TRAVELERS' RATIONALITY IN ANTICIPATORY ONLINE EMERGENCY RESPONSE

FINAL REPORT

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16. Abstract. In this study, the simulation of traffic demand and flow behaviors is integrated with optimization of emergency resource allocation to explore benefits to the travelers and emergency responders and to save lives, money, and time. This research fills the gaps in the rationality of travelers when unexpected events occur and improves the myopic dispatching of emergency vehicles. Online optimization model is extended for a decision-making of whether to change the allocation of emergency resources when the traveler rationality exceeds boundary. The non-myopic model considers future expected delay based on traffic flow dynamics. The choice parameters of traveler are estimated from probe vehicle data and loop detector data in the real-world transportation network. Data-driven path-size logit model illustrating traveler's route choice changes before and after incident occurrence is integrated to traffic simulation software. A boundedly rational travelers' choice indicate a better dispatching of emergency vehicles thereby reduce traffic delays to the network. The lookahead algorithm in an easy interface can train responders with less frustration of going back and forth due to less efficient response strategy. This project envisions a new era in which an optimal resource allocation adapts to external events effectively and anticipates the future learning from the past to produce effective solutions.

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EXECUTIVE SUMMARY

A prompt response to emergency has been the top priority of traffic incident management to save lives, money, and time. In this study, the simulation of traffic demand and flow behaviors is integrated with optimization of emergency resource allocation to explore benefits to the travelers and emergency responders. This research fills the gaps in the rationality of travelers when unexpected events occur and improves the myopic dispatching of emergency vehicles. Online optimization model is extended for a decision-making of whether to change the allocation of emergency resources when the traveler rationality exceeds boundary. While previous studies have focused on minimizing the response time of emergency vehicles, this study minimizes the delay to the transportation network under the emergency scenarios with the same severity. The non-myopic model considers future expected delay based on traffic flow dynamics. The choice parameters of traveler are estimated from probe vehicle data and loop detector data in the real-world transportation network. Data-driven path-size logit model illustrating traveler's route choice changes before and after incident occurrence is integrated to traffic simulation software. A boundedly rational travelers' choice indicate a better dispatching of emergency vehicles thereby reduce traffic delays to the network. Although the simulation-based optimization model handles complex behaviors, the abstracted decision making can provide transportation agencies a simple command of which to allocate emergency vehicles with real-time situation awareness. The lookahead algorithm in an easy interface can train responders with less frustration of going back and forth due to less efficient response strategy. This project envisions a new era in which an optimal resource allocation adapts to external events effectively and anticipates the future learning from the past to produce effective solutions.

1. DESCRIPTION OF PROBLEM

Traditional decision makings for emergency resources to attend to the current emergency does not account for traffic flow behavior nor the rationality of travelers in the transportation network. These models are based on a priority for fastest response, regardless of the severity of the incidents nor available resources in the later stage. Even though future events can be anticipated, previous studies follow an assumption that events over a time interval are *independent.* This study follows an assumption that events are *interdependent*, because speed reduction and rubbernecking due to an initial incident provoke secondary incidents on freeways and the resource availability depends on service times of each request. The misconception that secondary incidents are not common has resulted in overlooking a look-ahead concept. This study is the pioneer in relaxing the structural assumptions of independency during the assignment of servers and approaching the challenge from an operational perspective, *online optimization.* With the different combinations of dispatching emergency vehicles, the stochastic decisions will produce a better performance for a sequence of events occurring over a time interval. Frequent independent incident scenarios, at least two incidents occurring within a certain region and time interval, were not mentioned in previous studies. This research will prove that the events are interdependent, because of speed reduction and rubbernecking, due to an initial incident provoke secondary incidents (Khattak et al.,2009, 2011; Yang et al.,2014b,2017; Ng et al.,2013).

Lack of information of previous emergencies and dismissal of an individual traveler's behavior from a system optimal has bounded previous researchers from an optimal emergency management. Most of emergency management studies have made resource allocation decisions to serve the *current* emergency without knowing which *future* emergency will be occurring. Different ordered combinations of emergencies result in different performance outcomes.

This project overcomes two limitations of the state-of-the art literature. First, the rationality of travelers when unexpected road incidents occur and second, the simulation-based optimization algorithm to consider availability of emergency units in the near future as a result of the current stage decision.

1.1.Online dispatching strategy based on robust prediction

To accommodate the online and predictive emergency dispatching strategy, a study of accurate prediction of incident duration and secondary prediction was also investigated by project investigator with same period of this project published in Journal of Analysis & Prevention (Park et al., 2018) and IEEE SoutheastCon 2019 (Pugh and Park, 2019).

It is crucial to capture the behavior of an individual traveler in a crowded freeway during a clearance of an unforeseen emergency. Instead of just considering response time of emergency vehicles in a system optimum, travelers suffering from unexpected congestion during their commuting and the choice of switching to a different route to maximize their utility function need to be considered. This research extends the relocation model by (Park et al., 2016a) to make a better dispatching decision with interdependent events, anticipatory interactions to the future events, and emergency induced congestion with bounded rational traveler's choice behavior in decision making of emergency operation in the simulation-optimization environment.

Even though fictitious play is "belief based", it is also myopic. Approximating this predicted information will reduce the accuracy of the solution greatly. The choice of scenarios in an approximation model requires data that may not be available and could fail to capture the importance of real-world emergency scenarios on the freeway. The relocation decision after a server had finish their job, the online dispatching decision have a high limitation to saving lives due to the calculation time. Instead of approximating the future, the configuration of the past sequence to look-ahead at specific time stages is important to get close to the best solution.

Most of the freeway operations are not based on a decision model, but on the experience of a dispatcher who knows the position and status of all resources (e.g., vehicle and manpower) available. He or she usually picks on the closest emergency vehicle. The model proposed in this study considers the existing dependencies between incidents at different freeway exits, presented in Figure 1.

EXIT	5	7	11	13	15	17	18	20	22	23	25	27	29	31	32	34	36
5	13.9	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	6.5	1.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	4.6	3.3	2.7	2.0	2.0	2.7	2.0	1.3	0	0	0	1.3	0	1.3	0	0	0
13	0	0	5.2	17.1	6.5	2.6	1.3	1.3	0	0	0	0	0	1.3	0	0	0
15	0	2.6	3.9	5.2	9.1	5.2	2.6	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	10.8	4.6	1.5	0	0	0	0	0	0	0	0	0
18	0	2.9	1.0	0	0	3.8	9.5	4.8	0	0	1.9	0	0	1.9	0	0	0
20	0	2.9	0	0	0	0	1.9	1.9	2.9	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	1.8	3.6	5.4	0	0	0	0	0	0	0	0
23	1.0	2.1	0	0	2.1	1.0	0	3.1	7.2	0	0	0	2.1	1.0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	8.1	2.7	2.7	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	2.3	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	3.6	7.1	0	3.6	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.6	0	0
32	0	0	0	0	0	0	0	0	0	9.8	0	2.4	4.9	19.5	0	0	0
34	0	0	0	0	0	0	0	0	0	0	0	0	0	30.8	0	7.7	0
36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.1	0

Figure 1 The existing interdependency structure (percentage) between primary incidents (vertical line) and secondary incidents (horizontal line) at different locations on freeways (Park et al., 2018b)

As shown in previous study by (Park, 2016), the k-server problem is a special case of the online metrical task systems (Figure 2). To serve a request at *y*, a corresponding algorithm moves a server to *y*. When the algorithm moves a server from a location *x* to *y*, it incurs a cost equal to travel time between *x* and *y* in *G*. Emergency vehicles (k-mobile servers) residing at some vertices of the graph move from point-to-point in the network (metric service). The algorithm receives a sequence of emergency requests, each a point in the metric space.

For the further clarification, as shown in (Park, 2016), consider a 2-server problem on three points *x*, *y*, and *z*. A total of (n=5) incidents are predicted during a fixed time-period. An emergency request arrives for the point *z* followed by a series of requests alternating between the points *x* and *y* ($\sigma = r_z, r_x, r_y, r_x, r_y$). An online algorithm first decides which of the two servers to move to *z*. The initial server locations are *x* and *z*, therefore there is no cost to serve the first request.

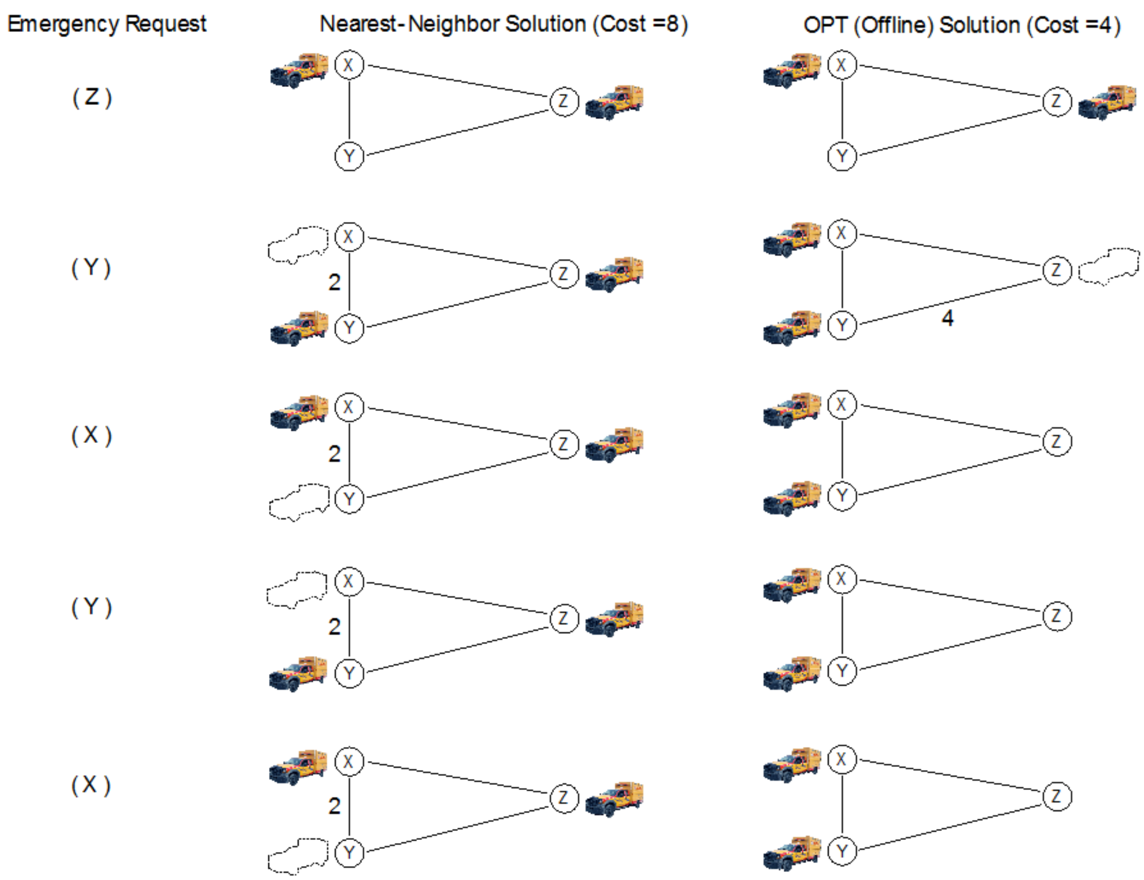


Figure 2 The k-server problem (Park, 2016)

As shown in (Park, 2016), lookahead model performs better than the *nearest-neighbor* (GREEDY) algorithm to minimize the immediate cost of moving a vehicle to an emergency request but is not optimal. In the above scenario, GREEDY would assign one of its two vehicles at z., then serve all future requests by moving the remaining vehicle back and forth between *x* and *y*. In other words, even when there is only one candidate emergency request on the network, GREEDY fails to serve this request (e.g., when an online server is far away). On the other hand, an optimal offline algorithm (OPT) would move the server from *z* to *x* or *y* after the first request is served. Then it is easy to demonstrate that GREEDY does poorly (Cost=8) compared to OPT (Cost=4).

In the previous study by (Park, 2016), the lookahead model presented significantly quicker response than other benchmarks (e.g., GREEDY, BALANCE, WFA), and WFA was further improved to accommodate the future predicted information. This project tests the model in various scenarios to see the robustness of the model, and further developed a new model that integrates the availability of the resource in the future stages.

1.2. Server availability

The service time of each request is further considered in addition to the lookahead model (L-WFA). Because an emergency vehicle can be busy serving a previous request, a grid-network Lookahead Busy-server WFA (LB-WFA) is developed and tested. This paper integrates a busy-server into the lookahead, applying a shortest path algorithm (Haghani et al.,2004) to emergency dispatching considering the traffic congestion of the network. In this section, LB-WFA is explained with a description, an example, and a performance evaluation.

1.3.Traveler rationality influencing their route choice

Under tight transportation capacity due to a lane-blockage for clearing an emergency, user equilibrium will be considered on the network. This research will find rationality of each traveler to minimize dis-utility within rational bands, choosing user optimal path from a limited number of capacity feasible routing options. It will be different path travel time and path dependent utilities based on time-dependent transportation networks.

User equilibrium, for the morning commuters seeking to minimize the cost of their trip, must have a pattern of bottleneck arrivals and departures that allows no commuter to reduce his or her own cost by choosing another arrival position at the bottleneck. In this research, correlations between morning rush hour demand and rest of the day are also considered through optimal dispatching policy for each scenario based on conditional probability and expected delay savings. This is reasonable due to the time it takes for the travelers to learn a new system. More advantageous users may change their routine by switching to different routes and explore new system. On the contrary, more conservative users may stick to their routine because they are reluctant to explore the new system. As time goes by after onset of each new system associated with dispatching policy, proportion of users switching to different routes will increase.

This research focuses on traveler's behavior perspective followed by on each dispatching decision. This research finds significant impact of dispatching decision on travelers' decision making but will assume that output of traveler's decision making has no influence on the control action of emergency resources. With significant computational cost in iteration process for convergence, next phase of this research includes the stochastic user equilibrium, which assumes travelers do not have perfect information concerning network attributes and they perceive travel costs in different ways. The model can be tested using a simulation model and observe the results of the model.

2. APPROACH AND METHODOLOGY

2.1. Traveler's choice model

In this study, the bounded rationality models are used for route choice that serve as a guide to creating the rational choice model (Di et al.,2016). Amirgholy et al. created a multivariable utility function for the flexibility of on traveler's choice behavior (Amirgholy et al.,2017). The multivariable utility includes different factors that can impact the route choice behavior of travelers in the transportation network that is unique for each traveler. Traffic conditions, trip duration, and are example of primary factors that travelers consider when choosing their routes. We had assumed that each traveler's route choice contains a different factor that need to be considered. Since the travelers update the information they had obtain on the route through the network, they use the collected information for future trips.

The multivariable utility function can include different factors that can impact the route choice behavior of travelers in the transportation network. Traffic conditions and trip duration are examples of primary factors that travelers consider when choosing their routes. Let $U_{j,t}^{n}$ be the multivariable utility for individual person *n* for route *j* at time *t* and X_i is the i_{th} explanatory variable.

$$U_{j,t}^{n} = \sum_{i=0}^{J} \theta_i * X_{i,j,t} \quad (1)$$

The mixed logit model is a discrete choice model that we use to study the traveler's behavior over a period of time. Thus, the probability of choosing route *j* can be calculated with combining equation 2. Let $P_{j,t}^{n}$ be the probability of traveler n choosing route j from the total number of available route J over a period of time.

$$P_{j,t}^{n} = \frac{e^{U_{j,t}^{n}}}{\sum_{k=1}^{J} e^{U_{k,t}^{n}}} \quad (2)$$

We had considered that some factors from the explanatory variable be more significant than the other factors for an indifference band. Di et al. investigated traveler's route choice before and after the collapse of a bridge in Minneapolis and if the travelers have previously taken the bridge before it collapsed was a significant factor than any other factors (Di et al.,2016). In our study, the significant factors were the number of available routes, incident duration, and the number of lanes closed.

Equation 3 created an appropriate fit for traveler's growth in learning and estimate the behavior of the travelers in the network. For example, two available routes $J = 2$ are given to traveler $n = 1$. The traveler's probability of taking the first route $j = 1$ is 35% and the second route $j = 2$ is 65%.

$$\epsilon^{(n)} = \epsilon\text{^}(\sum_i \theta_i^{(n)} X_i^{(n)} + \eta_2 \sim lognormal(\sum_i \theta_i X_i^{(n)}, \sigma^2)) \quad (3)$$

The commuter's indifference band for n travelers is a random variable based on their perception error and travel time saving. Let $\epsilon^{(n)}$ represent traveler n indifference band and η_2 is a normal distribution with $\mu = 0$ and $\sigma > 0$.

This indifference band is to show the deviation of the actual utilized path cost from the minimum path cost.

The traveler will switch routes if the time saving taking a route exceeds the traveler's indifference band. Figure 3 shows an example of a traveler's indifference band. The traveler will switch if the time saving for that route is outside of the 20% indifference band.

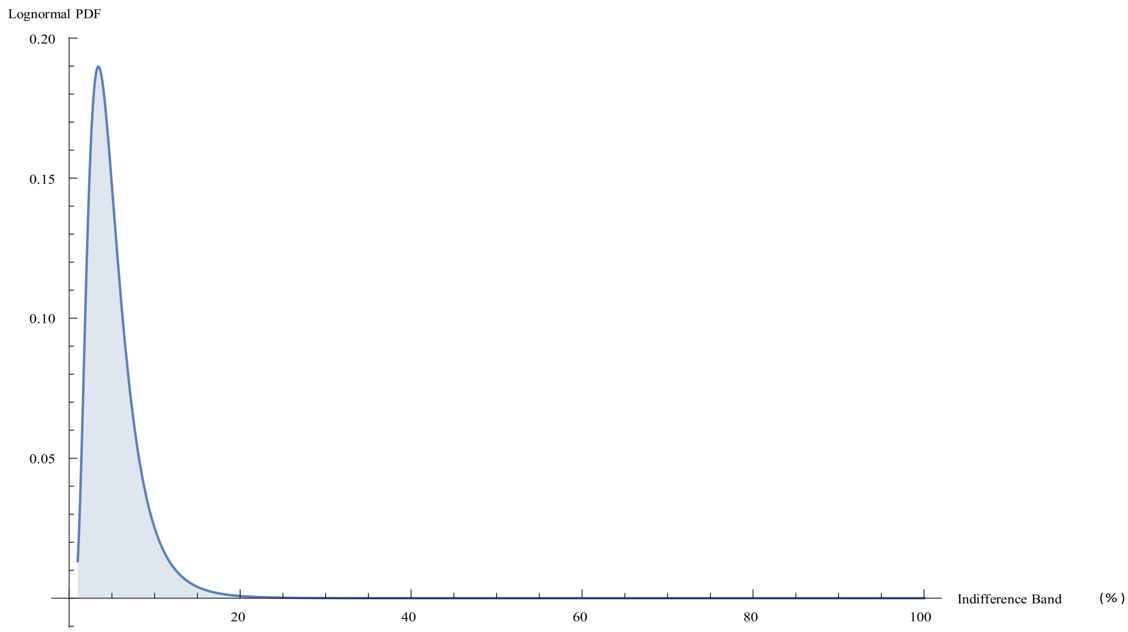


Figure 3 Indifference Band for an Individual Traveler

The perceived time saving can be described as $\Delta^{(n)} = \frac{c_p^n - c_e^n}{c_e^n}$, where C_p^n, C_e^n are the perceived travel time and the expected travel time of the traveler. Let y_j^n be a binary indicator to describe traveler *n* switching from *j*. y_j^n is 1 if the travel saving exceed the traveler's indifference band and 0 otherwise. The indicator for the traveler switching route is

$$y_j^n = \begin{cases} 1 & \tilde{\Delta}_j^{(n)} > \log\left(\epsilon_j^{(n)}\right) \\ 0 & \tilde{\Delta}_j^{(n)} \leq \log\left(\epsilon_j^{(n)}\right) \end{cases} \tag{4}$$

where $\Delta_j^{(n)} = \log\left(\Delta^{(n)}\right) + \eta_1$ is the logarithm of traveler *n*'s travel time saving and η_1 is a normal random variable with $\mu = 0$ and $\sigma > 0$. Please note that η_1 and η_2 are independent and identically distributed normal. Meaning that both are independent functions from the same distribution. Using Figure 3 for an example, if $\Delta_j^{(n)}$ is more than traveler's *n* indifference band, then $y_j^n = 1$ and the traveler will switch from the current route.

