Measures Estimation Software User Manual

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# Introduction

The Measures Estimation (ME) Software is designed to test the effectiveness of different connected vehicle messaging strategies in estimating key transportation measures.The ME modules read in and use Basic Safety Messages (BSMs), Probe Data Messages (PDMs) or any other messaging protocol, and specialized network definitions to produce a series of transportation measure estimations. The key measures that are estimated using this software are: Queues, Cycle Failures, Shockwaves, Travel Time, Delay and Space Mean Speed. The ME modules were programmed in open source Python programming language (<http://www.python.org>) and are protected under the Apache License Version 2 license agreement (<http://www.apache.org/licenses/LICENSE-2.0>).

# Installation and Running the Measures Estimation Programs

To install the Measures Estimation modules you must have Python version 2.7.5 or later installed on your computer, but has not been tested with Python versions 3 and higher. Python is available at no charge from <http://www.python.org/download/releases/2.7.5>. Python runs in Windows, Linux and Mac operating environments and does not have any prerequisites to install.

The Measures Estimation programs also rely on the free external Python libraries Pandas, Numpy, Dateutil, and SciPy. These will need to be installed as well for Python version 2.7.5. These external Python libraries can be found at the following locations:

* Pandas - <http://pandas.pydata.org/>
* Numpy - <http://www.numpy.org/>
* Dateutil - <http://labix.org/python-dateutil>
* SciPy - http://sourceforge.net/projects/scipy/files/scipy/

Also many Python Windows binary files for the libraries can be downloaded from the Unofficial Windows Binaries for Python Extension Packages Website (<http://www.lfd.uci.edu/~gohlke/pythonlibs/>)

Once Python and the additional libraries are installed there are eight Measures Estimation programs that you can run from the command line. Each has their own separate inputs and command line function to execute them.

First is the program for queues at known bottleneck locations. To run this program you need a messages file and a bottlenecks input file. To run from the command line write:

python ME\_Queue.py [messages filename] [bottlenecks filename] --out [output name]

For all modules there is an option to define your own output file name adding --out [output name] to the end of the command as you see in the example. Otherwise a default filename specific to that program will be used.

Second is the program for queues at unknown bottleneck locations. To run this program you need a trajectorites file and a Queue/Shockwaves superlinks input file. To run from the command line write:

python ME\_UnknownQueue.py [messages filename] [superlinks filename] --out [output name]

Third is the program for route based travel time using BSM. To run this program you need a non-PDM messages file, a routes input file, a full routes input file, a link lengths input file and a link endpoints input file. To run from the command line write:

python TravelTime\_BSM.py [BSM filename] [routes filename] [full routes filename] [link positions filename] [link lengths filename] [simulation seconds] --out [output name]

Simulation seconds is the cutoff time in seconds for finding average travel times.

Fourth is the program for route based travel time using PDM. To run this program you need a PDM messages file, a routes input file, a full routes input file, a link lengths input file and a link endpoints input file. To run from the command line write:

python ME\_TravelTime\_PDM.py [PDM filename] [routes filename] [full routes filename] [link positions filename] [link lengths filename] [simulation seconds] --out [output name]

Running Travel Time for superlinks instead of routes (to use as input for the Speed program) requires using a Travel Time superlinks input file rather than the routes input file, a downstream superlinks file and using two new modules. To run a non-PDM based Superlink Travel Time from the command line you would write:

python TravelTime\_BSM\_Superlinks.py [BSM filename] [routes filename] [full routes filename] [link positions filename] [link lengths filename] [downstream superlink filename] [simulation seconds] --out [output name]

And to run a PDM based Superlink Travel Time from the command line you would write:

python TravelTime\_PDM\_Superlinks.py [PDM filename] [routes filename] [full routes filename] [link positions filename] [link lengths filename] [downstream superlink filename] [simulation seconds] --out [output name]

The fifth program is Cycle Failures which requires a messages file, a bottlenecks input file, a signal controllers input file, a cycletimes input file, a link endpoints input file, a link length input file, a full routes input file and a downstream superlinks input file. To run from the command line you would write:

python ME\_CycleFailures.py [BSM/PDM filename] [bottleneck filename] [signal controllers filename] [cycletimes file] [link positions filename] [link lengths filename] [downstream superlink filename] [BSM/PDM] [last time step] --out [output name]

The BSM/PDM flag indicates whether the file contains BSMs or PDMs for file reading purposes. If it is neither, the file reading can be edited in MEFileReader.csv for all modules. Last time step is the last time there is data available for.

The sixth program is Shockwaves which requires a messages file, a Queue/Shockwaves superlinks input file and a link endpoints input file. To run from the command line you would write:

python MEShockwavesNP.py [messages filename] [superlinks filename] [link endpoints filename] [BSM/PDM] --out [output name]

The seventh program is Delay. Delay requires that you have already run ME Route Travel Time and takes the following as inputs: a ME Route Travel Time output file, a full routes input file, a link length input file and a speed limits input file. To run Delay from the command line you would write:

python ME\_Delay.py [travel time output] [full routes filename] [link lengths filename] [speed limits filename] --out [output name]

The eighth program is Space Mean Speed. Similar to Delay, Space Mean Speed requires that you have already run ME Superlinks Travel Time. It takes the following inputs: a ME Superlinks Travel Time output file, a full Travel Time superlinks input file and a link length input file. To run Speed from the command line you would write:

python ME\_Speed.py [travel time output] [full superlinks filename] [link lengths filename] --out [output name]

# Input Files

## Message File

Any message data can be used with the Measures Estimation code provided it has the required elements detailed in Table 3-1. If the message file is not generated using the TCA: Queue, Cycle Failure, Shockwave and Unknown Queue all have a File Reader module that can be edited to read the appropriate data elements. Travel Time reads the message file into a pandas database at the end of the file in the main method which can be edited to read the appropriate data elements.

