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Business and Logistics Plan
For
The Healthy Veggies (THV)

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1. Executive Summary

We at Pennant Consulting provide state of the art solutions to our customers to help them achieve their business goals. Our team has been approached by The Healthy Veggies to help them design a strategic plan to establish their business in customer-direct sales of fresh vegetables to customers in the city of Sanitago, Chile.

To launch a business successfully, several crucial factors must be considered. Primarily, it's essential to evaluate the local demand for the product, develop a plan for facility placement, establish a sound supplier selection strategy, devise effective inventory planning, and create a transportation strategy for seamless product delivery from suppliers to end-users.

The Pennant Consulting team has conducted an in-depth market analysis and formulated a robust supply chain and logistics strategy, ensuring the profitability of The Healthy Veggies company within the highly competitive online ordering sector. The logistics plan is meticulously crafted, encompassing elements such as supplier choice, transportation tactics, facility location decisions, product inventory policies, and thorough estimations of demand and costs. These strategies are devised to optimize the company's overall profit while upholding its commitment to quality and service excellence.

To comprehend the target market, the company conducts a market analysis, identifying high-demand areas through the average basket size (CBA) per communa. Estimations for product demand are derived by utilizing ODEPA data on product volumes reaching wholesale markets, coupled with census data on household numbers to calculate average volume consumption per year. Opting for optimal business efficiency, Pennant has concluded to establish a single distribution center. The decision was reached through solving the location allocation problem, considering two potential locations, Huechuraba and Cerro Navia. After solving this problem, Pennant has settled on placing the distribution center in Huechuraba.
Utilizing modern machine learning methods, Pennant has chosen to establish nine dark stores in strategic locations across Santiago, focusing on areas with significant demand.
Pennant suggests that The Healthy Veggies (THV) addresses only 15% of the overall demand within Santiago. To manage initial-year investments judiciously, the proposal is for THV to exclusively cater to regions where their dark stores are located. This approach minimizes initial capital expenditure. Following demand calculations, the company has opted to concentrate on serving the 95,761 households in the nine communas where they plan to establish their dark stores.
THV will target 8 fresh products: Roma Tomatoes, Banana, Cauliflower, Avocado, Pineapple, Broccoli, Asparagus, Green Bell Pepper. These suppliers are selected such that they have minimal lead time and low costs for products and Transportation.
To strategize inventory management, we suggest implementing a modified Q, R model. This approach aims to guarantee freshness, particularly crucial for perishable goods. The objective for The Healthy Veggies (THV) is to consistently provide customers with the highest quality products.
The transportation is planned in three stages. The first stage consists of transportation of produce from suppliers. In this stage the complete trucks are owned by the supplier and THV only pays for the delivery. The second stage is delivery from distribution center to dark store which is done using mini trucks (10 Ton). This is completely owned and controlled by THV. Third stage is last mile delivery which is which is also completely owned and controlled by THV and is done using motorbikes.

After a thorough analysis it is predicted that THV makes an annual income of CLP 45,122,076,203 with a profit of CLP 9,232,584,619.

Our suggestion for THV is to initiate the business on a small scale and gradually expand, gaining insights into the market. To minimize carbon emissions, we propose substituting conventional motorbikes with electric two-wheelers, offering the additional benefit of reducing fuel costs for the company.

2. Introduction and Objective

The Healthy Veggie (THV) has identified a potentially lucrative business opportunity to offer the direct-to-customer sale of fresh vegetables in the metropolitan region of Santiago, Chile. To assist THV in capitalizing on this opportunity, Pennant Consulting has selected an elite team of analysts and supply chain engineers from Pennsylvania State University (PSU) in the United States and Universidad de Los Andes (UAndes) in Santiago.

The Objective of the Pennant Consulting is to plan a logistics model for The Healthy Veggies Company for its online grocery ordering business in Santiago, Chile. The pennant consulting team will identify the sources of suppliers for the vegetables with respect to lead time and transportation cost. The team will also identify the location of the Distribution Center and the location of the Dark Stores and the Inventory planning of the distribution center and the Dark Store. The Team will also design a transportation strategy for the products from the origin to the DC, also the team will plan a last mile strategy for the transportation of products to the customer with also considering the impact on the environment because of the Carbon Emissions. Finally, the pennant consulting team will estimate the overall sales, overall costs, and overall profits of the plan.

This team knows that to ensure the success of any new endeavor, numerous elements - including sustainability, customer service, scalability, technology, networking, and location - must be incorporated into a robust business plan and supply chain strategy. Pennant Consulting ensures that all such important variables are considered during the business plan and is highly motivated to help THV reach its objectives – your success is our success.

Our Scope

Pennant Consulting will be working on overall strategy analysis and logistics network design. Pennant will be estimating the market potential, potential suppliers for each product, harvesting times, purchase costs, transportation costs and location of DC (Distribution Center) and dark stores. To demonstrate that Pennant is invested in the success of THV, the team has already begun investigating methodologies to provide cost-effective and sustainable solutions to THV's strategy and logistics network design problems. In some cases, initial data acquisition and analysis has been performed. The remainder of this proposal provides details of these initial investigations.

Also, another main project's primary goal is to guarantee quick and effective supply. We pledge to meet client demand by delivering all orders to them in less than eighteen hours. This promise demonstrates a strong dedication to meeting customer needs by placing a high value on timeliness and speed in the logistical process. This guarantees our users the best possible shopping experience and prompt delivery of their supply needs.

3. Problem Description

Our proposed strategy to fulfill grocery orders online for The Healthy Veggies company includes decisions made regarding supplier selection, distribution center and dark store locations, inventory models needed for distribution center operations, distribution center and dark store layouts, and the modes of transportation required to move goods from point of origin to final consumer at each stage of the supply chain.

3.1. Methodology

Market Analysis

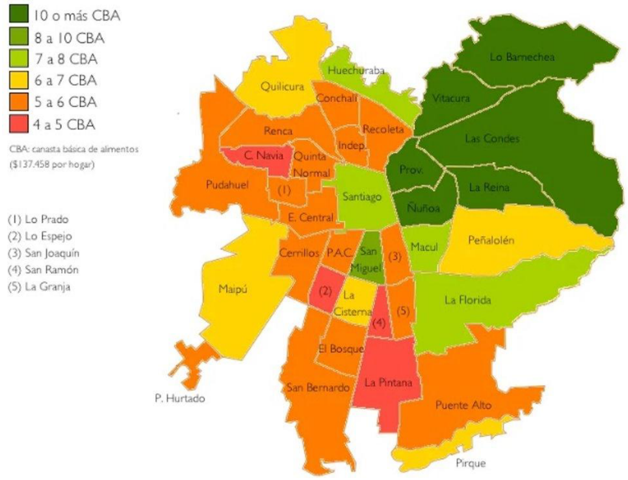

Figure 1 Map of Santiago

The initial market analysis was performed by evaluating the **(Average Basket Size) CBA** index across Santiago. This index is expected to roughly correspond to demand for the produce which THV provides and is combined with city-wide demand data to construct a geographically distributed demand profile. In the Figure *1,* the high demand areas (high demand *comunas*) can be seen in the northeastern area of the city. This is the area where we can expect the highest number of orders. As a result, Pennant notionally proposes locating the Dark Stores in these areas so that THV has the capacity to handle the high number of orders. By locating the Dark Stores strategically based on the CBA we can ensure that the Dark Stores remain profitable and there is a constant stream of orders with low probability of either Overstocking or Stock Outs due to understocking. Additional detail on the proposed Distribution Center (DC) strategy is provided in the next section. The market analysis was done by using the **(Average Basket Size) CBA** index across Santiago. The High demand area can be seen here marked in the northeastern area of the city. This is the area where we can expect a high number of orders and we must locate the greatest number of Dark Stores in the area so that we have the capacity to handle the high number of orders. By locating the Dark Stores strategically based on the CBA we can make sure that the Dark Stores remain profitable and there is a constant stream of orders without any possibility of either Overstocking or Stock Outs due to understocking.

4. Demand estimation

To estimate the demands of the products THV offers on different months, data from **ODEPA** about the volumes of said products that arrive to wholesale markets throughout the country, together with census data about the amount of households (to calculate the households we have used **Microdato_Censo2017-Hogares.csv** and extracted the number of households using python) in each communa was used in order to compute the average volume of consumption of all the products for every month of the year. The last process was done to obtain an average of the ***Poisson*** **distribution** that household orders follow.

Some important assumptions were made, which include:

1. All households are identical and independent from each other, and the demand is distributed equally for every household. The reason behind these was to facilitate some calculations, and to make the aggregation of the demand easier.

2. The company only serves in the areas of Santiago where we locate our dark stores as the last mile delivery is done only using motorbikes and a new dark store is opened year by year which introduces the company newer markets and respectively investments are made to expand the business.

So, for every month, and every product, a parameter for the *Poisson* distribution was computed. To obtain demand values, some simulations were made for every product, and for every month. Said simulations were done following the ***Monte Carlo* methods**, so for every case already mentioned we computed a demand average and standard deviation. In terms of repetitions, ten thousand were made for each case. This was done to introduce variability into the simulations.

It is important to mention that said calculations are estimates and might be subject to variation. But they were necessary for further stages of the report.

