

E-commerce and the environment: Finding the optimal location for in-store pick-up

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Summary:



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KEY INSIGHTS

- 1. By selecting the optimal number of stores as pick-up locations, an American chain of department stores can save up to 13% in transportation costs.**
- 2. The number of packages per route in the last mile delivery plays an important role in measuring the environmental impact.**
- 3. Having more than 66% of customers to pick up their packages in motor vehicles might involve higher overall CO₂ emissions.**

maximizing the number of packages in one route; and on the other side, there is the quality constraint, which is a customer-focused variable that might have a bigger impact on the company's profit than the operational efficiency itself. Within their e-commerce business, retailers are providing more delivery options to customers, from changing the time frame of delivery to offering alternative pick-up locations.

The Company is an American chain of upscale department stores headquartered in Seattle, Washington. Each year, The Company delivers millions of packages by national parcel carriers, such as UPS, USPS, and FedEx, spending millions of dollars. The Company has a physical infrastructure of about 350 stores in the network. The Company looks to optimize the e-commerce network by reducing the transportation cost while maintaining high service level.

The goal of this project is to determine the optimal locations for consolidating parcel packages in order to reduce costs and evaluate the resulting carbon dioxide emissions. To accomplish the objective, the project will analyze potential methods such as binary integer programming and last mile vehicle routing, and then compare results to suggest a comprehensive solution that can be both optimal and feasible in the organization.

Methodology

We did not generate new data on The Company's logistic network but relied on 9 months of historical data. With this data, we ran a cost reduction function and a CO₂ emission function with Python.

Summary

Our research focuses on an American department store chain with the aim to select the optimal stores as pick-up spots and evaluates the environmental impact of the findings. We use and develop more than 10 million records provided by The Company and develop a binary integer linear programming model to estimate potential savings and perform a sensitivity analysis to analyze the impact of the customer's decisions in both economic and environmental magnitudes.

Introduction

Retailers often struggle with optimizing the route design of their deliveries in a way that does not alter the service level. On one side, there is the operational efficiency per trip, which can be achieved by

1. Cost reduction function

To find out the optimal solution we create a Binary Integer Programming model where the binary variables dictate the selection of the stores to the customers. There is also a parameter P which represents the willingness of the demand to pick up their orders in stores for a certain range of distance. In regards of costs, we use the original transportation cost of orders delivery from The Company and assume a fixed cost of opening store as a pick-up location. The objective function aims to maximize the cost savings for The Company.

2. CO₂ emission reduction function

The CO₂ emissions savings will result from subtracting the CO₂ emissions of the proposed scenario (buy online and pick up in store) from the current scenario (home delivery).

In the current scenario, the CO₂ emissions will come from the last-mile delivery trucks contracted by The Company, to deliver packages from the store to the customer's household.

In the proposed scenario, the CO₂ emissions will come from the portion of customers using private vehicles (cars) to pick up their packages in The Company's store.

Emissions from trucks

The methodology of this project is based on the NTM (Network for Transport Measures) Methodology, at a level of aggregation in which the following parameters are considered: the distance traveled, the fuel consumption per unit of distance, and the load factor,

We use a local routing equation to estimate the distance used by the trucks, in which one store distributes to many customers. In addition, to estimate the linehaul distance we assume that the maximum distance of a person to consider a pick-up location is 10 miles.

Emissions from customers' cars

According to the United States Environmental Protection Agency (EPA), the average passenger vehicle emits about 404 grams of CO₂ per mile.

Total emissions savings

We estimate the CO₂ savings by subtracting the total cars' emissions from the trucks' emissions.

There is also a parameter B which represents the percentage of customers willing to walk, bike, or use public transportation. We will explore the sensitivity of this variable.

Results

To get a representative sample of the total US population, we use the data from one state from the East Coast and one state from the West Coast: Massachusetts and California.

We performed a sensitivity analysis with different P values. After running the cost optimization function, we compared the cost savings and optimal number of enabled stores for the period of the 9-month study. Figure 1 and Figure 2 show the impact of different P values in the cost savings and number of stores selected.

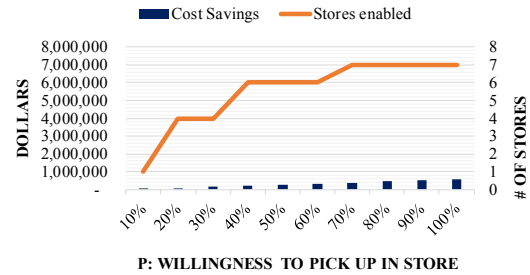


Figure 1. Optimal cost solutions in MA

Figure 1 shows that in Massachusetts The Company can save \$77K (6% of transportation costs) with 4 stores selected when P=20%.

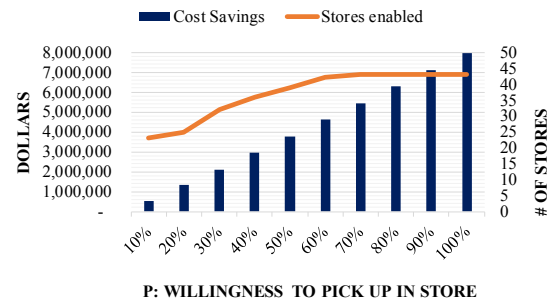


Figure 2. Optimal cost solutions in CA

Figure 2 shows that in California The Company can save \$1,319K (13% of transportation costs) with 25 stores selected when P=20%.