Table ‑. Required Message file fields

| Parameter Name | Description | Values | |
| --- | --- | --- | --- |
| Speed | Speed [mph] at the end of the simulation step | Float (mph) |
| Acceleration | Acceleration [ft/s²] during the simulation step | Float (ft/s2) |
| Simulation Time (t) | Seconds from the beginning of the simulation | Float (seconds) |
| X-Coordinate | X Coordinate (vehicle front end at the end of the simulation step) | Float (meters) |
| Y-Coordinate | Y Coordinate (vehicle front end at the end of the simulation step) | Float (meters) |
| Link | Identifier for roadway segment vehicle is travelling on | Integer |

## Bottlenecks File

This is a file of the superlinks and lane\_groups immediately after a signalized intersection or stop sign, going back until the previous intersection. The Bottlenecks file has the structure outlined in Table 3‑2 and an example is shown in Figure 3‑2.

Table ‑: Bottlenecks file fields

| Element | Description | Values |
| --- | --- | --- |
| superlink\_name | The road name for a collection of roadway segments.  NOTE: Each superlink\_name should be unique. | Character String |
| lane\_group | Measures Estimation does not resolve to lane level, this is a place holder to more accurately match Ground Truth output. | Character String |
| stopbar\_x | The x or latitudinal position in feet of the location where vehicles begin queuing on the bottleneck. | Integer (ft) |
| stopbar\_y | The y or longitudinal position in feet of the location where vehicles begin queuing on the bottleneck. | Integer (ft) |
| link\_end\_x | The x or latitudinal position in feet of the location where the roadway ends.  NOTE: This is intended to capture vehicles that have queued slightly past the stopbar location. | Integer (ft) |
| link\_end\_y | The y or longitudinal position in feet of the location where vehicles begin queuing on the bottleneck. | Integer (ft) |
| link\_number | Unique identifier for each roadway segment that makes up the superlink.  NOTE: link\_number, lane\_number, link\_length is repeated in that order for each roadway segment in the superlink | Integer |
| lane\_number | Unique identifier for each lane in the given roadway segment. Each link\_number, lane\_number pair should be unique. | Integer |
| link\_length | The length of the given roadway segment in feet. | Float |

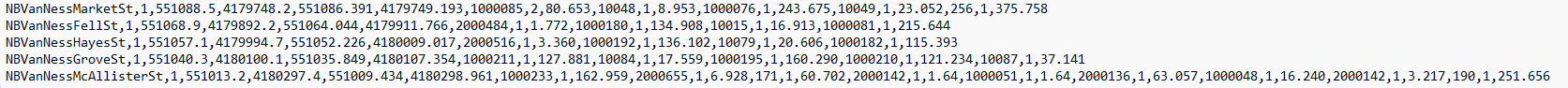


Figure ‑: Bottlenecks File example

## Queue/Shockwaves Superlinks File

The Queue/Shockwaves Superlinks file has the structure outlined in Table 3-3 and an example is shown in Figure 3-3. The Queue/Shockwaves file should cover the entire network where Unknown Queues or Shockwaves are being searched for.

Table ‑: Queue/Shockwaves Superlinks file fields

| Element | Description | Values |
| --- | --- | --- |
| superlink\_name | The road name for a collection of roadway segments.  NOTE: Each superlink\_name should be unique. | Character String |
| lane\_group | Measures Estimation does not resolve to lane level, this is a place holder to make output look similar to Ground Truth output. | Character String |
| link\_end\_x | The x or latitudinal position in feet of the location where the roadway ends. | Integer (ft) |
| link\_end\_y | The y or longitudinal position in feet of the location where vehicles begin queuing on the bottleneck. | Integer (ft) |
| link\_number | Unique identifier for each roadway segment that makes up the superlink.  NOTE: link\_number, lane\_number, link\_length is repeated in that order for each roadway segment in the superlink | Integer |
| lane\_number | Unique identifier for each lane in the given roadway segment. Each link\_number, lane\_number pair should be unique. | Integer |
| link\_length | The length of the given roadway segment in feet. | Float |