(Calculations can be found in Appendix H)

Selected Suppliers

Supplier	Harvest Seasonality. This decision should be based on the information provided (Additional Information II). Products											
	January	February	March	April	May	June	July	August	September	October	November	December
Roma Tomato Sourcing Region	Chile, RC	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RC	Chile, RM	Chile, RM	Chile, RC
Banana Sourcing Region	Ecuador, TPA	Ecuador, ATI	Ecuador, TPA	Ecuador, TPA	Ecuador, TPA	Ecuador, SAI	Perú, SAI	Ecuador, TPA	Ecuador, TPA	Ecuador, VAP	Ecuador, TPA	Ecuador, TPA
Cauliflower Sourcing Region	Chile, RM	Chile, RM	Chile, RMA	Chile, RMA	Chile, RM	Chile, RM	Perú, CHA	Chile, RMA	Chile, RM	Chile, RM	Chile, RMA	Chile, RM
Avocado Sourcing Region	Chile, RM	Chile, RM	Chile, RA	Chile, RA	Chile, RA	Chile, RA	Chile, RA	Chile, RA	Chile, RA	X	X	X
Pineapple Sourcing Region	Chile, RM	Chile, RV	X	X	Argentina, LB	Perú, CHA	Perú, CHA	Perú, CHA	Perú, CHA	Perú, CHA	Perú, CHA	Perú, CHA
Broccoli Sourcing Region	Chile, RM	Chile, RM	Ecuador, TPA	Ecuador, TPA	Ecuador, TPA	Ecuador, TPA	Ecuador, TPA	Ecuador, TPA	Bolivia, CHU	Ecuador, TPA	Ecuador, VAP	Ecuador, TPA
Asparagus Sourcing Region	Chile, RMA	Chile, RM	Chile, RMA	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RM	Chile, RMA	Chile, RM
Green Bell Pepper Sourcing Region	Perú, CHA	Perú, CHA	Perú, CHA	Perú, SAI	Perú, CHA	Perú, CHA	Perú, CHA	Perú, CHA	Chile, RMA	Chile, RMA	Chile, RM	Chile, RMA

Acronim	Full name
RM	Lo valledor
RV	Famacal de la Calera
RMA	Macroferia regional de Talca
RC	Terminal La Palmera La serena
RA	Arica
CHA	Complejo Fronterizo Chacalluta
SAI	Puerto de San Antonio
TPA	Puerto de Arica
VAP	Puerto Valparaíso
CHU	Paso Froterizo Chungará
LB	Paso Fronterizo Los Libertadores
ATI	Puerto de Antofagasta
X	No availablity

Table 1 Selected list of suppliers for each vegetable/fruit

We plan to use an **individual policy** where individual trucks are allotted as per the product and supplier we choose. Our choice of supplier can be seen in the table above. For example, we have chosen a supplier RM who supplies us with Roma tomatoes, Cauliflower, Avocado, Pineapple, Broccoli, and Green Bell Pepper in some seasons. We have chosen some individual policy with suppliers like SAI from whom we only source Green Bell Pepper. The suppliers that have been selected are selected based on the lead time, the perishability factors of the goods and with minimal cost of transportation of the products to the Distribution Center.

5. Transportation from the Origin to Distribution Center

In general, produce for THV from the supplier reaches the DC in a Truck with a load capacity of 45 Ton. If the produce comes from air or marine, the produce is transported from the airport/Shipping port to DC in the form of a big trailer. If they come by road, then the produce is directly transferred from the supplier to the DC. Most of the suppliers are chosen as close geographically to Chile as possible to avoid larger tariff rates. Transportation is done all by trucks which cost around $1,921 (CLP) per Kilometer.

(all the calculations can be found in the spreadsheet)

6. Location of Facilities

6.1 Method of Locating the Dark Stores:

To strategically locate the dark stores in the Santiago, we first identified the communas with high demand based on the **average basket size (CBA)** of the city as done before in the market analysis. We strategically located the dark stores in these areas that we found out using the below mentioned method.

6.1.1 K means Clustering and Elbow Method

Based on the number of households present in each communa and the market we plan to service, we estimate the demand for each communa. We obtain 200 household coordinates (using google maps we randomly selected 200 addresses throughout each communa) from the addresses of these household using **geopy library**. We form clusters using these coordinates. This technique allows us to identify the pivotal points, or **"elbows,"** in the data that correspond to the optimum sites for Dark Stores. Using the **K- means clustering** we can find the **centroids** which are used to locate the Dark Store. Placing these Dark Stores near the centroids of demand simplifies access to areas with strong consumer demand. In addition to improving operational efficiency, this

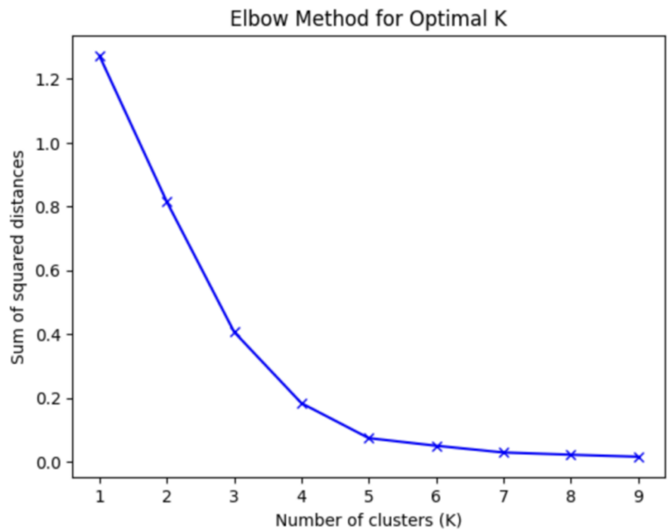

Figure 2 Elbow method to obtain the optimal number of centroids.

strategic location also directly affects important performance measures, particularly in last-mile delivery. We significantly cut the time needed for the crucial last-mile delivery phase by reducing the distance between Dark Stores and areas of strong demand. This results in a significant decrease in last-mile delivery costs and time, which is crucial in the competitive environment of modern logistics and e-commerce. In essence, our strategy makes use of geographic analysis and data-driven decision-making to ensure that Dark Stores are strategically positioned in demand centroids, improving our capacity to respond to consumer needs quickly and affordably.

6.2 Location Allocation for Distribution Centers:

For locating the distribution center there were two possible locations where a distribution center could be set up.

The **1st Possible Location** is in the industrial area of Huechuraba.

Advantage: Huechuraba is in the outskirts of the city. This will lower the Distribution center setup cost if we decide to locate it here.

Disadvantages: If the DC is in the outskirt of the city the transportation cost will get higher when transporting goods from the DC to the dark store.

The **2nd Possible Location** is the center of the city of Cerro Navia.

Advantage: It is in the center of the city which can reduce the transportation cost from the DC to DS as it located in the center of the city.

Disadvantage: As Cerro Navia is in the center of the city this will have higher land acquisition cost which will raise the Distribution Center Setup Cost.

To decide on the which is the better location for the Distribution Center we formulated a model.

6.2.1 Location Allocation Model for THV:

Assumptions:

1. Costs are in CLP.
2. Shipping cost is based on distance (in km) vice time.
3. Mini trucks take the shortest distance route between Distribution Center(s) (DC) and Dark Stores (DS) every load.
4. A mini-truck has one-seventh the cost per kilometer of a 40-ft container truck. We assume the same cost at less than truckload (LTL) or at full truckload (FTL).
5. Due to the low transportation costs per kg of produce per mile, we formulate this model in terms of round-trip truckloads.
6. Each DC can meet the entire demand of all DSs by itself (capacity is sum of all truckloads per dark stores).

Objective:

The objective for the allocation model is to minimize the Total Fixed Cost and the Shipping Cost from the DC to DS.

Constraints:

(1) The first constraint needs to ensure that the demand is met at all the dark stores.

(2) The second constraint needs to ensure that distribution center capacity is maintained and that we cannot ship from a DC unless we build it.

A more detailed explanation of the model is in the appendix.

From the model we observe that locating a **distribution center in the Huechuraba** is optimal as it has the lower investment cost of about CLP 36,966,875) when compared to the investment cost of a DC in Cerro Navia with about CLP 46,695,000.

<u>**Location of Distribution Center and Dark Stores**</u>

The location of the Distributor Center is marked in Red, and the Dark Stores is marked in Orange. The address of the Distribution Center: **Av. Recoleta 5905, 8580842 Santiago, Huechuraba, Región Metropolitana, Chile**

Dark Store 1: Golf Lomas de La Dehesa 12452-12040, Lo Barnechea, Región Metropolitana, Chile
Dark Store 2: Lampa 8483-8489, Las Condes, Región Metropolitana, Chile
Dark Store 3: Regimiento Cazadores 1270-1214, Providencia, Región Metropolitana, Chile
Dark Store 4: Lo Beltrán 2474, 7640276 Vitacura, Región Metropolitana, Chile
Dark Store 5: Estados Unidos 135, La Florida, Región Metropolitana, Chile
Dark Store 6: Rosa Reyes 7170, 9100781 Santiago, Cerro Navia, Región Metropolitana, Chile
Dark Store 7: Ismael Valdés 1931, 8460082 Pedro Aguirre Cerda, Región Metropolitana, Chile
Dark Store 8: Larga 172-134, El Bosque, Región Metropolitana, Chile
Dark Store 9: El Cid 495, Maipú, Región Metropolitana, Chile

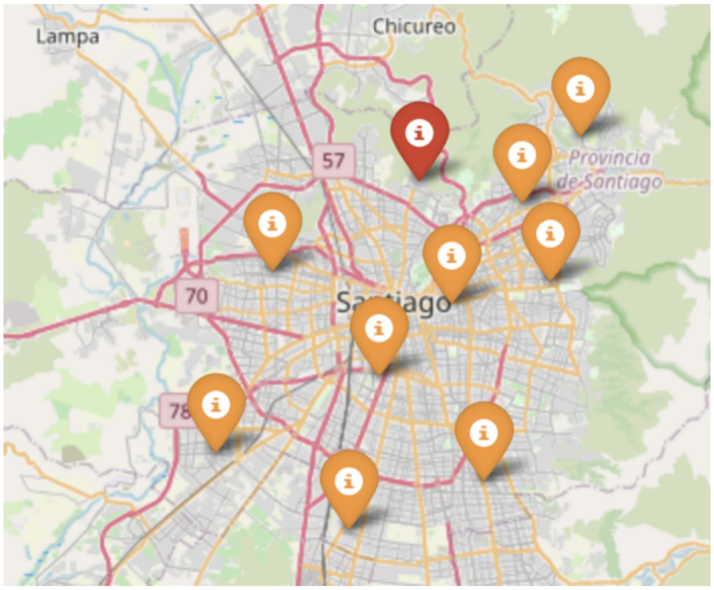

Figure 3 Location of Distribution Center and Dark Store

(Calculations can be found in Appendix B)

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7. Layout of Facilities

7.1 Distribution Center Layout

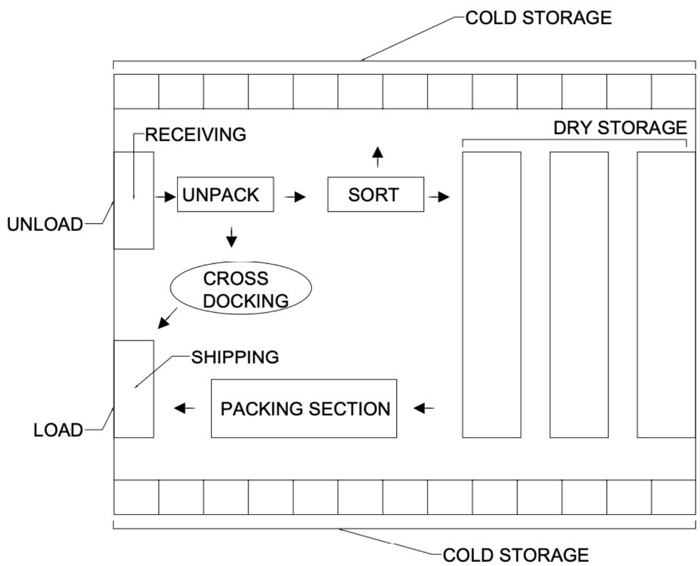

Figure 4 Distribution Center Layout

The flow of distribution center starts with the receiving of products from the suppliers this is then unloaded and unpacked, and a cross docking function is available for those goods which needs to be shipped in a short time. The unpacked goods are then sorted and are stored in the storage. The shipping consists of picking the order from the storage and packing it and loading to the trucks.