To incorporate the traveler's behavior into code, we used Mathematica for its variation of technical computing and vast system of functions, tools, and so forth. Using Mathematica, the algorithm for the rational choice model on Table 1 is the general process for a multivariable mixed logit model in programming.

TABLE 1 Algorithm for Traveler's Rational Choice

Initialize the variables for iteration

for n==0, n<4000, n++ **do**

for t==0, t<1, t++ **do**

Initialize random variables for θ_i, $X_{i,j,t}$, C_{pn}, and C_{en}

Calculate $U_{j,t}^{n} = \sum_{\substack{i=0 \\ n}}^{J} \theta_i * X_{i,j,t}$

Calculate $P_{j,t}^{n} = \frac{e^{U_{j,t}}}{\sum_{k=1}^{J} e^{U_{k,t}^{n}}}$

Calculate $\epsilon^{(n)} = e^{\sum_i \theta_i^{(n)} X_i^{(n)} + \eta_2} \sim lognormal(\sum_i \theta_i X_i^{(n)}, \sigma^2)$

Calculate $y_j^n = \begin{cases} 1 & \tilde{\Delta}_j^{(n)} > log(\epsilon_j^{(n)}) \\ 0 & \tilde{\Delta}_j^{(n)} \leq log(\epsilon_j^{(n)}) \end{cases}$

end for

end for

Equation 5 is the Path-Size Logit (PS-Logit) model that is formulated into TransModeler to calculate the probability of the travelers:

$$P\left(i \middle| C_n(t)\right) = \frac{e^{V_{in}(t) + lnPS_{in}}}{\sum_{j \in C_n(t)} PS_{jn} e^{V_{jn(t)}}} \qquad (5)$$

where $P\left(i \middle| C_n(t)\right)$ is the probability of traveler n chooses path i from choice set $C_n(t)$, $C_n(t)$ is the set of alternative paths for vehicle n at time t, $V_{in}(t)$ is the utility of path I for vehicle n at time *t*, and PS_{in} is the size of path *i* for vehicle *n* (Yang et al.,2014a). The path-size term in the equation (5) is defined as:

$$PS_{in} = \sum_{a \in \Gamma} \left(\frac{l_a}{L_i}\right) \frac{1}{\sum_{j \in C_n} \left(\frac{L_i}{L_j}\right)^{\gamma} \delta_{aj}} \quad (6)$$

where l_a is the length of link *a*, L_i is the length of path *i* , δ_{aj} is the link-path incidence matrix where 1 if link *a* is included in the path of j or 0 otherwise, Γ_i is the set of links that are included in path *i*, and γ is defined as the path-size parameter (Ramming,2002 ;Bekhor et al.,2001).

2.2. Emergency vehicle dispatching model considering server availability

The service time of each request is further considered in addition to the lookahead model (L-WFA). Because an emergency vehicle can be busy serving a previous request, a grid-network Lookahead Busy-server WFA (LB-WFA) is developed and tested. This study integrates a busy-server into the lookahead, applying a shortest path algorithm (Haghani et al.,2004) to emergency dispatching considering the traffic congestion of the network. In this section, LB-WFA is explained with a description, an example, and a performance evaluation.

LB-WFA algorithm

In Algorithm 1, L-WFA uses the summation of previous configurations to predict the location of the next request. L-WFA creates a "cost" at every point, excluding the server's location, and finds every possible configuration by moving one server to every point in space at a time. It then calculates the cost of that movement, resulting in a permutation of configurations. The configurations have a work cost associated with the distance, and the best configuration is chosen to respond to the current and next requests.

A previous *k* — 1 server algorithm by Wolfgang et al. (Wolfgang et al.,2005) presented that once a server moves to serve a request, it must wait for one round to move again, but could serve a repeated request to the same point. In our paper, we add a lookahead scheme to develop two-dimensional capture points (e.g., longitude and latitude) that differentiate location-specific incident duration (Park et al., 2016a) via historical occurrences, geographic conditions, and responses to emergencies.

Algorithm 1 L-WFA

```
/Step 1: Initialization/
Initialize the parameter of the algorithm ;
set the values for k,s,n;
calculate the euclidean distance between the points and set that as the space_pts;
generate the grid and the space in points space_pts = gen_grid(n);
generate the sequence of requests;
generate the initial configuration (servers should be in different locations from each other);
/Step 2: L-WFA/
set the parameters (space points, ecludian distance, initial configuration);
look-up index of requests points pt_idx = space_pts.index(pt);
expand work_cost array if full;
get a list of all current possible configs cur_confs = confs_dict[pt_idx];
if n == 0 then
   for i,conf in enumerate(cur_confs) do
      calculate the work cost;
      get the minimum value of the cost min_idx = work_cost[:,0].argmin();
      set the best configuration best_conf = cur_confs[min_idx];
   end for
else
   get the list of the last iterations configurations;
   generate the minimum cost path from previous to next configs;
end if
for i,conf in enumerate(last_confs) do
   find the permutation of the possible configurations by moving one server with a swap method;
   for cost,perm in post_perm do
      calculate the cost of the movement path_cost = work_cost[i, n − 1]+cost;
      if path_cost < path_dict[conf] then
         set path_dict[perm] = path_cost;
      end if
   end for
end for
for i,conf in enumerate(cur_confs) do
   store the minimum path costs;
   calculate the work function objective function obj_score = path_dict[conf] +
   sum(self.___conf_dist(self.prev_conf, conf) for conf in conf );
   store the request;
   store chosen configuration according to the work function algorithm;
end for
return the chosen configuration;
/Step 3: Plot
for i,req in enumerate(seq) do
   give the results of the next configuration next_conf = L-WFA.serve(req);
   store the request for plotting;
   store the configuration for plotting;
end for
```

L-WFA with k — 1 server, in Algorithm 2, prevents a server from moving after responding to a request at a location when the expected service time is longer than the interval between requests. In Algorithm 2, the responding server is moved to a temporary variable and removed from the configuration. It is captured and will be available after the expected service time has elapsed.

Algorithm 2 L-WFA with $k-1$ servers

```
/Step 1: Initialization/
set the parameters for WFA ;
/Step 2: /
for i,req in enumerate(seq) do
  if i!=0 then
    set parameters for WFA ;
  end if
  if if temp!=[] and next_conf!=[] then
    set the request for L-WFA next_conf = L-WFA.serve(req);
    store the request and configs;
    add the server that was busy back to the configuration next_conf.append(temp);
    Step 3: /
    while j<len(next_conf) do
      if if next_conf[j]==req then
        store the server into a temporary variable temp = next_conf[j]
        remove the server from next_conf[j]
      end if
      set j → j+=1;
    end while
    set j → j=0;
    Step 4: /
    set parameters for L-WFA;
  else
    give the results of the next configuration next_conf = L-WFA.serve(req);
    store the request for plotting;
    store the configuration for plotting;
  end if
  if i==0 then
    set j → j=0;
    repeat Step 3;
  end if
end for
```

Another server from the remaining $k - 1$ server will respond to the next request. The process is repeated until s-requests are completed.

L-WFA with k — 1 server capture-points, in Algorithm 3, captures a server that responds to a request at a certain location, each capture point having a timer that controls when the server

Algorithm 3 L-WFA with $k-1$ server capture points

```
/Step 1: Initialization/
set the parameters for L-WFA ;
set random capture time between 1-5 with size n, pt = random(1, 5, size = n)
/Step 2: /
for i,req in enumerate(seq) do
  if i!=0 then
    set parameters for WFA (space_pts,d_euc,next_conf,1);
    give the results of the next configuration next_conf = WFA.serve(req)
    store the request for plotting
    store the configuration for plotting
  end if
  while j<len(next_conf) do
    for s in range(0,p) do

      server is captured iff the request is in the same location as one of the capture points and
      next_conf is not empty
      if next_conf[j]==req and next_conf[j] == prison[s] and next_conf !=() then
        store the server into a temporary array temp = next_conf[j]
        remove that server from the configuration
        get index in the grid where the prison cell is located
        start the capture time for that server
        break
      end if
      set j → j+=1;
    end for
  end while
  set j → j=0;
  for t in range of len(temp) do
    if capture time = i and len(next_conf)<k then
      add the server back into the next_conf next_conf.append(temp[t]])
    end if
  end for
  if next_config is empty due to all the servers captured then
    add the server that was captured the longest to next_conf
  end if
end for
```

becomes available. Similar to Algorithm 2, the captured server is released the capture-point's timer elapses.

The swap module generates a fist of ordered permutations by moving one server and removing one of the elements, giving a possible configuration for the server to move to the request. The server moves from point-to-point until it has reached the request location and then compares each permutation to find the minimum distance and cost to move the server.

3. NUMERICAL EXAMPLE OF ANTICIPATORY MODEL

Even if we were not able to obtain a real original destination matrix, we estimate the routing change for each incident scenario using travel time difference.

1) Each traveler's factor is from a probability distribution function
2) Created scenario for each simulation, and
3) Travelers' satisfaction can be for more than one route.

The scenario consists of two routes, A and B, that the ERV can travel to the requests. The scenario has a percentage of the total vehicles in the network for each route and we compared the total delay for each scenario to find the minimum delay and the best scenario for ERV.

Table 2 is the numerical results with different values for the demand on each route, but same incident location. Since the demand for each route is different, the traveler switching route will cause a change in the demand and a change in the delay.

TABLE 2 Numerical Example of Incident Data: The demand changed after the traveler switch route from the original demand that was set in the simulation

Scenario	Incident	Time	Duration (min)	Volume (veh)	Travel Time Before Incident (sec)	Travel Time Before Incident (sec)
1	I-695 near Providence Rd	8:06 am	46	560	54.88	57.26
	I-695 EB/WB at MD-2	9:15 am	33	548	54.06	17.83
2	I-695 near Providence Rd	8:06 am	46	560	54.88	57.26
	I-695 EB/WB at MD-2	9:15 am	33	548	54.06	17.83

3.1. Evaluation Method

Let $C_{ALG}(\sigma)$ be the total cost incurred by ALG on σ, and $C_{OPT}(\sigma)$ be the minimum total cost on σ. We design an online algorithm that never does much worse than the optimal offline solution. An online algorithm ALG is c-competitive if its performance is estimated to be only a bounded number of times worse than that of OPT on any input with another constant *a* such that on every σ it holds:

$$C_{ALG}(\sigma) \leq c \times C_{OPT}(\sigma) + a \qquad (7)$$

Suppose that the adversary generates a total of n requests. We can apply this concept to Figure2: GREEDY $(\sigma) \geq \mu(y,z) + (n-1) \times \mu(x,y)$ and OPT $(\sigma) \leq \mu(x,y) + 2 \times \mu(y,z)$. As n can be made arbitrarily large, GREEDY(σ) is unbounded. Hence, there are no constants c and a such that GREEDY $(I) \leq c \times C_{OPT}(I) + a \;\; I$, and so GREEDY is not competitive.

3.2. Scenario Analysis of the Lookahead Model

Dispatching strategies are tested and compared in various scenarios in a real transportation network. The response time and competitive ratio of proposed model (L-WFA) is compared to the adversary model that is modified in look-ahead dispatching setting. As other studies assumed (Schmid, 2012), time-dependent temporal and spatial distribution of request arrivals (i.e. for their interarrival times and their corresponding location) are assumed to be available. However, the duration of time during which ambulance vehicles are assumed to be unavailable in previous study (Schmid, 2012). On the contrary, an emergency vehicle is assumed to have a unique value associated with traffic condition and other factors (Park and Haghani, 2016a; Park et al., 2016a). The expected incident duration is used in estimating availability of emergency vehicle in the next stage. The available number of emergency vehicles are altered between two and three. As explained by Equation 7, when the expected clearance time of current incident is higher than expected time until the next incident, the emergency vehicle will be busy serving previous request, thus we have only two vehicles to choose from.

Table 3 presents the response time on various hypothetical networks generated based on different network sizes. The resulting average response time can be decreased to 4.1 minutes, which corresponds to a decrease of 15% on average with respect to the benchmarks. Compared to ambulance allocation studies, the characteristic of freeway emergency response forces the network size not very large. Most of the result of the proposed model and benchmarks were within 60 seconds. This is a reasonable computational time considering that dispatching solution should be quickly made.

Incidents on 1-695 are grouped within 1.9-miles or 1.3-miles to generate total 17 nodes or 34 nodes respectively. Prom the total 1,981 incidents (e.g., disabled vehicles, crashes, etc.,) that occurred between October 2012 and September 2013 (261 weekdays) during morning peak hour (i.e., 6:30-9AM), major emergencies (crashes) are selected. An average of 6 emergencies (6 stages) occurred in each 150-minutes, following a distribution. Note that Poisson distribution (Daneshgar et al., 2013; Mirchandani and Odoni, 1979), applied to ambulance studies, cannot represent the dependency of emergencies on a freeway network. In this study, the probability distribution of interarrival times was estimated to have parameter A^4, which depends on the current time of the day £, with a global mean of 25 minutes.

TABLE 3 Performance of proposed models with three emergency vehicles

Network size	Distribution	Proposed model	Response time (min)		
			Average	Min	Max
Node 17	Uniform	L-WFA	4.7	1.3	10.2
		WFA	5.0	1.3	13.8
		GREEDY	5.4	1.4	13.4
		ADVERSARY	4.9	1.6	9.4
	Non-uniform	L-WFA	4.6	1.6	10.8
		WFA	4.9	1.6	14.5
		GREEDY	5.6	1.6	13.9
		ADVERSARY	4.8	1.8	9.7
Node 34	Uniform	L-WFA	4.1	0.7	9.8
		WFA	4.9	0.7	13.3
		GREEDY	5.3	0.7	13.1
		ADVERSARY	4.8	0.8	9.0
	Non-uniform	L-WFA	4.2	0.8	10.8
		WFA	4.8	0.8	14.5
		GREEDY	5.6	0.8	13.8
		ADVERSARY	4.7	0.9	9.3

3.3. TransModeler based simulation

TransModeler allows the users to add or substitute the values of the utility function. Table 4 show TransModeler allowing custom variable input for the PS-Logit model. The flexibility of the PS-Logit model could include more utility functions if needed. The number of blocked lanes and incident duration is generalized so that there is an estimate of the average incident duration and number of blocked lanes for a segment.

TABLE 4 TransModeler Input Variable:

β	$V_{in}(t)$	Variable
0.384	10	Time Saving
0.482	1.2	Incident Duration
0.877	1.1	Number of Lanes Blocked

4. NUMERICAL EXAMPLE OF TRAVELER CHOICE

We input the values for the coefficient β of the utility function $V_{in}(t)$, which can be used from the coefficient θ_i and utility function U_i in equation 1, and t. We use the volume from the detector data to put in the simulation to indicate that the travelers in the simulation would switch from their original path to the destination to an alternative path. Upon observing the volume difference, we found any changes in the travel time after the incident occurred. Observing the travel time changes after the incident provided us the necessary data for the parameter estimation of our utility function.

Figure 4 presents the satellite visual of where the detectors are located. and the green is highway I-695. If the travelers take an alternative route to reach their destination, the number of vehicles from the sensors will indicate a switch if the initial demand of the vehicles is different from the final demand. The simulation will include multiple origin and destination around I-695 for a realistic OD-matrix.

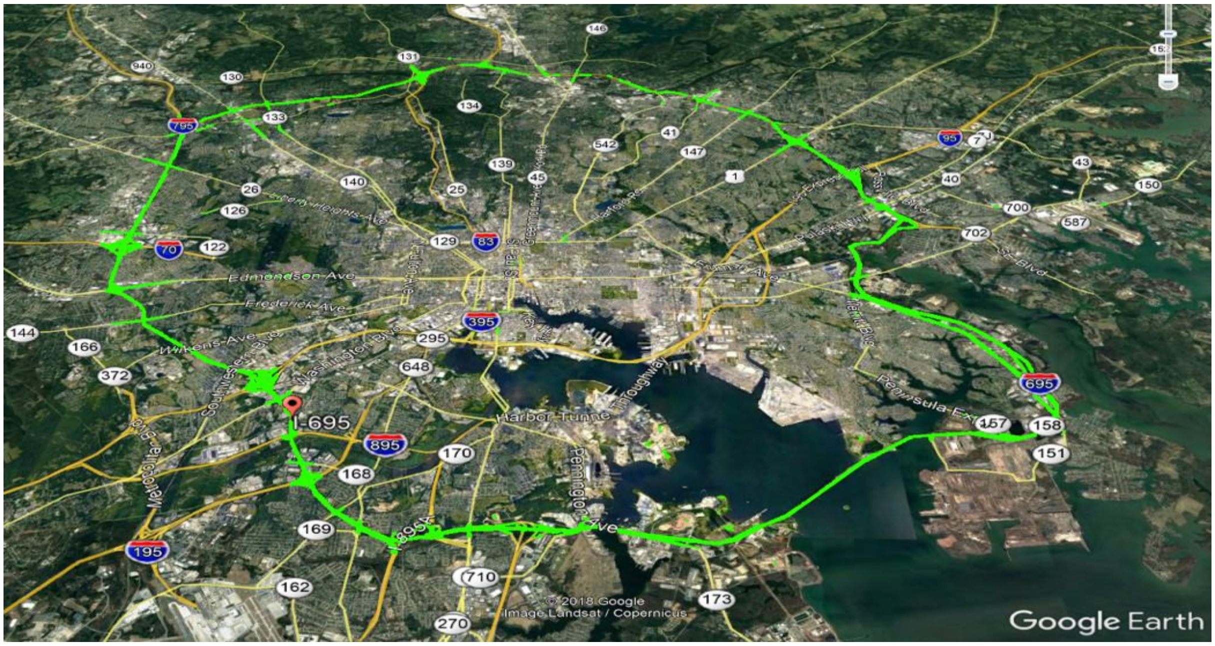


Figure 4 Representation of incidents (blue) on I-695 (green)

There are sensors placed on the origin and destination of the highlighted route, which are labeled respectfully on the graph. For example, an origin is located near Exit 2, and a destination is located near Exit 24. We have chosen the incident locations at random to find a pattern from the incident selected from the fluctuation of the volume and a trend before and after the incident. The volume input for transmodeler will re-create real-world traffic from I-695. The goal is to choose the scenario with the minimum delay to attend to an emergency. Let x_{ij} be the decision variable, ω is the number of scenarios, and Z is the objective variable

$$Z(\omega) = Min(\sum_i \sum_j x_{i,j} * D_{i,j}(\omega)) \qquad (8)$$

where D_{ij} *came* from Equation 8 Each scenario has two routes, A and B, and the demand of vehicles in the network is 4000. Both routes have a total of 4 lanes and at least one service vehicle is near each route; thus, two service vehicles are on opposite sides of the network. The scenarios each have two incidents occurring at different locations and time. No changes for the dispatch of each scenario or else an inconsistency in the data will occur. We used I-695 route in Baltimore, Maryland for our road network to show our work in a realistic road network.