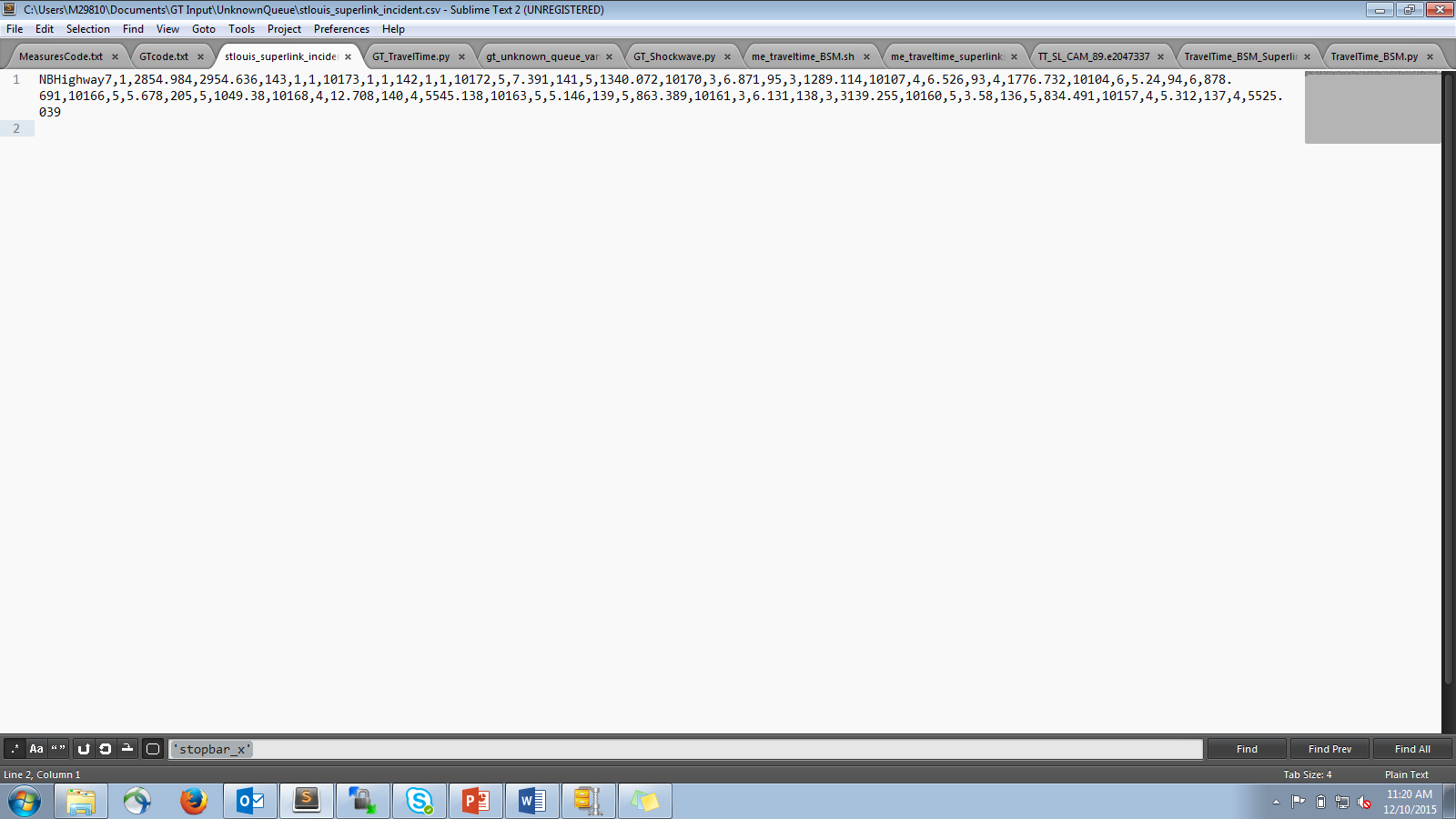


Figure ‑: Queue/Shockwave Superlinks File example

## Routes File

The Routes file has the structure outlined in Table 3-4 and an example is shown in Figure 3-4.

Table ‑: Routes file fields

| Element | Description | Values |
| --- | --- | --- |
| route\_group | A unique identifier for all routes that originate from the same point. | Character String |
| route\_num | A unique identifier for each individual route in the group.  NOTE: Each route\_group/route\_num combination should be unique and each route\_num should have a unique destination. | Character String |
| origin\_link | The roadway segment where the route starts. | Integer |
| destination\_link | The roadway segment where the route ends. | Integer |
| start\_x | The x-coordinate of the start of the route. | Float (ft) |
| start\_y | The y-coordinate of the start of the route. | Float (ft) |

