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DC Food Truck Vending Location Trading Platform

George Mason University
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Executive Summary

This project strives to solve the problem of secondary trading of Mobile Roadway Vehicle (MRV) locations among Washington D.C. food trucks. After the MRV schedule is created via lottery and usually not getting the locations that they prefer, the food trucks are subject to a trading system that is burdensome and not worth using.

The stakeholders of this project desire a system that will maximize the number of trades and allow food trucks to enter preferences for location/day assignments they prefer in exchange for the ones that they have. In addition, the stakeholders desire software that is inexpensive and easy to use.

This project presents two approaches to this problem: a customized matching algorithm and linear optimization. Both approaches are presented because where the linear optimization clearly allows more trucks obtain new positions, a customized matching algorithm allows more generation of output within a single script. In addition, this project will present a web interface that allows food trucks to enter preference data that in turn can be used by the trading algorithms in order to create new schedule.

This project allows the stakeholders to choose the algorithm that they feel is right for them, given all of their requirements and constraints in secondary MRV trading.

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Background

Prior to December 2013, all Washington D.C. locations where food trucks were permitted to do business were available on a first come-first serve basis. In numerous locations, this led to traffic congestion due to multiple food trucks attempting to occupy a limited number of available spaces.

Beginning in December 2013, in an effort to regulate the most valuable locations where food trucks do business, the Washington D.C. Department of Consumer and Regulatory Affairs (DCRA) implemented the Mobile Roadway Vending (MRV) lottery system. The MRV lottery system assigns the most valuable Washington D.C. food truck locations by lottery. In November 2014, 182 food trucks in the "District of Columbia-Maryland-Virginia" Food Truck Association (DMVFTA) are subject to this schedule. The vending locations are assigned on a monthly basis, with an associated cost of $25 for a vendor to enter the lottery, and $150 to use the space on the day assigned. Currently, the nine current MRV locations are:

- Farragut Square 17th Street (17 paces)
- Metro Center (11 spaces)
- Virginia Ave (State Department) (10 spaces)
- Franklin Square 13th Street (17 spaces)
- Waterfront Metro (3 spaces)
- Navy Yard/Capital River Front (8 spaces)
- Union Station (15 spaces)
- Patriots Plaza (4 spaces)
- L'Enfant Plaza (19 spaces)

The purpose of these lottery assignments is to allow food trucks to do business while maintaining traffic flow in D.C., while attempting to be fair to all food trucks that are a part of the lottery. The lottery is designed such that there is only a maximum difference of on assigned location between any two food trucks. For example, if the minimum number of spots a vendor is assigned in a given week is two, then the most spot assignments any other vendor could have in that week is three. Currently, each truck receives either two or three spots per week, but this could change if more food trucks enter the lottery. According to DCRA regulations, spot assignments cannot be sold, but they can be traded on a "one spot for one spot" basis. Each trade must be approved by the DCRA and the current trading system is informal, inefficient, and, as a result, not generally used. This project provides the Food Truck Association (FTA) of D.C. a linear programming-based spot-swapping optimization platform that automates the reassignment of trucks to spots based on their preferences.

The primary sponsor and stakeholder for this project is the DMVFTA. This project seeks to improve the food trucks' monthly MRV schedule. Other stakeholders in this project are the DCRA, D.C. government, and food truck customers. The DCRA administers the MRV schedule and is responsible for approving all trades that occur between trucks after trading occurs. The D.C. government for the streets and sidewalks in which the food trucks so

business, and food truck customers are the reason why food trucks wish to occupy the spaces that they do.

Problem Definition

This problem first arose because Washington D.C. has very limited space for food trucks, especially space that is highly profitable for food trucks. The D.C. government attempted to solve this problem by implementing the MRV lottery system to generate a monthly schedule for the food trucks. This however led to dissatisfaction for the food trucks because it limited where they could do business, and forced them into certain locations on days when they did not want to be in their assigned location. This led to underutilization of MRV locations. In addition, although vendors are asked to submit their preferences for MRV locations, the DCRA assigns spots randomly and without regard to the vendors' preferences.

In addition to dissatisfaction with the lottery, food trucks are also dissatisfied with the current trading mechanism available to them after lottery results are released. According to DCRA regulations, spot assignments cannot be sold, but they can be traded on a "one spot for one spot" basis. All trades must be approved through multiple emails involving the DCRA. Because of this, very few trades occur after the MRV schedule is released. In both the initial lottery and secondary trading, food trucks are usually unable to obtain their preferred locations.

The problem of limited space is not solvable, simply because more space in Washington D.C. cannot be obtained. The problem of the MRV lottery system cannot be solved in the scope of this master's project because it would involve changing a regulation set in place by the Washington D.C. government. However, the problem of secondary trading is solvable and is the focus of this project.

Objective

The objective of this project is to create a new trading platform that is usable and abides by current regulations. The intention of the new trading platform is to maximize the number of trades that occur between food trucks and ease of use for both members of the DMVFTA and DCRA. It will also allow food trucks to identify location/day preference locations for location/day assignments that they would like to trade.

Derived Requirements

The following is a list of requirements derived from the group after conversations with the sponsor:

- The system shall not reassign food trucks to locations which they do NOT prefer
    - Rational: No food truck can be made worse off than what they were assigned in the initial schedule. Only unambiguous improvements are allowed

- The system platform shall maximize utilization of open source and freely available software
    - Rational: The system users do not want to have to purchase costly software licenses in order to use the system
- The system shall output the new, post-trade schedule in the same format as the initial schedule
    - Rational: The system user desire consistency in the way that their schedule looks

Research

Food Truck Interviews

Interviews with food truck owners confirmed the problems the lottery assignments and secondary trading. The food truck owners indicated that they would be interested in any improvement to the current secondary trading system. They noted that they would like it to be mobile accessible and simple to use.

In addition to being dissatisfied with the current system, food truck owners also desired consistency in their weekly assignments, something that already happens in the current system. Therefore, the consistency of weekly assignments will be incorporated from the current system.

DCRA Administrators

The DCRA desires a system to facilitate food truck assignment trading after the lottery assignments to maximize mobile roadway vending utilization and associated revenue. They share the same "ease of use" desires as the food truck owners. In addition, they desire the system to be low cost and maintainable.

Current "As-Is" System

Primary Assignment

Assignments for each day of the week are done once a month by the MRV lottery assignment for nine Washington D.C locations. For each week of the month, the assignments are the same. Each truck in the MRV lottery has a unique permit ID number, for example, VSP-00000, which us used to identify each truck both on the schedule and while out doing business.