TransModeler requires an OD matrix for the vehicles to travel on the network and the demand. We set the demand 2800 for the first route and 1200 for the second route. Looking at the fire, the first incident occurred on the first route. Travelers that are already end route to the destination will experience a delay on the first route due to an incident. The travelers will have to decide to continue traveling on the current route or find an alternative route to get to their destination.

The dispatch for scenario 1 is to send ERV-1 to the first emergency and ERV-2 to the second emergency. For scenario 2, I want to send ERV-1 to the second emergency and ERV-2 to the first emergency. Figure 5 is an example where each scenario has the same number of servers, the location of the servers, location of the incidents, but different delay for each server.

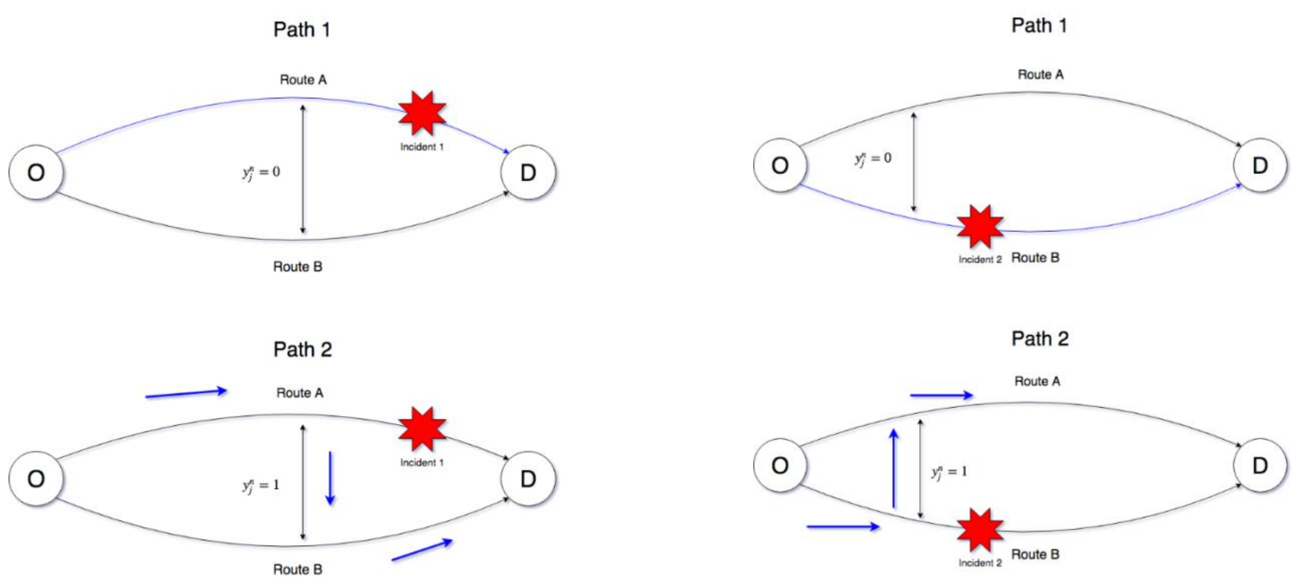


Figure 5 Example of a Scenario

We generated two sets of scenarios in transmodeler with two incidents at different locations. Transmodeler let you "save" the state of the travelers so that each scenario will begin with the same configuration and settings. Each incident occur at random locations on both routes and the duration is between 15 to 40 minutes and the simulation run from 8:00am to 12:00am to make sure that each traveler can reach their destination and we can get an accurate estimation on the delay. Each traveler in the simulation is assumed to be uninformed, without having prior knowledge of any incident nor the exact time saving of each route.

Figure 6 illustrates the stochastic network of the travelers and route switching is determined. If one path satisfies the traveler's indifference band then the traveler will take that path to their destination. TransModeler allows for the user to input custom variables for the probabilistic route choice (Ben-Akiva and Ramming,1998; Ramming,2002).

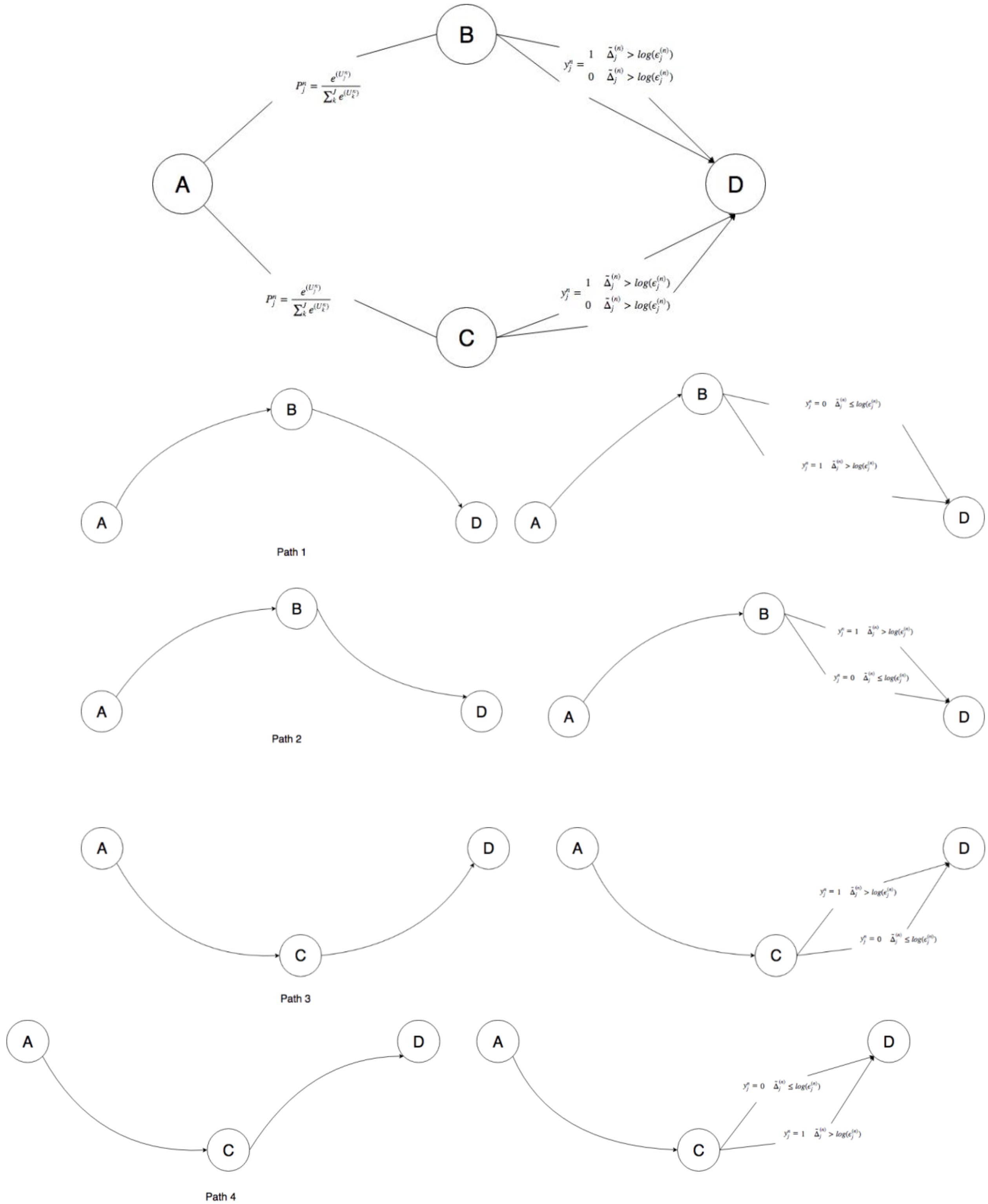


Figure 6 Probabilistic Route Choice Model: Based on the path observations, logit model has utility functions in the estimation result table such as U_1 is the time the traveler saves on the route, U_2 is the incident duration, and U_3 is the number of lanes opened. The path for one vehicle's destination can be different from another vehicle's path that satisfies their utility

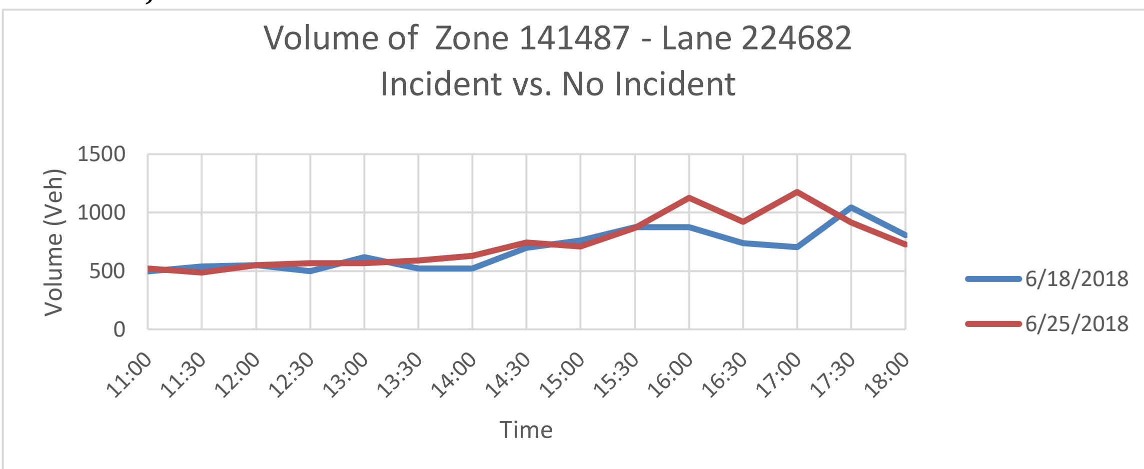
function. One traveler may use path 1 if the path satisfies the traveler than all the available paths while another travel satisfaction come from path 3

5. NUMERICAL EXAMPLE OF RATIONAL EMERGENCY RESPONSE

5.1. Empirical data analysis

We captured the volume for the detectors from 7am to 12pm to get a general idea of the volume during peak hours. Since we are comparing the detector data and incident data at the same location and time of day, we can compare the fluctuation in both data set. Figure 7 represents one of the detector's volume change over a period of time with no incident and with incidents.

Figure 7 Comparison of volume for incident versus non-incident over time: The incident occurred June 27, 2018 with a duration of 46 minutes from 8:06 am to 8:52 am. No incident



occurred on June 20, 2018 and was used to compare with the data from the incident. The trout from the incident data show the change of volume from an incident occurring and then increase right after the incident was cleared. The show a change in the volume at 8:30 am where the difference in volume is nearly in half and the rest of the data is nearly the same, indicating a change in route

We obtained detector data and incident data from RITIS to compare the change in the volume at the same time of day to find the change in volumes from route changing. We observed an incident that occurred Wednesday June 06, 2018 from 9:15am to 9:48am and we compared the travel time to Wednesday June 06, 2018. Figure 8 (a) shows the travel time before the incident and when no incident occurred. The time travel before the incident is much larger compared to no incident at the same time, which indicate a low delay in traffic flow and then increased when the time of incident is near. We expect that the volume percentage of one route may not be the same for alternative routes. Finding the change in volume of all the available alternative routes can be traced back to the volume change of the main route. Figure 8 (b) is the travel time compared to the time after the incident and for when no incident occurred. Comparing the time travel before and after the incident indicate that the travelers have already decided on an alternative route to their destination switch route while other travelers remain on the route. When no incident occurred, the overall graph has a steady flow of vehicles in comparison to the travelers after the incident meaning little to no congestion.

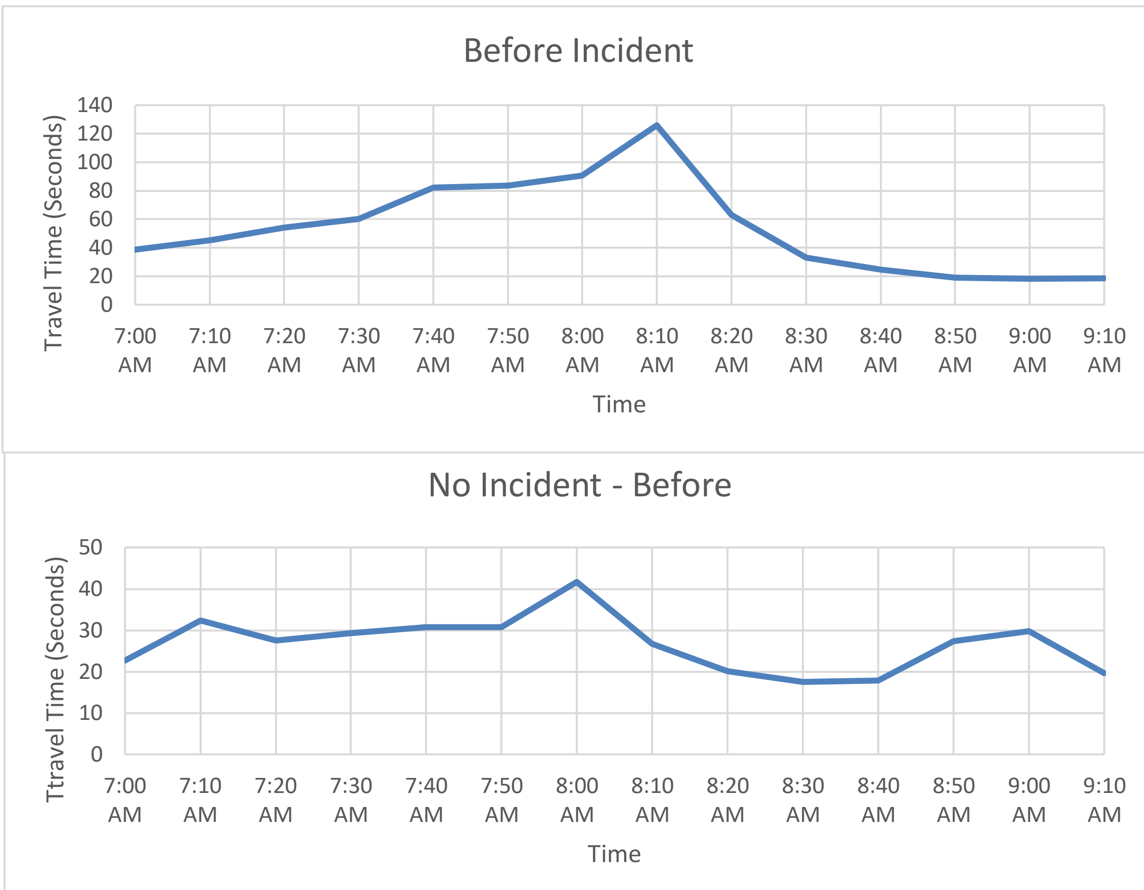


Figure 8 (a) Before onset of incident and no incident: Both graphs follow the same path until 8:40 am. The decline indicates that the vehicles are traveling slower and would consider choosing an alternative route for their destination

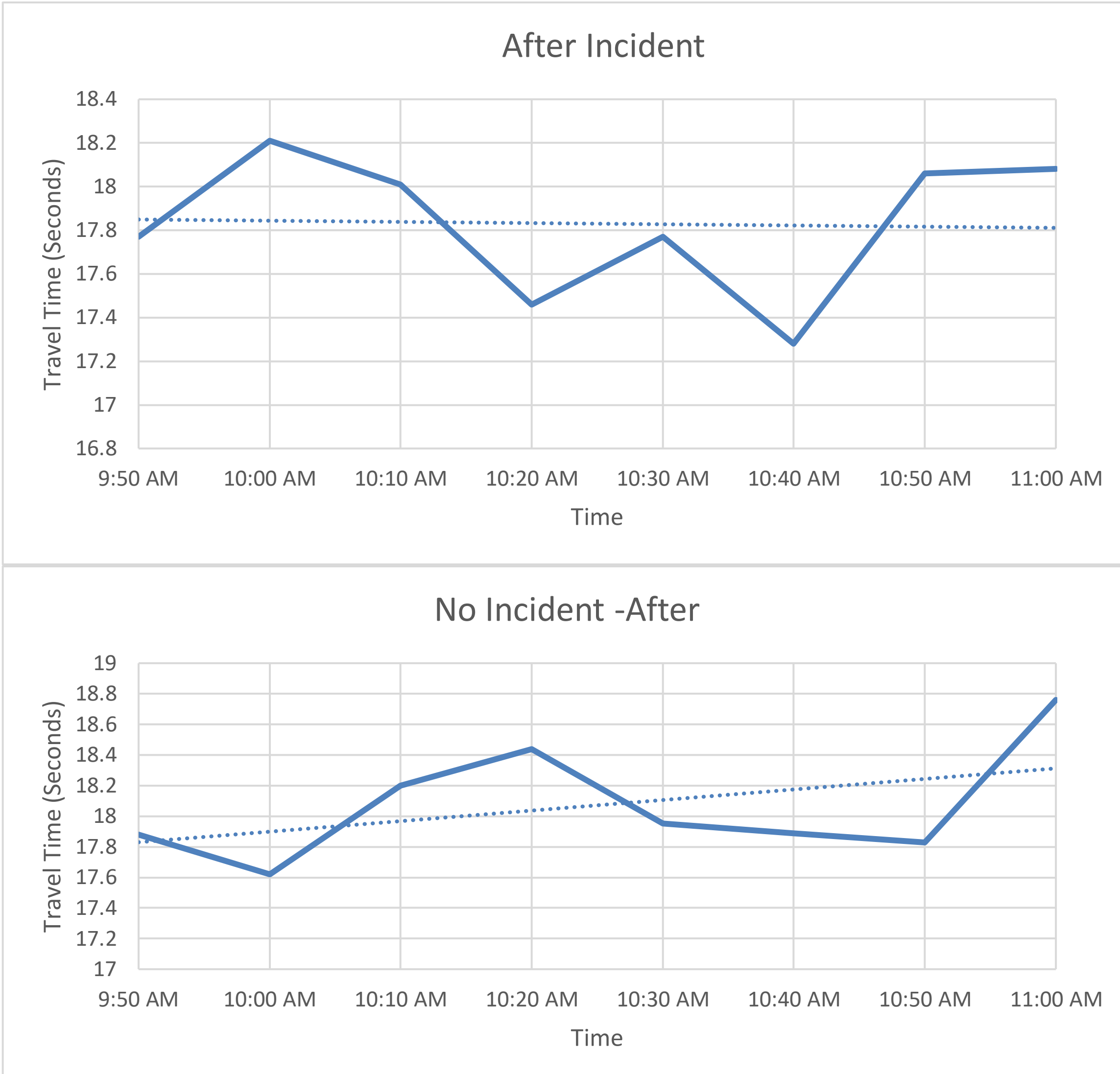


Figure 8 (b) After onset of incident and no incident: The trendline for when no incident occurs seem to slightly increase over time while the after-incident graph seems to be stable over time

Figure 8 compares before and after onset of incident and no incident. Using the probe vehicle and loop detector data gave an estimate on a choice parameter for the travelers. Figure 9 show the boundary percentage of the travelers changing their route and the impact of the L-WFA. The data provided show that when 22.34% of the travelers switch route the delay for the emergency vehicles decrease and Table 5 show the results of 10 simulations with at least 5 incidents in between the time. In this table, scenario 1 seems to have the least delay and would likely be chosen for how the ERV will be dispatched. Even though some of the other scenarios have somewhat similar results as the selected scenario, the ERV may deal with a larger congestion if they were to attend to the incident. This could potentially improve the performance of management of the incidents, especially when the transportation networks have a significant likelihood of secondary incidents.