Moreover, after developing our emissions estimation tools, we compare the trucks' CO₂ emissions and the cars' CO₂ emission. However, the difference in environmental impact also depends on two important variables:

- i) The percentage of customers who would be willing to walk, bike or use public transportation (B).
- ii) The number of packages that each truck delivers per trip. This number will determine the overall number of trips for the trucks.

The effect of these two variables mentioned above is reflected in Figures 3 and 4.

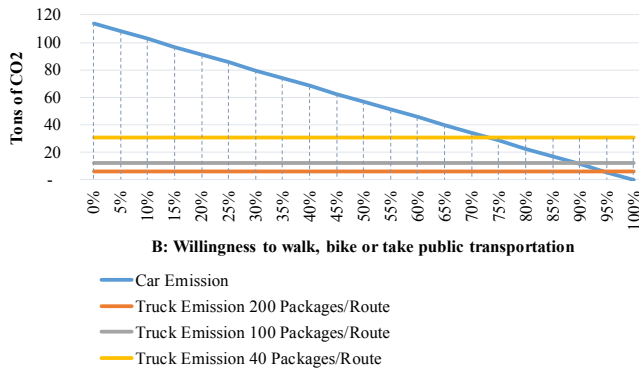


Figure 3. Trucks CO₂ emission vs. cars CO₂ emission in MA when P=20%

Figure 3 shows that, in Massachusetts, when the truck’s number of packages per route equals 40, the CO₂ emission is 30 tons, whereas when the number increases to 100 and 200, the emission decreases to 12 and 6 tons, respectively.

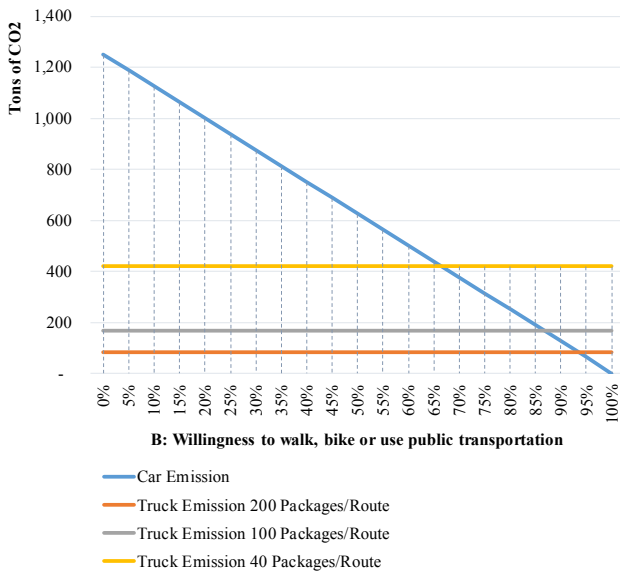


Figure 4. Trucks CO₂ emission vs. cars CO₂ emission in CA when P=20%

Figure 4 shows that, in California, when the truck’s number of packages per route equals 40, the CO₂ emission is 419 tons, whereas when the number increases to 100 and 200, the emission decreases to 168 and 84 tons, respectively.

In both cases, the cars’ CO₂ emission will depend on B and will reach a trade-off point with each package-per-route truck scenario. The results from both states can be surprising not only because B needs to reach high levels to achieve CO₂ emission savings, but also because the parcel carriers’ decisions about route design have a high degree of influence. Determining the number of packages that each of these parcel trucks delivers will directly impact the trucks’ CO₂ emission.

Additionally, that California requires lower minimum B values to achieve CO₂ savings when compared to Massachusetts. One of the reasons for this is the difference in customer density in both states. On the other hand, the difference can be compensated for if we analyze the differences in accessibility and infrastructure that both states have when it comes to walking, biking and taking public transportation.

Conclusions

By taking these results into account, we suggest that The Company should focus on encouraging the pick-up-in-store alternative in denser (in terms of customers, not population) locations like California.

In addition, we argue that, regardless of what the P value is, the amount of CO₂ emissions that the pick-up-in-store option can save depends on the customers’ willingness to avoid using motor vehicles, which, as a minimum, must stay within the ranges from 74% to 95% in Massachusetts and from 66% to 94% in California. In the future, this willingness can be estimated by studying the consumers’ behavior, urban infrastructure, public transportation system and accessibility to alternative transportation modes such as bikes, in each region of the country. We recommend to The Company to perform this study as a foundation base to create a program to incentivize and educate its customers in using more environmentally friendly transportation modes

Moreover, the number of packages per route in the last mile delivery plays an important role in measuring the environmental impact. By increasing the number of packages of each truck trip, the last mile home delivery becomes more environmentally friendly, meaning that the pick-up-in-store option would have more CO₂ emission than the home delivery option. We recommend that The Company shares the results of our study with its carriers in order to develop a cohesive and integral environmental plan.

Lastly, we believe that this sensitivity analysis will serve as a tool for The Company to make strategic decisions that will align with its environmental objectives. Our models’ robustness will allow The Company to expand the analysis to every state of the country and to change accordingly some of the important parameters we encountered and presented in this project.

