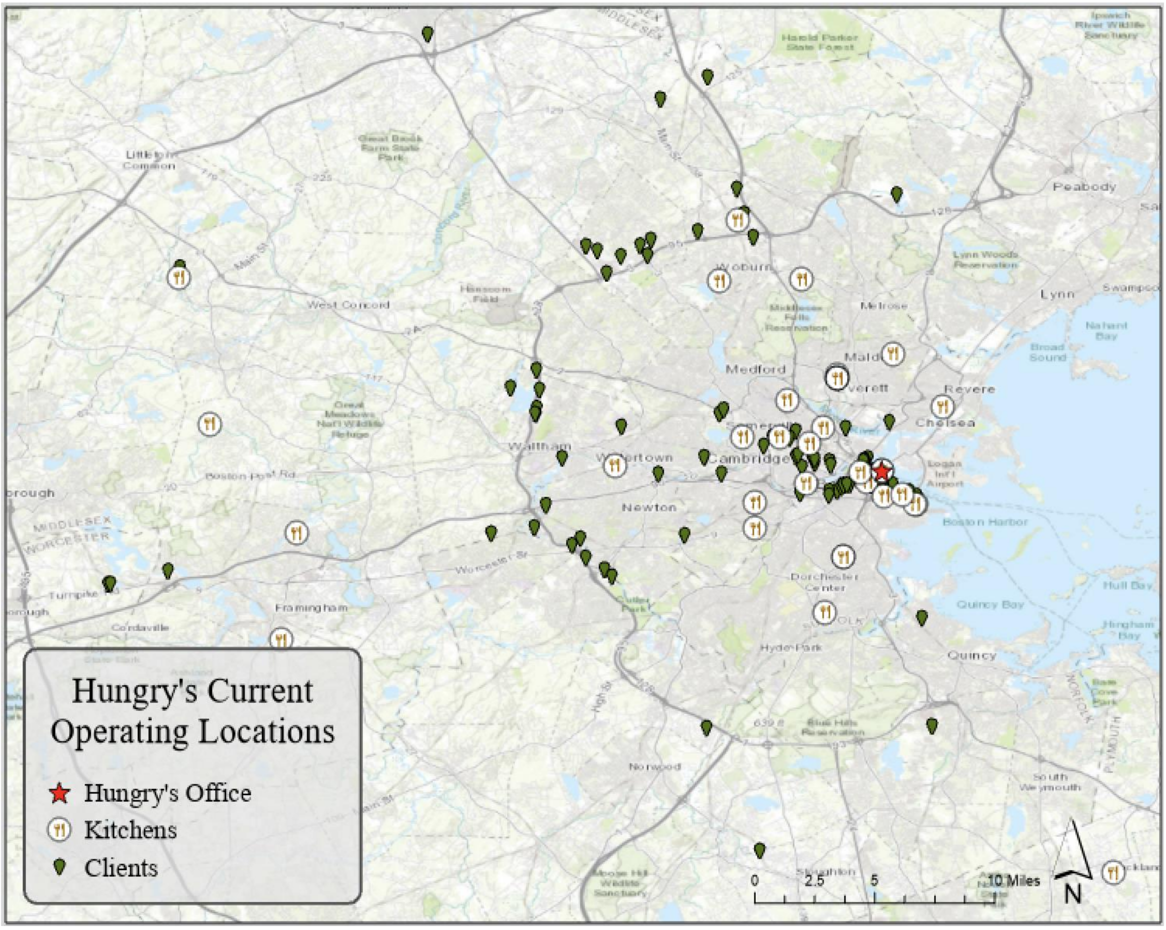

Figure 2 Hungry's Current Operating Locations

2.2 Literature Review

On-demand meal delivery is a relatively new space in the food industry, therefor not much literature has been published that specifically focuses on location and operational optimization for on-demand meal delivery companies. However, many scholars have presented supply chain models for the food industry (Bosona et al. 2013; Hekmatfar 2009). These models discuss locational considerations for the supply, demand, and fulfillment of food sources for traditional food industry companies like restaurants and grocery stores. In addition to supply chain analysis, site suitability analysis and database design are important considerations to build an operational optimization model. This literature review is divided into three sections that provide a greater understanding into related work that has been conducted for supply chain, site-suitability, and database design. Supply chain literature is first discussed, which defines the considerations necessary to find optimal locations for supply, demand, and fulfillment operations. Next, site-suitability literature is reviewed, discussing the tools used in a GIS that will provide spatial insight into various types of locations. Finally, database design literature is discussed which will inform the best ways to create a scalable database that can be used for business purposes. This thesis aims to recreate a similar methodology that takes these factors into account. This literature review provides context for the methodology presented in the next chapter.

2.2.1. *Supply Chain*

The food industry relies on a vast network of local supply and fulfillment locations that provide resources to companies providing a service to customer locations. On-demand meal delivery similarly relies on a supply chain network to deliver meals to customer locations. In the study *GIS-based Analysis of integrated Food Distribution Network in Local Food Supply Chain*, the authors discuss how local food producers need to integrate within networks of suppliers, distributors, and customers in order to increase their competitiveness (Bosona et al. 2013). The study uses GIS to conduct location and route analyses to determine the most optimal supply chain configuration to increase competitiveness for a company in Sweden. The study identifies that logistics problems are the bottleneck in the local food systems and that location decisions are one of the critical elements in strategic planning for different firms. The study considers supply and fulfillment center locations and uses GIS to optimize these locations. The study also builds on another study of location theory conducted by Farahani & Hekmatfar in 2009. Farahani & Hekmatfar aimed to locate a single warehouse at an optimal location that minimizes the distance between the warehouse and delivery points (customers) (Hekmatfar 2009). Both of these studies determined that the main factors to be considered are the nature of the facility itself, environment in which it is to be located, customers to be serviced by the facility, and a metric that indicated distance and time between customers and facilities. The metric that indicates distance and time between customers and facilities is presented in the next section discussing site suitability.

2.2.2. *Site Suitability*

In addition to the supply chain consideration required to find optimal operating locations, site-suitability methods can also be used to calculate the suitability of these locations. The suitability of a supply chain locations can be found by assigning each a pair of locations with a cost associated with transporting good from one location to another. In *Installing Public Electric Vehicle Charging Stations: A Site Suitability Analysis in Los Angeles County, California,* Jennifer Jin uses site suitability analysis to determine suitable vehicle charging station location in Los Angeles (Jin 2016). Although the study is not focused on the food industry, it uses GIS tools to assign suitability costs to charging station locations. Similarly, this thesis uses similar tools to assign costs to facility locations. In the book *The Esri Guide to GIS Analysis Volume 3: Modeling Suitability, Movement, and Interaction,* Andy Mitchell presents many of the tools ArcGIS Pro has to offer that were used to conduct this analysis (Mitchell 2012). The book gives context on the understanding for site suitability, and for the Network Analysis section of this report. For the network analysis section of this report, “finding suitable locations”, “rating suitable locations”, and “modeling interaction” are sections of this book that will lay the foundation for how the section was determined.

The tools used for this analysis include closest facility and origin destination matrices. Both of these tools use the vehicle routing problem (VRP) method, which is one of the most significant problems in the goods distribution management industry (Bosona et al. 2013). VRP finds the most optimal routes in a distribution system where vehicles should be assigned to serve a set of customers. When using VRP, important issues such as number of stages, fleet size, vehicle capacity, delivery time window, and supply/demand nature need to be addressed (Giaglis 2004). Although there are constraints such as location, vehicles, and paths between location, this thesis relies on Hungry's operational data, ArcGIS Pro and ESRIs road network to conduct VRP. The VRP results show costs for a pair of locations in terms of time and distance. These costs will be transformed into actual dollar amounts per minute and per mile using data from Hungry. Finally, the costs associated between two locations are assigned, and locations are selected that minimizes time and distance between a set of locations.

2.2.3. *Database Design*

The aim of this thesis is to discover insights from the data that was not only provided by Hungry but also created throughout the methodology. The data gathered and created in this thesis is not actionable by itself and needs to be collected and imported into a database not only to inform the results section of this thesis, but to also allow Hungry Marketplace to answer any remaining questions or to inform future work. In the USC Master's Thesis titled *Creating a Geodatabase and Web-GIS Map to Visualize Drone Legislation in the State of Maryland*, Brendan Blee shows that creating an effective database has several steps including determining what data is needed, specifying the relationships and interactions in the data by creating an entity relationship diagram (ERD), and arranging the data into a final database (Blee 2016). First, existing and candidate supply, demand, office, and order data was collected and is presented in Section 3.1 of this thesis. Additional data was created using network analysis and is presented in Section 3.2 of this thesis. Next, the relationships and interactions were created in an ERD which is presented in Section 3.3. Finally, the ERD was used to create the final database using Microsoft SQL Server. The final database was created in a scalable way so that future operational insights could be added if Hungry's operations continue in the Boston market. The database allows users to query information and gain insights into Hungry's operational data which is ultimately stored in the Orders table feature in section 3.1.4.