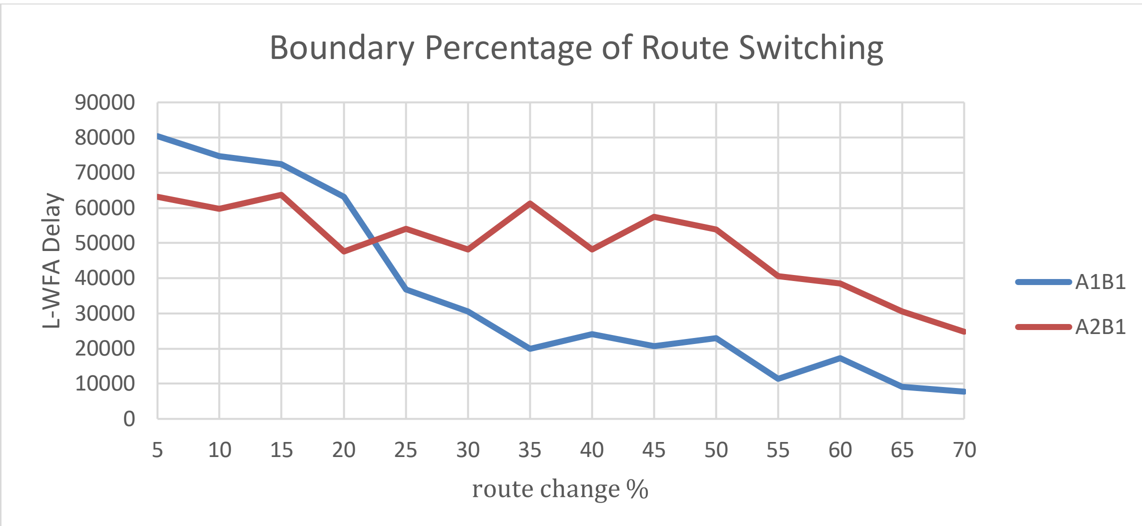


Figure 9 Boundary Percentage of Traveler's Routing Change Impacting on Solution to WFA

5.2. WFA Considering Traveler's Behavior

The TOC4 currently operates 5 emergency vehicles in the morning peak hour. We use 3 emergency vehicles for emergency response, assuming the other 2 back up will respond to minor incidents that are more frequent than crashes, we assume that only vehicles currently idle are available for dispatching. After responding to 6 emergency requests, the emergency vehicles can be relocated to optimal locations using the previously proposed models. In this study, we focus on dispatching policy before relocation occurs. The initial location of emergency vehicles follows the current practice.

TABLE 5 WFA Considering Traveler's Behavior

Scenario	Incident	Time	ERV	Duration (min)	Demand (veh)	Delay (min)
1	I-695 EB AT US 1, EXIT 32	7:00 am	1	30	2685	1893.1
	I-695 AT PROVIDENCE RD	7:40 am	2	15	1151	1926.4
	I-695 NEAR EXIT 36 MD-702	8:15 am	2	30	2811	1905.4
	I-695 AT EXIT 15B	8:30am	1	15	1199	1913.5
	US-1/SOUTHWESTERN BLVD/EXIT 12	9:00 am	2	30	3042	1629
	MD-10/EXIT 2B & 3B	9:50 am	1	50	7574	3460.2
	HOLLINS FERRY RD/EXIT 9	10:20am	1	30	4452	2290.8
	MD-140/REISTERSTOWN RD/EXIT 20	10:30am	2	10	1023	893
	EDMONDSON AVE/EXIT 14	11:20am	1	10	6234	1010.3
	MD-41/PERRING PKWY/EXIT 30	11:40am	2	20	4200	2339.2
2	I-695 EB AT US 1, EXIT 32	7:00 am	2	30	2966	1574.1
	I-695 AT PROVIDENCE RD	7:40 am	1	15	3159	2467.9
	I-695 NEAR EXIT 36 MD-702	8:15 am	1	30	2229	2059
	I-695 AT EXIT 15B	8:30 am	2	15	930	1192.7
	US-1/SOUTHWESTERN BLVD/EXIT 12	9:00 am	1	30	6343	4774.8
	MD-10/EXIT 2B & 3B	9:50 am	2	50	6926	3927.7
	HOLLINS FERRY RD/EXIT 9	10:20am	2	30	3458	1859.5
	MD-140/REISTERSTOWN RD/EXIT 20	10:30am	1	10	5306	2034.1
	EDMONDSON AVE/EXIT 14	11:20am	2	10	6057	1950.8
	MD-41/PERRING PKWY/EXIT 30	11:40am	1	20	3453	2604.4

Our problem setting is a real-time rolling horizon. The probabilities of secondary crashes and incident durations are sequentially updated along with traffic condition in real time. After an occurrence of an emergency, the updated traffic condition and characteristic of the emergency are used in calculating future probability of emergencies and server availability.

The result of extensive test is given in Table 6. The proposed L-WFA outperforms benchmark policies for different network densities and emergency distributions. The L-WFA solution, which minimizes the average response time, performs better than ADVERSARY, which minimizes the fraction of late arrivals. ADVERSARY assumes that all crashes are independent and distributes the probability of secondary crashes to the probability of independent crashes at other locations. A drawback of ADVERSARY was presented (Jagtenberg et al., 2015): it increases the average response time (up to 37 %) as the main purpose of dispatching ambulances is to save lives. As shown in the study (Jagtenberg et al., 2015), the fraction of late arrivals that focusing on worst case would not lead to large improvements over GREEDY.

Without the consideration of potential secondary crashes, as in L-WFA, the naive policies in GREEDY and WFA dispatch emergency vehicle far away from the next expected request. A secondary incident is more likely to occur if the primary incident has a long duration (Khattak et al., 2012). This means that when a secondary incident occurs, it is more likely that the previous emergency vehicle is busy serving the primary incident. This redistribution of probability will have discrepancy compared to the real-world cases, and eventually increases the response time to potential secondary crash locations. L-WFA also responds to independent crashes, but with less probability that has been allocated to secondary crash probabilities.

When taking into account the state of the system (i.e. the situation from the incident clearance point of view and the number of available emergency vehicles, as well as time dependent fluctuations in emergencies, travel time and the resulting changes in coverage) one can improve the system's performance dramatically by using L-WFA. In a non-uniform distributed network, L-WFA and WFA outperform GREEDY more than they do in a uniform distributed network. This is because WFA has the benefit of learning historical behaviors by taking into account the configuration of past requests. WFA is closer to OPT because of history, expected incident duration, and the assumption of dependency. L-WFA has the most benefit in denser network with more nodes in the network by having more accurate response time with the same frequency of emergencies.

In extreme scenarios, there are locations with more frequent crashes and more secondary crashes. The difference in the probability of different location is larger when we consider the dependency in the network. By predicting the available servers in the next stage, we can frequently avoid inefficient dispatching decisions. L-WFA model makes a decision by using all emergency vehicles all the time. By following L-WFA, when an emergency vehicle is busy from previous work, the next request may need to wait until the expected emergency becomes available. GREEDY will significantly increase the response time in the current and future time stages. Therefore, a single incident rate, assuming no dependency between two incidents (Daneshgar et al., 2013) cannot successfully dispatch appropriate units. This is in fine with a previous study (Schmid, 2012) where a poor decision for the current emergency request had bad impact on the system's ability to serve future requests.

Table 6 presents the competitiveness of the algorithms as the ratio between the cost incurred by the corresponding algorithm and the optimal cost incurred by OPT. The effectiveness of an online algorithm is measured by its competitive ratio, which defines the worst-case ratio between its cost and that of a hypothetical off-line algorithm.

TABLE 6 Competitive ratio of proposed model and benchmarks for non-uniform distributed network with 34 nodes

Competitive Ratio	Number of available emergency vehicles		
	2 Vehicles	3 Vehicles	4 Vehicles
$C_{l\text{—}wfa}/ C_{opt}$	1.97	1.73	1.54
C_{wfa}/ C_{opt}	2.13	1.98	1.77
C_{greedy} / C_{opt}	2.98	2.79	2.37
$C_{adversary}/ C_{opt}$	1.89	1.61	1.48

The trade-off between the worst case and average response time would provide good information. ADVERSARY with four emergency vehicles (1.48) have 5% reduction in worst case response time compared to L-WFA (1.54). ADVERSARY increases the average response time by 18% compared to L-WFA. In reality, L-WFA will be preferable to the transportation authority because it provides an accurate dispatching solution with minimum response time. ADVERSARY would be preferred by an ambulance dispatcher to maximize the patient survivability. As fewer vehicles are available, L-WFA outperforms compared to other benchmark algorithms. On typical request sequence, L-WFA performs well with a small competitive ratio and its behavior can never be too catastrophic.

The program begins by setting the parameters for grid points, the distance between each point, and the initial location of each server. A request is sent to the server module as a point in space (e.g., request #1 is at location (0,0)). The request location is sent to the configuration distance module, which finds the minimum bipartite matching-distance between the configurations by index. The server module then finds all possible configurations by moving one server at a time to the request and also find the cost of moving that server point-to-point. Then LB-WFA is used to find the best configuration for a server to attend to the request.

The user can define the grid size (n x n), number of servers (k), number of requests (s), and number of capture points (p). Figure 10(a) shows the location of servers, capture points, and a request. Figure 10(b) presents the best configuration, in this case the server at the bottom-center responds to the request while the other servers wait for the next request.

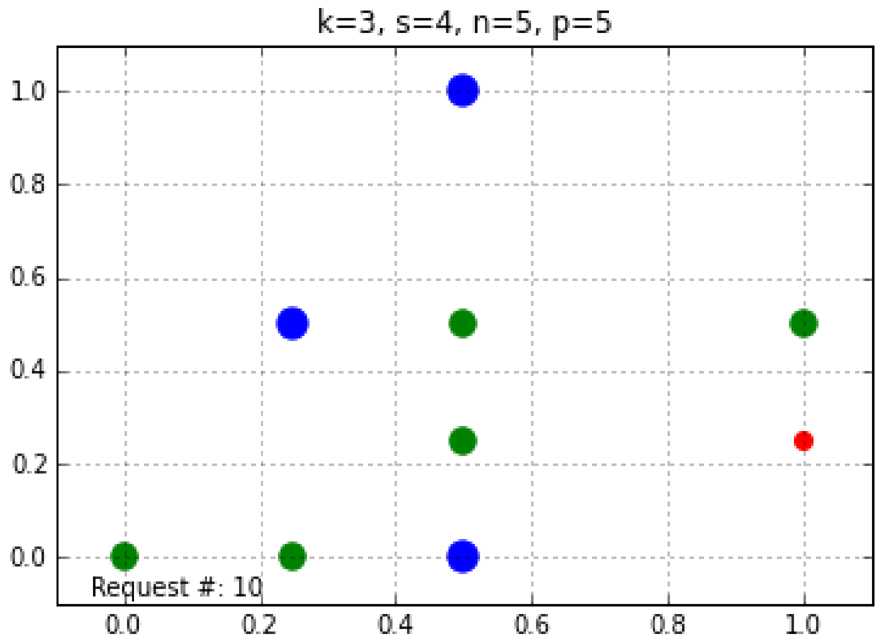


Figure 10(a) the location of servers (large dot), capture points, and a request (small dot)

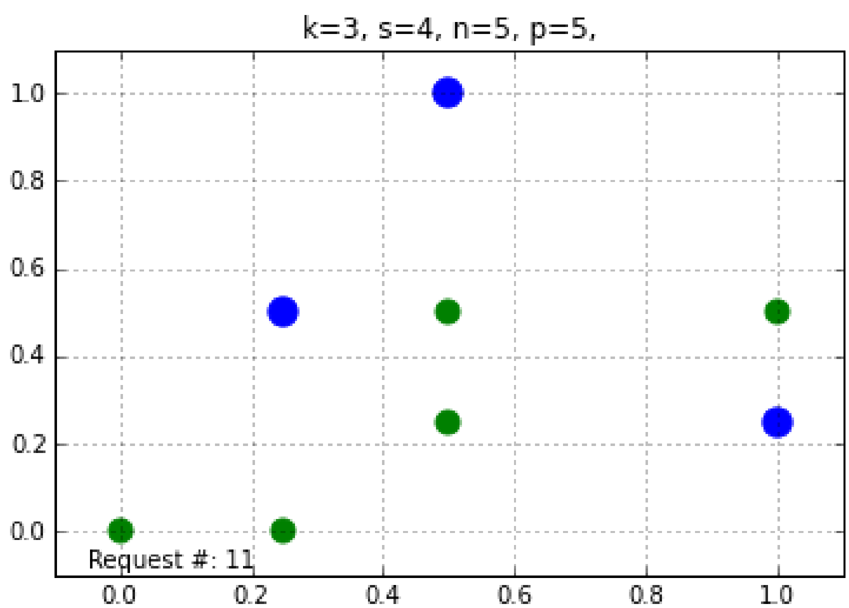


Figure 10(b) An example of a server (large dot) moving to a request (small dot) in a network with capture points (mid dot)

We test LB-WFA with various examples in a grid network with different settings. Let (x_i, x_f) be the initial and final x-grid components, (y_i, y_f) be the initial and final *y-grid* components, n_x, n_y be the number of points along the x-axis and *y*-axis, and x_i, y_i be the iteration variables. The grid-points are generated by

$$gridpoint = \sum_{x_i=0}^{n_x} \sum_{y_i=0}^{n_y} \frac{x_f - x_s * x_i}{(n_x - 1)}, \frac{(y_f - y_s) * y_i}{(n_y - 1)} \qquad (9)$$

For illustrative example, we set parameters to be $n_x = 3$, $n_y = 3$, $x_s = 0$, $x_f = 1$, $y_s = 0$, $y_f = 1$. The program scales the grid to a 1 x 1 grid, and the Euclidean distance to each point in space is calculated.

Step 1 can adapt to a proper scale by changing the setting for the grid as follows:

- Set $x_f = 10$and $y_f = 10$, or the number you set for *n*
- Set the axis for the draw configuration and request $\mathrm{ax.axis}([-0.1, \mathrm{n} + .1, -0.1, \mathrm{n} + .1])$
- For a current request (Figure 11(a)), considering the scenario when a server is captured (Figure 11(b)), with next request (Figure 11(c)), and next response (Figure 11(d)), LB-WFA makes a decision as shown in the supplemental video file attached with this paper.

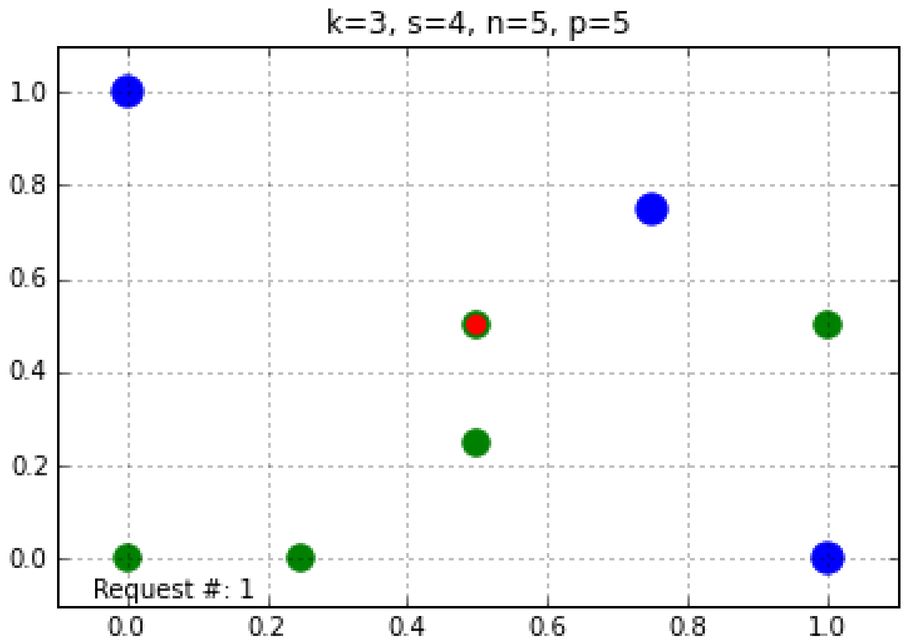


Figure 11(a) An example of a server (large dot) at a capture point (mid dot) moving to a request (small dot) for a current request considering the scenario when a server is captured

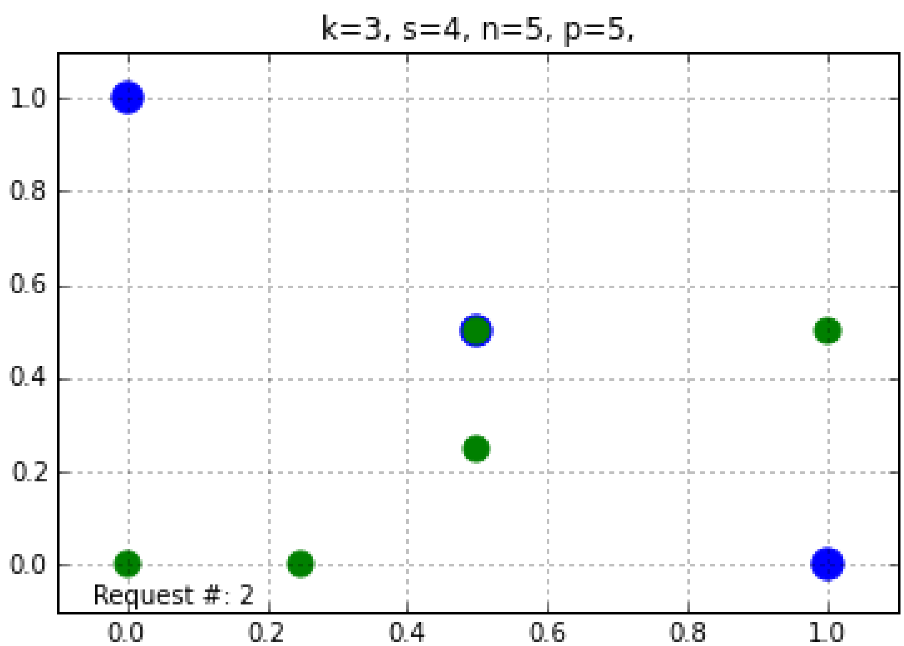


Figure 11(b) An example of a server (large dot) at a capture point (mid dot) moving to a request (small dot) for a current request with next request