7.1.1Distribution Center Area:

The area of the distribution center is about **3891.25 m^2 or 41885.066 sq ft.** The built area is about 2771.25 m^2 and the parking area is about 1120 m^2. We have taken the maximum demands from each month and calculated how many pallets they account to in a month. Then we have calculated how much area the pallets take which has summed up to 580 m^2. The area of the Pallet is taken as 1 * 1.2 [in meters]. By this we can know how much area the pallets consume, and the area is calculated for monthly demand because we wanted to take the maximum area so that if there is any chance that we have more business we will have the scope to store more. We have also added other factors that should be accounted during the calculation of total area of the DC. The table of these factors are available in the appendix.

	DC
Built M2	2771.25
Parking M2	1120
Total M2	3891.25

Table 2 Area of Distribution Center

7.1.2 Cost of the Distribution Center:

The costs of the distribution center are all included in the appendix. The main operating costs are given below.

Items	CLP
Construction	$7,393,375
equipment and maintenance DC	$8,218,320
Total CLP	$15,611,695

Table 3 Operating Costs of Distribution Center

The construction cost is taken as 9500 CLP/m^2 and the equipment and maintenance costs are taken as 20% of the construction cost which is 1900 CLP/m^2.

7.2 Dark Store Layout

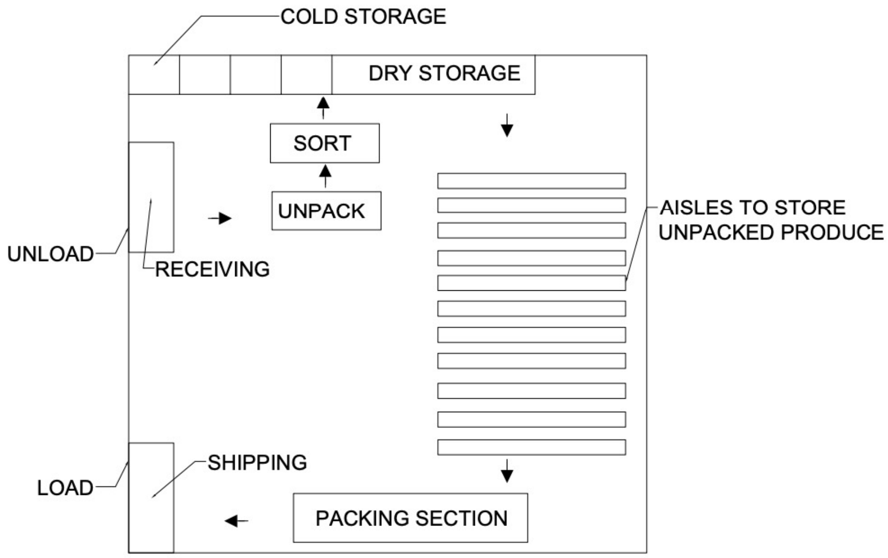

Figure 5 Dark Store Layout

In the dark store we receive the goods in trucks from the Distribution Center, these goods are then unloaded and unpacked and sorted these goods are then stored in refrigerated storage. Then the produce is transferred to storage in the aisles which makes it easier for the pickers to pick and pack the order. The pickers pick the product from the aisles and then pack them in the packing section and keep it ready for the drivers to take the order.

7.2.1 Area of Dark Stores:

All values are in m^2

	DS 1	DS 2	DS 3	DS 4	DS 5	DS 6	DS 7	DS 8	DS 9
Built m^2	67.5	266.25	157.5	71.25	97.5	75	120	390	288.75
Parking m^2	56	112	112	56	56	56	56	168	112
Total m^2	123.5	378.25	269.5	127.25	153.5	131	176	558	400.75

Table 4 Area of Dark Stores

The built-up area = Carpet area + 25% of Carpet area
The total area occupied by the pallets is calculated the same way we calculated for DC. Here we have taken the extra area for operations. This excess area is considered because in the dark store we have more of unpacking, packing and the movement of unpacked goods from the unpacking section to aisles. The number of trucks is a rough figure taken to calculate the amount of parking we must decide at the dark store. So, we have taken the amount of truck loads that usually operated in a day at a dark store. For the classification we have taken
If the area of the DS <100, then 1 truck
If the area of the DS<300, then 2 trucks
If the area of the Ds > 300 then 3 trucks
These Tables can be found in the appendix.

7.2.2 Cost of the Dark Stores:

	CLP
construction	2201862.5
equipment and maintenance	233130
total CLP	2434992.5

Table 5 Operating Costs of Dark Stores

The construction cost is taken as 950 CLP/m^2 and the equipment and maintenance costs are taken as 20% of the construction cost which is 190 CLP/m^2.

(Area Calculations can be found in Appendix C)

8. Perishability of the Products

The term "perishability" describes a product's propensity to deteriorate or lose its suitability for ingestion over time. Our company has a direct bearing on the caliber and freshness of the products we get since time and deliverable time is our priority.
In our case, controlling perishability is essential because the waste expenses related to unsold or expired goods fall on the terms of “Waste Cost”.

$$FractionRemainingShelflife_t = FractionRemainingShelflife_{t-1} - Decay_t$$

Using this formula, we can find the product's remaining shelf life as a percentage. Fresher and having a longer shelf life are products with a larger proportion remaining. In order to reduce waste costs, it is imperative that items are sold or used before they reach the end of their shelf life.

$$DaysShelflifeRemaining_t = T * FractionRemainingShelflife_t$$

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Product	k2	T
Roma Tomatoes	2	14
Banana	2	36
Cauliflower	2	12
Avocado	2	18
Pineapple	2	20
Broccoli	2	18
Asparagus	2	19
Green B, Pepper	2	18

Table 6 Perishability of Our Products

It gives a concrete deadline for selling or using the goods to preserve its freshness. We can efficiently organize our sales and distribution plans by keeping a close eye on this measure, which guarantees that items are delivered to manufacturers or consumers before their quality noticeably declines.

We can now calculate the number of days that have passed since the harvest of fruits or vegetables by using the two formulae and the variables from the dataset. We can determine how quickly these things need to be found or sold thanks to this computation. Through these computations, we can ascertain that a negative value denotes a possible loss, highlighting the necessity of selling or using the goods as soon as possible. Our ability to make prompt judgments ensures product freshness and reduces waste costs in our operations thanks to this real-time evaluation.
Wastage costs are calculated as 5% of the total sales which come up to be CLP 7,729,907. (The calculations are mentioned in the spreadsheet)
(Calculations and graphs can be found in Appendix A)

9. Inventory Policy

9.1 Inventory Policy at Distribution Center

For the inventory policy at the Distribution Center we use continuous review Q, R method with a service level of 95%. With constant monthly demands, we can compute economic order quantities for each month, as found in the Q columns of the Aggregated EOQ tab in the Deliverable2 spreadsheet. This also gives us reorder frequency (EOQ/monthly demand). The lead times normally distributed in hours. To apply the continuous review model, we compute the standard deviation of demand in units of lead time, we calculate the mean demand over lead time per product and per month. Finally, we compute our reorder points for each product and each month as

$$R^{ij} = \mu_{DLT}^{ij} + z_{0.95}\sigma_{DLT}^{ij}$$

Note that for products with the same supplier, and lead time distribution, we can combine orders.

$$Q = \sqrt{\frac{2AD}{iv}}$$

To consider perishability as factor we have an updated Q, R model where to calculate the Q we have decided that

$Q = \sqrt{\frac{2AD}{iv}}$ if T + L < P_{time}

Q = (P_{time} - L). D if T + L >= P_{time}

T= Remaining Shelf life after 40
P_{time}= Perishable time
L = lead time
A= ordering cost (Acquisition price + Transportation cost per KG of that item)
D= Demand
i = inventory holding rate(20%)
v=item value
We have chosen.

$$Q = \sqrt{\frac{2AD}{iv}}$$

if T + L < P_{time}

The calculations for this are mentioned in the appendix and detailed calculations are done in the spread sheet

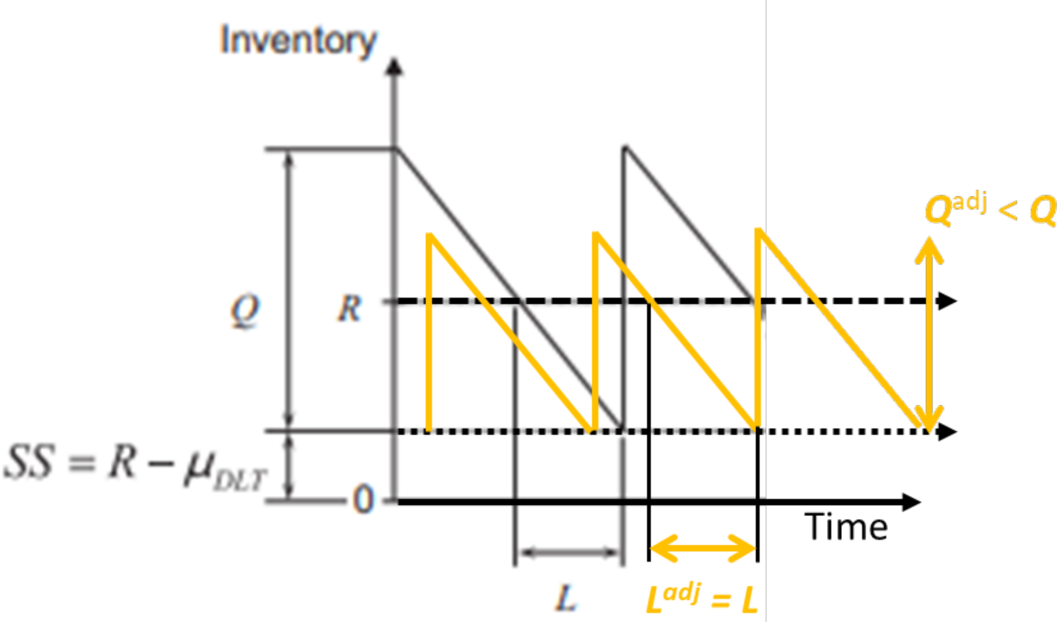

Figure 6 Graph for adjusted Q,R method

Because our lead times are very less, and they do satisfy the condition T + L < P_{time}.
We plan to order weekly once. Each item is packed in boxes and bags, and the boxes are stacked on to pallets. The pallet dimensions are.