Chapter 3 Methodology

The goal of this study's methodology is not only to analyze transportation costs of Hungry's current operations in Boston, but to also look at alternative operational locations that could optimize its future operations. Hungry provided historical data to support current operational analysis which was presented in Chapter 2. Additionally, Hungry provided resources and discussion for how they look at future developments, including candidate commercial kitchens and office locations. Taking both existing and candidate location data into account, the methodology presented below outlines the workflow used to achieve a comprehensive review of Hungry's meal delivery operations in Boston, Massachusetts.

Figure 3 represents the general methodology and workflow that was followed. All analysis was conducted using the WGS 1984 spatial reference system. There are four main components to the study's methodology which are expanded upon in much greater detail in subsequent sections. First, existing and candidate location data was collected and processed to be used in the network analysis section. The results from the network analysis are used to analyze transportation costs for Hungry's historical orders as well its recommended optimized operations.

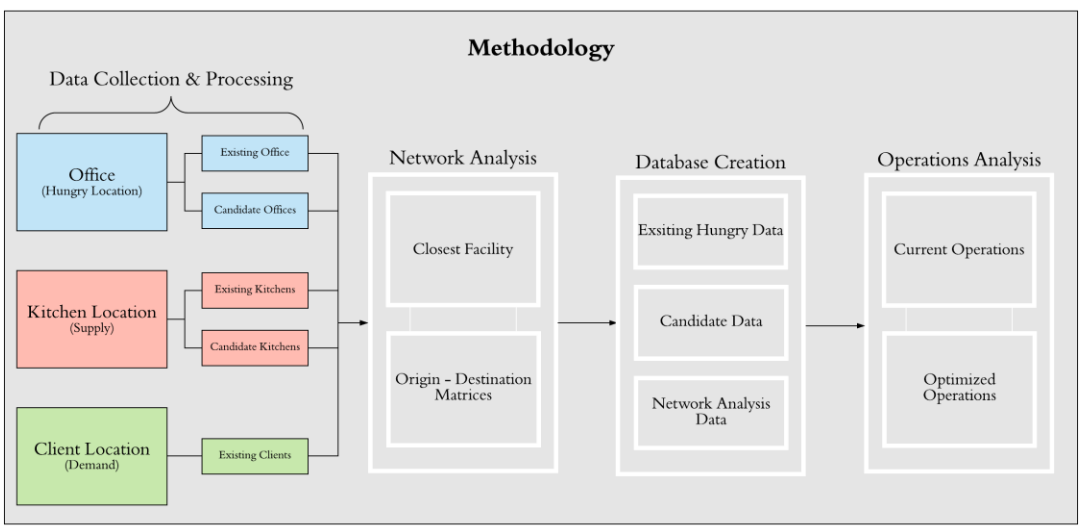

Figure 3 Methodology

3.1 Data Collection and Processing

The first step of the methodology consists of collecting and processing the necessary data to analyze Hungry's meal delivery operations. As described previously in section 2.1.1 of this study, a typical Hungry order begins at their office location where supplies are acquired by Hungry Captains. Captains travel to each order's specific kitchen to pick up the meals and then continue to the client's location where they deliver their service. This operation consists of three main locations: Offices, Kitchens, and Clients. Existing and candidate data for each of these locations was collected for the model. Additionally, Hungry provided a comprehensive dataset detailing its orders from June 1, 2019 to March 31, 2020. Subsequent sections detail each of the datasets collected.

3.1.1. *Offices*

Currently, Hungry operates out of one office location in downtown Boston which was presented in section 2.1.2 of this study. In addition to Hungry's existing office location (71.0507800°W 42.3634400°N), candidate locations for additional offices were also identified. A zip code shapefile for the Boston downtown area was obtained from the US Census Bureau and was imported into ArcGIS Pro for processing. The *drivetime buffer tool* in ArcGIS Pro was used to create a drive-time polygon using Hungry's existing office location as the origin point. Drive-time areas were created for 0-30 minutes away from the origin point. The resulting polygon area was then used to select zip codes that were within a one-hour drive-time from Hungry's existing office location, which can be seen in Figure 4 below. In order to select the most relevant zip codes, a drive-time buffer was created. The *Make Service Area Analysis Layer tool* was used to calculate drive-time away from a facility. Boston's city center was used as the facility, and a 30-minute cutoff was used. Hungry required their office to be within a 30-minute drive-time from

Boston, so zip codes were selected that fell within that the 30-minute drive-time area. Once the relevant zip codes were selected, the *Central Feature tool* was used to generate one point-location in the center of each zip code. The point feature class was exported as the ‘Offices’ feature class and Hungry’s existing office location was manually added. Existing and Candidate Office Locations can be seen in Appendix A: Offices.

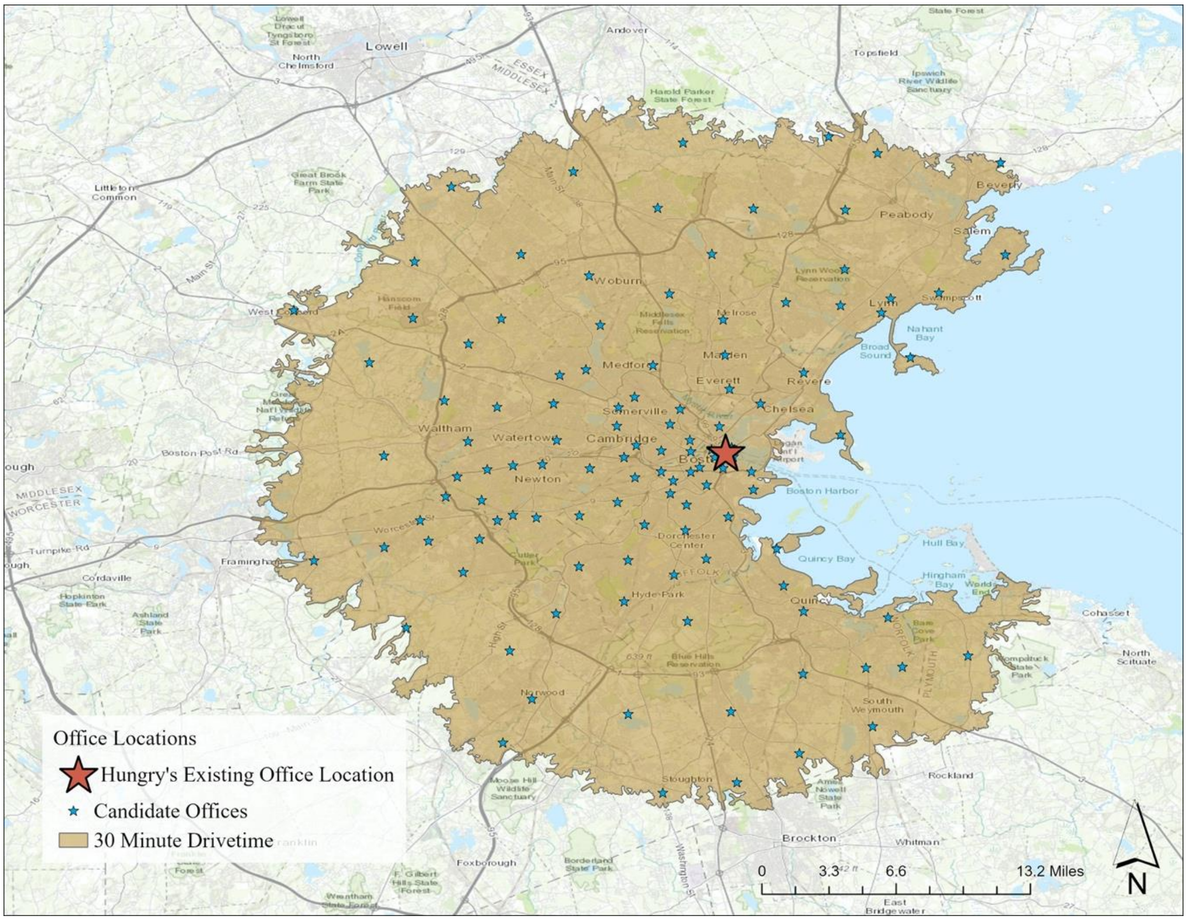

Figure 4 Office Locations

The resulting ‘Offices’ dataset contains 118 point-locations with five fields, described in Table 1 below. For each of the zip code point-locations, the *Office_Name* field was set to the numerical zip code itself and the *Status* field was set to ‘candidate.’ Hungry’s existing office point-location *Office_Name* field was set to ‘Hungry’ and the *Status* field was set to ‘existing.’