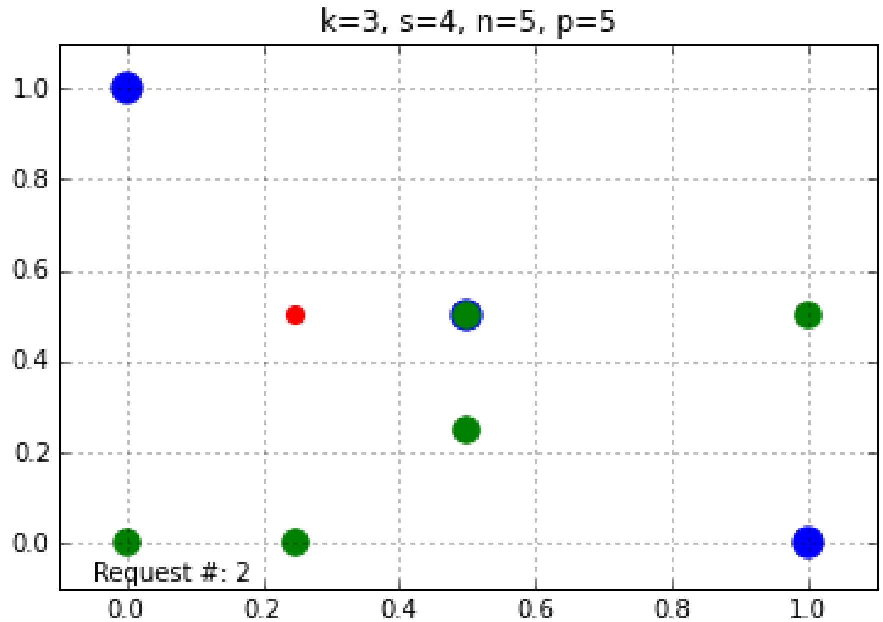


Figure 11(c) An example of a server (large dot) at a capture point (mid dot) moving to a request (small dot) for current request and next response

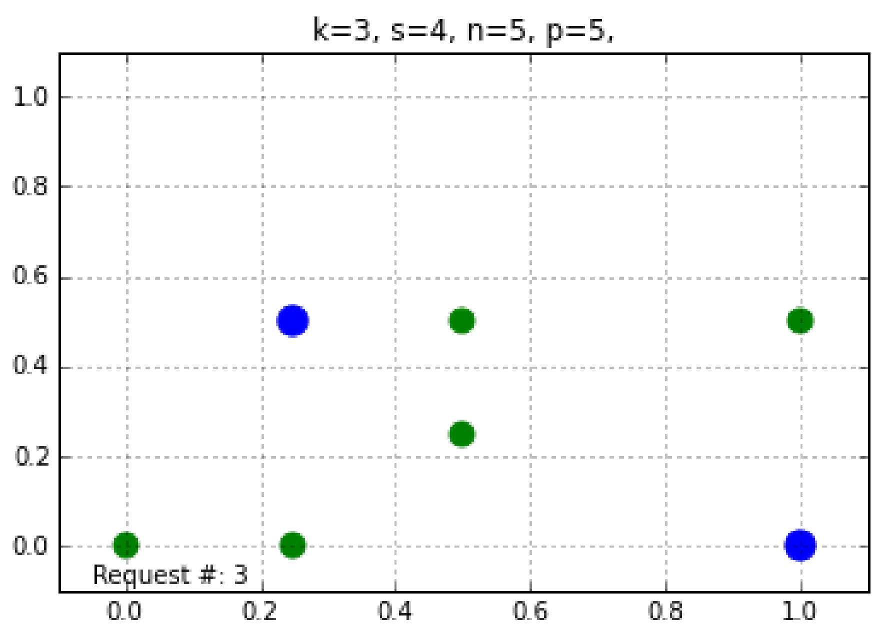


Figure 11(d) An example of a server (large dot) at a capture point (mid dot) moving to a request (small dot) for a current request LB-WFA makes a decision

We assume that any cell with an expected request frequency greater than once per 15 minutes will capture a server. Table 7 presents the CPU time (sec), total cost, and total capture time for different numbers of servers k G K — $(2,3,4,5\}$, sizes of the network $n \times n$ G N — {5,10}, capture cells $p \epsilon P$ = {5,15}, and sequences of requests s E S — {5,10,15}. In 10 x 10 network with more than 4 servers, the computation time takes longer than one minute. In a future study, a parallel computing strategy can be used to distribute the processing among multiple cores to increase throughput and reduce latency. We extended the open-source WFA code (https://github.com/adfriedm/WorkFunctionAlgorithm) for image and video illustration by incorporating lookahead embed in every stage and serving time as capture points.

TABLE 7 Performance test of LB-WFA on different number of servers (k G K), grids (n G N), capture cells (p G P), and requests (s, G S) (continued)

K	N	P	S	CPU (sec)	Total Cost	Total Capture Time(min)
		5	5	0.0066	2.0607	0
			10	0.0098	4.9152	45
			15	0.0121	8.2256	135
		15	5	0.0068	2.5049	0
			10	0.0104	4.8520	105
			15	0.0142	7.2258	60
	10	5	5	0.0321	7.1516	0
			10	0.0529	11.8504	30
			15	0.0604	28.1336	105
		15	5	0.0302	9.4416	0
			10	0.0504	24.8224	45
			15	0.0562	25.4788	150
		5	5	0.0778	2.8585	15
			10	0.0949	3.2806	75
			15	0.2134	5.5728	60
		15	5	0.0240	1.9977	90
			10	0.1279	3.1787	90
			15	0.1417	5.6579	120
	10	5	5	2.0585	5.2856	0
			10	4.5378	5.3496	0
			15	5.3629	22.1316	0
		15	5	2.5618	3.3208	0
			10	3.5711	12.4256	30
			15	4.5538	29.9375	90

TABLE 7 Performance test of LB-WFA on different number of servers (k G K), grids (n G N), capture cells (p G P), and requests (s, G S)

K	N	P	S	CPU (sec)	Total Cost	Total Capture Time(min)
		5	5	0.7528	1.5590	30
			10	1.0403	4.6787	165
			15	2.3741	4.9247	135
		15	5	0.8774	1.6626	120
			10	1.0604	4.4732	165
			15	1.6911	6.1197	105
	10	5	5	77.7051	5.2172	15
			10	209.7021	9.552	0
			15	287.5486	16.4492	0
		15	5	93.7232	5.6152	15
			10	223.1725	10.2276	0
			15	166.0152	17.6052	180
		5	5	6.4233	1.2071	30
			10	16.1900	3.3730	15
			15	29.0373	4.6197	0
		15	5	2.7582	1.4126	120
			10	5.0684	3.2104	195
			15	12.0859	4.2071	210
	10	5	5	5049.2531	5.0484	0
			10	9261.1224	12.1364	0
			15	10853.4539	15.8408	45
		15	5	1756.1586	4.2156	45
			10	6534.3758	10.5792	30
			15	8264.8500	16.3176	75

6. FINDINGS, CONCLUSIONS, RECOMMENDATIONS

We have created a stochastic model for traveler's route choice, indifference band, and binary switch variable. From the L-WFA and the traveler's behavior model, the delay-vehicle formula was created for finding the minimum total delay considering the traveler's behavior. The simulation showed the delay as a result of the L-WFA and how the demand changes according to the traveler's behavior. We have simulated our data using TransModeler and the L-WFA improved the ERV dispatching and the transportation network.

The modified WFA can be used for any traffic simulation and applied to the emergency dispatch system. The simulation can apply to city or highway road system with frequent incidents and for any emergency vehicle. One ERV can experience more congestion from attending one incident than the other available ERVs. The observation of everyday traffic through the simulation help understand the traveler's behavior and how the emergency vehicle influence the traveler's behavior and vice versa. This algorithm can be useful for a city area or highway with frequent accidents and can reduce the response time for emergency response vehicles, ambulances, and so forth. The modified WFA we created can be used when a limited number of servers are used for a large network or any emergency transportation. The flexibility of the availability of servers can reduce the computational time for emergency response system. Since the emergency response vehicles are expected to have various availability due to the length of clearing the current incident and frequent incidents in the network. The simulation would be one step closer to predicting incidents and to the true model of a perfect dispatch system.

Each stage has a history of crash locations and their expected probabilities. We assume that the random spatial sequence with historical incident for each location at each time interval. An approximate random number generator was used to generate a sequence of requests. Among all possible scenarios, 1000 random scenarios were sampled for 34 nodes and 500 scenarios were sampled for 17 nodes. We explore a uniform and non-uniform distribution of emergency requests. In the uniform distribution, the probability of incidents in each location is evenly distributed, while in the non-uniform distribution, some locations have more frequent requests. Traffic conditions and the geometric features of the freeway make non-uniform distribution more representative of actual freeway incident occurrences.

In this paper, a resource allocation decision for the current emergency has to be made before the next occurs. Due to the belief that emergencies on a transportation network may occur at unpredictable locations and times, deciding which emergency vehicle to dispatch is inherently an online problem. Requests arrive one-by-one, and a sequence of dispatch decisions has to be made without perfect knowledge about future incidents. The proposed algorithm based on dynamic programming presents better performance than current benchmarks. It identifies the best unit to respond in the real-world operation, and its performance is close to the optimal offline solution. We enhance the solution with a look-ahead to the next stage request.

In the future, we may decide to assign more than one vehicle to reduce expected clearance time. Reducing clearance time is also important, because the time to serve an incident is relatively large compared to the time to approach (respond to) the incident (Larson, 1974).
The introduced k-server problem has many applications in network modeling when we have a sequence of requests served by fc-servers. For example, the *k*-server problem can be reduced to computing the minimal-cost maximal flow on a suitable constructed network (Chrobak and Larmore, 1991). Better competitive ratio can persuade dispatchers to use our algorithm. The proposed algorithm can be improved to accommodate asymmetry of emergency response service systems on arterial networks. However, complexity of the model will increase, and the network will not have an advantage of using metric space.

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APPENDIX. Publications, presentations, posters resulting from this project:

1. Folsom, L., Darko, J., Pugh, N., Park, H., "Travelers' rationality in anticipatory online emergency response", 2019 Safe Systems Summit, Durham Convention Center (2019) April 23-24.

2. Folsom, L.., Park, H., "Semi-Autonomous Human Safe Driving", 2020 NCDOT Innovation Summit, NCAT Alumni-Foundation Event Center (2019) May 7.

3. Park, H., Waddell, D., Haghani, A. “Online emergency vehicle dispatching with look-ahead on a transportation network”. *Transportation Research Part C: Emerging Technologies*. In production.

4. Park, H., Haghani, A., Samuel, S., and Knodler, M.A. "Real-time prediction and avoidance of secondary crashes under unexpected traffic congestion." *Accident Analysis & Prevention* 112 (2018): 39-49.

5. Park, H. "Travelers' rationality in anticipatory online emergency response", 6th Annual UTC Conference for the Southeastern Region, Center for Connected Multimodal Mobility (C2M2) Madren Conference Center (2018) October 24-25.

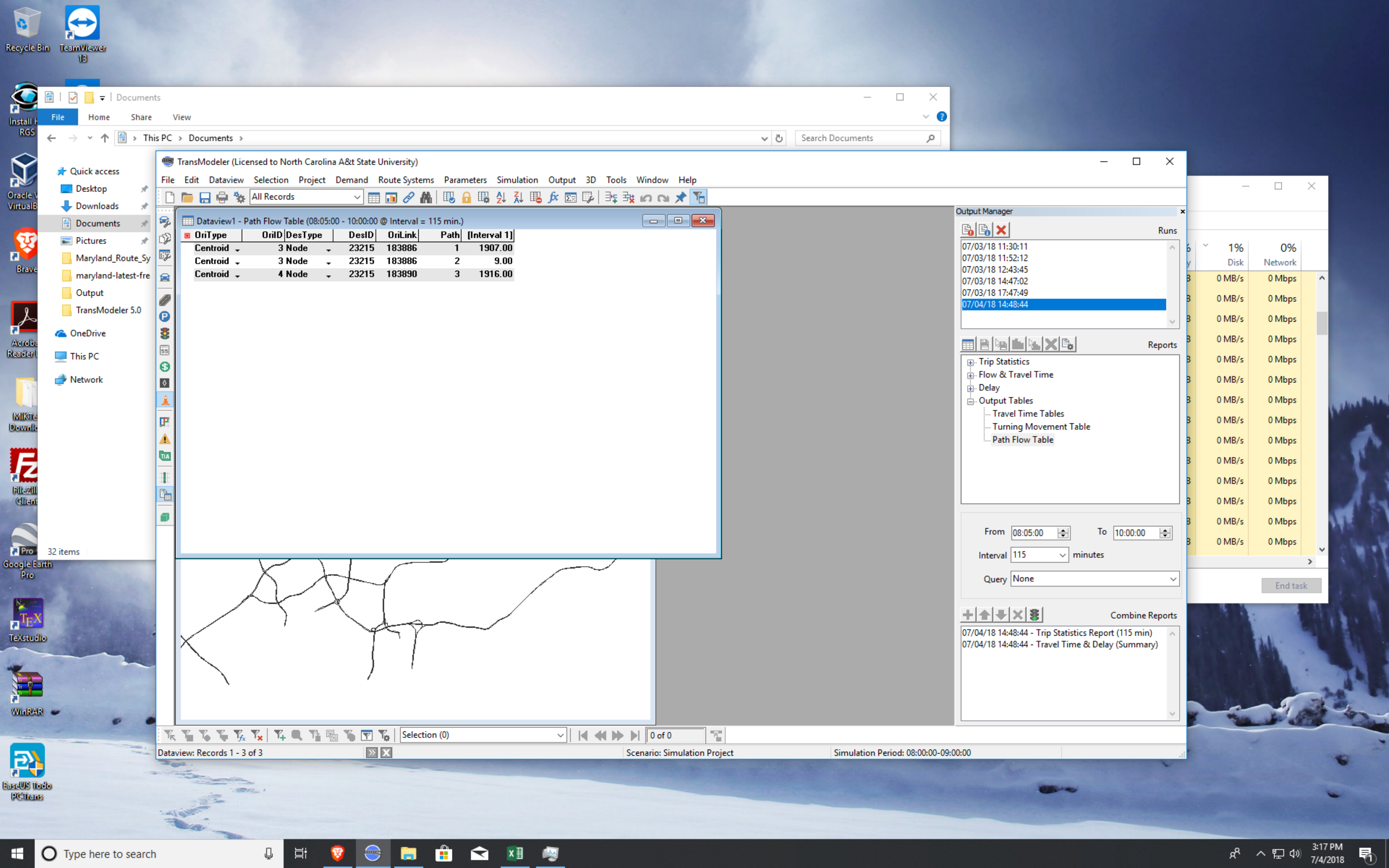
6. Park, H. Travelers' rationality in anticipatory online emergency response, Second Annual Center for Advanced Transportation Mobility (CATM) Symposium, Blacksburg, Virginia (2018) November 5.

7. Pugh, N., Park, H., "Prediction of Secondary Crash Likelihood considering Incident Duration using High Order Markov Model", IEEE SoutheastCon, Huntsville, AL, (2019) April 11-14.

8. Pugh, N., Park, H., High-Order Markov Model for Prediction of Secondary Crash Likelihood considering Incident Duration. Transportation Research Board 2020 Annual Meetings, **under review.**

9. Waddell, D., Pugh N., Shirzad, K., Park, H., "Simulation-Based Optimization of Emergency Response Considering Rationality of Travelers". The 98th Annual Meeting of TRB2019 (2019) #19-05975.

10. Waddell, D., Pugh, N., Park, H. "Visualization-based Dynamic Dispatching of First Responders". The 98th Annual Meeting of TRB2019 (2019) #19-05569.