As a result of the primary assignment, all trucks must have comparable number of unassigned (OFF) days, and cannot be assigned more than one location on a given day.

Secondary Trading

In order for a trade to occur between two trucks, both trucks must agree to the trade, and then have the trade approved by the DCRA via email. This is a very time consuming process.

Food trucks usually indicate that they would like to trade through an email listserv to indicate the location/day assignment that they want to trade and associated location/day assignments that they would prefer instead. If another food truck prefers the first food truck's location/day assignment and they have the first food truck's preference, then the two food trucks email DCRA proposing the trade. The DCRA then verifies that after the proposed trade, both trucks will have the same number of off days that they had before the trade, and that neither truck would be assigned more than one location on either of the two days.

There currently is no way to directly trade between three or more trucks. That is, if three or more trucks wish to trade (call them trucks A, B and C), then trucks A and B would need to trade first, then trucks A and C would need to trade, all while abiding by the same process described in the paragraph above.

Elements being used from As-Is System in Trading Platform

From the primary assignment, the trading platform will use the permit numbers to identify each specific truck. From the secondary trading, the trading platform will abide by the rules that in order to obtain a preferred location/day, the truck must be willing to trade an assigned location/day. From both the primary assignment and secondary trading, the trading platform will abide by each truck having the same number of off days before and after each trade, and that each truck cannot be scheduled for more than two locations on any given day.

System Concept

For the system concept, it is assumed that the food trucks know the initial schedule before using the system. Using a web interface, the food trucks first identify which location/day assignments they have and would like to trade. Then, for those location/day assignments, they indicate their location/day preferences that they would like instead.

That data is then submitted into an algorithm that resigns the location/day assignments based on the food trucks' preferences and trading constraints. A new schedule in then generated and distributed to the food trucks. Figure 1 below shows the inputs and outputs for the system.

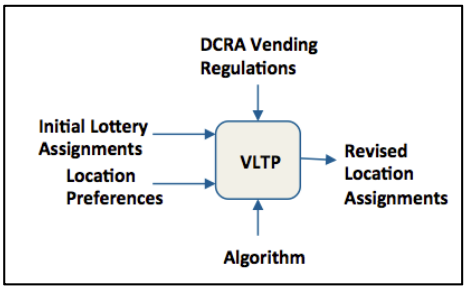

Figure 1: System put/Output

Figure 2 below shows the use case associated with the system concept. Note that the sequence of events occurs during the month prior to the one in which MRV trades are conducted. For example, if trades were being considered for January, then the MRV trading process for January occurs in December.

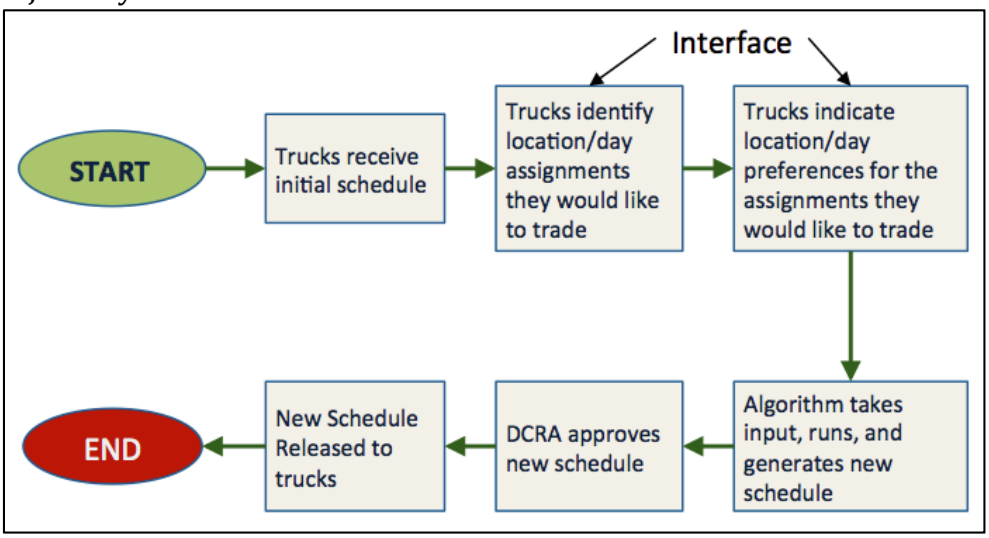

Figure 2: Use Case

Approaches to Problem

This project will solve this problem with two approaches: the linear-programming based approach and the matching based approach. Both approaches are used in order to provide the DMVFTA with the option of which one they ultimately would want to use. For example, the linear-programming based approach will usually result in more trucks that are willing to trade obtaining their preferences, where the matching algorithm provides additional output showing each trade that occurs.

Assumptions

The following assumptions are taken into account by both approaches:

- By entering location preferences into secondary trading platform, food trucks agree to accept any potential trades identified (i.e. no reneging)
- System will ensure the new truck assignment is an improvement, or there is no change to the initial assignment
- Per DCRA regulation, for all trades, trucks must offer an assigned location/day to receive a preferred location/day
- Each truck is treated as single truck with no relation to other trucks (trucks owned by the same company treated as separate trucks)

Sample Data

The problem was solved using the MRV schedule from 2104 and potential trades identified by the sponsor.

Linear Optimization Approach

Single Spot Improvement: Formulation and Results

The Food Truck Association provided data from November 2014 showing the lottery assignments and sample preferences for each truck. There were 182 trucks that participated in the lottery. The LP solves by trying to maximize the number of preferred spots assigned to each truck. Constraints are added that prevent any truck from being worse off, i.e. a truck can only receive as an assignment either a preferred spot or what they were initially assigned in the lottery. Additional constraints ensure that the number of trucks assigned to a given location does not exceed the MRV capacity allowed at that location, and all trucks end with a number of spots equal to what the entered with (this enforces the one for one trading rule). Note that the preference data is preprocessed to make sure that no truck enters preferences for a day block in which they are certain to receive an assignment.