1 m x 1.2 m
Pallet capacity 2500 Kg

So, the supplier packs all the vegetables as per the packing requirements mentioned above and sends them in full truckloads of capacity 45 Tons.
The number of trucks per vegetable as per our demand requirements are calculated by.

$$Number\ of\ Trucks = \frac{Maximum\ Average\ Demand\ over\ an\ year(Kgs)}{45{,}823\ (Kgs)}$$

The number of trucks is calculated for each month, and they are mentioned in the aggregated sheet of the excel file.

9.2 Ordering Strategy

We have found the EOQ from the data that we collected. But the Q values seems to be very less, and this might lead to ordering many numbers of times. So, we have come up with a strategy of ordering once every week and we will be ordering in the multiples of Q.

$$Frequency\ of\ order\ in\ a\ week = \frac{Average\ Demand\ per\ week}{Q}$$

For example, if we take the Q for Roma tomatoes in January the Q = 2,571.35. So, to satisfy the average demand of 624,086 we must order 240 (approx.) times in a month and 60 (approx.) times in a week which might increase our transportation charges.

So, we plan to place an order once a week and the order quantity will be.

$Order\ Quantity\ per\ week = Frequency\ of\ order\ in\ a\ week * Q$

So, in the above example the order quantity per week for Roma tomatoes in January is (60*2571.35=154281) 154,281 Kgs which is 3.42 trucks. So, the trucks are accordingly adjusted as per the orders.

9.3 Inventory Policy for Dark Store

We assume that demand is constant within a month. Thus, we know exactly how much demand is needed each month and have inventory by dark store and by month for each product given in the Demand for DCDS tab of the Deliverable3 spreadsheet.

(Calculations can be found in Appendix D)

10. Transport from DC to Dark Stores

Figure 7 Mini Truck (Capacity 10 Ton)

Mini truck [9] (The truck which we are going to purchase is given in the reference), for simplicity we will call it mini truck, which is used to transport produce from the DC to local dark stores.
Once again, optimization models are anticipated to be used to solve for efficient usage of both delivery modes. Due to the different timescale from the supplier to DC problem, the models used here are more like the "dial-a-ride" optimization problem may be different. Additionally, the team at Pennant will carefully address the uncertainty inherent to local ordering. LA modeling assumptions likely will be that customers in Santiago have cost-minimizing order policies, and that, and their orders can be these orders may be modeled with a Poisson distribution.

10.1 Methodology

We plan to buy 30 trucks(we got 25 trucks from the calculations and we have taken 5 trucks extra for emergency or sudden demand situations). The calculations for this are done by taking the need of trucks as per the consumption at each dark store. The Calculations are listed in the appendix and the costs are listed in the table below.

list of items for DC to DS transportation	per truck	annual cost
Truck buying costs	4367150	131014500
driver and maintenance costs	426	28110888
	Total Costs	$159,125,388.00

Table 7 Costs for Transportation from DC to DS

The mini-truck price and details are mentioned in the references [9]
The driver and maintenance costs are roughly calculated. As we know that the costs for a 45-ton long haul truck is 1921 CLP, so from this we can say that per ton the cost is 42.68. So, we have roughly estimated that for a 10-ton truck the cost is CLP 426/km. Therefore, the total annual costs for DC to DS transportation is.
CLP 159,125,388.00

(Calculations can be found in Appendix F and Appendix G)

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11. **Last Mile Transportation**

Figure 8 Motorbike Used for Last Mile Delivery

The last mile strategy consists of using motorcycles with affixed thermal containers to deliver to customers. Motorcycles are selected due to their fuel efficiency and low upfront costs compared to full-size or mini trucks. In addition, motorcycles produce approximately 45% less emissions compared to petrol cars [13], allowing THV to lower its environmental impact as compared to companies using larger vehicles.
These motorcycles will pick up an average of 5 orders (each order of 1.38 kgs calculations are done in the appendix) to deliver at a Dark Store every hour and use commercial vehicle routing software to plan a route for that hour.
Under this scheme and based on the 9 *comunas* (markets) THV will serve, we estimate Last Mile costs at **27,294,084,312.14 CLP**. With a $1736.06 CLP ($2 USD) revenue per order, annual revenues are estimated at **18,163,604,481.75 CLP**. A conceptual overview for how these numbers are estimated is provided below, and the corresponding mathematics can be found in the Last Mile Appendix.

We have taken the area Maipu and have calculated the requirements for a single area then extrapolated it to all the areas that we are serving. The extrapolation was done by taking the total number of orders that we are going to execute with the help of Poisson distribution calculations that are mentioned in the appendix.

We compute the Last Mile cost of THV as a function of the number of delivery motorcycles (or equivalently the number of drivers), which is dependent on the expected number of orders THV will fulfill. The number of orders per hour to a particular dark store is dependent on three things: the number of households in the Dark Store's *communa*, the ordering policies of those households, and the probability distribution of order placement for a given hour. Each of these is addressed below.

11.1 Household ordering policy
We note first that households can be assumed to adopt independent order policies which minimize their own costs. Since each order is a flat rate of $2, this implies that households wish to minimize their number of orders. We further assume that households are aware of THV's 40% freshness guarantee and develop ordering policies assuming that all products will be received with 40% freshness. The customers thus estimate the minimum

number of days of shelf life remaining when they receive their produce, which will inform how many days before the households must reorder.

We can estimate the customers' time between reorders from perishability curves and yield given in the appendix.

Thus, we have that customers place a reorder every 4 days. Since households order independently, we will assume that one-fourth of households order each day of the month. Therefore, the mean daily orders are computed and can be referred from the appendix.

(Calculations can found in Appendix H)

12. **Environment impact**

The analysis of the environmental impact generated by our transportation of products is based on an estimate per kilometer traveled. According to the distance travelled we have calculated the amount of CO_2 emitted at each level.

Stage of transport	CO2 emitted (in Ton)
Supplier to Distribution Center	1674.678936
Distribution center to Dark Store	32.61768929
Dark Store to Customer	373.9106551

By choosing motorcycles for last mile delivery, we have decreased the amount of CO_2 produced. If we have chosen trucks in the place of motorcycles, it would have produced 45% more CO_2.

Recommendations

We plan to substitute electric motorbikes in the place of petrol run motorbikes. Every year 10% of the last mile delivery fleet is converted to electric. By this we can reduce the CO_2 emissions drastically.

(Calculations can be found in Appendix I)

Results and Conclusions

13.1 Profit Estimation:

Annual Incomes	Total Landed Cost to DC	DC operating costs	Last mile costs	Other Costs	Annual Profit
$45,122,076,203	$8,126,540,194	$15,611,695	$27,294,084,312	$453,255,383	$9,232,584,619

Annual Income: Annual income includes the income due to sales + income due to delivery fee.
Total landed Cost to DC: Acquisition price + Transportation costs
DC operating Costs: DC construction cost + DC maintenance costs
Last Mile Costs: Cost of last mile transportation
Other costs: Inventory in transit + Inventory in DC + Waste Cost + Safety Stock Cost
Annual Profit: Annual Income- Total Landed Cost to DC-DC operating costs- Last mile costs- Other cost

13.2. Recommendations

With respect to recommendations that we can make for the development of the project, they would have to be accompanied by assumptions to be able to accompany these, one of these, for example we could mention the following ones:

1.- Selling our products, which have experienced a decrease of over 40% in freshness, to companies not reliant on freshness, such as factories producing condiments like ketchup or similar items.

2.- Assume that in the long term the Dark Stores do have an advantage and the assumption that has been made or proposed by the teacher that the distribution center can cover all the demand and satisfy it with respect to the 18-hour promise is not met. Also, by assuming that the demand will increase with every period because of the growth of the company.

3.- Because the demand of asparagus is very low, other types or product presentations should be analyzed, for example canned asparagus, to make meeting the demand of said product easier thought the year.

13.3 Conclusions

In conclusion, the study carried out in this research is supported by rigorous mathematical models that use actual data. It is advised that the distribution center be in Huechuraba given the project to run profitable and effective operations. The seasonality and perishability of food items are considered by the inventory policies in use. The goal of the transportation strategy, on the other hand, is to maximize the logistics network by cutting costs and accelerating deliveries.

Based on the significant insights gained during the project's evolution, a series of suggestions has been developed to optimize logistical processes and augment overall effectiveness. These suggestions are the result of a careful examination of the difficulties and achievements had throughout the project's implementation, offering useful information for upcoming initiatives.

By limiting our service to the locations where we operate dark stores, we may assist THV in lowering their initial outlay of funds and facilitating their expansion following market observation. When motorbikes are used, the company can deliver goods more quickly than trucks while maintaining freshness and at a very low cost. Additionally, this may aid in lowering carbon emissions.