TransModeler (Licensed to North Carolina A&t State University)
File
Edit
Dataview
Selection
Project
Demand
Route Systems
Parameters
Simulation
Output
3D
Tools
Window
Help
All Records
Dataview1 - Path Flow Table (08:05:00 - 10:00:00 @ Interval = 115 min.)
OriType | OriID | DesType | DesID | OriLink | Path | [Interval 1]
Centroid | 3 | Node | 23215 | 183886 | 1 | 1907.00
Centroid | 3 | Node | 23215 | 183886 | 2 | 9.00
Centroid | 4 | Node | 23215 | 183890 | 3 | 1916.00
Output Manager
Runs
07/03/18 11:30:11
07/03/18 11:52:12
07/03/18 12:43:45
07/03/18 14:47:02
07/03/18 17:47:49
07/04/18 14:48:44
Reports
Trip Statistics
Flow & Travel Time
Delay
Output Tables
Travel Time Tables
Turning Movement Table
Path Flow Table
From 08:05:00
To 10:00:00
Interval 115 minutes
Query None
Combine Reports
07/04/18 14:48:44 - Trip Statistics Report (115 min)
07/04/18 14:48:44 - Travel Time & Delay (Summary)
Selection (0)
0 of 0
Dataview: Records 1 - 3 of 3
Scenario: Simulation Project
Simulation Period: 08:00:00-09:00:00
Documents
File
Home
Share
View
This PC
Documents
Search Documents
Quick access
Desktop
Downloads
Documents
Pictures
Maryland_Route_Sy
maryland-latest-fre
Output
TransModeler 5.0
OneDrive
This PC
Network
32 items
Type here to search
3:17 PM
7/4/2018

Project:	Simulation Project
Scenario:	Psued_Maryland_I695
Run(s):	07/04/18 14:48:44
Simulated:	07/04/18 14:48:44
Time:	08:05:00 - 10:00:00
Interval:	115 min
Selection:	--

Trip Statistics Report

Interval	Number of Trips	Vehicle Miles Traveled (VMT)	Vehicle Hours Traveled (VHT)	Total Delay (hr)	Total Stopped Time (hr)	Total Number of Stops	Avg Trip Length (mi)	Avg Travel Time	Avg Speed (mph)
8:05:00	608	17,916.9	805.0	298.2	3.9	1,475	29.5	79.4	22.3
En Route Start	168	3,008.1	269.1	172.7	142.0	193	17.9	96.1	20.4
En Route End	3,224	26,914.3	2,693.8	1,891.2	1,502.5	3,637	8.3	50.1	17.3
Completed:	**608**	**17,916.9**	**805.0**	**298.2**	**3.9**	**1,475**	**29.5**	**79.4**	**22.3**

Project:	Simulation Project
Scenario:	Psued_Maryland_I695
Run(s):	07/04/18 14:48:44
Simulated:	07/04/18 14:48:44
Time:	08:05:00 - 10:00:00
Interval:	Summary
Selection:	--

Travel Time & Delay

[UNNAMED STREET] DIRECTION: EB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
4	1	38.3	0.0	6.8
11075	2	17.6	1.4	1.6
18848	1,290	128.5	16.6	52.7
42273	1	34.8	0.0	5.2
67362	--	--	--	--
100698	--	--	--	--
100759	--	--	--	--
100760	--	--	--	--
100762	--	--	--	--
100763	--	--	--	--
101046	--	--	--	--
101047	--	--	--	--
101049	--	--	--	--
101050	--	--	--	--
182725	1	54.5	0.0	8.1
183736	--	--	--	--
183737	--	--	--	--
183738	--	--	--	--
183741	--	--	--	--
183743	--	--	--	--
183746	--	--	--	--
183776	--	--	--	--
183781	--	--	--	--
183795	--	--	--	--
183796	--	--	--	--
183817	--	--	--	--
183828	--	--	--	--
183830	--	--	--	--
183831	--	--	--	--
183838	--	--	--	--
183839	--	--	--	--
183861	2	3.7	0.3	1.1
183862	2	14.0	1.3	3.4
183865	2	3.9	0.4	1.2
183866	2	37.4	3.4	8.5
183886	--	--	--	--
183887	1,912	16.2	2.0	4.5
183888	1,915	4.1	0.5	1.4
183889	1,916	6.5	0.7	2.0
183898	--	--	--	--

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
183899	--	--	--	--
183907	--	--	--	--
183908	--	--	--	--
183909	--	--	--	--
183921	1	37.0	0.0	5.6
183940	--	--	--	--
183968	1	15.4	0.0	2.5
183974	1	20.5	0.0	3.1
183991	--	--	--	--
184344	--	--	--	--
185613	--	--	--	--
185614	--	--	--	--
186564	1	27.1	0.0	4.2
189561	1,302	97.5	7.7	37.1
189580	--	--	--	--
189581	2	1.5	0.0	0.1
189582	--	--	--	--
189584	--	--	--	--
189585	--	--	--	--
189599	--	--	--	--
190866	--	--	--	--
190874	--	--	--	--
191225	1	8.3	0.0	1.4
191226	1	2.4	0.0	0.5
191229	1,717	119.4	10.1	44.3
191231	1,683	168.4	11.7	63.7
191381	--	--	--	--
191427	--	--	--	--
191429	--	--	--	--
191695	--	--	--	--
191698	--	--	--	--
191704	--	--	--	--
191705	--	--	--	--
191706	--	--	--	--
194174	1,915	19.7	1.8	6.8
194204	--	--	--	--
194205	--	--	--	--
194238	1,918	3.4	0.3	1.4
194239	1,908	21.3	2.2	7.2
194241	1,916	5.3	0.6	2.0
194244	1,912	34.8	3.5	11.8
194488	--	--	--	--
194489	--	--	--	--
195562	--	--	--	--
195570	--	--	--	--
195575	--	--	--	--
195576	--	--	--	--

[UNNAMED STREET] DIRECTION: EB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
195577	--	--	--	--
195715	1,681	4.1	0.3	1.7
195830	1,793	30.4	3.0	11.1
195902	1,893	100.3	8.5	32.6
196080	--	--	--	--
196100	--	--	--	--
196535	--	--	--	--
196545	--	--	--	--
209558	1	103.9	0.0	15.7
209560	--	--	--	--
218036	--	--	--	--
223373	--	--	--	--
223375	--	--	--	--
223377	--	--	--	--
223458	--	--	--	--
223743	1,274	19.0	17.1	14.2
223760	2	30.4	2.4	2.8
223773	2	7.7	0.6	0.9
224961	1	1.9	0.0	1.6
224963	1	36.7	0.0	5.5
224965	2	10.7	0.0	1.8
225032	--	--	--	--
226910	--	--	--	--
226911	--	--	--	--
236852	--	--	--	--
260110	--	--	--	--
260111	--	--	--	--
260117	--	--	--	--
261096	--	--	--	--
261136	--	--	--	--
266088	--	--	--	--
283452	2	28.3	0.0	4.3
360579	--	--	--	--
363164	--	--	--	--
363180	--	--	--	--
364195	--	--	--	--
371531	--	--	--	--
371532	--	--	--	--
371645	--	--	--	--
371646	--	--	--	--
371906	--	--	--	--
372219	--	--	--	--
377003	--	--	--	--
377004	--	--	--	--
381014	--	--	--	--
385978	--	--	--	--
394225	--	--	--	--

[UNNAMED STREET] DIRECTION: EB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
394226	--	--	--	--
405802	2	17.4	1.6	4.1
408356	--	--	--	--
408591	1,909	25.5	2.5	7.6
408599	1,909	23.5	2.2	8.2
413327	--	--	--	--
413328	--	--	--	--
416299	--	--	--	--
418124	2	13.3	0.0	2.2
446464	--	--	--	--
446466	--	--	--	--
446481	1,916	9.9	0.9	3.3
446484	--	--	--	--
446485	--	--	--	--
446503	1	16.5	0.0	2.7
446531	2	6.4	0.6	1.6
446532	2	12.3	1.1	3.0
446533	2	6.0	0.5	1.6
446534	2	8.3	0.8	2.1
446535	2	2.4	0.2	0.8
446536	2	35.0	3.2	8.0
446537	2	25.7	2.3	5.9
446538	2	38.8	3.5	8.8
446539	2	8.9	0.8	2.2
446540	2	4.3	0.4	1.2
446541	2	26.8	2.5	6.2
446542	2	10.8	1.0	2.7
446543	2	0.9	0.1	0.5
446544	2	13.1	1.2	3.1
446545	2	8.4	0.8	2.1
446606	1	8.1	0.0	2.4
446607	2	70.8	0.0	10.5
446617	1	14.7	0.0	2.3
446626	--	--	--	--
446656	2	5.2	0.5	2.3
446658	2	33.9	3.1	7.7

[UNNAMED STREET] DIRECTION: NB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
7	--	--	--	--
25	--	--	--	--
7764	--	--	--	--
22665	--	--	--	--
42247	1	104.3	0.0	15.4
44509	--	--	--	--
67006	--	--	--	--

[UNNAMED STREET] DIRECTION: NB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
67008	--	--	--	--
67009	--	--	--	--
67010	--	--	--	--
67012	--	--	--	--
67016	--	--	--	--
74096	--	--	--	--
100740	--	--	--	--
100748	--	--	--	--
100751	--	--	--	--
100780	--	--	--	--
100785	--	--	--	--
100786	--	--	--	--
100994	--	--	--	--
100995	--	--	--	--
100997	--	--	--	--
101026	--	--	--	--
182603	--	--	--	--
182604	--	--	--	--
182633	--	--	--	--
183231	--	--	--	--
183232	--	--	--	--
183235	--	--	--	--
183236	--	--	--	--
183750	--	--	--	--
183753	--	--	--	--
183754	--	--	--	--
183755	--	--	--	--
183756	--	--	--	--
183841	1	5.7	0.0	1.0
183935	1	4.7	0.0	0.9
183951	--	--	--	--
183952	--	--	--	--
183955	--	--	--	--
183999	1	2.3	0.0	0.5
184001	1	10.5	0.0	1.7
184019	--	--	--	--
184020	--	--	--	--
185578	--	--	--	--
185609	--	--	--	--
185610	--	--	--	--
185611	--	--	--	--
185612	--	--	--	--
185616	--	--	--	--
185617	--	--	--	--
185618	--	--	--	--
185619	--	--	--	--
185620	--	--	--	--

[UNNAMED STREET] DIRECTION: NB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
185621	--	--	--	--
188895	--	--	--	--
188896	--	--	--	--
188897	--	--	--	--
189562	1,324	4.7	0.4	2.0
189601	1,394	13.5	1.2	5.2
189606	1,367	47.0	4.0	17.8
189613	1,388	9.1	0.8	3.6
189614	1,365	7.7	0.7	3.1
189615	1,359	54.7	4.4	20.9
189622	1,347	68.7	5.4	26.2
189623	1,326	23.1	1.8	8.9
189643	1,568	57.1	4.9	21.6
191431	--	--	--	--
191434	689	135.7	13.3	46.0
191521	--	--	--	--
192215	1	4.0	0.0	0.8
192509	1,172	59.8	5.8	20.1
192876	--	--	--	--
192877	--	--	--	--
192878	--	--	--	--
193342	--	--	--	--
193646	693	45.7	5.5	14.6
194106	--	--	--	--
194107	--	--	--	--
194108	--	--	--	--
194109	--	--	--	--
194193	--	--	--	--
194590	--	--	--	--
194761	--	--	--	--
194762	--	--	--	--
194763	--	--	--	--
194764	--	--	--	--
194767	--	--	--	--
194871	--	--	--	--
194950	--	--	--	--
194951	--	--	--	--
194986	--	--	--	--
194987	--	--	--	--
194988	--	--	--	--
194989	--	--	--	--
195538	--	--	--	--
195571	--	--	--	--
195834	1	1.3	0.0	0.4
196155	--	--	--	--
196249	--	--	--	--
196252	--	--	--	--

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
196253	--	--	--	--
196537	--	--	--	--
196547	--	--	--	--
197067	3	8.6	0.8	2.0
197072	3	6.6	0.6	1.5
197158	--	--	--	--
197607	--	--	--	--
200332	--	--	--	--
200333	--	--	--	--
200334	--	--	--	--
200337	--	--	--	--
205825	--	--	--	--
205834	--	--	--	--
205835	--	--	--	--
205837	--	--	--	--
205838	--	--	--	--
205890	--	--	--	--
205896	--	--	--	--
205897	--	--	--	--
205900	--	--	--	--
210586	--	--	--	--
216059	--	--	--	--
221277	--	--	--	--
221313	--	--	--	--
221342	--	--	--	--
222452	--	--	--	--
222542	--	--	--	--
236848	3	69.3	6.1	13.9
245298	--	--	--	--
245307	--	--	--	--
245313	--	--	--	--
260104	--	--	--	--
260108	--	--	--	--
260109	--	--	--	--
261099	--	--	--	--
263624	--	--	--	--
295196	--	--	--	--
363094	--	--	--	--
363163	--	--	--	--
363168	--	--	--	--
363169	--	--	--	--
363170	--	--	--	--
363171	--	--	--	--
363172	--	--	--	--
363173	--	--	--	--
363175	--	--	--	--
363176	--	--	--	--

[UNNAMED STREET] DIRECTION: NB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
363179	--	--	--	--
371618	--	--	--	--
371640	--	--	--	--
371641	--	--	--	--
371755	--	--	--	--
371756	--	--	--	--
371757	--	--	--	--
371762	--	--	--	--
371853	--	--	--	--
371854	--	--	--	--
372129	--	--	--	--
372130	--	--	--	--
372156	--	--	--	--
372157	--	--	--	--
377061	--	--	--	--
377064	--	--	--	--
377078	--	--	--	--
382202	3	10.0	0.9	3.1
386563	--	--	--	--
386564	--	--	--	--
398528	--	--	--	--
401247	--	--	--	--
401962	1	18.0	0.0	2.9
401963	1	8.6	0.0	1.5
403671	--	--	--	--
413283	--	--	--	--
413284	--	--	--	--
413285	--	--	--	--
413286	--	--	--	--
413324	1	7.1	0.0	1.3
413723	--	--	--	--
413724	--	--	--	--
413725	--	--	--	--
416221	--	--	--	--
416512	1	14.2	0.0	2.3
416513	1	5.8	0.0	1.1
416514	1	19.4	0.0	3.0
416515	1	96.7	0.0	14.2
416525	--	--	--	--
416526	--	--	--	--
416527	--	--	--	--
416528	--	--	--	--
416541	579	26.1	4.4	9.5
416542	656	15.2	1.6	5.5
416543	724	22.6	2.3	8.5
417223	1,158	36.1	10.6	16.4
432688	--	--	--	--

[UNNAMED STREET] DIRECTION: NB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
446473	--	--	--	--
446502	1	18.7	0.0	3.4
446519	--	--	--	--
446520	--	--	--	--
446521	--	--	--	--
446523	--	--	--	--
446524	--	--	--	--
446525	--	--	--	--
446528	--	--	--	--
446556	1	76.5	0.0	11.3
446557	1	3.4	0.0	0.7
446558	1	30.2	0.0	4.6
446559	1	25.0	0.0	3.8
446560	1	4.2	0.0	0.8
446561	1	10.0	0.0	1.6
446562	1	4.2	0.0	0.8
446563	1	71.7	0.0	10.6
446564	1	4.6	0.0	0.9
446579	3	23.8	1.7	6.6
446601	--	--	--	--
446613	--	--	--	--
446621	--	--	--	--
446625	808	7.7	0.8	2.9
446629	703	12.6	1.4	4.6
446630	1	11.4	0.0	4.6
446632	1	47.3	0.0	7.0
446637	1	63.0	0.0	9.3
446638	1	6.7	0.0	1.2
446639	1	9.4	0.0	1.6
446640	1	6.4	0.0	1.2
446641	1	29.4	0.0	4.4
446642	1	43.0	0.0	6.5
446643	1	11.8	0.0	2.0
446644	1	5.6	0.0	1.0
446645	1	3.5	0.0	0.8
446646	1	26.5	0.0	4.1
446647	1	5.2	0.0	1.0
446648	1	23.3	0.0	3.5
446657	1	1.1	0.0	0.4

[UNNAMED STREET] DIRECTION: NEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
5	1	4.3	0.0	1.6
5567	--	--	--	--
25782	--	--	--	--
42271	1	20.1	0.0	3.2

[UNNAMED STREET] DIRECTION: NEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
42908	1	1.8	0.0	0.9
66986	--	--	--	--
66988	--	--	--	--
67003	--	--	--	--
67004	--	--	--	--
67005	--	--	--	--
67011	--	--	--	--
100585	--	--	--	--
100586	--	--	--	--
100741	--	--	--	--
100992	--	--	--	--
182656	--	--	--	--
182657	--	--	--	--
182680	1	166.0	0.0	24.2
182693	--	--	--	--
182694	--	--	--	--
183742	--	--	--	--
183774	--	--	--	--
183775	--	--	--	--
183777	--	--	--	--
183803	--	--	--	--
183804	--	--	--	--
183805	--	--	--	--
183806	--	--	--	--
183814	--	--	--	--
183815	--	--	--	--
183816	--	--	--	--
183824	--	--	--	--
183825	--	--	--	--
183826	--	--	--	--
183827	--	--	--	--
183829	--	--	--	--
183832	--	--	--	--
183833	--	--	--	--
183834	--	--	--	--
183835	--	--	--	--
183859	2	60.3	5.5	13.7
183874	1,787	278.1	20.7	101.9
183876	1,771	29.0	2.2	10.9
183924	--	--	--	--
183936	1	7.4	0.0	1.3
183943	--	--	--	--
183959	--	--	--	--
183960	--	--	--	--
183969	1	2.3	0.0	0.5
184462	--	--	--	--
184463	--	--	--	--

[UNNAMED STREET] DIRECTION: NEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
184464	--	--	--	--
184465	--	--	--	--
184474	--	--	--	--
184475	--	--	--	--
186563	1	27.6	0.0	4.3
187742	--	--	--	--
188918	--	--	--	--
188919	--	--	--	--
189564	1,301	15.8	1.3	6.2
189642	1,599	6.4	0.6	2.6
191368	1	9.3	0.0	1.6
191369	--	--	--	--
191380	--	--	--	--
192205	--	--	--	--
192216	1	103.6	0.0	15.2
192490	--	--	--	--
192491	--	--	--	--
192492	--	--	--	--
192870	--	--	--	--
192875	--	--	--	--
192880	--	--	--	--
192887	--	--	--	--
192888	--	--	--	--
195371	--	--	--	--
195561	--	--	--	--
195563	--	--	--	--
195685	--	--	--	--
195687	--	--	--	--
195716	1,636	69.8	5.5	26.4
195721	1,602	36.7	3.1	13.9
195722	1,610	8.1	0.7	3.3
195832	1	37.7	0.0	5.7
195840	1,871	3.6	0.3	1.5
195934	1,879	6.6	0.6	2.5
195938	1,873	64.1	5.9	22.8
196546	--	--	--	--
196548	--	--	--	--
197573	--	--	--	--
197609	--	--	--	--
207343	--	--	--	--
207353	--	--	--	--
209550	1,611	71.7	5.5	27.2
209556	1,871	138.5	11.6	48.3
209563	1	20.1	0.0	3.1
214531	1,765	8.4	0.8	3.0
216061	--	--	--	--
220179	--	--	--	--

[UNNAMED STREET] DIRECTION: NEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
220181	--	--	--	--
220183	--	--	--	--
220186	--	--	--	--
220187	--	--	--	--
220231	--	--	--	--
221390	--	--	--	--
221392	--	--	--	--
221414	--	--	--	--
221418	--	--	--	--
222394	--	--	--	--
222540	--	--	--	--
222541	--	--	--	--
223741	1,257	36.6	3.9	11.6
223742	1,769	11.2	1.0	4.4
223747	1,757	32.0	3.2	11.6
223748	1,765	1.5	0.0	1.1
224957	1	87.0	0.0	12.8
224968	--	--	--	--
224970	--	--	--	--
226196	--	--	--	--
261085	--	--	--	--
261123	--	--	--	--
263625	--	--	--	--
278077	--	--	--	--
278078	--	--	--	--
283432	--	--	--	--
295079	--	--	--	--
295080	--	--	--	--
295081	--	--	--	--
295087	--	--	--	--
296183	1	7.4	0.0	1.7
296184	1	5.6	0.0	1.3
296185	--	--	--	--
296187	--	--	--	--
296189	1	13.5	0.0	2.1
296191	1	14.9	0.0	2.4
296192	--	--	--	--
312643	--	--	--	--
313105	--	--	--	--
313108	--	--	--	--
315364	--	--	--	--
315366	--	--	--	--
321783	--	--	--	--
361560	--	--	--	--
361561	--	--	--	--
361570	--	--	--	--
361571	--	--	--	--

[UNNAMED STREET] DIRECTION: NEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
371458	2	4.3	0.0	0.8
371617	--	--	--	--
371834	--	--	--	--
371835	--	--	--	--
377001	--	--	--	--
377318	--	--	--	--
377326	--	--	--	--
377474	--	--	--	--
379712	1	0.7	0.0	0.3
379713	1	4.1	0.0	0.9
379714	--	--	--	--
379715	--	--	--	--
381573	--	--	--	--
382200	--	--	--	--
385148	--	--	--	--
400544	1,765	21.6	2.0	7.1
400545	1,765	22.8	2.6	10.8
403665	--	--	--	--
403678	--	--	--	--
403857	--	--	--	--
405924	1	15.1	0.0	2.4
405928	--	--	--	--
405929	--	--	--	--
406011	--	--	--	--
406014	--	--	--	--
408592	1,919	9.3	0.9	3.1
413323	1	23.0	0.0	3.5
416516	3	10.3	0.9	2.3
416517	--	--	--	--
416518	--	--	--	--
416519	--	--	--	--
445262	--	--	--	--
445263	--	--	--	--
446482	--	--	--	--
446486	1	16.3	0.0	2.6
446487	1	58.9	0.0	9.6
446490	1	106.5	0.0	15.8
446491	--	--	--	--
446494	1	101.7	0.0	15.0
446495	1	44.6	0.0	7.3
446500	--	--	--	--
446501	1	82.2	0.0	12.7
446526	--	--	--	--
446527	2	41.8	3.8	10.7
446529	2	88.4	8.1	19.9
446530	2	1.6	0.1	0.6
446546	2	45.8	4.1	10.4