Definitions:
Let X_{ij} = the assignment of truck i to spot j, X_{ij} binary
Let P_{ij} = the preference of truck i for spot j, P_{ij} binary
Let R_{ij} = the preference or initial assignment of truck i to spot j, R_{ij} binary
Let $i = \{1, 2, 3, \dots, 182\}$ represent the 182 trucks
Let $j = \{1, 2, 3, \dots, 45\}$ represent the 45 possible day-location pairings

Note *j* has the enumerated format: [Day, Location] = [j], for example:

Table 1: MRV locations in Linear Optimization

Day	MRV Location	*j*
Monday	Farragut Square 17th St	1
	Metro Center	2
	Virginia Ave (State Dept)	3
	Franklin Square 13th St	4
	Waterfront Metro	5
	Navy Yard/Capital River Front	6
	Union Station	7
	Patriots Plaza	8
	LEnfant Plaza	9

$$Decision\ Variable: \quad X_{ij} = \begin{cases} 1 & if\ truck\ i\ is\ assigned\ spot\ j \\ 0 & otherwise \end{cases}$$

$$P_{ij} = \begin{cases} 1 & if\ truck\ i\ prefers\ spot\ j \\ 0 & otherwise \end{cases}$$

Objective Function:

$$Maximize \sum_i \sum_j X_{ij} * P_{ij}$$

Subject To:

1) Each truck starts and ends with the same number of initially assigned spots (only 1-for-1 trades permitted):

$$\sum_j X_{ij} = 1 \qquad \forall\, i$$

2) The number of trucks assigned do not exceed the MRV location capacity:

We define the following 9 sets representing each location on each day of the week as follows:

$Let\ s_1 = \{1, 10, 19, 28, 37\}\ representing\ Farragut\ Sq.\ 17th\ St\ Monday - Friday, resp.$
$Let\ s_2 = \{2, 11, 20, 29, 38\}\ representing\ Metro\ Center\ Monday - Friday, resp.$
$Let\ s_3 = \{3, 12, 21, 30, 39\}\ representing\ Virginia\ Ave\ (State\ Dept)\ Monday - Friday, resp.$
$Let\ s_4 = \{4, 13, 22, 31, 40\}\ representing\ Franklin\ Square\ 13th\ St\ Monday - Friday, resp.$
$Let\ s_5 = \{5, 14, 23, 32, 41\}\ representing\ Waterfront\ Metro\ Monday - Friday, resp.$
$Let\ s_6 = \{6, 15, 24, 33, 42\}\ representing\ Navy\ Yard\ Capital\ River\ Front\ Monday - Friday, resp.$
$Let\ s_7 = \{7, 16, 25, 34, 43\}\ representing\ Union\ Station\ Monday - Friday, resp.$
$Let\ s_8 = \{8, 17, 26, 35, 44\}\ representing\ Patriots\ Plaza\ Monday - Friday, resp.$
$Let\ s_9 = \{9, 18, 27, 36, 45\}\ representing\ L'Enfant\ Plaza\ Monday - Friday, resp.$

$$\sum_i X_{ij} \le 17 \qquad j \in \{s_1\}$$
$$\sum_i X_{ij} \le 11 \qquad j \in \{s_2\}$$
$$\sum_i X_{ij} \le 10 \qquad j \in \{s_3\}$$
$$\sum_i X_{ij} \le 17 \qquad j \in \{s_4\}$$
$$\sum_i X_{ij} \le 3 \qquad j \in \{s_5\}$$
$$\sum_i X_{ij} \le 8 \qquad j \in \{s_6\}$$
$$\sum_i X_{ij} \le 15 \qquad j \in \{s_7\}$$
$$\sum_i X_{ij} \le 4 \qquad j \in \{s_8\}$$

$$\sum_i X_{ij} \leq 19 \qquad j \in \{s_9\}$$

3) A truck can only be assigned according to their preferences, no truck can be made worse off. The matrix R_{ij} represents the preferences of truck i for spot j and the spots owned by truck i. Requiring the decision variable, X_{ij}, to be less than or equal to R_{ij} ensures that the LP assigns only a preferred spot or an owned spot to a given truck, and prevents arbitrary assignment by the LP.

$$R_{ij} = \begin{cases} 1 & if\ truck\ i\ prefers\ spot\ j\ or\ owns\ spot\ j \\ 0 & otherwise \end{cases}$$

$$X_{ij} \leq R_{ij}$$

$$\sum_j X_{ij} * R_{ij} = 1 \qquad \forall\, i$$

The formulation was coded in MPL and solved with LPSolve, a mixed integer linear programming (MILP) solver. LPSolve uses the revised simplex method and the branch-and-bound method to solve MILP problems.

Of the 182 trucks, 32 trucks provided preference data. There were a total of 32 spots assigned from the initial lottery to the 32 trucks that entered preferences. Out of those 32 spots, 30 spots were improved with a preferred spot without violating any constraints. This is an improvement nearly 94% of the spot assignments to preference-entering trucks.

Multiple Spot Improvement: Approach and Results

This approach requires an input that gives each vendor preference for spots in relation to each spot they were assigned. For example, if a truck is assigned spots 5, 18, 45, and suppose the truck prefers those spots in that order, then it should follow that the preference input should look something like the following (if spot 5 is also the most highly desired spot for truck *i*, then there is no possible improvement, and the set is a null set):

For Truck *i*:
Preferred spots over spot 5 = {set of spots}
Preferred spots over spot 18 = {set of spots + at least one additional spot}
Preferred spots over spot 45 = {set of spots + at least two additional spots}

This adds a dimension to the problem and the rows in the assignment matrix X_{ij} are expanded by the number of spots each truck is assigned. The LP is no longer assigning spots based on each truck's preference, but rather assigning spots based on what is preferred over a specific assigned spot for each truck.