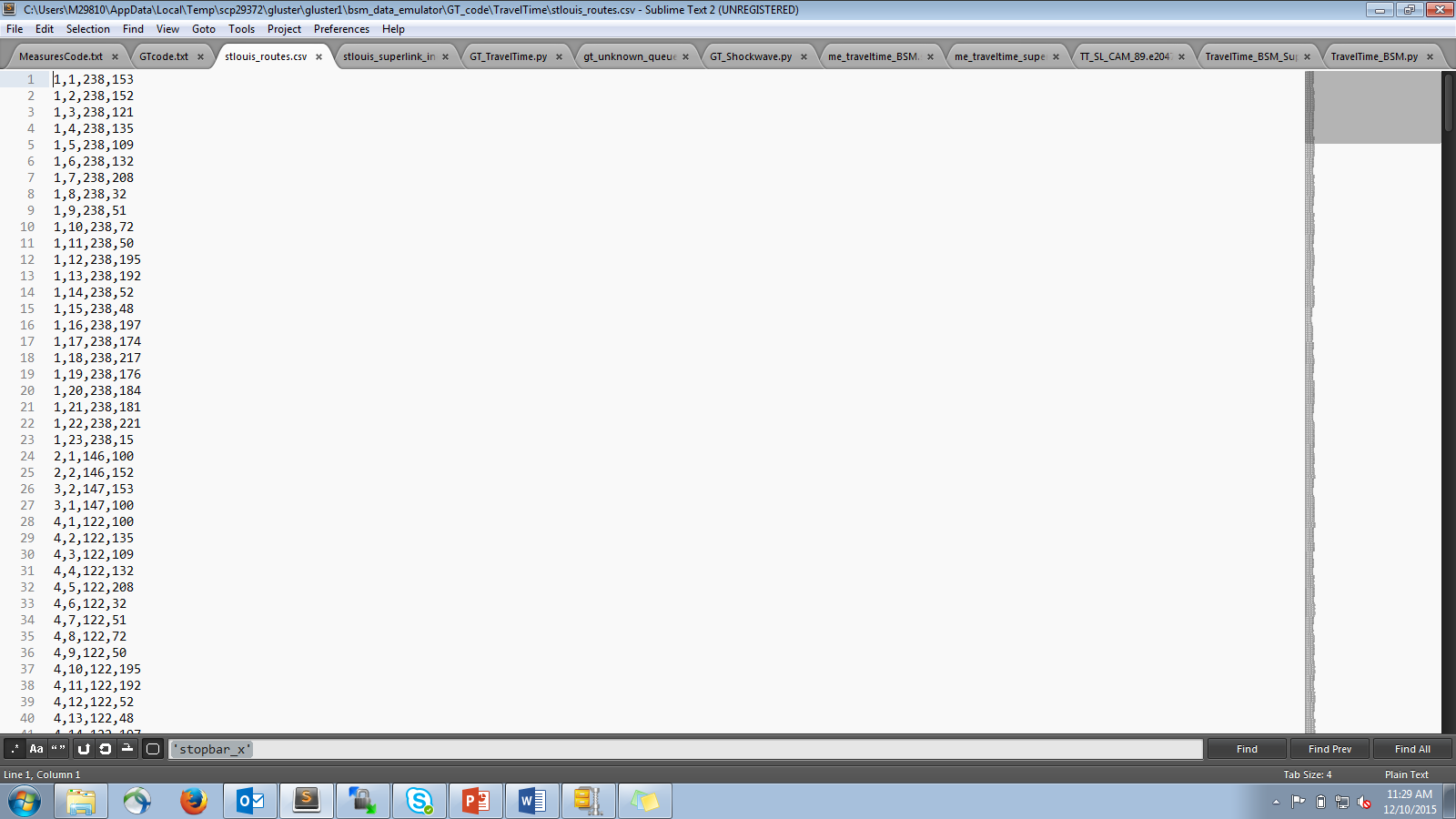


Figure ‑: Routes File example

## Link Lengths File

This is a file with every individual link on the route and its length used for reference. The Link Lengths file has the structure outlined in Table 3-5 and an example is shown in Figure 3-5.

Table ‑: Link lengths file fields

| Element | Description | Values |
| --- | --- | --- |
| link | The roadway segment | Integer |
| link\_length | The length of the link in feet | Float (ft) |

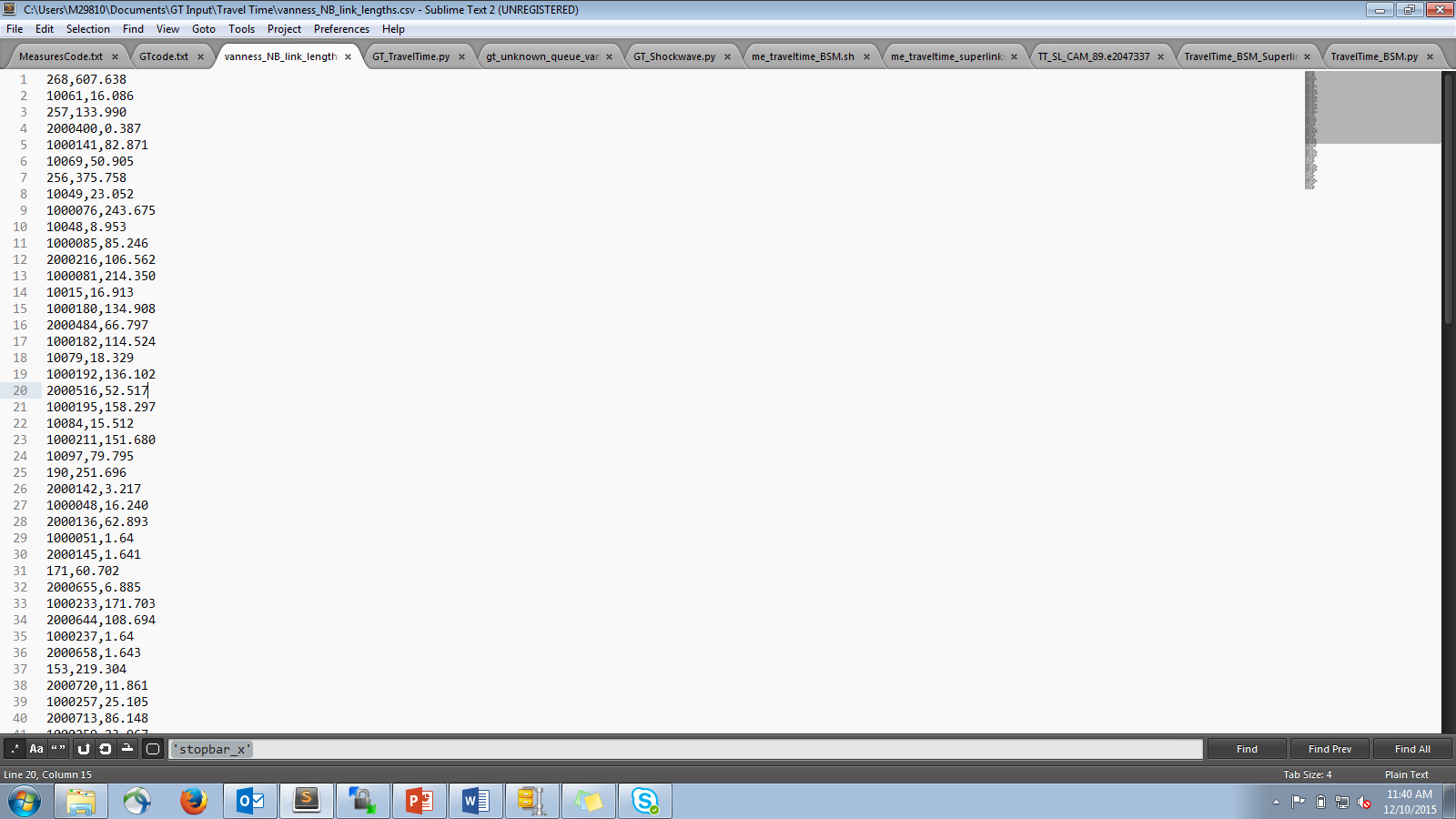


Figure ‑: Link lengths File example

## Link Endpoints File

This file is a list of each link in the route and the x,y or lat,long coordinate of the end of that link for reference. The Link Endpoints file has the structure outlined in Table 3-6 and an example is shown in Figure 3-6.