[UNNAMED STREET]

DIRECTION: NEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
446547	2	29.5	2.7	6.8
446548	2	173.2	15.7	38.7
446549	2	3.8	0.4	1.0
446550	2	8.8	0.8	2.2
446551	2	2.3	0.2	0.8
446552	2	4.1	0.4	1.2
446553	2	10.6	0.9	2.8
446554	2	2.2	0.2	1.0
446555	2	14.7	1.3	3.5
446565	1	27.4	0.0	4.3
446566	1	11.8	0.0	1.9
446567	1	27.7	0.0	4.2
446568	1	4.0	0.0	0.9
446569	1	12.2	0.0	2.0
446570	1	42.1	0.0	6.3
446571	1	15.2	0.0	2.4
446572	1	4.6	0.0	0.9
446573	1	34.1	0.0	5.6
446574	--	--	--	--
446575	1	31.2	0.0	4.8
446576	1	16.9	0.0	2.7
446577	1	32.4	0.0	4.9
446578	2	12.5	0.0	2.1
446581	3	14.8	1.3	3.2
446599	--	--	--	--
446600	--	--	--	--
446603	--	--	--	--
446608	--	--	--	--
446609	1	0.6	0.0	0.5
446615	--	--	--	--
446624	--	--	--	--
446636	1	10.9	0.0	1.8
446649	--	--	--	--
446650	--	--	--	--
446651	--	--	--	--
446652	--	--	--	--
446654	--	--	--	--
446662	--	--	--	--
446663	--	--	--	--
446664	--	--	--	--
446666	--	--	--	--
446667	--	--	--	--
446668	--	--	--	--

[UNNAMED STREET] DIRECTION: NWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
5723	--	--	--	--
12078	--	--	--	--
14294	--	--	--	--
18849	1,409	147.5	8.7	56.8
22663	--	--	--	--
25149	--	--	--	--
66963	1,578	16.0	24.8	6.5
66976	--	--	--	--
66977	--	--	--	--
66979	--	--	--	--
66994	--	--	--	--
67013	--	--	--	--
71840	--	--	--	--
100680	--	--	--	--
100742	--	--	--	--
100762	--	--	--	--
100960	--	--	--	--
100961	--	--	--	--
100962	--	--	--	--
100963	--	--	--	--
100972	--	--	--	--
100993	--	--	--	--
100996	--	--	--	--
101017	--	--	--	--
101018	--	--	--	--
101027	--	--	--	--
101031	--	--	--	--
101032	--	--	--	--
101039	--	--	--	--
101040	--	--	--	--
101063	--	--	--	--
101064	--	--	--	--
182630	--	--	--	--
182631	--	--	--	--
182632	--	--	--	--
182681	--	--	--	--
182690	--	--	--	--
182691	--	--	--	--
182692	--	--	--	--
182701	--	--	--	--
182702	--	--	--	--
182703	--	--	--	--
182704	--	--	--	--
182705	--	--	--	--
182706	--	--	--	--
182707	--	--	--	--
182708	--	--	--	--

[UNNAMED STREET] DIRECTION: NWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
183743	--	--	--	--
183745	--	--	--	--
183747	--	--	--	--
183748	--	--	--	--
183749	--	--	--	--
183751	--	--	--	--
183752	--	--	--	--
183784	--	--	--	--
183785	--	--	--	--
183809	814	32.4	3.3	12.2
183810	534	16.9	6.2	6.4
183812	1,088	3.8	0.4	1.4
183813	983	34.1	3.4	11.3
183848	1,268	2.0	0.7	1.2
183849	1,265	2.8	1.0	1.6
183850	1,261	2.3	1.1	1.5
183851	1,099	18.4	1.9	5.9
183914	1,655	5.4	17.4	2.6
183945	--	--	--	--
183946	--	--	--	--
183947	--	--	--	--
183948	--	--	--	--
183956	--	--	--	--
184012	--	--	--	--
184761	--	--	--	--
184764	--	--	--	--
184765	--	--	--	--
184766	--	--	--	--
185622	--	--	--	--
185623	--	--	--	--
186893	--	--	--	--
186894	--	--	--	--
186895	--	--	--	--
189466	953	5.0	0.5	2.0
189467	940	46.5	4.7	17.1
189568	--	--	--	--
189569	--	--	--	--
189571	1,225	34.3	9.6	16.5
189572	--	--	--	--
189573	--	--	--	--
189576	1,232	41.2	4.1	13.9
189577	--	--	--	--
189578	--	--	--	--
189582	--	--	--	--
189596	1,405	22.2	1.7	8.6
189597	1,409	7.8	0.5	3.2
189608	1,400	6.8	0.6	2.8

[UNNAMED STREET] DIRECTION: NWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
189653	1,568	19.9	1.7	7.6
190860	937	4.9	0.5	2.0
190869	885	15.5	1.7	5.7
190873	885	5.1	0.6	2.1
191430	--	--	--	--
191532	--	--	--	--
191697	--	--	--	--
191698	--	--	--	--
192497	1,225	2.4	0.3	0.9
192498	1,225	29.8	3.2	9.0
192505	1,224	9.9	1.0	3.3
192510	1,220	5.2	0.5	1.9
192513	1,225	4.7	0.5	1.7
192871	1	73.7	0.0	25.5
192872	1	49.9	0.0	7.5
192923	--	--	--	--
192927	--	--	--	--
193340	--	--	--	--
194320	--	--	--	--
194321	--	--	--	--
194322	--	--	--	--
194765	--	--	--	--
194766	--	--	--	--
194768	--	--	--	--
194933	--	--	--	--
194934	--	--	--	--
194935	--	--	--	--
194940	--	--	--	--
194941	--	--	--	--
194942	--	--	--	--
194943	--	--	--	--
195118	--	--	--	--
195119	--	--	--	--
195125	--	--	--	--
195130	--	--	--	--
195134	--	--	--	--
195137	--	--	--	--
195138	--	--	--	--
195142	--	--	--	--
195143	--	--	--	--
195145	--	--	--	--
195728	--	--	--	--
195729	--	--	--	--
195730	--	--	--	--
195731	--	--	--	--
195735	1,038	2.5	0.2	1.1
195736	958	73.2	7.5	26.4

[UNNAMED STREET] DIRECTION: NWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
196080	--	--	--	--
196088	--	--	--	--
196100	--	--	--	--
196148	--	--	--	--
196152	--	--	--	--
196165	--	--	--	--
196544	--	--	--	--
196986	--	--	--	--
196987	--	--	--	--
196988	--	--	--	--
196989	--	--	--	--
197580	--	--	--	--
200056	--	--	--	--
200057	--	--	--	--
205827	--	--	--	--
205840	--	--	--	--
205841	--	--	--	--
210572	--	--	--	--
210587	--	--	--	--
210644	--	--	--	--
210645	--	--	--	--
210649	--	--	--	--
210650	--	--	--	--
218057	1,225	9.2	1.0	3.3
218058	--	--	--	--
218059	--	--	--	--
218060	1,228	5.0	0.5	1.9
218062	--	--	--	--
220756	--	--	--	--
222456	--	--	--	--
223291	--	--	--	--
223292	--	--	--	--
223293	--	--	--	--
223294	--	--	--	--
223295	--	--	--	--
223296	--	--	--	--
223374	1,403	48.1	39.1	18.2
223376	--	--	--	--
223378	64	29.6	5.3	10.7
223379	1,669	56.5	16.5	19.9
223653	1,040	296.0	23.7	101.1
225031	--	--	--	--
225324	--	--	--	--
226212	--	--	--	--
226910	--	--	--	--
227788	--	--	--	--
227789	--	--	--	--

[UNNAMED STREET] DIRECTION: NWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
245038	--	--	--	--
245054	--	--	--	--
245060	--	--	--	--
245289	--	--	--	--
257984	--	--	--	--
260111	--	--	--	--
260113	--	--	--	--
261097	--	--	--	--
261098	--	--	--	--
263658	--	--	--	--
266069	--	--	--	--
295197	--	--	--	--
321715	--	--	--	--
358146	1,124	146.2	13.5	48.8
360577	1,251	2.5	1.5	1.5
360578	1,271	2.1	0.9	1.4
360580	1,845	12.6	1.2	4.6
360581	1,831	4.7	2.3	1.9
360584	1,621	11.9	21.5	5.0
360587	1,539	14.7	31.5	6.4
360590	1,294	11.2	46.2	7.1
363062	733	45.9	4.3	17.1
363064	723	27.1	2.9	10.3
363065	750	61.2	5.4	23.0
363095	--	--	--	--
363096	--	--	--	--
363103	1,039	2.0	0.2	0.9
363104	1,005	6.7	0.8	2.6
363106	1,006	32.4	3.5	11.6
363107	987	42.3	4.5	15.1
363108	1,024	33.1	3.6	11.7
363155	--	--	--	--
363156	--	--	--	--
363174	--	--	--	--
363177	--	--	--	--
363178	--	--	--	--
363180	--	--	--	--
364279	--	--	--	--
369667	--	--	--	--
369668	--	--	--	--
370342	--	--	--	--
371240	1,107	50.1	9.4	20.7
371241	1,099	24.6	2.6	7.3
371612	1,356	18.2	46.5	8.1
371619	--	--	--	--
371885	--	--	--	--
371907	--	--	--	--

[UNNAMED STREET]

DIRECTION: NWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
372047	--	--	--	--
372048	--	--	--	--
372154	982	24.2	2.6	8.8
376977	953	34.0	3.4	12.5
377075	--	--	--	--
377475	--	--	--	--
378316	--	--	--	--
382225	--	--	--	--
384120	--	--	--	--
385147	--	--	--	--
387577	--	--	--	--
399383	--	--	--	--
399414	--	--	--	--
403821	--	--	--	--
412753	--	--	--	--
413282	--	--	--	--
413726	--	--	--	--
413727	--	--	--	--
415012	--	--	--	--
415358	--	--	--	--
415359	--	--	--	--
415360	--	--	--	--
416277	--	--	--	--
416278	--	--	--	--
416279	--	--	--	--
416280	--	--	--	--
416529	--	--	--	--
416530	--	--	--	--
416531	--	--	--	--
416535	164	24.4	67.3	10.0
416536	1,159	8.1	0.9	3.3
416537	464	25.2	17.1	9.8
416538	235	21.7	58.2	10.7
416539	284	24.6	39.2	10.6
416540	350	42.1	43.2	17.3
416545	931	12.4	1.3	4.4
416546	970	4.2	0.5	1.7
417224	1,198	12.4	1.2	4.3
417225	1,203	34.9	3.4	11.4
446462	--	--	--	--
446517	1,870	75.9	7.0	26.0
446522	--	--	--	--
446580	1,275	21.0	3.5	9.1
446584	1,156	23.5	2.5	7.1
446598	--	--	--	--
446627	--	--	--	--
446631	152	3.8	0.7	1.8

[UNNAMED STREET] DIRECTION: NWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
446635	--	--	--	--

[UNNAMED STREET] DIRECTION: SB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
7	--	--	--	--
5723	--	--	--	--
7764	--	--	--	--
12078	--	--	--	--
14294	--	--	--	--
18851	--	--	--	--
22660	--	--	--	--
22664	--	--	--	--
22665	--	--	--	--
25149	--	--	--	--
42270	--	--	--	--
67004	--	--	--	--
67008	--	--	--	--
67009	--	--	--	--
67010	--	--	--	--
67011	--	--	--	--
67361	--	--	--	--
71285	1	8.8	0.0	2.7
74096	--	--	--	--
75950	--	--	--	--
100680	--	--	--	--
100746	2	196.6	0.0	56.7
100747	2	5.6	0.0	1.8
100752	2	100.5	0.0	29.1
100753	2	2.8	0.0	1.1
100779	2	3.8	0.0	1.3
100784	2	31.5	0.0	9.3
100787	2	3.0	0.0	1.1
100960	--	--	--	--
100994	--	--	--	--
100996	--	--	--	--
100997	--	--	--	--
101028	2	3.2	0.0	1.1
182603	--	--	--	--
182604	--	--	--	--
182682	--	--	--	--
183237	2	3.9	0.0	1.3
183238	2	83.5	0.0	25.0
183748	--	--	--	--
183750	--	--	--	--
183753	--	--	--	--
183754	--	--	--	--

[UNNAMED STREET] DIRECTION: SB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
183755	--	--	--	--
183756	--	--	--	--
183840	--	--	--	--
183869	--	--	--	--
183870	--	--	--	--
183937	--	--	--	--
183938	--	--	--	--
183948	--	--	--	--
183951	--	--	--	--
183952	--	--	--	--
183955	--	--	--	--
183956	--	--	--	--
183998	--	--	--	--
184000	--	--	--	--
184019	--	--	--	--
185578	--	--	--	--
185609	--	--	--	--
185610	--	--	--	--
185611	--	--	--	--
185612	--	--	--	--
185616	--	--	--	--
185617	--	--	--	--
185618	--	--	--	--
185619	--	--	--	--
185620	--	--	--	--
185621	--	--	--	--
185623	--	--	--	--
188895	--	--	--	--
188896	--	--	--	--
188897	--	--	--	--
189559	--	--	--	--
189560	--	--	--	--
189589	--	--	--	--
189611	--	--	--	--
189619	--	--	--	--
189620	--	--	--	--
189621	--	--	--	--
189843	--	--	--	--
191179	--	--	--	--
191180	--	--	--	--
191202	--	--	--	--
191203	--	--	--	--
191210	--	--	--	--
191211	--	--	--	--
191252	--	--	--	--
191259	--	--	--	--
191284	--	--	--	--

[UNNAMED STREET] DIRECTION: SB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
191285	--	--	--	--
191287	--	--	--	--
191341	--	--	--	--
191342	--	--	--	--
191430	--	--	--	--
191433	--	--	--	--
192499	--	--	--	--
192873	--	--	--	--
192881	--	--	--	--
192889	--	--	--	--
192890	--	--	--	--
194106	--	--	--	--
194107	--	--	--	--
194108	--	--	--	--
194109	--	--	--	--
194193	--	--	--	--
194761	--	--	--	--
194762	--	--	--	--
194763	--	--	--	--
194951	--	--	--	--
194987	--	--	--	--
194988	--	--	--	--
194989	--	--	--	--
195837	--	--	--	--
195841	--	--	--	--
196155	--	--	--	--
196249	--	--	--	--
196252	--	--	--	--
196253	--	--	--	--
196544	--	--	--	--
197068	--	--	--	--
197156	1	169.9	0.0	49.1
197158	--	--	--	--
197162	1	3.6	0.0	1.3
197606	2	33.3	0.1	9.8
200332	--	--	--	--
200333	--	--	--	--
200334	--	--	--	--
200337	--	--	--	--
205825	--	--	--	--
205835	--	--	--	--
205838	--	--	--	--
205841	--	--	--	--
205890	--	--	--	--
205896	--	--	--	--
205897	--	--	--	--
209554	1	37.7	0.0	11.1

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
209557	--	--	--	--
210587	--	--	--	--
216060	2	2.5	0.0	0.9
221277	--	--	--	--
221313	--	--	--	--
221342	--	--	--	--
222452	--	--	--	--
222542	--	--	--	--
223749	--	--	--	--
224962	--	--	--	--
225324	--	--	--	--
226196	--	--	--	--
226213	--	--	--	--
226215	--	--	--	--
229046	--	--	--	--
236849	--	--	--	--
237995	--	--	--	--
245298	--	--	--	--
245307	--	--	--	--
245313	--	--	--	--
260108	--	--	--	--
260109	--	--	--	--
261129	--	--	--	--
263658	--	--	--	--
266070	--	--	--	--
268952	--	--	--	--
295197	--	--	--	--
296306	--	--	--	--
296307	--	--	--	--
331987	--	--	--	--
363163	--	--	--	--
363168	--	--	--	--
363169	--	--	--	--
363170	--	--	--	--
363171	--	--	--	--
363172	--	--	--	--
363173	--	--	--	--
363175	--	--	--	--
363176	--	--	--	--
363179	--	--	--	--
371413	2	14.8	0.0	4.5
371414	2	44.8	0.0	13.1
371524	--	--	--	--
371618	--	--	--	--
371640	--	--	--	--
371641	--	--	--	--
371755	--	--	--	--

[UNNAMED STREET] DIRECTION: SB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
371756	--	--	--	--
371762	--	--	--	--
371853	--	--	--	--
371854	--	--	--	--
372157	--	--	--	--
376995	2	17.6	0.0	5.2
377061	--	--	--	--
377064	--	--	--	--
377326	--	--	--	--
377348	--	--	--	--
382201	--	--	--	--
383905	--	--	--	--
383906	--	--	--	--
384118	--	--	--	--
384120	--	--	--	--
385981	--	--	--	--
386564	--	--	--	--
386565	--	--	--	--
386895	--	--	--	--
398536	2	59.9	0.0	17.4
401247	--	--	--	--
413283	--	--	--	--
413284	--	--	--	--
413285	--	--	--	--
413286	--	--	--	--
413330	--	--	--	--
413723	--	--	--	--
413724	--	--	--	--
413725	--	--	--	--
415012	--	--	--	--
415360	--	--	--	--
415361	--	--	--	--
416221	--	--	--	--
416272	2	45.2	0.0	13.2
416300	2	21.6	0.1	6.4
416301	2	32.1	0.0	9.4
416302	2	17.4	0.0	5.2
416525	--	--	--	--
416526	--	--	--	--
416527	--	--	--	--
416528	--	--	--	--
446475	--	--	--	--
446492	--	--	--	--
446509	--	--	--	--
446510	--	--	--	--
446516	1	44.3	0.0	13.9
446518	1	14.1	0.0	4.3

[UNNAMED STREET] DIRECTION: SB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
446616	--	--	--	--
446620	--	--	--	--
446653	--	--	--	--
446655	--	--	--	--
446659	--	--	--	--
446661	--	--	--	--
446669	--	--	--	--

[UNNAMED STREET] DIRECTION: SEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
5565	--	--	--	--
18850	--	--	--	--
22663	--	--	--	--
23723	--	--	--	--
44509	--	--	--	--
66976	--	--	--	--
66977	--	--	--	--
66978	--	--	--	--
66979	--	--	--	--
66994	--	--	--	--
67012	--	--	--	--
67013	--	--	--	--
67016	--	--	--	--
67812	--	--	--	--
71840	--	--	--	--
100961	--	--	--	--
100962	--	--	--	--
100963	--	--	--	--
100972	--	--	--	--
100995	--	--	--	--
101017	--	--	--	--
101018	--	--	--	--
101029	2	7.3	0.1	2.3
101030	1	28.0	0.0	8.3
101033	2	26.4	0.1	7.8
101034	2	3.6	0.0	1.3
101038	1	4.5	0.0	1.5
101043	--	--	--	--
101048	--	--	--	--
101065	--	--	--	--
101066	--	--	--	--
101067	--	--	--	--
182630	--	--	--	--
182631	--	--	--	--
182632	--	--	--	--
182633	--	--	--	--