Table 1 Offices Feature Class

Field	Description
OBJECTID	Unique identifier for each office
Office_Name	Name of the office location
Status	Whether the office is an 'existing' or 'candidate' location
X	X-coordinate
Y	Y-coordinate

3.1.2. *Chefs and Kitchens*

Hungry chefs are responsible for sourcing and maintaining their own operations at a licensed kitchen. Chefs can cook from leased spaces in commercial kitchens, or they could cook from their own restaurant. Hungry provided existing chef data including the chef's name, address, and other details which can be seen in Table 2 below. The chef data was provided as a .csv format and this table was imported in ArcGIS Pro as the 'Chefs' table. The *Geocode Addresses Tool* was used with the default ArcGIS World Geocoding Service and the Chefs table to determine each chef's geographic location in coordinates from their address information in the Chefs table. The Chef's addresses were geocoded, and the 'Chefs' point feature class was created.

Table 2 Chefs Feature Class

Data	Description
OBJECTID	Unique identifier for each chef
Chef_Name	Chef name
KitchenID	ID for corresponding kitchen in the 'Kitchens' Table
Priority	Designates whether the chef is an 'anchor', 'new', or 'inactive'
Chef_Amount	Amount of money the chef has made with Hungry
Toll	Designates wheter the chef will or will not pay for tolls encurred
City	City where the chef works
Subregion	Subregion where the chef works
Region	Region where the chef works
Postal	Zip code of where the chef works
X	X-coordinate
Y	Y-Coordinate
Address	Chef's full address

In addition to Hungry's existing chef's locations, candidate kitchen locations were also identified. Hungry provided a .kml file of all commercial kitchens in the United States. The commercial kitchens dataset was imported into ArcGIS Pro. In order to select the most relevant kitchens, a drive-time buffer was created, similar to steps outlined in section 3.1.1. The *Make Service Area Analysis Layer tool* was used to calculate drive-time away Boston's city center, and 30,60,120-minute cutoffs were used. 120-minute cutoff was used as the maximum cutoff time because Hungry specified that typically, in the Boston market, they would not work with chefs whose kitchens are over a two-hour drive from Boston. Candidate kitchen locations were selected that fell within the 30,60, or 120-minute drive-time areas and were exported as the 'Kitchens' feature class. The Kitchens feature class field description are shown in Table 3 below.

Table 3 Kitchens Feature Class

Data	Description
OBJECTID	Unique identifier for each kitchen
Kitchen_Name	Kitchen name
Status	Whether the kitchen is an 'existing' or 'candidate' location
Num_Chefs	Number of chefs that work out of that kitchen location
City	City where the kitchen is located
Subregion	Subregion where the kitchen is located
Region	Region where the kitchen is located
Postal	Zip code of where the kitchen is located
X	X-coordinate
Y	Y-Coordinate
Address	Kitchen's full address

Next, the Chefs and Kitchens feature classes were then cross-referenced to make sure the Kitchens feature class had one entry for every Chef listed in the Chefs feature class. If a Chef's address was not listed in the Kitchens feature class, it was manually entered into the Kitchens feature class. Additionally, a new field called 'KitchenID' was added to the Chef's feature class where each Chef corresponded to one kitchen in the Kitchen feature class. This new field was updated for each Chef. The Kitchens and Chefs relationship is described in more detail in Section 3.3. The resulting 'Kitchens' dataset contains 45 point-locations, shown in Appendix B: Kitchens.

3.1.3. *Clients*

Hungry's typical client is a company that has over twenty employees. Clients typically order catered meals for their staff, and Hungry Captains deliver the food to the clients specified address. Hungry provided a dataset of existing Clients. The 'Clients' table field descriptions can be seen in Table 4 below.

Table 4 Clients Feature Class

Data	Description
OBJECTID	Unique identifier for each client
Client_Name	Client name
Total_Orders	Total number of orders the client has made with Hungry
City	City where the client is located
Subregion	Subregion where the client is located
Region	Region where the client is located
Postal	Zip code of where the client is located
X	X-coordinate
Y	Y-Coordinate
Address	Client's full address

Similar to section 3.1.2, the *Geocode Addresses Tool* was used using the default ArcGIS World Geocoding Service and the Clients table to determine each client's geographic location. The resulting 'Clients' dataset contains 108 point-locations which represent each client location and can be seen in Appendix C: Clients.

3.1.4. *Orders*

In addition to Hungry's office, chef's, and client's location data, the company also provided order data from June 1, 2019 to March 31, 2020. There were 788 orders delivered throughout the Boston market during this time period, which can be seen in Figure 5 below. The green origin line represents origin kitchen locations, or where the meal was prepared. The line connects each kitchen location with the corresponding client destination location for each order. Figure 3 shows that Hungry's market extends far beyond downtown Boston, with orders originating in Worcester and Lowell and being delivered to clients in Downtown Boston. This initial representation of Hungry's order data confirms that there will be locational inefficiencies in regard to transportation costs throughout the region.

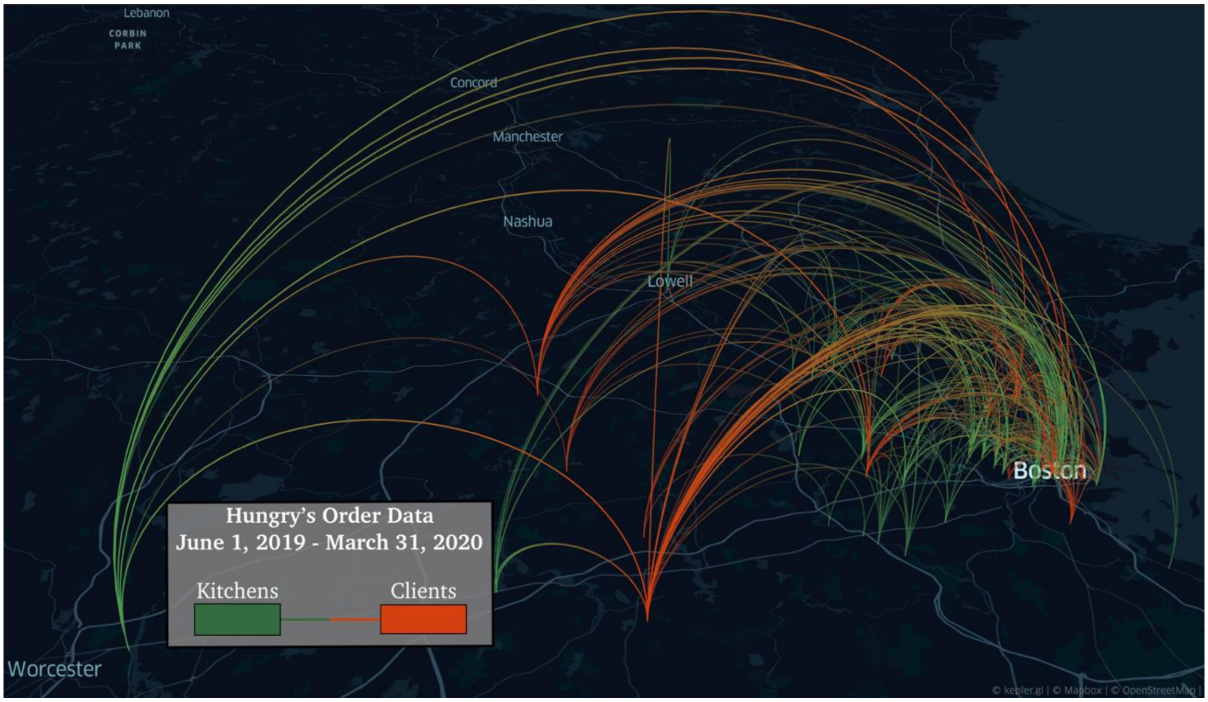

Figure 5 Hungry's Kitchen to Client Orders

The orders data ties all of the previous, existing, data in the datasets presented above together into one table. The 'Orders' table represents all orders Hungry has completed in the Boston market within the given time period.