Table ‑: Link Endpoints file fields

| Element | Description | Values |
| --- | --- | --- |
| link | The roadway segment | Integer |
| x | The x or latitudinal position in feet of the location where the link ends. | Integer (ft) |
| y | The y or longitudinal position in feet of the location where the link ends. | Integer (ft) |

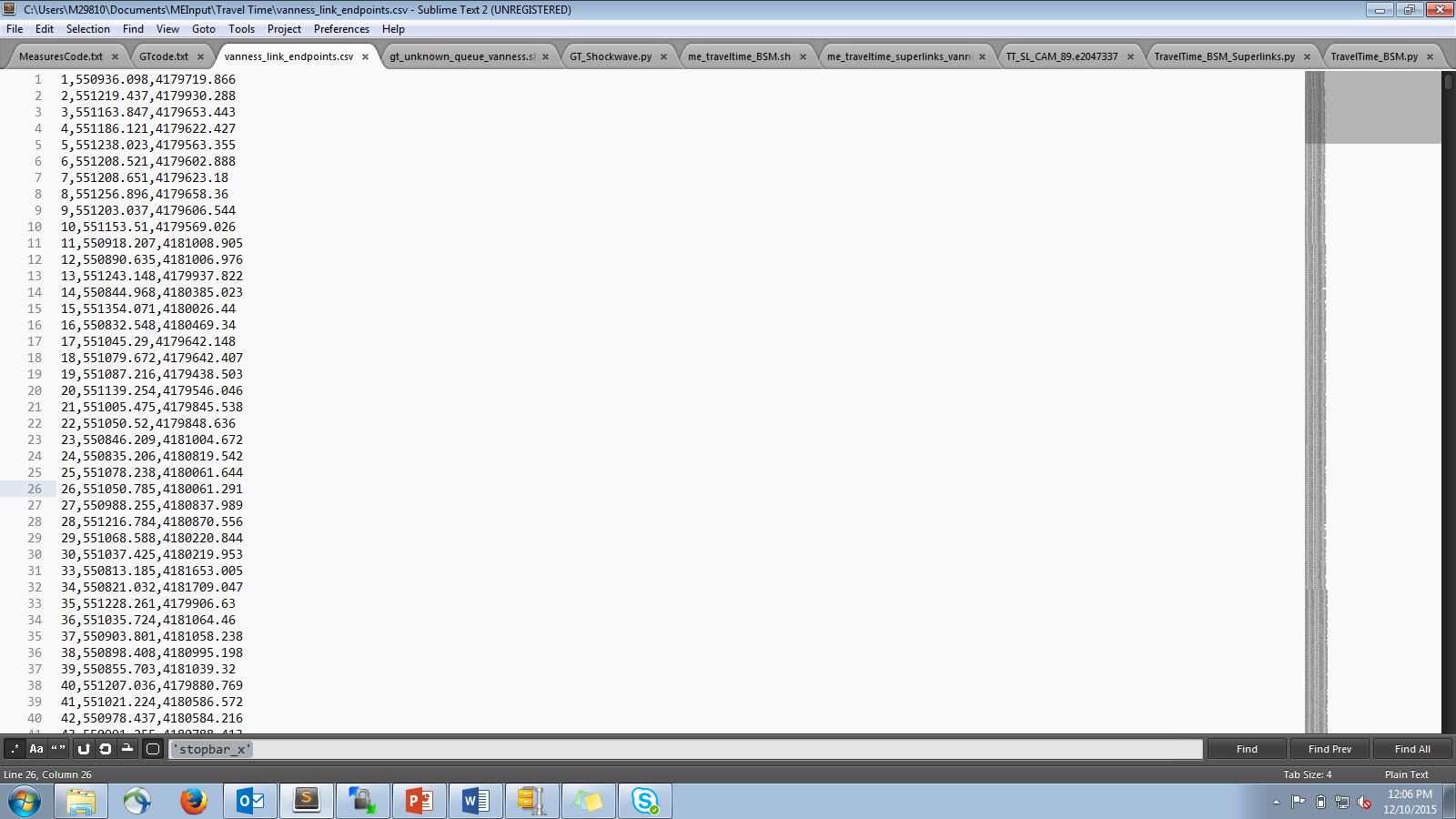


Figure ‑: Link Endpoints File example

## Travel Time Superlinks File

A Travel Time Superlinks File is identical to a Routes file, except for this time the origin link is the first link in the superlink and the destination link is the last link in the superlink rather than in the route. Superlinks for Travel Times should be divided segments of the road, rather than the entire network like a Queue/Shockwave superlink. The Travel Time Superlinks file has the structure outlined in Table 3-7 and an example is shown in Figure 3-7.

Table ‑: Travel Time Superlinks file fields

| Element | Description | Values |
| --- | --- | --- |
| superlink\_route\_group | A unique identifier for all superlink routes along the same roadway. | Character String |
| superlink\_route\_num | A unique identifier for each individual superlink route in the group.  NOTE: Each superlink\_route\_group/superlink\_route\_num combination should be unique and each should have a unique origin/destination combination. | Character String |
| superlink\_origin\_link | The roadway segment where the superlink route starts. | Integer |
| superlink\_destination\_link | The roadway segment where the superlink route ends. | Integer |
| start\_x | The x-coordinate of the start of the superlink route. | Float (ft) |
| start\_y | The y-coordinate of the start of the superlink route. | Float (ft) |