[UNNAMED STREET] DIRECTION: SEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
182690	--	--	--	--
182691	--	--	--	--
182692	--	--	--	--
182701	--	--	--	--
182702	--	--	--	--
182703	--	--	--	--
182704	--	--	--	--
182705	--	--	--	--
182706	--	--	--	--
182707	--	--	--	--
182708	--	--	--	--
183744	--	--	--	--
183745	--	--	--	--
183747	--	--	--	--
183749	--	--	--	--
183751	--	--	--	--
183752	--	--	--	--
183782	--	--	--	--
183787	--	--	--	--
183788	--	--	--	--
183807	--	--	--	--
183808	--	--	--	--
183811	--	--	--	--
183852	--	--	--	--
183853	--	--	--	--
183854	--	--	--	--
183912	--	--	--	--
183913	--	--	--	--
183945	--	--	--	--
183946	--	--	--	--
183947	--	--	--	--
184012	--	--	--	--
184020	--	--	--	--
184343	--	--	--	--
184761	--	--	--	--
184764	--	--	--	--
184765	--	--	--	--
184766	--	--	--	--
185622	--	--	--	--
186893	--	--	--	--
186894	--	--	--	--
186895	--	--	--	--
189464	--	--	--	--
189465	--	--	--	--
189566	--	--	--	--
189567	--	--	--	--
189568	--	--	--	--

[UNNAMED STREET] DIRECTION: SEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
189572	--	--	--	--
189573	--	--	--	--
189574	--	--	--	--
189575	--	--	--	--
189577	--	--	--	--
189578	--	--	--	--
189579	--	--	--	--
189598	--	--	--	--
189602	--	--	--	--
189603	--	--	--	--
189612	--	--	--	--
189650	--	--	--	--
190859	--	--	--	--
190862	--	--	--	--
190865	--	--	--	--
190867	--	--	--	--
191697	--	--	--	--
192496	--	--	--	--
192507	--	--	--	--
192508	--	--	--	--
192511	--	--	--	--
192512	--	--	--	--
192882	--	--	--	--
192923	--	--	--	--
192927	--	--	--	--
193341	--	--	--	--
194320	--	--	--	--
194321	--	--	--	--
194322	--	--	--	--
194764	--	--	--	--
194765	--	--	--	--
194766	--	--	--	--
194767	--	--	--	--
194768	--	--	--	--
194871	--	--	--	--
194933	--	--	--	--
194934	--	--	--	--
194935	--	--	--	--
194940	--	--	--	--
194941	--	--	--	--
194942	--	--	--	--
194943	--	--	--	--
194950	--	--	--	--
194986	--	--	--	--
195118	--	--	--	--
195119	--	--	--	--
195124	--	--	--	--

[UNNAMED STREET] DIRECTION: SEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
195125	--	--	--	--
195130	--	--	--	--
195134	--	--	--	--
195137	--	--	--	--
195138	--	--	--	--
195142	--	--	--	--
195143	--	--	--	--
195145	--	--	--	--
195573	--	--	--	--
195728	--	--	--	--
195729	--	--	--	--
195730	--	--	--	--
195731	--	--	--	--
195733	--	--	--	--
195734	--	--	--	--
196088	--	--	--	--
196106	--	--	--	--
196148	--	--	--	--
196152	--	--	--	--
196165	--	--	--	--
196986	--	--	--	--
196987	--	--	--	--
196988	--	--	--	--
196989	--	--	--	--
197580	--	--	--	--
200056	--	--	--	--
200057	--	--	--	--
205827	--	--	--	--
205834	--	--	--	--
205837	--	--	--	--
205840	--	--	--	--
205900	--	--	--	--
210572	--	--	--	--
210586	--	--	--	--
210644	--	--	--	--
210645	--	--	--	--
210649	--	--	--	--
210650	--	--	--	--
218033	--	--	--	--
218058	--	--	--	--
218059	--	--	--	--
218062	--	--	--	--
220756	--	--	--	--
221353	--	--	--	--
222456	--	--	--	--
223291	--	--	--	--
223292	--	--	--	--

[UNNAMED STREET] DIRECTION: SEB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
223293	--	--	--	--
223294	--	--	--	--
223295	--	--	--	--
223296	--	--	--	--
223459	--	--	--	--
223652	--	--	--	--
225031	--	--	--	--
227788	--	--	--	--
227789	--	--	--	--
229047	--	--	--	--
245038	--	--	--	--
245054	--	--	--	--
245060	--	--	--	--
245289	--	--	--	--
257984	--	--	--	--
260105	2	200.3	0.0	57.8
260113	--	--	--	--
261097	--	--	--	--
266069	--	--	--	--
295196	--	--	--	--
299115	--	--	--	--
321715	--	--	--	--
350147	--	--	--	--
360582	--	--	--	--
360583	--	--	--	--
360585	--	--	--	--
360586	--	--	--	--
360588	--	--	--	--
360668	--	--	--	--
360669	--	--	--	--
363061	--	--	--	--
363094	--	--	--	--
363095	--	--	--	--
363096	--	--	--	--
363101	--	--	--	--
363102	--	--	--	--
363174	--	--	--	--
363177	--	--	--	--
363178	--	--	--	--
364279	--	--	--	--
369667	--	--	--	--
369668	--	--	--	--
370342	--	--	--	--
371619	--	--	--	--
371757	--	--	--	--
371885	--	--	--	--
372156	--	--	--	--

[UNNAMED STREET] **DIRECTION: SEB**

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
377046	2	3.3	0.1	1.2
377475	--	--	--	--
378316	--	--	--	--
378317	--	--	--	--
382225	--	--	--	--
383904	--	--	--	--
385147	--	--	--	--
399383	--	--	--	--
399414	--	--	--	--
401248	--	--	--	--
401250	--	--	--	--
403821	--	--	--	--
408348	--	--	--	--
412753	--	--	--	--
413282	--	--	--	--
413329	--	--	--	--
413331	2	39.4	0.1	11.5
413726	--	--	--	--
413727	--	--	--	--
415358	--	--	--	--
415359	--	--	--	--
415362	--	--	--	--
415363	--	--	--	--
415364	--	--	--	--
415997	--	--	--	--
415998	--	--	--	--
416277	--	--	--	--
416278	--	--	--	--
416279	--	--	--	--
416280	--	--	--	--
416529	--	--	--	--
416530	--	--	--	--
416531	--	--	--	--
445592	--	--	--	--
446470	--	--	--	--
446474	--	--	--	--
446585	--	--	--	--
446586	--	--	--	--
446590	--	--	--	--
446592	--	--	--	--
446593	--	--	--	--
446595	--	--	--	--
446602	--	--	--	--

[UNNAMED STREET] DIRECTION: SWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
5565	--	--	--	--
5566	--	--	--	--
12243	--	--	--	--
22206	--	--	--	--
42246	--	--	--	--
43536	--	--	--	--
43537	--	--	--	--
67003	--	--	--	--
67005	--	--	--	--
67006	--	--	--	--
74097	--	--	--	--
100587	2	5.8	0.1	1.9
100590	2	8.3	0.0	2.6
100591	2	23.7	0.0	7.0
100699	2	3.8	0.1	1.3
100750	2	178.2	0.0	51.4
182658	--	--	--	--
182659	--	--	--	--
182694	--	--	--	--
183385	--	--	--	--
183742	--	--	--	--
183772	--	--	--	--
183779	--	--	--	--
183798	--	--	--	--
183805	--	--	--	--
183806	--	--	--	--
183814	--	--	--	--
183815	--	--	--	--
183816	--	--	--	--
183817	--	--	--	--
183824	--	--	--	--
183826	--	--	--	--
183831	--	--	--	--
183832	--	--	--	--
183833	--	--	--	--
183834	--	--	--	--
183856	--	--	--	--
183875	--	--	--	--
183895	--	--	--	--
183927	--	--	--	--
183928	--	--	--	--
183941	--	--	--	--
183942	--	--	--	--
183961	--	--	--	--
183970	--	--	--	--
183971	--	--	--	--
183975	--	--	--	--

[UNNAMED STREET] DIRECTION: SWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
184466	--	--	--	--
184467	--	--	--	--
184468	--	--	--	--
184469	--	--	--	--
184470	--	--	--	--
184471	--	--	--	--
184472	--	--	--	--
184473	--	--	--	--
186560	--	--	--	--
186561	--	--	--	--
186562	--	--	--	--
186565	--	--	--	--
187742	--	--	--	--
188918	--	--	--	--
188919	1	6.8	0.0	1.9
189563	--	--	--	--
189570	--	--	--	--
189641	--	--	--	--
189647	--	--	--	--
189649	--	--	--	--
191230	--	--	--	--
191232	--	--	--	--
191309	--	--	--	--
191310	--	--	--	--
191358	--	--	--	--
191365	--	--	--	--
191367	--	--	--	--
191431	--	--	--	--
191432	2	51.8	0.0	15.1
191521	--	--	--	--
191533	--	--	--	--
191567	--	--	--	--
192214	--	--	--	--
192490	--	--	--	--
192491	--	--	--	--
192492	--	--	--	--
192887	--	--	--	--
192888	--	--	--	--
193610	--	--	--	--
193611	--	--	--	--
194171	--	--	--	--
194195	2	7.1	0.1	2.2
194202	2	94.8	0.0	27.4
195538	--	--	--	--
195561	--	--	--	--
195562	--	--	--	--
195563	--	--	--	--

[UNNAMED STREET] DIRECTION: SWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
195570	--	--	--	--
195685	--	--	--	--
195687	--	--	--	--
195720	--	--	--	--
195725	--	--	--	--
195835	--	--	--	--
195842	--	--	--	--
195937	--	--	--	--
197073	--	--	--	--
197574	2	6.6	0.0	2.1
197576	2	82.1	0.0	23.8
197577	2	114.9	0.1	33.2
197605	--	--	--	--
197610	2	3.5	0.0	1.2
204273	--	--	--	--
204274	--	--	--	--
207343	--	--	--	--
209555	--	--	--	--
214530	--	--	--	--
220179	--	--	--	--
220180	--	--	--	--
220181	--	--	--	--
220183	--	--	--	--
220184	--	--	--	--
220185	--	--	--	--
220187	--	--	--	--
220188	--	--	--	--
220231	--	--	--	--
221390	--	--	--	--
221392	--	--	--	--
221414	--	--	--	--
221418	--	--	--	--
222394	--	--	--	--
222540	--	--	--	--
222541	--	--	--	--
223744	--	--	--	--
223745	--	--	--	--
223746	--	--	--	--
223750	--	--	--	--
224959	--	--	--	--
224966	--	--	--	--
224970	--	--	--	--
247601	--	--	--	--
247602	--	--	--	--
257632	--	--	--	--
261585	--	--	--	--
263624	--	--	--	--

[UNNAMED STREET] DIRECTION: SWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
263625	--	--	--	--
278077	--	--	--	--
278078	--	--	--	--
283432	--	--	--	--
295079	--	--	--	--
295080	--	--	--	--
295081	--	--	--	--
295082	--	--	--	--
295087	--	--	--	--
296186	--	--	--	--
296188	--	--	--	--
296190	--	--	--	--
296193	--	--	--	--
299135	2	13.2	0.0	4.5
312643	--	--	--	--
313105	--	--	--	--
313108	--	--	--	--
315365	--	--	--	--
315522	--	--	--	--
315523	--	--	--	--
321783	--	--	--	--
331908	--	--	--	--
331978	--	--	--	--
361556	--	--	--	--
361560	--	--	--	--
361561	--	--	--	--
361570	--	--	--	--
361571	--	--	--	--
365522	--	--	--	--
365526	--	--	--	--
365527	--	--	--	--
371385	--	--	--	--
371471	--	--	--	--
371834	--	--	--	--
371835	--	--	--	--
376993	2	50.6	0.0	14.7
377318	--	--	--	--
379711	--	--	--	--
379720	--	--	--	--
379721	--	--	--	--
379722	--	--	--	--
379723	--	--	--	--
381573	--	--	--	--
385148	--	--	--	--
394508	--	--	--	--
400546	--	--	--	--
400547	--	--	--	--

[UNNAMED STREET] DIRECTION: SWB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
401935	--	--	--	--
403671	1	40.1	0.0	11.7
403678	--	--	--	--
403857	--	--	--	--
405729	--	--	--	--
405923	--	--	--	--
405928	--	--	--	--
405929	--	--	--	--
406011	--	--	--	--
406014	--	--	--	--
408351	--	--	--	--
411404	--	--	--	--
415351	--	--	--	--
416273	2	31.7	0.0	9.4
416274	2	72.1	0.0	20.9
416275	2	27.2	0.0	8.0
416518	--	--	--	--
416519	--	--	--	--
416532	--	--	--	--
416533	--	--	--	--
416534	--	--	--	--
432688	--	--	--	--
445262	--	--	--	--
445263	--	--	--	--
446476	--	--	--	--
446488	--	--	--	--
446489	--	--	--	--
446493	--	--	--	--
446505	--	--	--	--
446506	--	--	--	--
446583	--	--	--	--
446588	--	--	--	--
446589	--	--	--	--
446594	--	--	--	--
446596	--	--	--	--
446597	--	--	--	--
446604	--	--	--	--
446605	--	--	--	--
446611	--	--	--	--
446618	--	--	--	--
446634	--	--	--	--
446665	--	--	--	--

[UNNAMED STREET] DIRECTION: WB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
13545	--	--	--	--

[UNNAMED STREET] DIRECTION: WB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
22662	--	--	--	--
25782	--	--	--	--
39885	--	--	--	--
42269	--	--	--	--
42272	--	--	--	--
43535	--	--	--	--
66978	--	--	--	--
67473	--	--	--	--
100759	--	--	--	--
100760	--	--	--	--
100763	--	--	--	--
101044	2	5.0	0.0	1.6
101045	2	35.0	0.0	10.9
182724	--	--	--	--
183736	--	--	--	--
183737	--	--	--	--
183738	--	--	--	--
183741	--	--	--	--
183744	--	--	--	--
183746	--	--	--	--
183773	--	--	--	--
183778	--	--	--	--
183783	--	--	--	--
183786	--	--	--	--
183797	--	--	--	--
183827	--	--	--	--
183828	--	--	--	--
183829	--	--	--	--
183830	--	--	--	--
183835	--	--	--	--
183836	--	--	--	--
183837	--	--	--	--
183857	--	--	--	--
183860	--	--	--	--
183863	--	--	--	--
183864	--	--	--	--
183867	--	--	--	--
183868	--	--	--	--
183877	--	--	--	--
183890	1,914	9.0	1.1	2.7
183891	1,904	40.3	4.0	11.4
183893	--	--	--	--
183894	--	--	--	--
183895	--	--	--	--
183906	1,879	10.1	1.0	4.7
183922	--	--	--	--
183992	1,907	6.4	0.6	2.4

[UNNAMED STREET] DIRECTION: WB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
184343	--	--	--	--
184344	--	--	--	--
185613	--	--	--	--
185614	--	--	--	--
189565	--	--	--	--
189584	--	--	--	--
189585	--	--	--	--
189652	1,445	469.4	25.6	179.9
190861	888	114.0	11.3	41.6
190868	885	5.0	0.5	2.0
190872	807	374.2	30.4	139.1
191224	--	--	--	--
191227	--	--	--	--
191228	--	--	--	--
191282	--	--	--	--
191359	--	--	--	--
191428	2	28.6	0.0	8.4
191545	--	--	--	--
191546	--	--	--	--
191549	--	--	--	--
191551	--	--	--	--
191552	--	--	--	--
191557	--	--	--	--
191566	--	--	--	--
191569	--	--	--	--
191570	--	--	--	--
191573	--	--	--	--
191574	--	--	--	--
191695	--	--	--	--
191704	--	--	--	--
191705	--	--	--	--
191706	--	--	--	--
193645	710	7.8	1.0	2.5
193647	710	2.2	0.3	0.9
194175	--	--	--	--
194203	2	3.1	0.0	1.2
194237	--	--	--	--
194240	--	--	--	--
194242	--	--	--	--
194243	--	--	--	--
194488	--	--	--	--
194489	--	--	--	--
195124	--	--	--	--
195573	--	--	--	--
195575	--	--	--	--
195576	--	--	--	--
195577	--	--	--	--

[UNNAMED STREET] DIRECTION: WB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
195717	--	--	--	--
195718	--	--	--	--
195936	--	--	--	--
196106	--	--	--	--
196535	--	--	--	--
196545	--	--	--	--
196546	--	--	--	--
196548	--	--	--	--
206384	2	2.4	0.0	0.9
206385	2	12.9	0.0	3.9
209551	--	--	--	--
209559	--	--	--	--
209560	--	--	--	--
209561	--	--	--	--
221353	--	--	--	--
224960	--	--	--	--
224964	--	--	--	--
225032	--	--	--	--
226213	--	--	--	--
226911	--	--	--	--
236850	--	--	--	--
236851	--	--	--	--
237396	--	--	--	--
260110	--	--	--	--
260117	--	--	--	--
261096	--	--	--	--
266067	714	34.1	28.3	20.6
266068	2	8.6	0.1	2.8
283433	--	--	--	--
296289	--	--	--	--
360589	1,911	33.3	3.2	11.3
363063	2	13.6	0.1	4.2
363164	--	--	--	--
364195	--	--	--	--
370676	--	--	--	--
371531	--	--	--	--
371532	--	--	--	--
371906	--	--	--	--
371985	--	--	--	--
371986	--	--	--	--
376991	2	53.4	0.1	15.6
377045	780	115.4	8.8	43.5
378317	--	--	--	--
381014	--	--	--	--
385979	--	--	--	--
385980	--	--	--	--
394225	--	--	--	--

[UNNAMED STREET] DIRECTION: WB

Segment ID	Number of Vehicles	Average Travel Time (sec)	Std Dev Travel Time (sec)	Average Delay (sec/veh)
394226	--	--	--	--
400542	--	--	--	--
400543	--	--	--	--
401245	886	3.1	0.3	1.4
405803	--	--	--	--
408361	--	--	--	--
408593	--	--	--	--
408600	--	--	--	--
415349	--	--	--	--
415350	--	--	--	--
416276	2	54.8	0.1	15.9
416299	--	--	--	--
445592	--	--	--	--
446468	1,919	0.8	0.1	0.5
446471	1,883	48.1	4.1	16.6
446472	--	--	--	--
446478	1,894	86.3	7.0	29.3
446479	--	--	--	--
446515	1,919	5.1	0.5	2.5
446582	--	--	--	--
446610	--	--	--	--
446612	--	--	--	--
446614	--	--	--	--
446619	1,921	1.4	0.1	0.9
446622	1,922	1.3	0.1	0.9
446623	1,900	30.1	2.9	10.4
446628	--	--	--	--
446633	--	--	--	--
446660	--	--	--	--