Each line in the Orders table represents an order that was placed through the Hungry platform. Each order is given a unique order number and the table records the meal information including the date it was place, requested to be delivered, who ordered the meal, and how many people the order is for. The Orders table records what chef the order was placed with as well as the cost information including how much the client paid, how much the chef receives, and how much Hungry receives after all necessary account are paid. A detailed description of all the fields in the Orders table is presented in Table 5 below.

Table 5 Orders Feature Class

Data	Description
Order_Number	Unique identifier for each order
Created_At	Date and time the order was placed
Event_Date	Date and time the order was requested to be delivered
Order_Type	Specifies whether the order was for breakfast, lunch, or dinner
Service_Type	Specifies whether the order is VIP or regular
Is_Event	Specifies whether the order was for an event or regular delivery
Client	The Client name who requested the order
ClientID	The ClientID which corresponds to the OBJECTID Field in the Clients table
Chef	The Chef name who cooked the order
ChefID	The ChefID which corresponds to the OBJECTID Field in the Kitchens table
Head_Count	Number of portions to be cooked
Chef_Take	How much money the Chef received for cooking the order
Subtotal	The amount the Client pays before taxes and fees
Service_Fee	The service fee cost paid by the Client
Tax	The tax cost for the order
Tip	The tip paid for by the Client
Discounts	Discounts taken off the Clients required payment
Cust_Total	The amount paid by the Client after taxes, fees, tip, and discounts
Revenue	The total amount received by Hungry (after taxes and tip are removed)
Total_Chef_Take	The total amount the Chef receives for the order (including tip)
Supplies_Cost	The amount it costs for supplies
Service_Costs	The amount it costs for service
HUNGRY_Take	The amount Hungry receives for the order after the chef, supplies, and service costs are paid
Margin	The margin of Hungry_take vs. Revenue generated

3.2 Network Analysis

Once the data has been collected and processed, Network Analysis tools are run to create additional insights. *Closest facility* and *origin destination matrix tools* are run to create additional data that is then added back to the original data tables. The following sections explore these tools and how the data tables were updated to reflect the new insights that were created.

3.2.1. *Closest Facility*

The *closest facility tool* is used to find the closest facilities to certain locations or 'incidents.' First, a closest facilities analysis layer was created where Kitchens were imported as facilities and Clients were imported as incidents. The closest facilities tool was then run to generate the 3 closest facilities for each incident using drive-time over ESRI's road network without taking traffic into account. The results provide three locations for each of the 108 clients in the Boston area. Therefore, the resulting 'routes' feature class had 324 rows. Each incident (or Client) has three rows and each row has a field specifying the ClientID and field specifying that ClientID's corresponding closest KitchenID. Another field specifies whether the KitchenID is the first, second, or third closest facility to its corresponding ClientID. Additionally, there are two other fields specifying the drive-time miles and time it would take to travel from the ClientID to the KitchenID.

The results were exported as a table and the table was imported into Excel as another tab in the Clients Table. Excel was then used to generated 9 new fields in the Clients Table, which can be seen highlighted red in Table 6 below. Using the VLOOKUP function in Excel, each new field was populated using the corresponding data from the closest facility table that was imported.

Table 6 Clients

Data	Description
OBJECTID	Unique identifier for each client
Client_Name	Client name
Total_Orders	Total number of orders the client has made with Hungry
Kitchen1_ID	The closest kitchen by drive-time from the Client's location
Kitchen1_Time	The amount of time, in minutes, it takes to drive from the client to the closest kitchen
Kitchen1_Distance	The driving distance in miles from the client to the closest kitchen
Kitchen2_ID	The second closest kitchen by drive-time from the Client's location
Kitchen2_Time	The amount of time, in minutes, it takes to drive from the client to the second closest kitchen
Kitchen2_Distance	The driving distance in miles from the client to the second closest kitchen
Kitchen3_ID	The third closest kitchen by drive-time from the Client's location
Kitchen3_Time	The amount of time, in minutes, it takes to drive from the client to the third closest kitchen
Kitchen3_Distance	The driving distance in miles from the client to the third closest kitchen
City	City where the client is located
Subregion	Subregion where the client is located
Region	Region where the client is located
Postal	Zip code of where the client is located
X	X-coordinate
Y	Y-Coordinate
Address	Client's full address

In addition to updates in the Clients Table, the Kitchens Table was also updated with the new insights from the closest facility tool, which can be seen highlighted in red in Table 7 below. Using the PivotTable function in Excel, statistics were calculated for each kitchen. First, a priority was given to each kitchen based on the number of clients it serves as its closest facility. If a kitchen serves at least one client as its closest facility, the priority is set to 'High.' If a kitchen serves at least one client as its second closest facility, the priority is set to 'Medium.' If a kitchen serves at least one client as its third closest facility, the priority is set to 'Low.' The *Priority_Clients* field shows the number of clients that kitchen serves as its designated priority. For example, if priority = High and priority_clients = 10, then that kitchen is the first closest kitchen to 10 clients. The *Total_Clients* field shows the number of total clients that kitchen serves as either the first, second, or third closest facility.

Table 7 Kitchens

Data	Description
Num_Chefs	Number of chefs that work out of that kitchen location
City	City where the kitchen is located
Subregion	Subregion where the kitchen is located
Region	Region where the kitchen is located
Postal	Zip code of where the kitchen is located
X	X-coordinate
Y	Y-Coordinate
Address	Kitchen's full address

Table 8 Office_Kitchens_OD

Data	Description
OBJECTID	Unique identifier for each OD pair
OD_Pair	Identifies the origin-destination pair
Office_ID	Identifies the origin location with OfficeID that relates to the Offices table
Kitchen_ID	Identifies the origin location with KitchenID that relates to the Kitchens table
Destination_Rank	Identifies how close the destination is to the origin compared to the other destinations
Travel_Minutes	The amount of time, in minutes, it takes to drive from the origin to the destination
Travel_Miles	The driving distance, in miles, from the origin to the destination

3.2.2. *Origin Destination Matrices*

The *origin destination cost matrix tool* is used to create transportation costs between a set of origin and destination locations. First, an origin destination cost matrix layer was created where the Offices feature class was imported as origins and the Kitchens feature class was imported as destinations. The origin destination tool was then run to generate costs between every office – kitchen location pair.

There are 118 existing and candidate office locations and 45 existing and candidate kitchen locations, the resulting origin destination cost matrix has 6,490 different pairs that define certain transportation costs. The exported table was called the Offices_Kitchens_OD and the field description are shown in Table 8 below. The Offices_Kitchens_OD describes each OD pair and presents the transportation costs including minutes and miles it takes to drive from the Offices to the Kitchens.

Similar to the Offices_Kitchens_OD, an origin destination cost matrix layer was created where the Kitchens feature class was imported as origins and the Clients feature class was imported as destinations. The origin destination tool was then run to generate costs between every Kitchen – Office location pair.

There are 45 existing and candidate Kitchen locations and 108 existing Client locations, therefore the resulting origin destination cost matrix has 5,940 different pairs. The exported table was called Kitchens_Clients_OD and the field descriptions are shown in Table 9 below. The Kitchens_Clients_OD describes each OD pair and presents the transportation costs including minutes and miles it takes to drive from the Kitchens to the Clients locations.

Table 9 Kitchens_Clients_OD

Data	Description
OBJECTID	Unique identifier for each OD pair
OD_Pair	Identifies the origin-destination pair
Kitchen_ID	Identifies the origin location with KitchenID that relates to the Kitchens table
Clients_ID	Identifies the origin location with ClientsID that relates to the Clients table
Destination_Rank	Identifies how close the destination is to the origin compared to the other destinations
Travel_Minutes	The amount of time, in minutes, it takes to drive from the origin to the destination
Travel_Miles	The driving distance, in miles, from the origin to the destination

3.3 Database Creation

Now that the data has been collected, processed, and analyzed, the resulting tables need to be uploaded into a database to develop further insights into Hungry's operations. First, Microsoft Access was used to create the database structure by uploading each table and relating them to each other based on Primary and Foreign Keys. Once the relationships were developed, the Microsoft Access Database was then uploaded to Microsoft SQL Server where SQL could be used to query the tables and generate further insights about the data. The insights discovered are discussed in the next section. An entity relationship model is shown in Figure 6 below.