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APPENDIX A (Perishability)

Perishability Curves

Asparagus

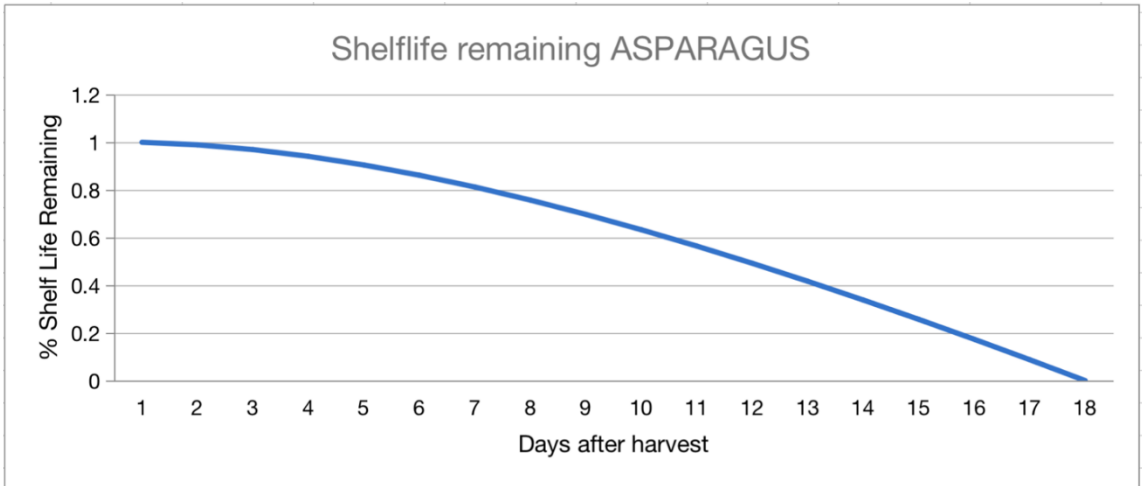

Figure 9 The Shelflife of Asparagus is about 17-18 days after that the product is lost

Roma Tomato

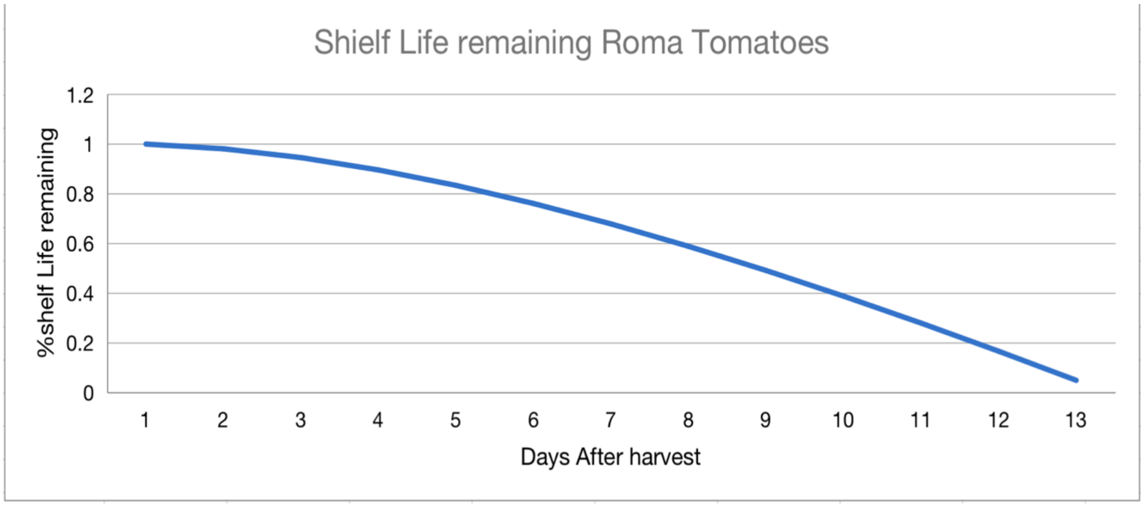

Figure 10 The Shelf Life of Roma Tomatoes are about 13 days and after that the product is lost.

Bananas

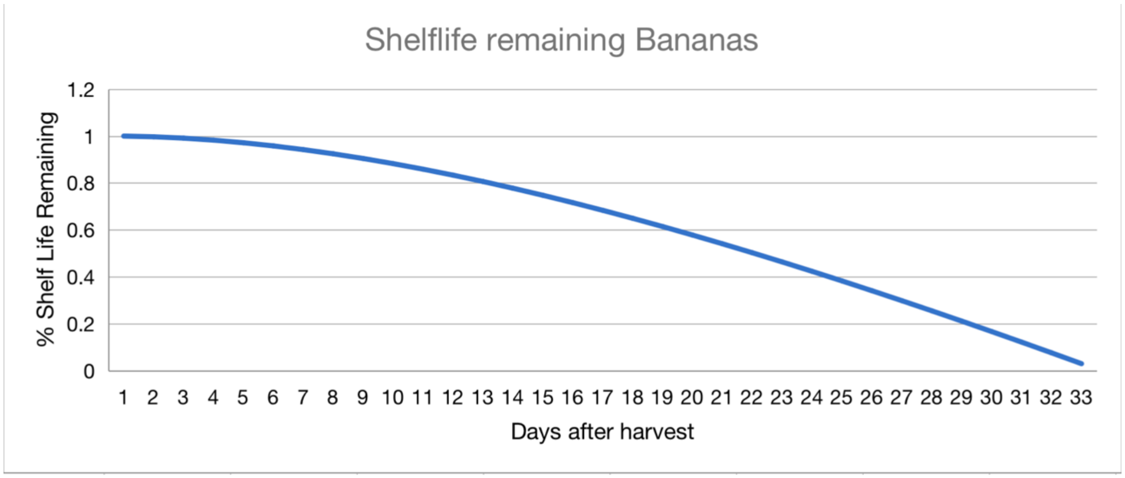

Figure 11 The Shelf Life of the Bananas is about 33 days after that the product is lost.

Pepper

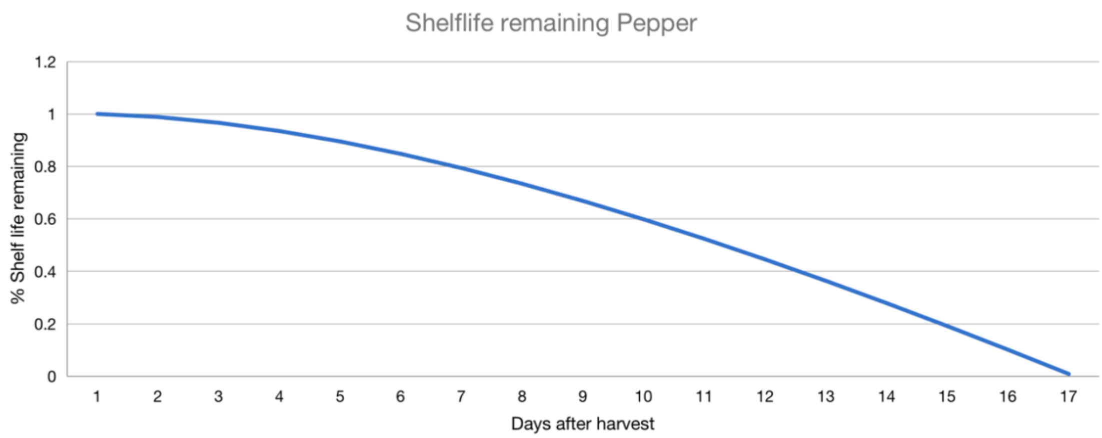

Figure 12 The Shelf Life of the peppers is about 17 days and after that the product is lost.

Cauliflower

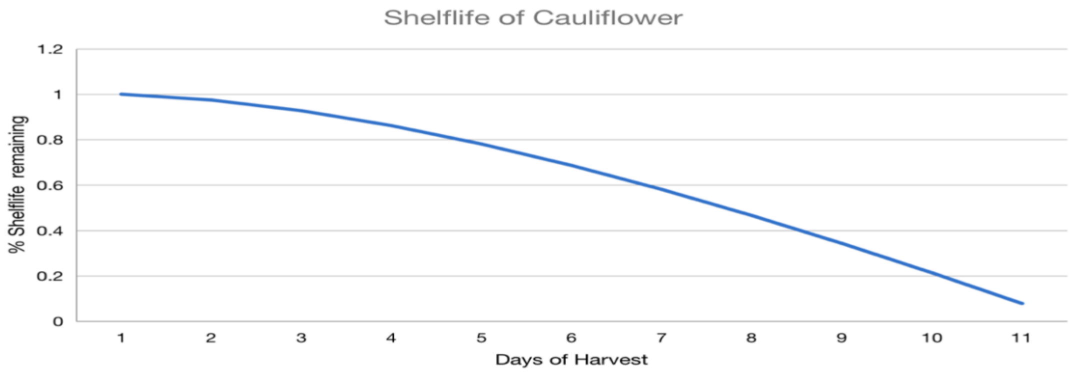

Figure 13 The Shelf Life of cauliflower is about 11 days after that the product is lost.

Avocado

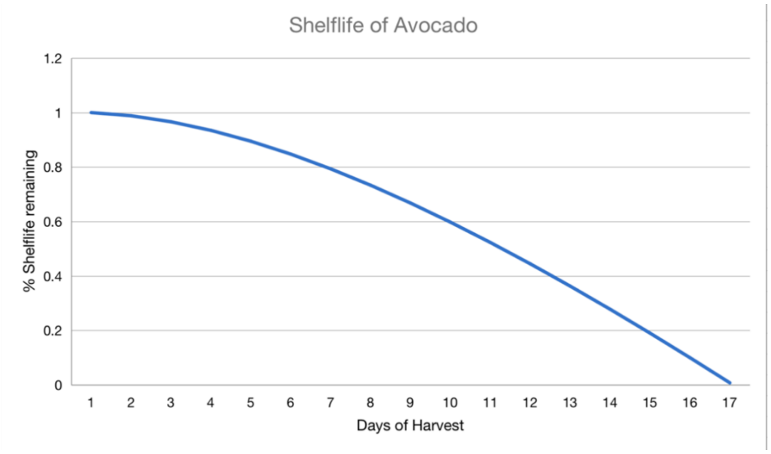

Figure 14 The Shelf Life of the Avocado is about 17 days and after that it is lost.

