Processing Collective Categorical Transport Planning Considering the Carbon Footprint

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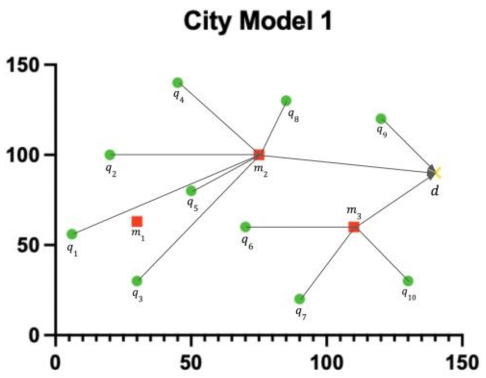
Abstract

The delivery system is inevitable as the consumers and the suppliers are far apart. The problem here is that the vehicles being used in the process are emitting excessive amounts of carbon. As atmospheric CO2 has been causing significant environmental issues in the 21st century, we propose this new method of implementing meeting points in the delivery process to optimize carbon emissions. Consideration of carbon emissions not only benefits the environment but also benefits the firms. The focus of this study is on considerations to consider when performing a collective traveling planning (CTP) query. This query collects the objects satisfying the specific condition via a hub and allows them to arrive from the starting point to the endpoint. The contribution of this paper can be considered as two significant points. As the already existing CTP does not consider the category, we redefined the problem regarding the class. Also, we proposed a method that reduces the time complexity. We proved that the proposed practices are acceptable for each process by analyzing time complexity and providing examples. In conclusion, we presented that the proposed methods are applicable in the real world with evidence. Moreover, the paper suggests more significant points about this problem

1. Introduction

Atmospheric CO2 has been increasing until the recent 21st century. Although it significantly contributes to the total carbon emissions, the delivery system is inevitable in recent years as the consumers and the suppliers are located far apart. Consideration of carbon emissions not only benefits the environment but also benefits the firms. Therefore, we propose this new method of implementing meeting points in the delivery process to optimize carbon emissions.

The focus of this study is on considerations to consider when performing a collective traveling planning (CTP) query. This query collects the objects satisfying the specific condition via a hub and allows them to arrive from the starting point to the endpoint. We consider the carbon footprint as a base 'conditional' factor for the reasons mentioned earlier.



Considering <*Figure 1*>, ten query points Q = $\{q_1, q_2, q_3, q_4, q_5, q_6, q_7, q_8, q_9, q_{10}\}$, three meeting points M = $\{m_1, m_2, m_3\}$, and arbitrarily selected destination d, if we don't think of CTP (not considering meeting points), the total footprint would be:

$$\sum_{i=1}^{n} dist\,(q_i\ , d)$$

The CTP(A) would be:

CTP(A) = $\sum_{i=1}^{n} dist\,(q_i\ , m) + \sum_{l=1}^{m} dist\,(m_l\ , d)$ (1)

Distance (*u*, *v*) marks the smallest distance between point *u* and point *v*, and q_i and m_l are a query vertex and a meeting point, respectively. CTP assumes that the cost of transportation considering the meeting point is cheaper than transportation from each q to the d. Using the formula *CTP*(A), we are going to locate the optimum routes between q, m, and d in the euclidean plane, which makes *CTP*(A) query less than or equal to the upper bound $\sum_{i=1}^{n} dist\,(q_i\ , d)$.

In this case, the best transportation cost is realized when the suppliers work together q_1, q_2, q_3, q_4, q_5, and q_8 are assigned to the meeting point m_2, the suppliers q_6, q_7, and q_{10} are assigned to m_3 and supplier q_9 is directly assigned to destination d leaving the meeting point m_1 not assigned to any suppliers. Under the resource capacities of food transporters, the transportation cost associated with this allocation is the lowest. Therefore, considering the shortest distance required and gas usage, the best meeting points to choose from which comes out with the least CTP are m_2 and m_3.

Applying existing CTP has two limitations that we solved: the first limitation was that in our work, q_i, the query locations cannot change their spots. Therefore, the cost should be measured twice. Also, it is more practical to view the footprint cost of personal vehicles and HDV differently.

Thus, we define the new score function.

The other contribution point is that we considered the category. Depending on factors such as supply and demand in the real world, we separate products into category C. For example, among the query point categories of chicken farms, soda factories, and clothing factories, if supply and demand for animal products decrease, the combination has to satisfy the fixed number of inputs in the category due to an epizootic. We defined a problem CTPC (Collective Transport Planning with Category).

Considering <figure 1>, assume category C = {C_chicken, C_salmon, C_cabbage }. The query point can be separated:

C_chichen = {q_1, q_3, q_5}, C_cabbage = {q_2, q_4, q_8}, C_salmon = {q_6, q_7, q_9, q_10}.