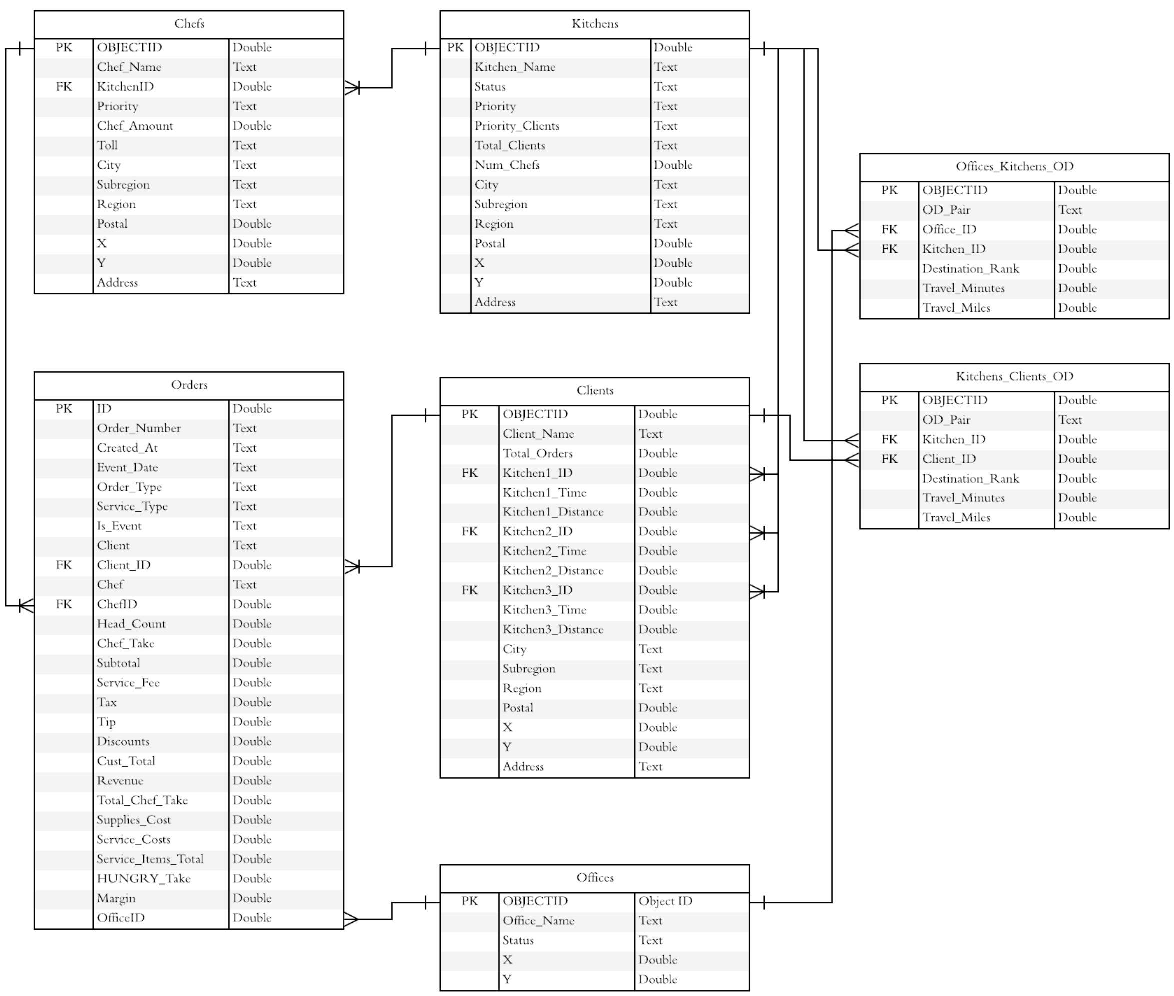

Figure 6 Database ERD

3.4 Operations Analysis

Now that the database has been created, we can query the results to find insights about Hungry's current operational costs and compare the results to its operations if the company were to optimize its locations to minimize transportations costs. The results will show how much money Hungry currently spends on transportation as well as how much money they could save if they were to optimize its operations.

There are a few assumptions we need to make in order to calculate transportation costs. The origin destination cost matrix calculated transportation costs incurred for travel across a road network without taking traffic into consideration. As a result, travel distance (miles) and time (minutes) were calculated. Hungry provided that it pays its Captains $17 per hour and they drive vehicles that average 20 miles per gallon. Additionally, they provided that gas is typically $2.50 per gallon. Breaking these numbers down, the study found Hungry's transportation costs per mile and per minute. Transportation costs can be found in Table 10 below.

Table 10 Transportation Costs

Inputs	Values
Captain Pay per hour	$17.00
Fuel Costs per gallon	$2.50
Average miles per gallon per vehicl	20

Costs	
1 mile	$0.13
1 minute	$0.28

3.4.1. *Current Operations*

Hungry's current operation has been defined by the Orders Table, which has information on the 788 orders it has already conducted in the Boston market. The data shows which kitchen the meals were cooked from and where the meals were delivered to for each order. The origin-destination cost matrix gathered insights into transportation costs for transporting supplies from its office to the kitchens, and the meals from its kitchens to the clients. Using the database created in section 3.3, and the costs outlined at the beginning of this section, SQL queries were written to gather insights to determine the transportation costs for Hungry's current operations. The insights are then used to create a new table called 'Current_Costs' that shows the transportation costs for Hungry's 788 orders they completed. The Current_Costs Table's field descriptions can be seen in Table 11 below.

Table 11 Current Costs

Data	Description
Order_Number	Hungry Order Number specifying the unique order
Office_Name	Office Name of where the order began (all orders originated at Hungry's current office location)
Office_ID	Office ID of where the order began
Client_Name	Client name who requested the order
ClientID	Client ID who requested the order
Chef_Name	Chef name who prepared the meal
KithenID	Kitchen ID for where the meal was prepared
OK_TravelMiles	Miles traveled on a road network to get from the office to the kitchen
OK_TravelMinutes	Minutes it would take to travel by road from the office to the kitchen
OK_FuelCosts	How much it costs for fuel to travel from the office to the kitchen (at $0.13/mile)
OK_TimeCosts	How much it costs to pay the Captain to travel from the office to the kitchen (at $0.28/minute)
OK_TransportCosts	Sum of OK_FuelCosts and OK_TimeCosts
KC_TravelMiles	Miles traveled on a road network to get from the kitchen to the client
KC_TravelMinutes	Minutes it would take to travel by road from the kitchen to the client
KC_FuelCosts	How much it costs for fuel to travel from the kitchen to the client (at $0.13/mile)
KC_TimeCosts	How much it costs to pay the Captain to travel from the kitchen to the client (at $0.28/minute)
KC_TransportCosts	Sum of KC_FuelCosts and KC_TimeCosts
Current_Total_Transport_Cost	Total transportation costs for the order. Sum of OK_TransportCosts and KC_TransportCosts

3.4.2. *Optimized Operations*

Hungry's current operations are determined by its clients. The client choses which meals they would like, and these meals are cooked by a specific chef, at a set location. This reality introduces inefficiency and waste into the operation where a client could order meals from a chef that cooks the meals in a location that is far away. In reality, the client's location could be blocks away from another kitchen that could be used, saving transportation costs. By optimizing the location of where the meals are cooked in relation to where the client is located, Hungry could save money. By gathering insights into the costs Hungry would save by this optimization, and comparing them to Hungry's current operation, this analysis could determine how much money Hungry could save if it optimized its operations.

Using the database created in section 3.3, and the costs outlined at the beginning of this section, SQL queries were written to gather insights to determine the transportation costs for Hungry if it were to use the most optimal locations in terms of optimizing its transportation costs.

Not only do Kitchen-Client location pairs need to be optimize, but an office needs to be found that optimizing the distance between all kitchen. To determine the best location for a Hungry office, optimal Kitchen-Client location pairs are first assessed to determine the existing or candidate kitchens that would be used if hungry were to choose the most optimal kitchen for each client's order. In this scenario, each client would order from the closest kitchen to the client's location. Once the most optimal kitchens are found, an office location is chosen from existing and candidate office locations that minimizes transportation costs from the office to all of the optimal kitchens that were selected.

Once the optimal office location has been found, it is used along with the optimal client-kitchen pairs to calculate transportation costs for each order. Transportation costs are calculated from the office to the kitchen and then from the kitchen to the client location for each order. These costs are then used to create a new table called 'Optimal_Costs' that shows the transportation costs for Hungry's 788 orders if they were to use the most optimal office location and kitchen locations for each order. The Current_Costs Table's field descriptions can be seen in Table 12 below.