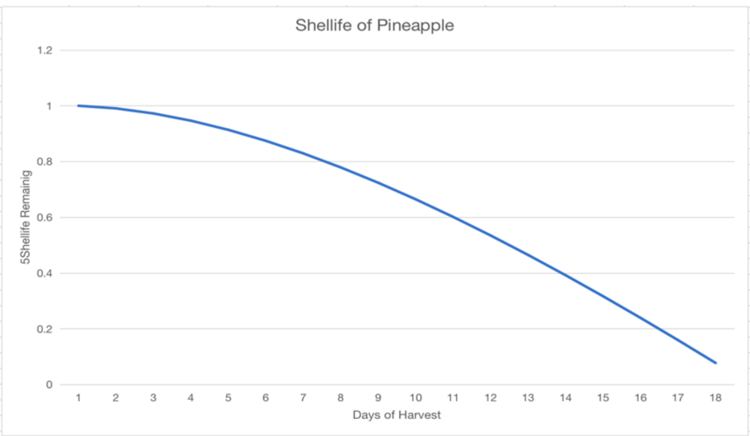

Figure 15 The Shelf Life of the Pineapple is about 18 days and after that it is lost.

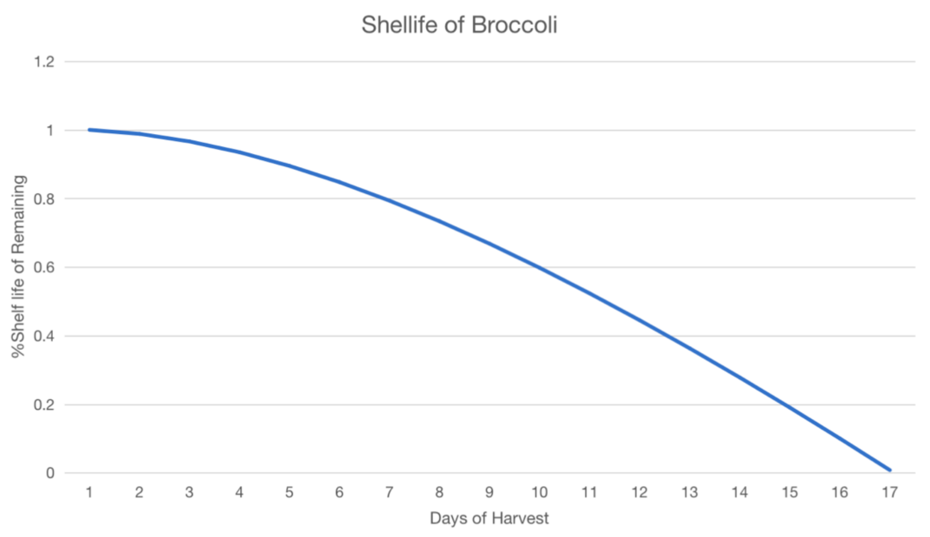

Figure 16 The Shelf Life of Broccoli is about 17days and after that it is lost.

APPENDIX B (Location Allocation for the Distribution Center)

Location Allocation Formulation for THV Distribution Center:
Assumptions

1. Costs are in USD.
2. Shipping cost is based on distance (in km) vice time.
3. Mini trucks take the shortest distance route between Distribution Center(s) (DC) and Dark Stores (DS) every load.
4. A mini-truck has one-seventh the cost per kilometer of a 40-ft container truck. We assume the same cost at less than truckload (LTL) or at full truckload (FTL).
5. Due to the low transportation costs per kg of produce per mile, we formulate this model in terms of round-trip truckloads.
6. Each DC can meet the entire demand of all DSs by itself (capacity is sum of all truckloads per dark stores).

Parameters

The fixed costs for locating a distribution center at a given location in Huecharaba and Cerro Navia are given by Fi. These costs and the capacities of the potential DCs are given below:

We denote the cost to ship a single truckload from DC *i* to *j* by c_{ij}

The corresponding cost table is provided below:

Route	Cost (CLP)
c11	10160.0352
c12	8320.32
c13	5861.2032
c14	6757.9488

c15	9540.6336
c16	12554.4384
c17	19478.7936
c18	18249.2352
c19	21207.5712
c21	16076.7072
c22	11278.656
c23	7811.856
c24	11334.1248
c25	1784.2464
c26	5472.9216
c27	11722.4064
c28	10603.7856
c29	13506.6528

Table 8 Cost table for each location to ship

We denote the set of Dark Stores DSj with their expected annual demands as follows:

Variable	Location	Expected Annual Demand (Mini-Truckloads)
DS1	Lo Barnechea	101
DS2	Las Condes	397
DS3	Providencia	232
DS4	Vitacura	105
DS5	Cerro Navia	144
DS6	Pedro Aguirre Cerda	112
DS7	El Bosque	177
DS8	Maipú	579
DS9	La Florida	429

Table 9 Expected Annual Demand (mini-truckloads)

Potential DC	Cost (CLP)	Annual Capacity (Truckloads)
Huecharaba	219661745.27	2276
Cerro Navia	277467464.30	2276

Table 10 Annual cost and capacity of potential DCs

Decision Variables

We define Zi as *binary* variables determining whether we build a particular distribution center (DC) i. In this model, we specifically have two potential DCs in Huecharaba and Cerro Navia.

We let Z1 be the potential DC in Huecharaba and Z2 be the potential DC in Cerro Navia.

We then define Xij as *nonnegative* variables which decide how many truckloads of total product (in kg) we wish to ship between distribution center DCi and Dark Store DSj.

Objective Function

$$\sum_{i} F_i Z_i + \sum_{ij} c_{ij} X_{ij}$$

This objective minimizes the total fixed and shipping costs between DC(s) and DS(s) for THV.

Constraints

$$(1) \sum_{i} X_{ij} \geq d_{ij} \forall_j$$

Constraint (1) ensures that demand is met at all Dark Stores DSj.

$$(2) \sum_{j} X_{ij} \leq A_i Z_i \forall_i$$

Constraint (2) ensures that distribution center capacity is maintained and that we cannot ship from a DC unless we build it.

The Distribution Center is in **Av. Recoleta 5905, 8580842 Santiago, Huechuraba, Región Metropolitana, Chile** in the industrial area of town as the fixed costs are low in that the area. As Huechuraba is considered an industrial part of the city we can find a larger land area to build a distribution center and expand in the future.

APPENDIX C (Area Calculations for DC and dark stores)

Product	demand per month	number of pallets	total area
Roma Tomato	6,24,086	249.6344	300
Banana	2,51,115	100.446	121
Cauliflower	30,232	12.0928	15
Avocado	1,01,383	40.5532	49
Pineapple	73,573	29.4292	35
Broccoli	13,933	5.5732	7
Asparagus	10	0.004	0
Green Bell Pepper	1,11,074	44.4296	53
		Total Area	580

Table 11 Area Calculation for DC

We have also added other factors that should be accounted during the calculation of total area of the DC and the table below is the data that contains all the data.

Design of DC	
enclosure - strut	0.5
long hallway	38.17
service area width	5
long cage load	5
total warehouse length	48.68
hallway width	7.8

total warehouse width	89.1
height to last beam	10.57
height until last load	12.37
necessary forklift height (meters)	10.73
total height under wax	12.88
total height of the warehouse	14.75
Total number of pallets	580
number of springs	22
forklift number	6
number of emergency doors	2
people capacity	155
Minimum distance between emergency doors	26
storage area	1740
docks area	100
service hallway area	100
porter area, offices, casinos and bathrooms	6
battery room area	68
garbage room area	12
fourth breakdown area	25
security area nursing industry	12
bathroom area	16
lockers area	12
other areas	100
total storage area	2217
total Parking	1120

Table 12 Factors Considered during the construction of DC

The above table is taken from the website given below.

Area calculation for parking at DC

Area for parking for DC			
Number of trucks	area occupied by a truck in m2	total parking area	excess area for moving the vehicles to move
10	56	560	1120

Table 13 Final Areas of DC

Area Calculation for dark stores

Area Calculation for Dark store					
Dark store	Area of a single pallet	Total number of pallets	TOTAL AREA OCCUPIED BY PALLETS	EXTRA AREA FOR OTHER OPERATIONS	TOTAL AREA OF EACH DS
Lo Barnechea	1.2	17.95881988	18	36	54

Las Condes	1.2	71.23162172	71	142	213
Providencia	1.2	41.54487912	42	84	126
Vitacura	1.2	18.79686253	19	38	57
Cerro Navia	1.2	25.80971024	26	52	78
Pedro Aguirre Cerda	1.2	19.98013868	20	40	60
El Bosque	1.2	31.64128509	32	64	96
Maipú	1.2	103.7643705	104	208	312
La Florida	1.2	76.90026238	77	154	231

Table 14 Area Calculation for Dark Stores

APPENDIX D (Inventory Policy)

Inventory Policy for the Distribution Center.

Veggies	P_{time}	L	Time after 40% shelf life(T)	L + T	Which Model we must choose
Roma Tomato	14	0.20833333	9	9.208333333	9.2<14 => $Q = \sqrt{\frac{2AD}{iv}}$
Banana	36	7.08333333	23	30.08333333	30.08<36 => $Q = \sqrt{\frac{2AD}{iv}}$
Cauliflower	12	1.70833333	7	8.708333333	8.7<12 => $Q = \sqrt{\frac{2AD}{iv}}$
Avocado	18	0.93416667	11	11.93416667	11.9<18 => $Q = \sqrt{\frac{2AD}{iv}}$
Pineapple	20	1.70833333	12	13.70833333	13.7<20 => $Q = \sqrt{\frac{2AD}{iv}}$
Broccoli	18	7.08333333	10	17.08333333	17.08<18 => $Q = \sqrt{\frac{2AD}{iv}}$
Asparagus	19	0.125	12	12.125	12.125<19 => $Q = \sqrt{\frac{2AD}{iv}}$
Green Bell Pepper	18	1.70833333	11	12.70833333	12.7<18 => $Q = \sqrt{\frac{2AD}{iv}}$

Table 15 Selection of Q for the adjusted policy

For each product i, we have that safety stock is given by.

$$SS_i = z_{s_i}\sigma_L$$

Here, s_i is the service level for product i, z_{s_i} is the corresponding z-score from the standard normal distribution, and σ_L is the standard deviation of the lead time for product procurement.