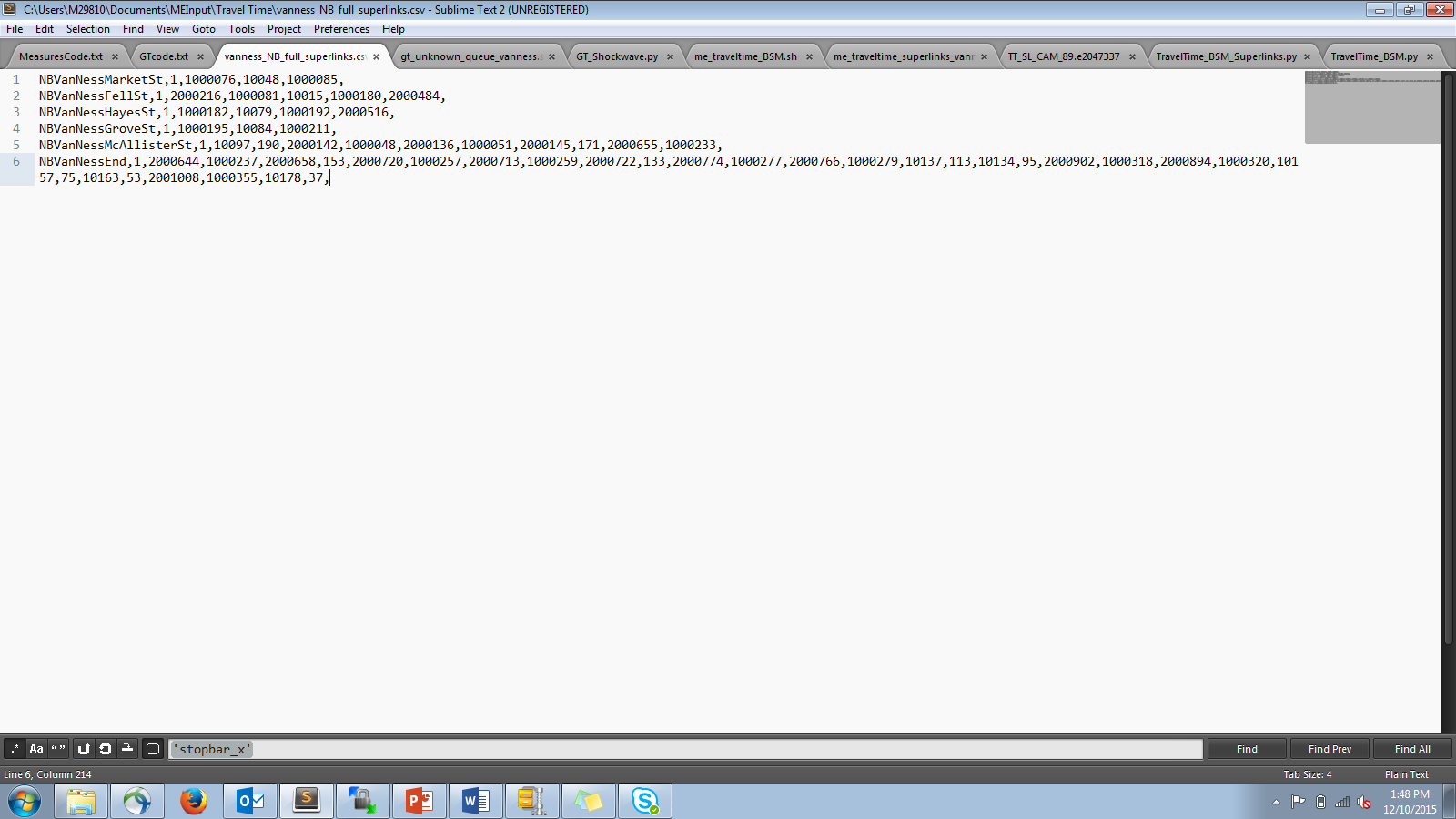


Figure ‑: Travel Time Superlinks File example

## Signal Controllers File

This maps the bottleneck identifiers to the traffic signal identifiers. The Signal Controllers file has the structure outlined in Table 3-8 and an example is shown in Figure 3-8.

Table ‑: Bottlenecks file fields

| Element | Description | Values |
| --- | --- | --- |
| superlink\_name | The road name for a collection of roadway segments.  NOTE: Each superlink\_name should be unique. | Character String |
| lane\_group | Measures Estimation does not resolve to lane level, this is a place holder to more accurately match Ground Truth output. | Character String |
| signal\_group | A unique identifier for each traffic signal at an intersection. | Character  String |
| signal\_number | A unique identifier for each specific traffic signal in the signal group.  NOTE: Each signal\_group/signal\_number pair should be unique. | Character  String |