Table 12 Optimized Costs

Data	Description
Order_Number	Hungry Order Number specifying the unique order
Office_Name	Office Name of where the order began (using the new optimized office location)
Office_ID	Office ID of where the order began
Client_Name	Client name who requested the order
ClientID	Client ID who requested the order
Chef_Name	Chef name who prepared the meal
KithenID	Kitchen ID for where the meal was prepared
OK_TravelMiles	Miles traveled on a road network to get from the office to the kitchen
OK_TravelMinutes	Minutes it would take to travel by road from the office to the kitchen
OK_FuelCosts	How much it costs for fuel to travel from the office to the kitchen (at $0.13/mile)
OK_TimeCosts	How much it costs to pay the Captain to travel from the office to the kitchen (at $0.28/minute)
OK_TransportCosts	Sum of OK_FuelCosts and OK_TimeCosts
KC_TravelMiles	Miles traveled on a road network to get from the kitchen to the client
KC_TravelMinutes	Minutes it would take to travel by road from the kitchen to the client
KC_FuelCosts	How much it costs for fuel to travel from the kitchen to the client (at $0.13/mile)
KC_TimeCosts	How much it costs to pay the Captain to travel from the kitchen to the client (at $0.28/minute)
KC_TransportCosts	Sum of KC_FuelCosts and KC_TimeCosts
Optimal_Total_Transport_Cos	Total transportation costs for the order. Sum of OK_TransportCosts and KC_TransportCosts

Chapter 4 Results

The methodology used network and operational analysis to create operational insights for Hungry and recommended actions the company could take to create better efficiencies, and ultimately save money. The results of the analysis also allow Hungry to gather information into its current operations by looking at historical order data to see how much money they are spending on transportation costs to deliver meals to their clients. The results also created a comprehensive database that allows Hungry to answer questions about its current and potentially optimized operations. Ultimately, the result of this study is a dynamic database that can be used to answer any question that may arise about Hungry's operations now or in the future. This section will outline some of the insights that the study set out to answer including how much money Hungry currently spends on transportation costs and how much money they could save if they optimized their operations.

From June 1, 2019 to March 31, 2020, Hungry delivered 788 orders in the Boston market. Transportation costs were defined as the distance and time it took to drive from Hungry's office location to the kitchen where the meals were prepared and then onto the client's location where the meals were delivered. It was assumed that Hungry Captains drive vehicles that average 20 miles per gallon and that gas costs $2.50 on average. Given these costs, it was calculated that for each mile the Captain drives, it costs Hungry $0.13 in fuel. This accounts only for fuel costs and no other costs including wear and tear, general service or other unforeseen costs. It was also assumed that Hungry Captains are paid $17 per hour. At this rate, each minute a Captain spends in the car costs Hungry $0.28.

4.1 Current Operations

Using the data that was collected, processed and created throughout the methodology, this study now looks to analyze the data to find relevant statistics that shed light on Hungry's current operations. To put the current operations into perspective, the study pulled summary statistics from Hungry's order data which can be seen in Table 13 below.

Table 13 Order Summary Statistics

Summary Statistics	Min	Max	Mean
Order Cost	$273.10	$10,099.71	$853.12
Delivery Miles Traveled	1.02	59.77	27.38
Delivery Minutes Traveled	6.66	100.56	55.26
Client Orders	1	112	16

An average Hungry order costs the customer $853. The average transportation costs for each order show that Hungry spends 55 minutes traveling 27 miles from their office to the kitchen to the customer. The summary statistics also show that Hungry Clients order from them 16 times on average, with Hungry's top customer ordering 112 times within the given time period. Breaking the transportation costs down further, the analysis shows that, on average, a Hungry captain spends 27 minutes driving 12 miles from the Hungry office to a kitchen to pick up a meal, and another 28 minutes driving 15 miles from the kitchens to the client's location. This equates to roughly one hour of driving 27 miles for each order, without taking traffic into consideration. Given these results, Hungry spent over $15,000 on transportation costs for the 788 orders during this time period, equating to roughly $20 of transportation costs for every order. The transportation costs identified here are significant considering Hungry's average profit per order, after costs were subtracted to pay the chef, service fee, supplies fee, and taxes, comes out to $39.

This means that nearly 50% of Hungry's profit is taken away in transportation costs alone. With that being said, the average service fee per order is $14. The average service fee cost does not fully cover the $20 transportation costs per order, but it does come close. If Hungry raised the average service fee to $20, they would recoup the majority, if not all, of the transportation costs incurred.

4.2 Optimized Operations

Although Hungry seems to be close to recouping their transportation costs with the $14 average service fee per order, there are still inefficiencies that could be recovered if they decided to optimize their kitchen locations to deliver the same service at reduced cost.

First, an optimal office location was determined by choosing an office out of the existing and candidate office locations that minimized transportation costs to all operational kitchens. Once the optimal kitchens per client were identified, transportation costs were calculated between each candidate office location and each operational kitchen. The costs were added together for each candidate office location and the office with the lowest transportation cost was chosen as the optimal office location. Coincidently, the optimal office location that was identified is within two miles from Hungry's current office location as can be seen in Figure 7 below.

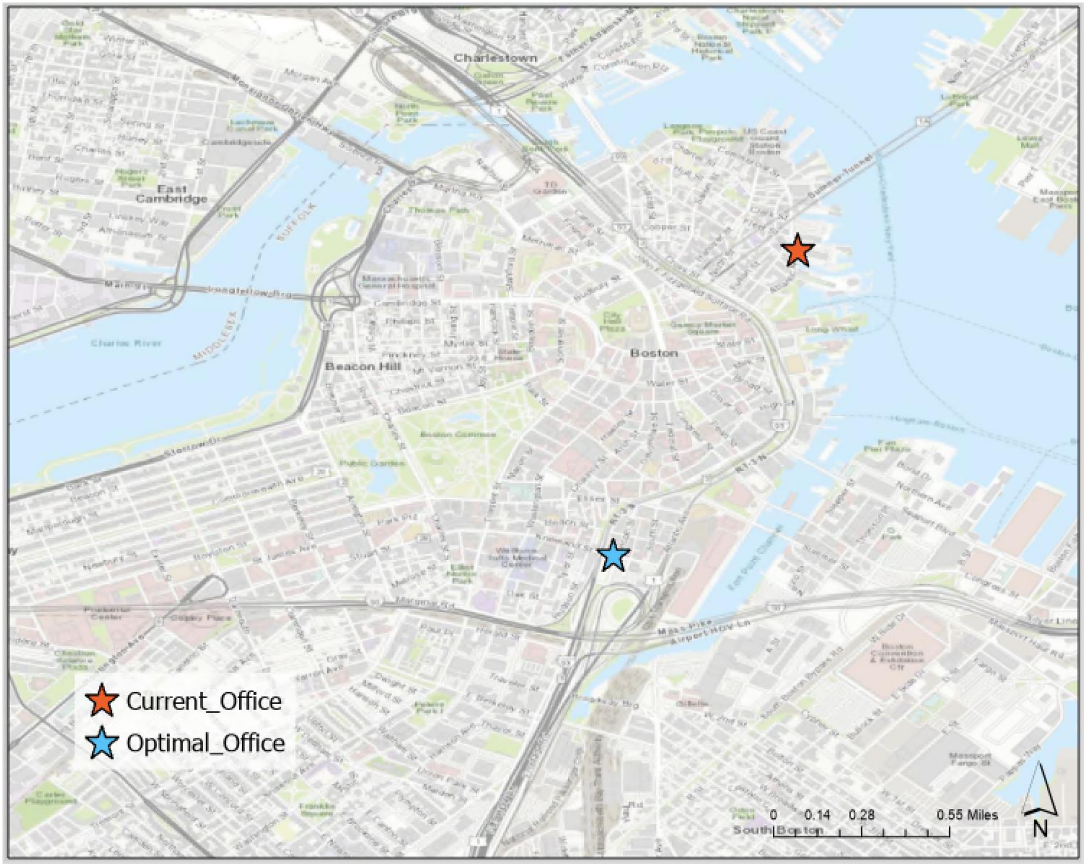

Figure 7 Current vs. Optimized Office Locations

The next locations to optimize are the kitchens that serve the clients. In section 2.1.3, a map was shown that displayed Hungry's current orders and kitchen-client pairs. A similar map was produced replacing Hungry's existing kitchens with each client's optimal kitchen that minimized transportation costs. Figure 8 shows a map of Hungry's current operations next to another map of their operations if they were to optimize kitchen locations for delivery their clients. As you can see on the top map, there are significant distances between the kitchen where the meal is cooked and the client where the meal was delivered. On the bottom map, the distances have been significantly reduced and kitchens as the closest kitchens are chosen for each client.