Since each truck is assigned either two or three spots from the initial lottery, we introduce a new index k which indicates the assigned spot number. The index k can take on values 1, 2, or 3. For

trucks only assigned two spots, the value corresponding to k = 3 is set to zero. In the example above, k = 1, 2, 3 would correspond to spots 5, 18, and 45 respectively. The formulation is as follows:

Definitions:

Let X_{ijk} = the assignment of the k^{th} spot number of truck i to spot j, X_{ijk} binary
Let T_i = the total number of spots initially assigned to truck i
Let P_{ijk} = the preference of the k^{th} spot number of truck i for spot j, P_{ijk} binary
Let R_{ijk} = the preference or initial assignment of the k^{th} spot number of truck I for spot j, R_{ijk} binary
Let N_{ik} = whether truck i has spot number k (differentiate between trucks assigned 2 or 3 spots), N_{ik} binary
Let $i = \{1, 2, 3, \dots, 182\}$ represent the 182 trucks
Let $j = \{1, 2, 3, \dots, 45\}$ represent the 45 possible day-location pairings
Let $k = \{1, 2, 3\}$ represent the spot number of the assignment

$$X_{ijk} = \begin{cases} 1 & if\ the\ kth\ spot\ number\ of\ truck\ i\ is\ assigned\ spot\ j \\ 0 & otherwise \end{cases}$$

$$P_{ijk} = \begin{cases} 1 & if\ spot\ j\ is\ preferable\ to\ the\ kth\ spot\ of\ truck\ i \\ 0 & otherwise \end{cases}$$

Objective Function:

$$Maximize \sum_i \sum_j \sum_k X_{ijk} * P_{ijk}$$

Subject To:

1) Each truck starts and ends with the same number of initially assigned spots (only 1-for-1 trades permitted):

$$\sum_j \sum_k X_{ijk} = T_i \qquad \forall\ i$$

2) The number of trucks assigned do not exceed the MRV location capacity:

We define the following 9 sets representing each location on each day of the week as follows:

$Let\ s_1 = \{1, 10, 19, 28, 37\}\ representing\ Farragut\ Sq.\ 17th\ St\ Monday - Friday$
$Let\ s_2 = \{2, 11, 20, 29, 38\}\ representing\ Metro\ Center\ Monday - Friday$
$Let\ s_3 = \{3, 12, 21, 30, 39\}\ representing\ Virginia\ Ave\ (State\ Dept)\ Monday - Friday$
$Let\ s_4 = \{4, 13, 22, 31, 40\}\ representing\ Franklin\ Square\ 13th\ St\ Monday - Friday$
$Let\ s_5 = \{5, 14, 23, 32, 41\}\ representing\ Waterfront\ Metro\ Monday - Friday$
$Let\ s_6 = \{6, 15, 24, 33, 42\}\ representing\ Navy\ Yard\ Capital\ River\ Front\ Monday - Friday$
$Let\ s_7 = \{7, 16, 25, 34, 43\}\ representing\ Union\ Station\ Monday - Friday$
$Let\ s_8 = \{8, 17, 26, 35, 44\}\ representing\ Patriots\ Plaza\ Monday - Friday$
$Let\ s_9 = \{9, 18, 27, 36, 45\}\ representing\ L'Enfant\ Plaza\ Monday - Friday$

$$\sum_i \sum_k X_{ijk} \leq 17 \qquad j \in \{s_1\}$$

$$\sum_i \sum_k X_{ijk} \leq 11 \qquad j \in \{s_2\}$$
$$\sum_i \sum_k X_{ijk} \leq 10 \qquad j \in \{s_3\}$$
$$\sum_i \sum_k X_{ijk} \leq 17 \qquad j \in \{s_4\}$$
$$\sum_i \sum_k X_{ijk} \leq 3 \qquad j \in \{s_5\}$$
$$\sum_i \sum_k X_{ijk} \leq 8 \qquad j \in \{s_6\}$$
$$\sum_i \sum_k X_{ijk} \leq 15 \qquad j \in \{s_7\}$$
$$\sum_i \sum_k X_{ijk} \leq 4 \qquad j \in \{s_8\}$$
$$\sum_i \sum_k X_{ijk} \leq 19 \qquad j \in \{s_9\}$$

3) A truck can be assigned to at most one spot for each day of the week (no truck can be assigned to two different locations on the same day):

$$\sum_j \sum_k X_{ijk} \leq 1 \qquad \forall\, i\,;\, j \in [1,9]$$
$$\sum_j \sum_k X_{ijk} \leq 1 \qquad \forall\, i\,;\, j \in [10,18]$$
$$\sum_j \sum_k X_{ijk} \leq 1 \qquad \forall\, i\,;\, j \in [19,27]$$
$$\sum_j \sum_k X_{ijk} \leq 1 \qquad \forall\, i\,;\, j \in [28,36]$$
$$\sum_j \sum_k X_{ijk} \leq 1 \qquad \forall\, i\,;\, j \in [37,45]$$

4) A truck can only be given an assignment to the kth spot if they were initially given k spots:

$$N_{ik} = \begin{cases} 1 & if\ truck\ i\ was\ assinged\ a\ kth\ spot \\ 0 & otherwise \end{cases}$$

$$X_{ijk} \leq N_{ik}$$

5) A truck can only be assigned according to their preferences:

$$R_{ijk} = \begin{cases} 1 & if\ spot\ j\ is\ owned\ or\ is\ preferable\ to\ the\ kth\ spot\ of\ truck\ i \\ 0 & otherwise \end{cases}$$

$$\sum_j X_{ijk} * R_{ijk} = N_{ik} \qquad \forall\, i, k$$

Matching Algorithm Approach

The key features to the customized matching algorithm are that it allows and shows trades between two or more food trucks, and only considers food trucks whose preferences are available. Therefore, all trucks involved in any given trade loop have location/day preferences that are other trucks' location/day assignments. This guarantees that a trade will be converged upon.

Checks before entering algorithm

Check #1: For each truck, disallow preferences for location/day assignments that truck owns and is trading.

This check ensures that any food truck does not prefer a location/day assignment that it already owns. If the food truck already owns a location/day assignment and they do not want to trade it, then that location/day should not be one of the food trucks preferences because it already owns it

Check #2: For each truck, disallow preferences on days that truck has a location/day assignment that it is NOT offering to trade.

This check ensures that the food truck will not end up owning more than one location on any given day. Basically, the food truck can can only prefer locations on days when it is not assigned a location or on the same day for which it is trading

For example, if a food truck has location A on Tuesday and location B on Thursday, and it does not have a location on Monday, Wednesday, or Friday. If the truck wants to trade location A on Tuesday, then all preferences need to be on Monday, Tuesday, Wednesday, or Friday, since the food truck is already assigned a location on Thursday.

Check #3: Eliminate trucks whose preferences are not available (i.e. location/day assignments not being traded by other trucks)

As described above, food trucks with location/day preferences that are not available need to be eliminated from trading because they cannot trade.

One-dimensional arrays needed before entering algorithm

The two arrays needed before entering trading are the "Location/Days to be Traded" array and the corresponding "Trucks that are Trading" array. These two arrays have the same indices, making it easy to identify what location/day a food truck is assigned or what truck is assigned a location/day.

Matching Algorithm

The Figure 3 below shows the basic flow chart in the customized matching algorithm.