Suppose if each category originally supplied a certain amount of their products depending on the demand/supply, in the case of infectious virus, the amount of supply can be reduced from any of the categories. For example, the supplier should consider all the queries if the given demand set = [3, 3, 4]. However, if the demand for chicken decreases from bird influenza and given the new demand set = [1, 3, 4], the discovery of a new optimum delivery path will be necessary.

Moreover, this problem is NP-hard because it contains a combination problem. It is not tolerable as the time complexity is too high at several query points. Thus, we propose a new method so the problem solving can be finished efficiently with theoretical proofs.

Design of Paper

1. Background

The economy is embedded within society but also the ecosystem. Atmospheric CO2 has been increasing until the recent 21st century. Therefore, we propose this new method of implementing meeting points in the delivery process to reduce the total carbon emissions.

Abatement policies such as taxes on emissions of pollutants and incentives to use fuel-efficient cars are needed to reduce environmental damages.

But the opportunity cost of an improved environment would be a reduction in consumption. People's views of proposed environmental policies differ partly because a deteriorating environment affects different people differently.

2. Problem Definition

The CTP (Collective Transportation Planning) query is a question that seeks out an assigned task that involves reducing carbon emissions in the delivery of food from several sources to a single destination. The request Collective Transport Planning provides a subset A (A ⊆ M), that optimizes overall carbon emissions in food transportation by connecting food suppliers and destinations via at least k meeting sites in M. The overall carbon dioxide emissions of the RCTP query subset A, designated as RCTP(A), are as follows:.

Symbol	**Meaning**
Q	A set of supplier locations $\{q_1$, q_2,... , $q_{\|Q\|}\}$ shown as the input
M	an intersection point locations $\{m_1, m_2, \ldots, m_{\|M\|}\}$shown as input
K	A set of integers 1 to $\|Q\|$
p	The maximum distance bound between a user and a destination.
k	The maximum number of vehicles the service provider has
d	A destination given as input
dist(u,v)	In a spatial system, the smallest length across edges u and v.
j	The difference in gallons per mile between trucks and light-duty vehicles, passenger cars (4)
C	Category of Q based on multiple different factors
MC	Combination list set of meeting points

<*Table 1: notations*>

$$CTP(A) = \sum_{i=1}^{n} dist\,(q_i\,, m) + \sum_{l=1}^{h} (dist\,(m_l\,, d) \times j_l \qquad (2)$$

Where the *dist*(*u*, *v*) is the the smallest length across edges u and v , and q_i and m_l are a query point and a meeting point, respectively, with j being the difference in fuel consumption in gallons per mile between HDV and the light-duty vehicles, passenger cars.

2. Proposed methods

A. Preprocessing

We preprocessed the distances between query points Q, meeting points M, and the destination D. We also preprocessed a dataset that stores the index number, which indicates the minimum distance among each dictionary key.

B. Baseline Algorithm

For the Baseline Algorithm, we used the brute force algorithm. The first things to consider are the m combinations (MC), and we have to calculate the distance based on the number of m combinations. The Brute Force is a base method for solving the minimum distance, which can be achieved by using meeting points m to the destination d from the query points q.

Algorithm 1 Brute Force
Input: point of intersection M, point of query Q, a target d, the difference in gallons per mile j, X_Q, DistSet, category set C
Output: The total amount of gas used of the CTP query in each case resultSet, The combination of chosen m, md, the answer set U.
resultSet = []
tempsum = 0
totalmd = 0
for mc in MC
temp=Sum of each distance from mc to d
Renew DistSet
for q in qset
qSum = qSum + DistSet[q][DistSet[q][-1]]
resultSet.append([mc,qSum +temp])
U = min(resultSet, key = 1st index)

<table 2>

Table 2 represents the baseline algorithm. In combination MC, which is a list of all possible combinations of m, we loop it for each mc, each possibility, and temp equals the sum of each distance from mc to d. To exclude meeting points that are not included in the mc, we renew the DistSet. Inside the loop for MC, we loop qset to find qSum, which is the minimum distance between each q and meeting points. Then we append it to the resultSet and ultimately find the minimum total distance.

For example, considering <figure 1>, mc = {m1, m2, d} and excluded meeting point m3 is the closest meeting point for q7, we need to assign a new nearest meeting point for q7, m1. We then need to find q with its minimum distance with the excluded m and find a new m with the minimum distance between q.

Analysis

The time complexity of the algorithm is defined as $\Theta(|M^M| \times |Q|)$ which is multiplying the number of query points to all possible m combinations. However, we should also consider the combination of categories. The time complexity of overall becomes $\Theta(|M^M| \times |Q| \times |a^b|)$ which is multiplying the number of query points to all possible m and categorical combinations.

A. Proposed method

1) AM algorithm

Instead of comparing all combinations in categories, we propose an algorithm with more tolerable time complexity.