If Hungry moved its office and delivered each meal from the client's optimal kitchen, it would significantly reduce transportation costs. Section 4.1 identified that Hungry currently spends roughly $20 per order on transportation costs. By calculating the transportation costs for

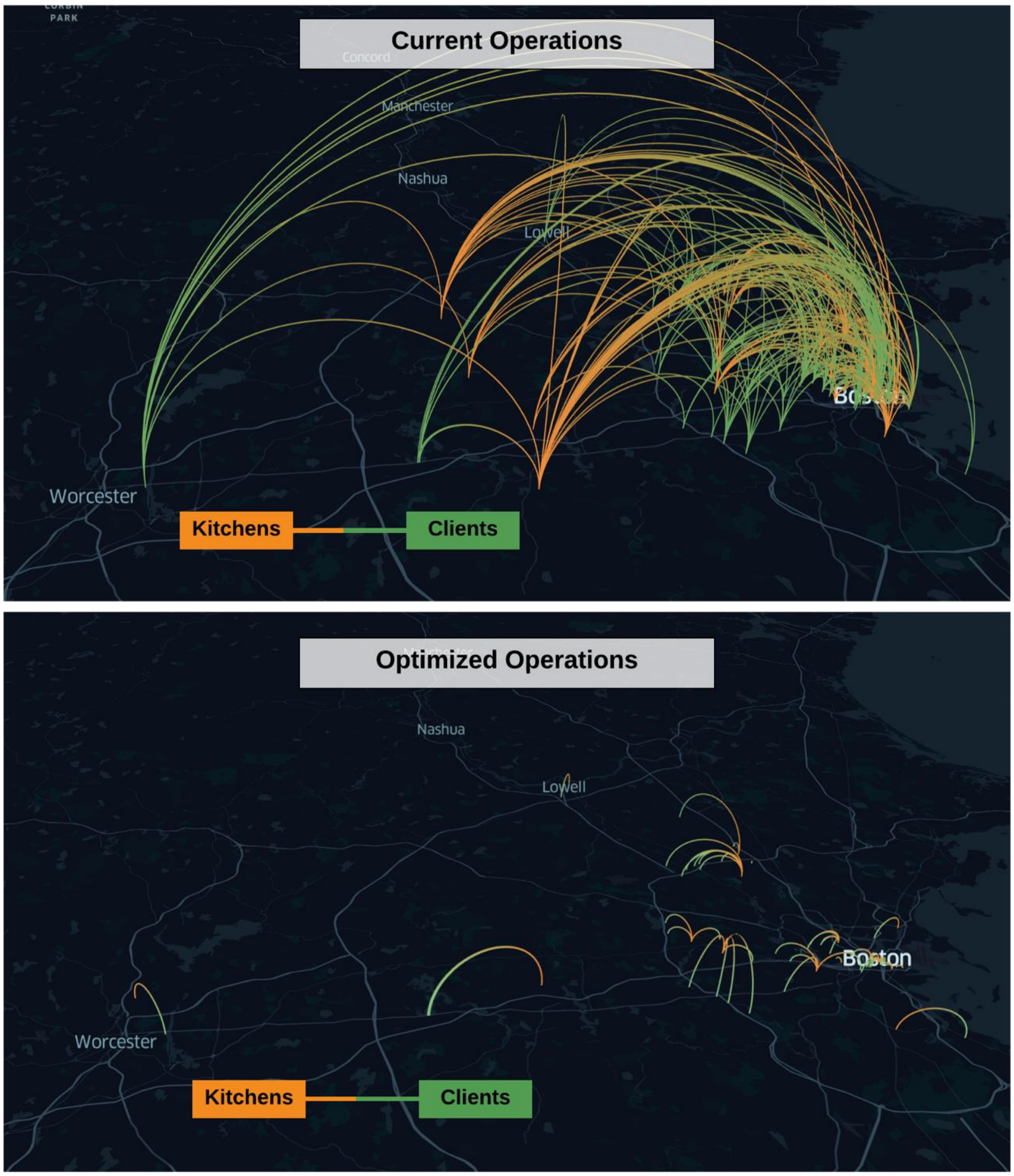

Figure 8 Current vs. Optimized Kitchen_Client_OD

the time and distance it took to pick up and deliver the meals for each of the 788 orders, using the optimized locations, it was found that on average a Hungry captain would spend 16 minutes driving 8 miles from the Hungry office to a kitchen to pick up a meal, and only 6 minutes driving 2 miles from the kitchens to the clients location. This equates to only 22 minutes of driving 10 miles for each order, as opposed to one hour of driving 28 miles in the current situation. Given these results, Hungry would only spend $7,000 on transportation costs for the 788 orders during this time period, equating to roughly $8 of transportation costs for every order. By optimizing its locations, Hungry would cut its transportation costs by nearly 50% compared to its current operations.

Chapter 5 Discussion and Conclusion

5.1 Assumptions and Limitations

This study is not meant to be a true model of reality, rather a starting point for future work that will be discussed in the next section. The model presented in this study makes various assumptions that could be altered to obtain different results. Additionally, this study was limited in scope and does not cover the full range of criteria that could be implemented to produce results that better reflect reality. The results and recommendations section of this study, presented in Chapter 4, reflect the model as it was built. It takes the assumptions into account and was constrained by the limitations, all of which will be presented in more depth below.

First, there are many assumptions the model made that need to be taken into consideration. Many of the assumptions that were made, were decided based on input from Hungry leadership. Assumptions Hungry provided include Captain cost per hour, average fuel economy for their vehicles and average fuel price. These assumptions could fluctuate over time and are at the discretion of Hungry. The assumptions were made under consideration from Hungry leadership and have been selected to reflect the current reality of Hungry's operations. The initial assumptions considered in this initial study could be altered over time to better reflect reality.

Other assumption in this study include relying on ArcGIS Pro's tools to calculate transportation costs. Transportation costs were calculated using ESRI's tools and road transportation network. The tool provided time and distance calculations between and origin and a destination pair. Transportation between these two points were calculated based on driving times on a Sunday in July. The tool estimates the time it would take based on these criteria and could be more or less given the actually travel conditions at the time. Ideally, the travel times presented in this study are the minimum time it would take to travel between two points. Sunday was chosen as the day to remove rush-hour traffic from consideration and present a baseline travel time where traffic could later be taken into consideration.

Other assumptions that were made in this study include the logistical aspects of picking up and dropping off orders. Each meal order is unique and could require more or less effort to fulfill. It was assumed that one Captain was need for each order, when in reality there could be multiple captains per order. Additionally, the study does not take additional destinations and time spent at each location into consideration. Captains could spend a significant amount of time at any one location picking up and/or dropping off the order. Captains also need to travel back to the Hungry office or their home at some point. These additional criteria were not taken into consideration.

The operations analysis conducted optimized location pairs based on minimizing transportation costs in the best-case scenario. In reality, the best-case scenario may not be achievable for some locations. Just because a client is located next to a candidate commercial kitchen does not mean that the kitchen could be used. Some kitchen may have high barriers to entry including lease cost, availability, and other factors that could not be determined until further research was conducted. However, the best-case scenario that was considered presents a general idea for how much money could save if it tried to optimize all location pairs.

There are other criteria that should be taken into consideration to present a more realistic picture of Hungry's operation, however, the limitations of the study did not allow for more inputs. The major limitation this study encountered was time. With more time, the limitations presented below could be implemented into future work.

A major limitation encountered in this study was the ability to conduct thorough research into candidate facility locations. For candidate office locations, zip code areas were used to generalize point locations instead of researching candidate office locations based on availability and current market conditions. The candidate office locations and resulting optimal office recommendation was given as a generalized idea of where an office location could go. In future work, more thought could be considered into the study area demographic and commercial considerations to determine optimal candidate office facilities. Population density, employment density, and age demographics are just some of the considerations that should be defined in future work. For this study, after the recommendation is given, it is assumed that more research could be done to research actual locations to find the best office location. For candidate kitchen locations, the study relied on a dataset provided by Hungry. There could be additional commercial kitchen within the market that were not considered in the study and further research could be done to identify additional candidate commercial kitchen locations. Candidate client locations were not considered in the study, however, competitive and sales research could be conducted to determine candidate clients Hungry could target for future business.