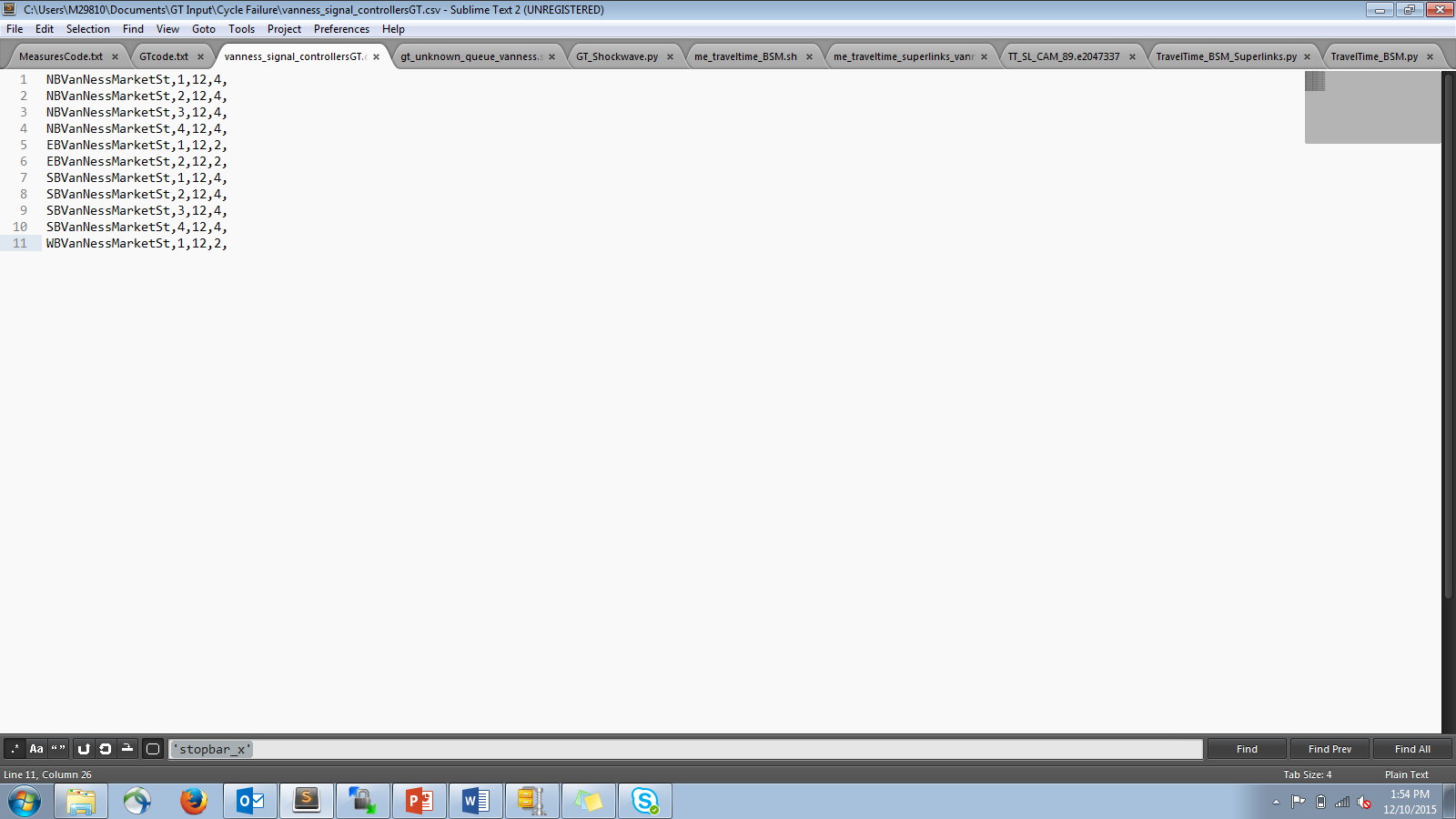


Figure ‑: Signal Controllers File example

## Cycle Times File

This file has for each traffic signal every time the light turns green and every time it turns red. The Cycle Times file has the structure outlined in Table 3-9 and an example is shown in Figure 3-9.

Table ‑: Bottlenecks file fields

| Element | Description | Values |
| --- | --- | --- |
| signal\_group | A unique identifier for each traffic signal at an intersection. | Character  String |
| signal\_number | A unique identifier for each specific traffic signal in the signal group.  NOTE: Each signal\_group/signal\_number pair should be unique. | Character  String |
| light\_color | Describes whether the light just turned green or red. | green or red |
| time | The local time when the light change occurred. | Float (secs) |

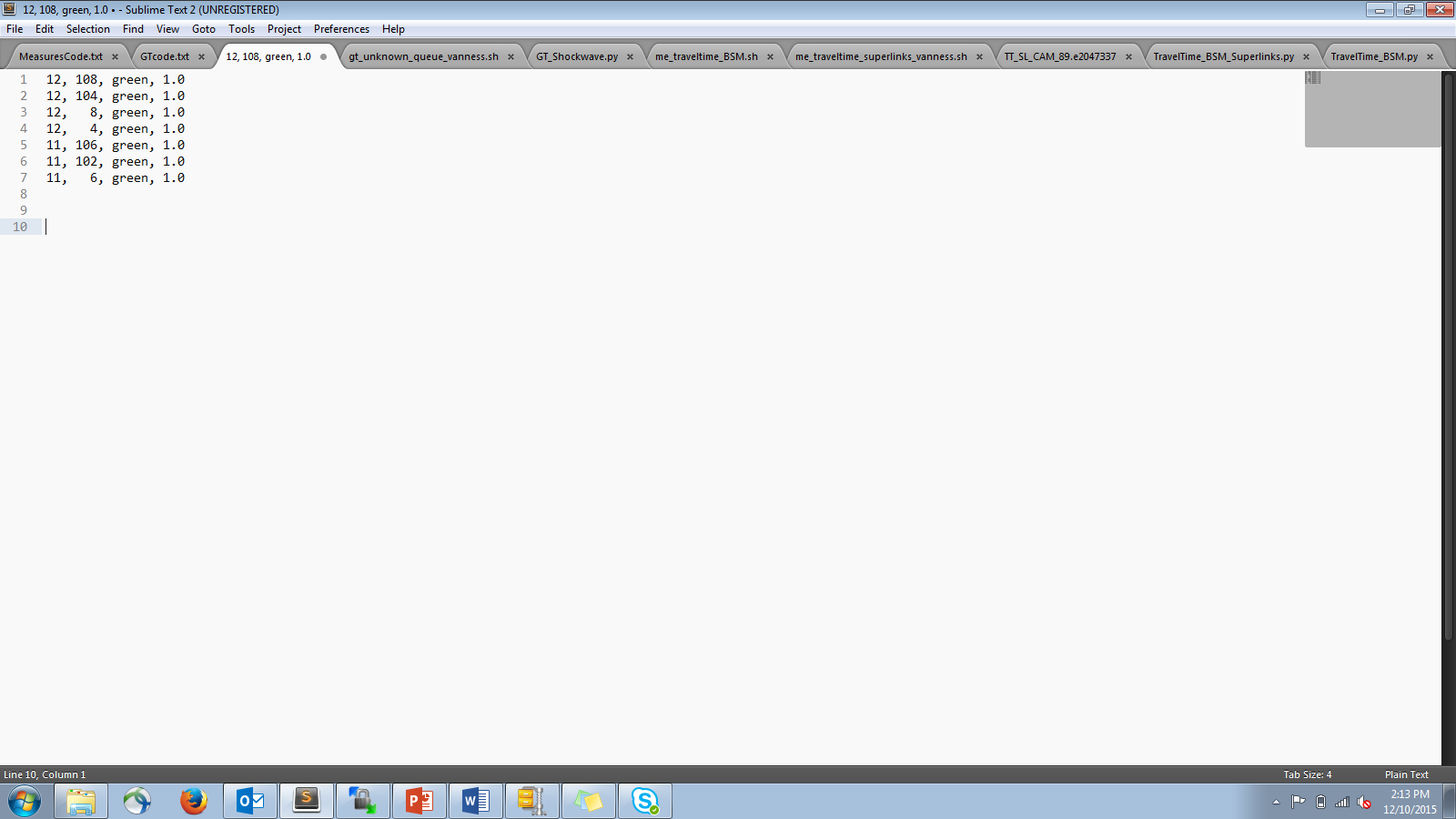


Figure ‑: Cycle Times File example

## Full Routes File

This is like the route file, but instead of just the origin and destination it has every link in the route in order from origin to destination. The Full Routes file has the structure outlined in Table 3-10 and an example is shown in Figure 3-10.