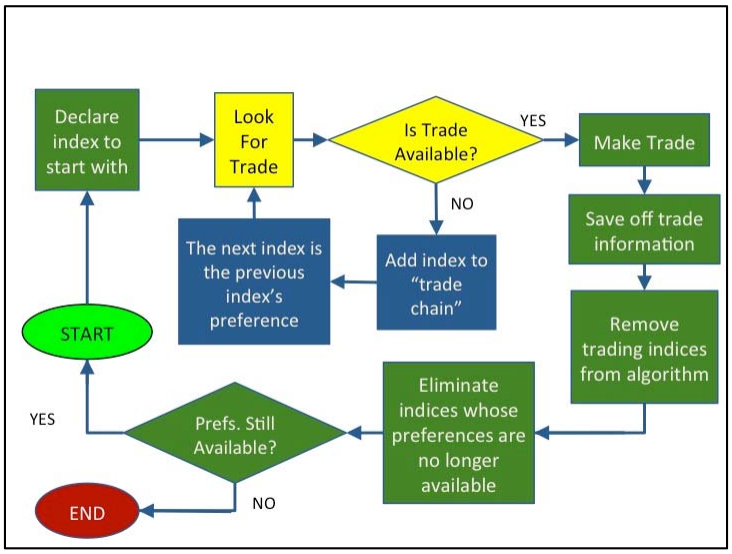

Figure 3: Customized Matching Algorithm Flow Chart

The actions of each position are described below:

"Start" Position
From the "Start" position, every truck considered for trading will have at least one preference available, guaranteeing that a trade will happen whenever the "Start" position is hit, whether to start the algorithm or after a trade occurs.

"Declare index to start with" Position
The algorithm will always start with the left most index in the "Location/Days to be Traded" and "Trucks that are Trading" arrays.

"Look For Trade" Position
This finds out what the truck corresponding to the index fed into this position prefers. For example, if index 0 corresponds a truck in location/day "Farragut/Monday" and that truck prefers "L'Enfant/Friday," the algorithm will find what truck has "L'Enfant/Friday" and what that truck's preference is.

"Is Trade Available Position"
This determines if a trade can be made from the indices in the "trade chain." From the example described above in the "Look for Trade" position, if the truck that has "L'Enfant/Friday" prefers "Farragut/Monday," then a trade is made. If the truck does not prefer "Farragut/Monday," then a trade does not occur.

"Add Index to 'trade chain'" and "The next index is the previous index's preference" positions
These two positions set up the next index whom to look for a trade.

"Make Trade" position

When a truck prefers a location/day that is currently in the "trade chain," then a trade is made between the truck trading the location/day, the truck that prefers that location/day, and all trucks in between.

"Save off trade information" position
This step notes the trade in a separate array, reassigning location/days. The indices stay consistent so that the trucks that have obtained new positions can be easily identified.

"Remove Trading indices from algorithm" position
The indices that have traded need to be removed from the algorithm because their continued trading consideration would cause the algorithm to diverge. This is done by simply crossing off indices in the "Location/Days to be traded" array.

"Eliminate indices whose preferences are no longer available" position
This runs through the indices that have not been crossed off and ensures that its preferences are still available after trading. If they are not available, then the indices are removed from the algorithm so that the algorithm can continue with convergence

"Prefs. Still Available?" position
This is a simple check to see if and preferences are still available if they are, a new trade is looked for from the "Start" position. If not, then trading is over.

This algorithm is to be run so that every index gets to start when no trading has occurred. Through the iterations, the maximum number of trades is found.

Matching Algorithm Example

The matching algorithm starts with the following data, described in Table 2. Note that all preferences are being traded, which makes the algorithm work

Table 2: Matching Algorithm Example Data Pre-Trade

Index	Location/Day [Position]	Truck	Preference(s)
0	11	A	22, 55
1	22	B	33,44
2	33	C	44
3	44	D	33
4	55	E	66
5	66	F	77
6	77	G	11

The algorithm starts with index 0, which in this case is truck A in position 11. Because truck A prefers position 22, the next truck considered is truck B. Because truck B does not prefer truck A's position (position 11), the algorithm then sees that truck B prefers position 33, occupied by truck C. Truck C prefers position 44, which is not being traded by trucks A or B. Therefore, the algorithm continues to the truck D, which occupies position 44.

Because truck D prefers position 33, which is occupied by truck C, a trade is made between trucks C and D. This trade process is shown in Figure 4 below.

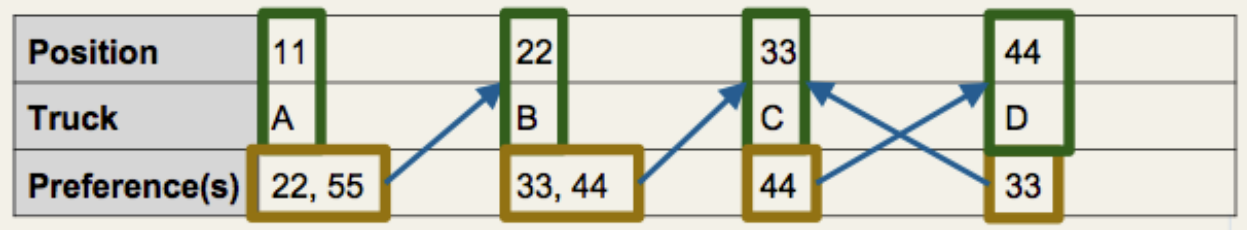

Figure 4: Two-Way Trade

Trucks C and D are then removed from trading consideration. A check is then made to ensure that the remaining trucks' preferences are still available. Truck B is eliminated because positions 33 and 44 are no longer available for trading. Trucks A, E, F, and G remain because their preferences are still available. The new status of the data is show in Table 3 below.

Table 3: Matching Algorithm Example Data Mid-Trade

Index	Location/Day [Position]	Truck	Preference(s)	Status
0	11	A	22, 55	Active
1	22	B	33,44	Eliminated
2	33	C	44	Traded
3	44	D	33	Traded
4	55	E	66	Active
5	66	F	77	Active
6	77	G	11	Active

The algorithm again starts with index 0, truck A in position 11. The algorithm then preforms the following actions, asking and answering its own questions as it goes:

- What does truck A have?
  - Truck A has position 11
- What does truck A prefer?
  - Truck A prefers position 55
- Who has position 55?
  - Truck E has position 55
- What does truck E prefer?
  - Truck E prefers position 66
- Can a trade be made between truck A and E?
  - No
- Who has position 66?
  - Truck F has position 66
- What does truck F prefer?
  - Truck F prefers position 77
- Can a trade be made between Trucks A, E and F OR E and F?
  - No

- Who has position 77?
  - Truck G has position 77
- What does truck G prefer?
  - Truck G prefers position 11
- Can a trade be made between Trucks A, E, F, and G?
  - Yes
- Four way trade occurs between trucks A, E, F, and G

Figure 5 below show this four-way trade.