Additionally, another limitation the study does not take into consideration is chef transportation costs. The recommendations outlined above only take Hungry captain transportation costs into consideration, and it does not take chef transportation costs from traveling from their home to the commercial kitchen location. If clients were to order meals from their closest commercial kitchen facility, thereby optimizing the transportation costs, clients could need to sacrifice the chefs they have the ability to order from as it may not make financial sense for chefs to drive to the client's closest commercial kitchen location. However, using the results and recommendations of this study, Hungry could not only assign optimal location pairs, but also limit a client's ability to order from certain locations and therefore chefs.

Another limitation that could be considered in future work is weighting locations based on certain criteria. Not every location should be considered equal as there are many factors above transportation costs that could be taken into consideration. First, the price of facilities is a large factor that will fluctuate throughout geographic space. Typically, an office location located downtown will be more expensive than a location in the suburbs. Similar to office costs, commercial kitchen's will also charge different amounts based on location. Clients should also be considered with different weights based on the value they bring to the company. Some client's may be repeat customers that order multiple times a week versus another client that may just order once a month. Different costs should be considered for all three location types in future work. By weighting each location based on different costs, it will better reflect reality by weighting their significance compared to other locations within the operation.

5.2 Conclusion

Meal delivery is a dynamic market within the food industry that requires geographic considerations to ensure the product is delivered in a timely and cost-effective way. Using geographic information systems and databases, this study built a model to effectively analyze Hungry Marketplace's meal delivery operations in Boston, Massachusetts. The model incorporated existing operational data as well as candidate facility locations provided by Hungry. The data was processed using ArcGIS Pro's network and spatial analysis tools, which were then incorporated into a database using Microsoft SQL Server. The database was used to gather insights into Hungry's operational data to develop results and recommendation that could save Hungry thousands of dollars in costs. The study found that Hungry could cut its transportation costs in half by optimizing its client and kitchen locations. Additionally, the study recommended optimal candidate kitchens to use over its existing kitchens in operation. The study recommends that Hungry look further into its operational data using the database that was created. By answering questions using the resulting database, Hungry could make changes to its operations in Boston as well as its other operating location throughout the United States that would result in significant cost savings. The model presented in this study is not a true representation of reality as there were time constraints that had to be taken into consideration. However, the study built a solid foundation that could be built upon in future work to resolve assumptions and include the limitations that were presented above. Ultimately, the study not only found and recommended optimal locations and operating guidelines the company could implement to maximize opportunities, but it also produced a comprehensive, data-driven, and reproducible methodology for optimizing spatial decisions for companies looking to operate in the meal delivery space within the food industry.

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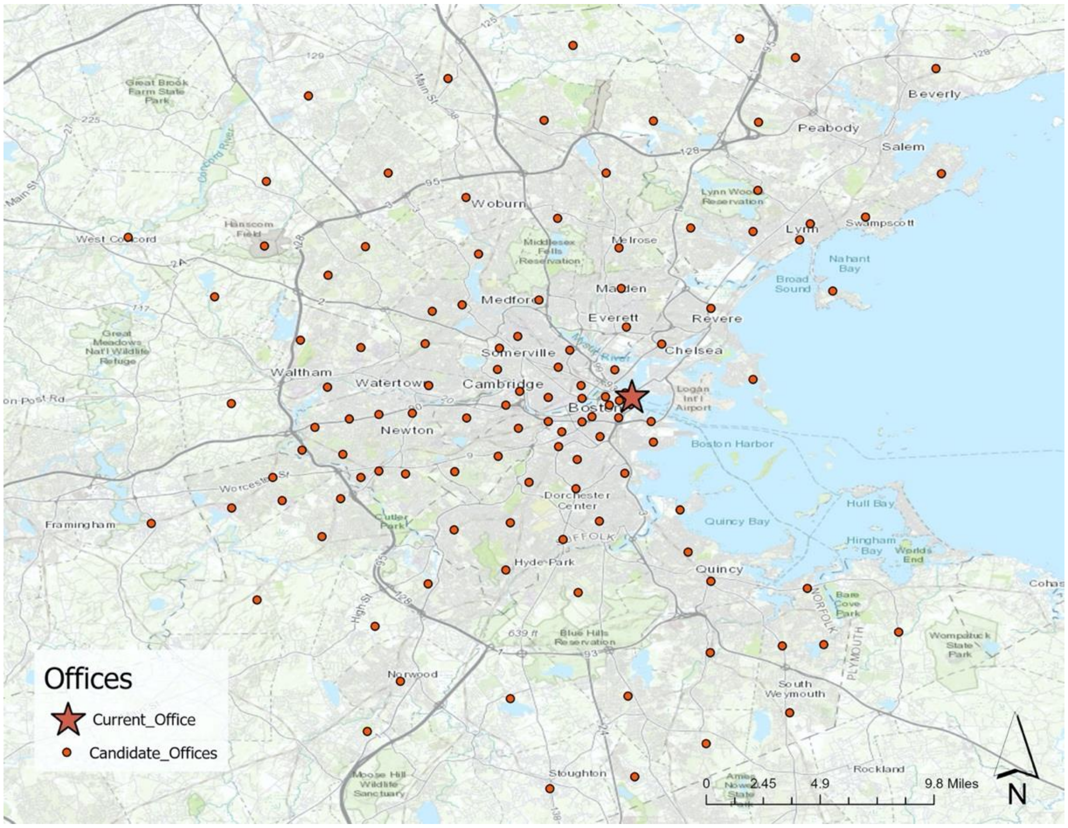
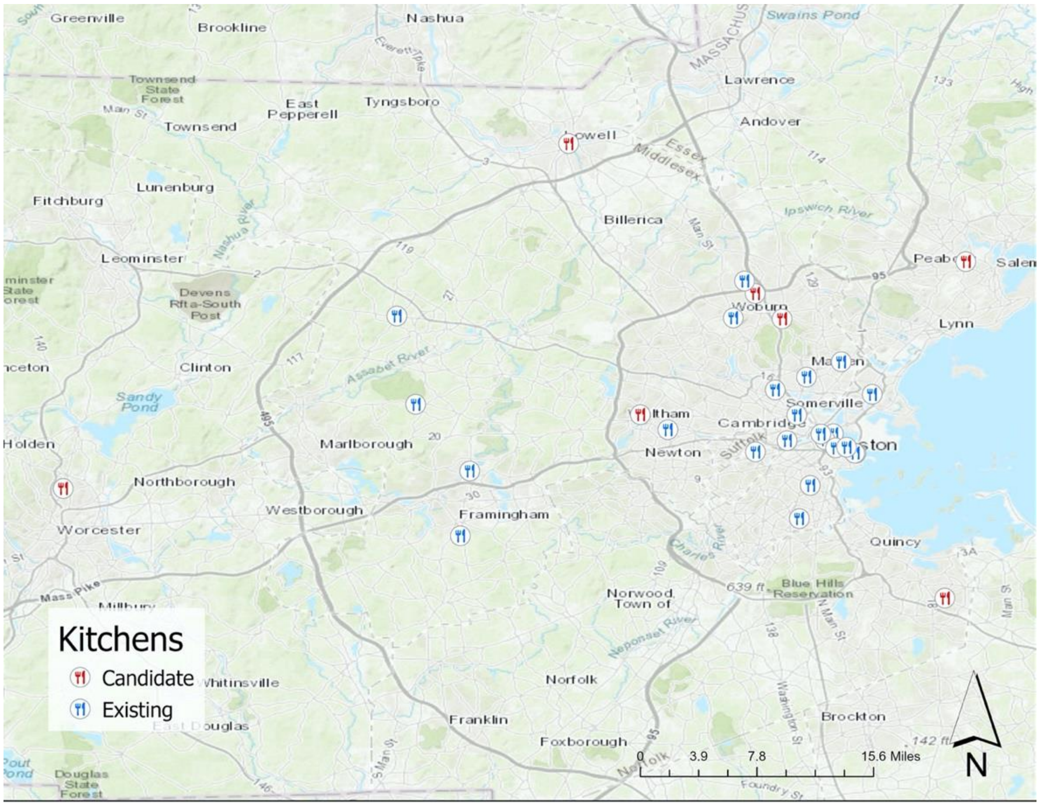
APPENDIX A: Offices



APPENDIX B: Kitchens



APPENDIX C: Clients