We have lead times normally distributed in hours as $L \sim N\left(\mu_L^{ij}, \sigma_L^{ij}\right)$ for each product i for each month j.

The Mean demand is given by $\mu_D^{ij} = \frac{d_{ij}}{24 y_j} \mu_L^{ij}$, where d_{ij} is the monthly demand for i and y_j is the number of days in the month.

Standard deviation of demand in units of lead time:

$$\sigma_D^{ij} = \sqrt{\frac{d_{ij}}{24 y_j}}\, \sigma_L^{ij}.$$

Next, we calculate the mean demand over lead time per product and per month as

$$\mu_{DLT}^{ij} = \mu_D^{ij} \mu_L^{ij}$$

and the standard deviation of demand over lead time by

$$\sigma_{DLT}^{ij} = \sqrt{\mu_L^{ij} \left(\sigma_D^{ij}\right)^2 + \left(\mu_D^{ij}\right)^2 \left(\sigma_L^{ij}\right)^2}.$$

APPENDIX E
Transportation Cost from Supplier to the Distribution Center

Product	Cost/week
Roma Tomato	$721,406
Banana	$5,203,767
Cauliflower	$211,395
Avocado	$1,656,668
Pineapple	$923,330
Broccoli	$1,215,620
Asparagus	$48,776
Green Bell Pepper	$2,296,448

Table 16 Transportation cost from supplier to the DC

APPENDIX F (Transportation costs from Distribution Center to Dark Stores)

Communas	average consumption per month	average consumption per week	Trucks needed per week (10 ton truck)
Lo Barnechea	44,897	11224.26243	1.0
Las Condes	178,079	44519.76357	4.0
Providencia	103,862	25965.54945	3.0
Vitacura	46,992	11748.03908	1.0

Cerro Navia	64,524	16131.0689	2.0
Pedro Aguirre Cerda	49,950	12487.58668	1.0
El Bosque	79,103	19775.80318	2.0
Maipú	259,411	64852.73157	6.0
La Florida	192,251	48062.66399	5.0

Table 17 Total Calculation for the number of trucks needed from DC to Dark Store

Communas	number of trucks per week	number of trucks per year	kms travelled by a single truck	Total kms travelled in a year
Lo Barnechea	1.0	52	38.2	1986.4
Las Condes	4.0	208	30.4	6323.2
Providencia	3.0	156	20	3120
Vitacura	1.0	52	23.8	1237.6
Cerro Navia	2.0	104	34.2	3556.8
Pedro Aguirre Cerda	1.0	52	45	2340
El Bosque	2.0	104	69.8	7259.2
Maipú	6.0	312	65.4	20404.8
La Florida	5.0	260	76	19760
	25.0			65988

Table 18 Total Kms travelled in an year.

APPENDIX G (Distance matrix for vehicle routing from Distribution Center to Dark Store)
Vehicle Routing
Distance Matrix

	Distribution Centre
Distribution Centre	0
DS 1 Lo Barnechea	19.1
DS 2 Las condes	15.2
DS 3 Providencia	10
DS 4 Vitacura	11.9
DS 5 La Florida	38
DS 6 Cerro Navia	17.1
DS 7 Pedro Cerda	22.5
DS 8 El Bosque	34.9
DS 9 Maipú	32.7

Table 19 Distances of each dark store from distribution center

APPENDIX H (Calculations for Last mile delivery and ordering policy)

Product	Order Size (Kg)	Frequency (days between orders)	Expected daily demand (Total over all comunas, 15% households)
Roma Tomato	0.5618530725	4	12861.61747
Banana	0.3651076725	4	8357.834902
Cauliflower	0.05069129821	4	1160.396051
Avocado	0.1338835013	4	3064.784129
Pineapple	0.08094541141	4	1852.955814
Broccoli	0.05335986614	4	1221.483374
Asparagus	0.00196867221	4	45.06571224
Green Bell Pepper	0.1490892818	4	3412.866113
Total	1.396898776	-	31977.00357

Table 20 Calculation of order size and frequency of ordering

	1 Municipality (Maipu, 15% households)	Extrapolation to all municipalities
Number of vehicles	105	441
Cost per vehicle (CLP)	$434,007.60	$434,007.60
# Average stops / 8 hr shift	40	40
Average speed (km/hr)	30	30
Average distance between stops (km)	2.916666667	2.916666667
Service time per order (min)	5	5
Fuel cost/km	32.5	32.5
Driver cost/km (CLP)	803.56	803.56
Capital recovery cost/km	$0.96	$0.96
Total km/day	202.5833333	202.5833333
Total cost per day per vehicle	$169,565.34	$169,565.34
Annual cost	$6,498,591,502.89	$27,294,084,312.14

Table 21 Calculation of costs incurred due to motor bikes

- Number of vehicles: Calculated using the inverse of a Poisson distribution on hourly orders at 95% service level assuming the Assumed number of deliveries per hour in Cell F17. No inverse Poisson fxn in excel, so used matlab.
- Cost per vehicle: Given in reference 10 [10]
- Average Stops: 8 hrs times number of deliveries per hour
- Average Distance Between stops: Distance traveled is a function of average speed and number of stops.
- Driver Cost/km : Taken from the Fig 3 in reference [11]. We have taken the median trip number of 80 trips and found out how much an uber driver is paid per km.
- Capital Recovery Cost: Taken from reference [12]. Calculations are done in the excel spread sheet.
- Total Km/day: Average stops per 13 hours (8am to 9pm) of deliveries per day times distance between stops.

Communa	*Mean Daily Orders to THV*
Lo Barnechea	1008.5
Las Condes	4000.3
Providencia	2333
Vitacura	1055.5
Cerro Navia	1449.5
Pedro Aguirre Cerda	1122
El Bosque	1777
Maipú	5827.3
La Florida	4318.5

Table 22 Mean daily Orders to THV

We have that the number of orders received at a dark store within a time interval is expressed as a random variable with a Poisson distribution. Equations (1)-(3) in the Last Mile Appendix describe this distribution in terms of mean daily demand.
However, THV can order motorcycles planning for each vehicle to be used hourly (based on our eight orders per driver per hour assumption), so it is beneficial to express the order distribution for a single hour rather than for an entire day. Thus, we use equations (4)-(5) in the Last Mile Appendix to express demand in terms of hours.
With a policy to package orders within 2 hours and less than an hour delivery from Dark Store to Customer, we obtain the following expected order fulfilment schedule:

Order Received (using 24 hours)	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Expected shipping time (today)	10	11	12	13	14	15	16	17	18	19	20			
Expected shipping time (tomorrow)												8	9	10
Expected delivery time (today)	11	12	13	14	15	16	17	18	19	20	21			
Expected delivery time (tomorrow)												9	10	11

Table 23 Table is for Expected order fulfillment time (Continental Chilean Time)

<u>Last Mile Costs</u>

Last mile costs are dependent on the number of vehicles used and the fuel, driver, and capital recovery costs for each of those vehicles. With an assumed 95% service level, the previously described household ordering policy and hourly order distribution, and some assumptions on fuel costs and average vehicle speed, we can compute the required number of vehicles and all associated costs.

First, we note that the percentiles for the computed order quantity distribution functions are equivalent to service levels. Therefore, we can calculate the required number of hourly orders at a particular service level, and the corresponding required number motorcycles and delivery drivers. Using a 95% service level, we have the below table for the number of motorcycles required. These computations are given by Equation (6) in the Last Mile Appendix and executed in MATLAB R2021b, since Excel does not have a Poisson Inverse function.

Communa	Number of Motorcycles
Lo Barnechea	22
Las Condes	75
Providencia	46
Vitacura	23
Cerro Navia	30
Pedro Aguirre Cerda	24
El Bosque	36
Maipú	105
La Florida	80
Total	441

Table 24 Number of Motorcycles needed for the last mile delivery

Motorcycle costs are annualized to include principal, maintenance, and fuel costs. Per-kilometer, these costs calculated by the Capital Recovery Cost (Equations (7) and (8) in the Appendix) at an assumed interest rate of 10% over 10 years with principals of 434,007.60 CLP [14,15].

We must therefore also calculate the average number of kilometers a motorcycle will travel per year. To do this, we assume that throughout the course of a 13-hour delivery day (THV is open from 8 am to 9 pm), a single driver travels an average of 30 km/ hour, makes 5 deliveries per hour, and takes 5 minutes at each delivery. This yields an estimate of just under 3 km between stops and an average of 10 kilometers traveled every hour, or 202.6 km per day, for a single motorcycle (Equations (9)-(11) in the Last Mile Appendix). Due to the relatively high population density of Santiago (9821 per square km, per World Population Review [4]), we assess this is a reasonable value.

Note: that delivering orders for 13 hours in a day does not imply that drivers are working 13-hour shifts; rather, this means that motorcycles are in use for 13 hours a day but may have different drivers. Shift duration does not impact estimated total distance traveled or cost.

With a standard fuel cost of $1300 CLP per L and an efficiency of 40 km/L, we have an average fuel cost of $130 CLP per kilometer. (Equation (12) in the Last Mile Appendix).

Driver costs per kilometer are taken from a 2021 peer-reviewed publication in *Transportation*, which estimated Uber Eats driver costs in Santiago [17].