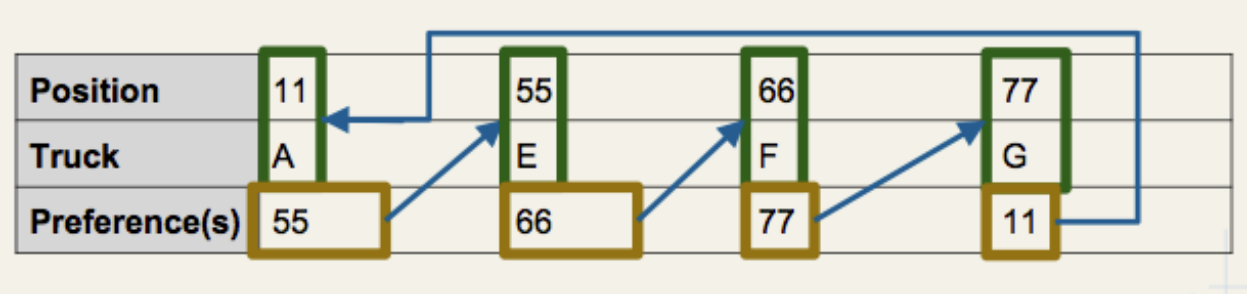

Figure 5: Four Way Trade

There are no remaining preferences after this trade, so trading ends. The final results of this example are shown in Table 4: Matching Algorithm Example Data Post-Trade.

Table 4: Matching Algorithm Example Data Post-Trade

Index	Location/Day [Position]	Truck	Obtained new position?	Position Post-Trade
0	11	A	YES	55
1	22	B	NO	22
2	33	C	YES	44
3	44	D	YES	33
4	55	E	YES	66
5	66	F	YES	77
6	77	G	YES	11

This simple example of the customized matching algorithm resulted in 6 of 7 trucks obtaining a new, preferred location/day [position] assignment. The trades were traceable through the algorithm, allowing the user to track and know which trades were being made when and where.

Matching Algorithm Results

Using the same input data as the linear optimization and assigning the trucks per the process described above, 23 of 32 trucks achieved new preferences, an improvement of over 69%. Three of those trucks were eliminated prior to trading because their preferences were not being traded by any of the other trucks, and six were eliminated during trading because their preferences became unavailable during trading. In addition,

the algorithm ran 29 times, with each truck getting a chance to start the trading process. Of these 29 runs, the minimum number of trucks in new, preferred positions was 17, and the maximum number of trucks in new, preferred positions was 23.

Comparison of Approaches

Both the Linear Optimization and Matching Algorithm are useable, expandable, and available via free software. The Linear Optimization truly allows more trucks to be assigned their preferences, provided that they are trading a location/day assignment, because it looks not only to assign trucks their preference based on what other trucks are trading, but also looks to fill the capacity of each MRV location. This pushes the DCRA regulation of one-for-one trading, because even though a truck is giving up a location/day assignment, they are only being reassigned, not trading with another truck. This is a consideration of the stakeholders of this project.

The matching algorithm does not assign as many trucks their preferences as the linear optimization, but it does still have good results with seven out of ten trucks receiving preferred location/day assignments. The matching algorithm also strictly abides by the current DCRA regulations, in that the only way a truck can obtain a preferred location/day assignment is by trading with another truck. The matching algorithm also outputs the trades that it makes, allowing the DCRA to physically approve each trade that is made. The truly innovative characteristic of the matching algorithm is the capacity for trades between more than two trucks, and showing that those multi-way trades occur through output. Without multi-way trading, it is unlikely that the matching algorithm could compete with the linear optimization.

In choosing between the linear optimization and matching algorithm approaches, the DMVFTA and DCRA need to determine what they prefer more. If they want the maximum number of trucks reassigned, with or without strict trading, then they should choose the linear optimization. If they want to abide by the strict trading regulations while not getting as many trucks reassigned, then they should use the matching algorithm.

System Interface and Integration

Inputs

The inputs for this system consist of the initial MRV schedule from the lottery, and the truck requested trades and their associated preferences.

System Interfaces

The system interface is web based, and mobile device compatible. It allows the food trucks to identify preferences per the location/day assignments that they would like to trade.

The web-based interface contains the following features:

- Login authentication
- Dynamic reference to initial lottery assignment

- Flexible input format
- Input confirmation provided

The web-based interface is able to uses the MRV lottery schedule as an input so that it can display the food trucks' assignments to them for trade identification.

The Login authentication is shown below in Figure 6. The web-based interface identifies each truck by their permit number.

Figure 6: Interface Login Authentication

Figure 7 below shows the location/day assignments for the truck, allowing easy reference to what it already has from MRV lottery schedule, making it easier for the truck to identify what location/day assignments they would like to trade.

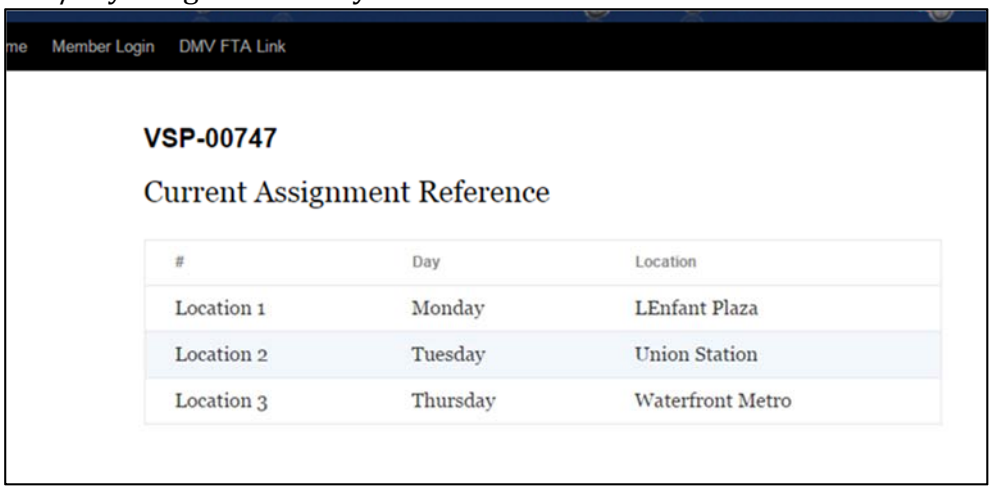

Figure 7: Interface Current Assignment Reference

As seen below in Figure 8, trucks can select multiple locations on a given day or multiple days for a given location. This allows the trucks the ability to focus on a given location or a given day in which they especially desire. In addition, they can also focus on specific location and day combinations that they desire. After their preferences and the location/day assignments they are trading are entered, the data is forwarded to either the linear optimization or matching algorithm for consideration.