Algorithm 2 All Meeting point algorithm	
Input: point of intersection M, point of query Q, a target d, the difference in gallons per mile j, X_Q, DistSet, category set C	
Output: selected q for each category and final distance sum	
1	For c in Categories :
2	For q in c :
3	Pick top c_n lowest distance of q
4	Return selected q for each category and final distance sum

This algorithm focuses on each category and selects the top c_n lowest distance between query point and destination. Where c_n is the given amount of each category set.

Analysis

The time complexity of the algorithm reduces from $\Theta(|\ M^M\ | \times |Q| \times |\ a^b\ |)$ to $\Theta(|M^M| \times |Q| \times |a|)$.

A. Early termination

Applying the proposed method in the previous section may reduce time complexity but still in exponential form. In this section, we offer a more time tolerable algorithm via early termination.

Module 1 count_category	
Input: point of intersection M, point of query Q, a target d, the difference in gallons per mile j, X_Q, DistSet, category set C	
Output: selected q for each category and final distance sum	
1	C = [empty list set corresponding to category]
2	C.insert(q at q_c)
3	If C == given producing amount list:
4	Return 1
5	Return 0

count_category() module stores category information. If all conditions are fulfilled, it returns one, and the algorithm can be terminated. This early termination also reduces the total distance.

Evaluation

Top 5 min distances with all query points included.	**Top 5 min distances with query points divided into categories.**
11338.436623	8023.34519666
11372.027327	8056.9359004
11602.7037	8287.612348
12852.365994	9490.4015245
13165.78078	12668.40034566
Sum : 60331.3145	Sum : 46526.69532

Difference: $\left|\frac{46526.69532 - 60331.3145}{60331.3145} \times 100\right| = 22.9\%$

Adapting early termination, CTP with category made 22.9% higher performance in distance cost than original CTP processing. It infers that not only reduce 23% of carbon footprint but also business cost reduction.

A. Proposed method 2) Heuristic algorithm

Moreover, we propose a heuristic algorithm that uses minimum meeting points. This algorithm checks the whole distance between the current query point's nearest neighbor meeting point and meeting point in the used meeting point list.

Algorithm 3 Heuristic algorithm	
1	Sort Q in regard of distance itself and d
2	curr = Q[0], Q.pop(0), M = [ ]
3	M.append (Q[0]'s NN M), store(curr, M[0])
4	count_category(C,Q[0])
5	For q in Q:
6	if dist(q, q's NN m) >= dis(q, m in M):
7	store(q, m in M)
8	continue
9	store(q, NN m), M.append(NN m)
10	If count_category(C, q) == 1:
11	break
	Return selected q for each category and final distance sum

I. Conclusion and Future works

In this current state, HDVs are the primary source for delivery services. Still, suppose electric trucks are introduced for the delivery services in the future. In that case, our algorithm will be more effective as it saves more CO2 from the vehicles in the delivery process. We currently consider CO2, but we will consider more factors such as the laborers, consumables, and more in the future. In the end, we wish to develop an extended algorithm considering all the factors mentioned above. To reduce environmental damages, abatement policies such as obligating electric vehicles in such industries, providing incentives for the use of fuel-efficient cars, and more are needed.[3] For example, as part of its efforts to reduce the city's greenhouse gas emissions, the Seoul Metropolitan Government (SMG) wants to supply 270,000 electric vehicles for public transit by 2025. To meet this target, the municipal government intends to increase the annual supply of new vehicles by 50% to 175,000 cars by 2025. By 2025, approximately 15% of all taxis in the capital, or 10,000, will be electric as part of this strategy.[2] But as mentioned above, improvement in the environment would create a reduction in consumption as a trade-off. People's views of proposed environmental policies differ partly because a deteriorating environment affects different people differently. Therefore, coming up with the best consensus for everyone and the environment will be necessary.

Numerous policies and results of experiments verify the validity of this paper, but the limit still exists. Due to the nature of the category, there will be suppliers that continue to be excluded. The study should consider supplying products based on the supply and demand and fair allocation considering the time and the space.

Sustainability and economy seem incompatible at first glance. Still, the movement of protecting the environment while also caring about the personal economy, such as reducing environmental problems via policy, is active. In the case of these policies, it causes terrible results at a fast pace if it gets biased to one side. In addition, traditional economic theories are slow in Optimizing wealth for individuals and the whole in a quick change in trend. This phenomenon appears in new industries such as the untact industry. As the untact sector does not require as much as a fixed cost of starting a business like other industries, economic theories are necessary. We are aware of this news and have our interest in them and that they are essential. Therefore, we would love to continue our study on minimizing the carbon emissions in the transportation process, considering various situations, and finding the best solution for each individual.

Reference

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[2]OECD," Policies for a Better Environment", page 96, https://www.oecd.org/environment/outreach/39274836.pdf, 2007