Finally, the annual Last Mile cost is computed by combining all three per-kilometer costs with the average number of kilometers driven per day and the number of days in a year (365). This equation is given by Equation (13)

Annual Last Mile Revenues

Equation (14) in the Appendix calculates the annual Last Mile Revenue at a service level of 95%, assuming a $1736.06 CLP ($2 USD) revenue per order. Results are given in the table below:

Communa	Number of Motorcycles Required	Number of Annual Orders per Communa	Annual Last Mile Revenue (CLP)
Lo Barnechea	22	521950	906136517
Las Condes	75	1779375	3089101763
Providencia	46	1091350	1894649081
Vitacura	23	545675	947324540.5
Cerro Navia	30	711750	1235640705
Pedro Aguirre Cerda	24	569400	988512564
El Bosque	36	854100	1482768846
Maipú	105	2491125	4324742468
La Florida	80	1898000	3295041880
Total	**441**	**10462725**	**18163918364**

Table 25 Annual revenue due to the delivery fee

Equations:

$$(1)\ f(k,\lambda) = \frac{\lambda^k e^{-\lambda}}{k!}$$

Equation (1) is the Probability Mass Function for a Poisson distribution of k orders in a specified time interval with a mean number λ of orders in that interval.

$$(2)\ \lambda_{day} = 0.25 * Number\ of\ Households\ in\ Comuna$$

Equation (2) gives the mean daily orders expected at the dark store of a single *communa*. This value is used as the parameter for a Poisson distribution for daily orders.

$$(3)\ f_{day}(k_{day}, \lambda_{day}) = \frac{(\lambda_{day})^k e^{-\lambda_{day}}}{k!}$$

Equation (3) combines Equations (1) and (2) to get the daily order distribution in a particular *communa*. Recall that the Poisson distribution is additive. For simplicity, we assume that the hourly demand distributions are the same. In reality, it is unlikely that this assumption is true; however, we were not able to find historical data on hourly online grocery orders on which to base a more accurate analysis. Since THV's outsourced call center receives orders for 13 hours in a given day (8 a.m. to 9 p.m.), we therefore have that

$$(4)\ \lambda_{hr} = \frac{\lambda_{day}}{13}$$

And

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$$(5)\ f_{hr}(k_{hr},\lambda_{hr}) = \frac{(\lambda_{hr})^k e^{-\lambda_{hr}}}{k!}$$

is the probability that k_{hr} orders (equivalent to the number of motorcycles required) will be placed in a given hour.

$$(6a)\ F_{hr}(k_{hr},\lambda_{hr}) = e^{-\lambda_{hr}} \sum_{0}^{k} \frac{\lambda_{hr}^k}{k!}$$

$$(6b)\ NumberMotorcycles = F_{hr}^{-1}(k_{hr},\lambda_{hr},S)$$

Equation (6a) gives the CDF of the Poisson distribution function for hourly orders. The inverse of this function at a given percentile (6b) is used to compute the number of orders that would be placed in an hour at that percentile (service level S).

$$(7)\ CRC = P\frac{i(1+i)^n}{(1+i)^n - 1}$$

Equation (7) gives the Capital Recovery Cost for an asset with principal investment cost Passuming an interest rate i and n annuities.

$$(8)\ n = 10 * (\#\ km\ driven\ per\ year)$$

In our case, we calculate the per-kilometer CRF over 10 years at an interest rate $i = 0.1$, so Equation (8) gives our value for n.

$$(9)\ DistTraveled_{km}^{hr} = Spd_{kmph}(1 - StopTime_{hr} * NumStops_{hr})$$

Equation (9) gives the distance traveled per hour in kilometers based on the average speed when in motion, the average stop duration, and the average number of stops made in an hour.

$$(10)\ DistTraveled_{km}^{day} = 13 * DistTraveled_{km}^{hr}$$

Equation (10) gives the distance traveled in a day as a function of the number of working hours in a day (13). Note that this does not imply that drivers are working 13-hour shifts; rather, this means that motorcycles are in use for 13 hours a day, but may have different drivers. Shift duration does not impact total distance traveled or cost.

$$(11)\ DistBetweenStops_{hr} = DistTraveled_{km}^{hr}/(NumStops_{hr} + NumReturnsToDS_{hr})$$

Equation (11) gives the Distance between stops in kilometers, including the number of returns to the DS in each hour. Note that with our assumption of 8 deliveries per hour and a capacity for 8 orders in our affixed thermal containers, drivers will on average only need to be at the Dark Store once each hour.

$$FuelCost_{km} = FuelCost_L * Efficiency_L^{km}$$

Equation (12) calculates per-kilometer fuel costs based on the per-Liter cost (given as 1300 CLP) and the motorcycle fuel efficiency per Liter.

$$(13)\ AnnualLastMileCosts_{CLP} =$$
$$365 * NumberMotorcycles * DistTraveled_{km}^{day}(CRC_{km} + FuelCost_{km} + DriverCost_{km})$$

MATLAB Code:

```
% Last Mile Analysis

% Communa Populations
pop = [4034;16001;9332;4222;5798;4488;7108;23309;17274];

% Proportion of Households ordering each day
dailyOrderProp = 0.25;
```

```
% Number of deliveries per hour
delivPerHr = 5;

% Daily delivery hours
hrsToDeliver = 13;

% lambda_day for each comuna
dailyOrders = dailyOrderProp*pop;

% lambda_hr for each comuna
hourlyOrders = dailyOrders/delivPerHr/hrsToDeliver;

% Cost per Motorcycle (Electric scooter) in Chilean Pesos
motoCost_CLP = 434007.60;

% Hourly wage for THV delivery drivers in Chilean Pesos
driverCost_hr_CLP = 5674.01;

% 90th Percentile hourly orders/motorcycles, fixed motorcycle costs, and
% annual driver costs per comuna
motorcyclesPerComuna_90 = poissinv(0.9*ones(9,1),hourlyOrders);
motoCostPerComuna_90 = motoCost_CLP*motorcyclesPerComuna_90;
deliveryCostPerComuna_90 = 365*13*driverCost_hr_CLP*motorcyclesPerComuna_90;

% 95th Percentile hourly orders/motorcycles, fixed motorcycle costs, and
% annual driver costs per communa
motorcyclesPerComuna_95 = poissinv(0.95*ones(9,1),hourlyOrders);
motoCostPerComuna_95 = motoCost_CLP*motorcyclesPerComuna_95;
deliveryCostPerComuna_95 = 365*13*driverCost_hr_CLP*motorcyclesPerComuna_95;

% 99th Percentile hourly orders/motorcycles, fixed motorcycle costs, and
% annual driver costs per communa
motorcyclesPerComuna_99 = poissinv(0.99*ones(9,1),hourlyOrders);
motoCostPerComuna_99 = motoCost_CLP*motorcyclesPerComuna_99;
deliveryCostPerComuna_99 = 365*13*driverCost_hr_CLP*motorcyclesPerComuna_99;

totalCost_90 = sum(motoCostPerComuna_90+deliveryCostPerComuna_90);
totalCost_95 = sum(motoCostPerComuna_95+deliveryCostPerComuna_95);
totalCost_99 = sum(motoCostPerComuna_99+deliveryCostPerComuna_99);
```

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APPENDIX I

CO2 emissions by long Haul Truck (45 Ton)

Pounds CO2 emitted by one gallon of gasoline:	19.4
Assumed efficiency (mpg):	6
Km per Mi:	1.60934
Tonnes per pound:	0.0005
Tonnes CO2 emitted per truck per kilometer:	0.002601766333

Table 26 Conditions for long haul trucks (Capacity 45 Tons)

Table: Tonnes CO2													
	January	February	March	April	May	June	July	August	September	October	November	December	Total
Roma Tomato	39.21382218	1.498617408	1.623502192	1.498617408	1.373732624	1.24884784	1.24884784	1.24884784	19.60691109	1.123963056	1.373732624	26.95950275	98.01894484
Banana	74.12432284	41.58663307	84.71351181	74.12432284	95.30270079	4.771639455	4.089976676	95.30270079	74.12432284	4.735214727	74.12432284	84.71351181	711.7131805
Cauliflower	0.124884784	0.124884784	1.40495382	1.40495382	0.249769568	0.249769568	21.37611219	1.40495382	0.124884784	0.249769568	2.80990764	0.124884784	29.64972913
Avocado	0.374654352	0.249769568	31.76756693	31.76756693	31.76756693	31.76756693	31.76756693	31.76756693	31.76756693	0	0	0	222.9973924
Pineapple	0.249769568	1.144777187	0	0	1.540245669	21.37611219	21.37611219	21.37611219	21.37611219	21.37611219	21.37611219	21.37611219	152.5675778
Broccoli	0.124884784	0.124884784	10.58918898	10.58918898	10.58918898	10.58918898	10.58918898	10.58918898	11.58306372	74.12432284	0.6764592467	10.58918898	160.7579382
Asparagus	1.40495382	0.124884784	1.40495382	0.124884784	0.124884784	0.124884784	0.124884784	0.124884784	0.124884784	0.124884784	1.40495382	0.124884784	5.338824516
Green Bell Pepper	32.06416829	32.06416829	42.75222439	2.726651117	42.75222439	42.75222439	42.75222439	42.75222439	4.21486146	4.21486146	0.374654352	4.21486146	293.6353484
Total	147.6814606	76.91861988	174.2559019	122.2361859	183.7003137	112.8802341	133.324914	204.5664797	162.9226078	105.9491286	102.1401427	148.1029468	1674.678936
Total Annual Tonnes CO2 Suppliers to DC:			1674.678936										

Table 27 Carbon emissions by trucks from suppliers to DC

CO_2 emissions by mini-truck (10 Ton)

Pounds CO2 emitted by one gallon of gasoline:	4.3
Assumed efficiency (mpg):	7
Km per Mi:	1.60934
Tons per pound:	0.0005
Tons CO2 emitted per truck per kilometer:	0.0004942972857

Table 28 Conditions for Mini Truck (capacity 10 Ton)

Pooling communas/ direct transfer	number of trucks per week	number of trucks per year	kms travelled by a single truck	Total kms travelled in a year
Lo Barnechea	1.0	52	38.2	1986.4
Las Condes	4.0	208	30.4	6323.2
Providencia	3.0	156	20	3120
Vitacura	1.0	52	23.8	1237.6
Cerro Navia	2.0	104	34.2	3556.8
Pedro Aguirre Cerda	1.0	52	45	2340
El Bosque	2.0	104	69.8	7259.2
Maipú	6.0	312	65.4	20404.8
La Florida	5.0	260	76	19760
	25.0			65988
total annual tons Co2 DC to Dark Stores			32.61768929	

Table 29 CO2 emissions by mini truck

CO_2 emissions by motorbike

Pounds CO2 emitted by one gallon of gasoline:	0.57
Assumed efficiency (kmpl):	40
Km per Mi:	1.60934
Tons per pound:	0.0005
Tons CO2 emitted per truck per kilometer:	0.0000114665475

Table 30 Conditions taken for motorbike.

total number of motorbikes	Km travelled by a driver in a day	total km travelled by 441 drivers in day	total km travelled by 441 drivers in an year	total annual tons Co2 from dark store to end user
441	202.5833333	89339.25	32608826.25	373.9106551

Table 31 CO2 emission by motorbike