Also note in Figure 8 the agreement acknowledgment. This ensure that that truck understands that by entering preferences for a location/day assignment that they agree to any trade in which they receive one of their location/day preferences.

Figure 8: Interface Preference Entering

Outputs

The main output of the system is the new, post trade schedule. The schedule is in the same dimensions as the MRV input schedule and contains the same general data, only with different assignments for each truck that reflect the trades that took place.

The matching algorithm generates two additional text files: one showing the trades that occur and trucks that were eliminated during trading, and one showing all the trucks that entered a location/day assignment to be traded. More information about these files can be found in Appendix B and Appendix C.

Future Direction

The next step in this project is to choose the linear optimization approach or the matching algorithm approach. Then, the chosen approach and preference entering must undergo a test and integration phase, first with using known schedules like the data used in this project, then having a sample size of trucks use the system to trade location/day assignments for their relative preferences. Once the system catches on with the food

trucks, the next step would to allow the trucks to rank or score their preferences relative to one another.

Conclusion

This project found two approaches by which the lottery assignments can be improved from the food truck perspective while leaving the lottery as-is. In addition, the project introduces a web interface by which preferences can be entered. The project also reports the findings of the two approaches. The linear optimization will result in more trucks reassigned to their preferences, but the matching algorithm provides more output and more closely abides to DCRA regulations. A prototype was also produced, which is capable of outputting a new, post trade MRV schedule.

Works Cited

"November 2014 MRV Location Lottery Results." *DCRA*. Web. 1 Nov 2014. <http://dcra.dc.gov/sites/default/files/dc/sites/dcra/publication/attachments/November%202014%20MRV%20Lottery%20Results%20-%20Final.pdf>

Appendix A: How to use Matching Algorithm Prototype

Prerequisites

1. Go to www.perl.org and download the latest version Perl.
2. Create a new folder on your desktop
3. Copy the following files from your CD to the new folder in your desktop
    a. Food_Truck_Matching.pl
    b. Lot_Ass_excell.csv (This is the MRV schedule in .csv format)
        i. NOTE: This file was edited to remove commas in the company names and the hyphen was taken out of all instances of "LEnfant"
    c. Desired_Trades.csv
        i. NOTE: This file is mostly ones and zeros. The 1 indicates that the truck owns the location/day assignment indicated in the first row, and wants to trade it
    d. Preferences_1.csv
        i. NOTE: This file is also mostly ones and zeros. The 1s indicate that the truck prefers the location/day corresponding to the first row.

Test Case

Step	Action	Expected Result
1	Open a terminal window	Terminal Window opens
2	Enter the following command to navigate to the folder you created in the prerequisites in the terminal window cd Desktop/<folder you created>	Terminal Window is in the Desktop directory
3	Enter the following command to run the PERL script perl Food_Truck_Matching.pl	The following text appears on the terminal window screen: Iteration 1... Total Trucks with new positions = 21 Total Trucks eliminated before trading = 3 Total Trucks eliminated during trading = 8 . . . Iteration 29... Total Trucks with new positions = 21 Total Trucks eliminated before trading = 3 Total Trucks eliminated during trading = 8 And there you go

Step	Action	Expected Result
4	In the folder you created, there should be 4 new files: trade_info.txt post_trade_schedule.csv trade_info_max.txt pre_trade_info.txt	Conditions shown as indicated
5	Open the file post_trade_schedule.csv in excel	post_trade_schedule.csv opens in excel
6	Open the file "Output_with_checks.xlsx" located on your CD	"Output_with_checks.xlsx" opens in excel
7	In the file post_trade_schedule.csv, select cells A1 through G183 (so that rows 1 through 183 and columns A through G are selected)	Condition shown as indicated
8	Copy the selected data	Data it copied
9	In the file Output_with_checks.xlsx, select cell K2	Cell K2 is selected in Output_with_checks.xlsx
10	Select Control to paste the data copied from post_trade_schedule.csv into Output_with_checks.xlsx	Data is pasted The permit truck numbers in column K should correspond to the permit truck numbers in column A
11	In column I of Output_with_checks.xlsx, verify that all rows for which food trucks are present on either side display "good"	Condition displayed as indicated. This is an indication that each truck has the same amount of off days before and after trading
12	Verify that in rows 202 to 211, columns C to G, that all cells say YES	This is a comparison of the number of assigned positions between the pre-trade schedule and to post trade schedule. This indicates that no erroneous trading occurred
13	In the folder on the desktop from which you created, open the file trade_info_max.txt	trade_info_max.txt opens

Step	Action	Expected Result
14	In Output_with_checks.xlsx, columns S through W indicate that a trade occurred (Hence the word TRADE) for the corresponding truck on the indicated day Use the trade_info_max.txt file to verify the trades that occurred on the new schedule NOTE: If "TRADE" appears on two days, it means that the truck was reassigned an OFF day in exchange for the trade that it made. If "TRADE" only appears on one day, that indicates that the truck traded and obtained a position on the same day	All data legit, and trades are traceable using the trade_info_max.txt file on the new post trade schedule

Matching Algorithm Prototype Release Notes

- The prototype currently can only handle one location/day assignment to be traded per truck.
- When searching using a trucks' preference to determine the next index (truck and location/day assignment) to be considered, it will always use the first preference it can find

Appendix B: Code and Full Results

Please see the CD submitted with this paper for this information. The LP code and results are located in the /LP directory. The Matching Algorithm code, inputs and outputs are located in the /Matching_Algorithm Directory.

The contents of the two directories are listed below:

LP Directory:

- Appendix – LP Raw Output.txt
- Appendix – MPL Code.docx

Matching_Algorithm Directory:

- Food_Truck_Matching.pl
- Lot_Ass_Excell.csv
- Desired_Trades.csv
- Preferences_1.csv
- pre_trade_info.txt
- trade_info.txt
- trade_info_max.txt
- post_trade_schedule.csv

Appendix C: Matching Algorithm Sample Results

pre_trade_info.txt

The Pre_Trade_Schedule.txt text file shows each truck entering consideration for trading and the location/day assignment that they are trading. In addition, it also shows the trucks that are eliminated from trading before trading begins due to their preferences not being available, that is their location/day preferences are not being traded by other trucks.

In the test case, here is a sample of what the pre_trade_info.txt file looks like. The entire file can be found in Appendix B.

```
.....Pre-Trade Notes.....
Number of trucks looking to trade = 32
Permit IDs of trucks that are trying to trade and the locations that they are
offering for trading:

VSP-00747 (Adilmo) owns and is looking to trade
[Waterfront Metro on Thursday]

VSP-00160 (Amorini Panini Inc.) owns and is looking to trade
[LEnfant Plaza on Wednesday]
.
.
.
.
.
VSP-00676 (The Gyro Brothers) owns and is looking to trade
[Navy Yard/Capital River Front on Thursday]


Trucks/owned positions eliminated from trading before trading because their
preferences are not available:
VSP-00160/[LEnfant Plaza on Wednesday] (Amorini Panini Inc.)
VSP-00350/[Waterfront Metro on Thursday] (DC Kabob & Grill)
VSP-00169/[Navy Yard/Capital River Front on Tuesday] (DC Slices)
.....End Pre-Trade Notes.....
```

trade_info_max.txt

The trade_info_max.txt file displays each trade that occurs within the trading algorithm. In addition, it shows the trucks that are eliminated during trading because their preferences become unavailable during trading, that is, their location/day preferences are not being traded by other trucks.

In the test case, here is a sample of what the trade_info_max.txt file looks like. The entire file can be found in Appendix B.

```
...Entering Trading...

#===#Beginning of Trading Events for Trade ID 1#===#
###Beginning of Trade ID 1###
There are 2 trucks involved in this trade:
Truck VSP-00723 traded [Franklin Square 13th St on Tuesday] and received
[Union Station on Tuesday]
(Kabob Bites)
Truck VSP-00161 traded [Union Station on Tuesday] and received [Franklin
Square 13th St on Tuesday]
```

```
(Amorini Panini Inc.)
###End of Trade ID 1###

After the last trade, Trade ID 1, this truck/owned position was eliminated
from trading because its preferences are no longer available:
VSP-00358/[Virginia Ave (State Dept) on Tuesday] (DC Loco's)
#===#End of Trading Events for Trade ID 1#===#



#===#Beginning of Trading Events for Trade ID 2#===#
###Beginning of Trade ID 2###
There are 3 trucks involved in this trade:
Truck VSP-00170 traded [Union Station on Wednesday] and received [Farragut
Square 17th St on Monday]
(South Meets East)
Truck VSP-00147 traded [Farragut Square 17th St on Monday] and received
[Virginia Ave (State Dept) on Tuesday]
(Sate)
Truck VSP-00322 traded [Virginia Ave (State Dept) on Tuesday] and received
[Union Station on Wednesday]
(Feelin' Crabby)
###End of Trade ID 2###

After the last trade, Trade ID 2, this truck/owned position was eliminated
from trading because its preferences are no longer available:
VSP-00680/[Franklin Square 13th St on Thursday] (DC Greek Food)
#===#End of Trading Events for Trade ID 2#===#
.
.
.
.
#===#Beginning of Trading Events for Trade ID 8#===#
###Beginning of Trade ID 8###
There are 3 trucks involved in this trade:
Truck VSP-00249 traded [Waterfront Metro on Friday] and received [Union
Station on Monday]
(Beirut Delights LLC)
Truck VSP-00020 traded [Union Station on Monday] and received [Navy
Yard/Capital River Front on Thursday]
(Borinquen Lunch Box)
Truck VSP-00549 traded [Navy Yard/Capital River Front on Thursday] and
received [Waterfront Metro on Friday]
(Phidelphia Steak Bites 2)
###End of Trade ID 8###

#===#End of Trading Events for Trade ID 8#===#



#===#Beginning of Trading Events for Trade ID 9#===#
###Beginning of Trade ID 9###
There are 2 trucks involved in this trade:
Truck VSP-00150 traded [Union Station on Tuesday] and received [Virginia Ave
(State Dept) on Monday]
(Rebecca Cusine)
Truck VSP-00023 traded [Virginia Ave (State Dept) on Monday] and received
[Union Station on Tuesday]
(Feelin' Crabby)
###End of Trade ID 9###

After the last trade, Trade ID 9, this truck/owned position was eliminated
from trading because its preferences are no longer available:
```

```
VSP-00370/[Waterfront Metro on Wednesday] (DC Ballers)
After the last trade, Trade ID 9, this truck/owned position was eliminated
from trading because its preferences are no longer available:
VSP-00142/[Union Station on Monday] (DC Empanadas LLC)
#===#End of Trading Events for Trade ID 9#===#


.....Trading Completed! Final Statistics.....
Total Trucks with new positions = 23
Total Trucks eliminated before trading = 3
Total Trucks eliminated during trading = 6
```

trade_info.txt

The trade_info.txt file is to be ignored. It automatically generates at the end of each set of trades. The algorithm saves it off to "trade_info_max.txt" when the algorithm finds the maximum number of trades. It effectively shows the trades that occur in the last iteration of the trading portion of the algorithm.

post_trade_schedule.csv

The post_trade_schedule.csv is the generated new schedule produced from the trading iteration with the maximum number of trades. It has the same dimensions and data identifiers as the input schedule. A very small part of it is shown below. The entire post_trade_schedule.csv file can be found in Appendix B.

Site Permit	Business	Monday	Tuesday
VSP-00747	Adilmo	LEnfant Plaza	Union Station
VSP-00573	Ali Abdelghany	Farragut Square 17th St	OFF
VSP-00160	Amorini Panini Inc.	Union Station	OFF
VSP-00161	Amorini Panini Inc.	OFF	Franklin Square 13th St
VSP-00048	Ana Olmos	Farragut Square 17th St	OFF
VSP-00049	Ana Olmos	OFF	LEnfant Plaza
VSP-00626	Arepa Zone	OFF	Farragut Square 17th St