Table ‑: Full Routes file fields

| Element | Description | Values |
| --- | --- | --- |
| route\_group | A unique identifier for all routes that originate from the same point. | Character String |
| route\_num | A unique identifier for each individual route in the group.  NOTE: Each route\_group/route\_num combination should be unique and each route\_num should have a unique destination. | Character String |
| origin\_link | The roadway segment where the route starts. | Integer |
| link | Each roadway segment that makes up the route between origin\_link and destination\_link.  NOTE: This is repeated for each link until the destination\_link is reached. | Integer |
| destination\_link | The roadway segment where the route ends. | Integer |

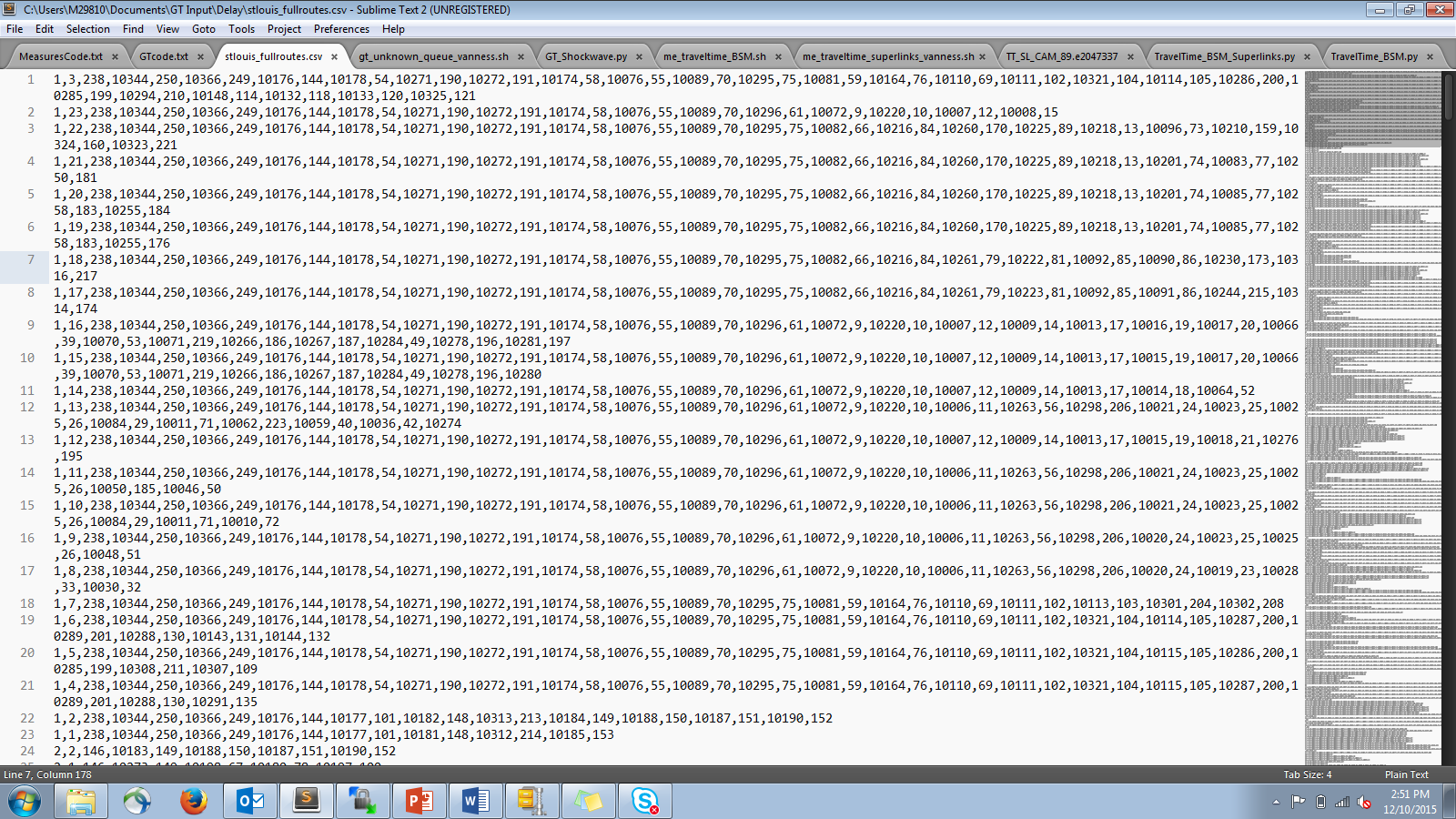


Figure ‑: Full Routes File example

## Speed Limits File

This file only needs to contain the links on any route where the speed limit changes and that new speed limit, as well as the origin link for each route and its speed limit. The Speed Limits file has the structure outlined in Table 3-11 and an example is shown in Figure 3-11.

Table ‑: Speed Limits file fields

| Element | Description | Values |
| --- | --- | --- |
| link | The roadway segment. | Integer |
| speed\_limit | The new speed limit starting at that roadway segment/ | Float (mph) |

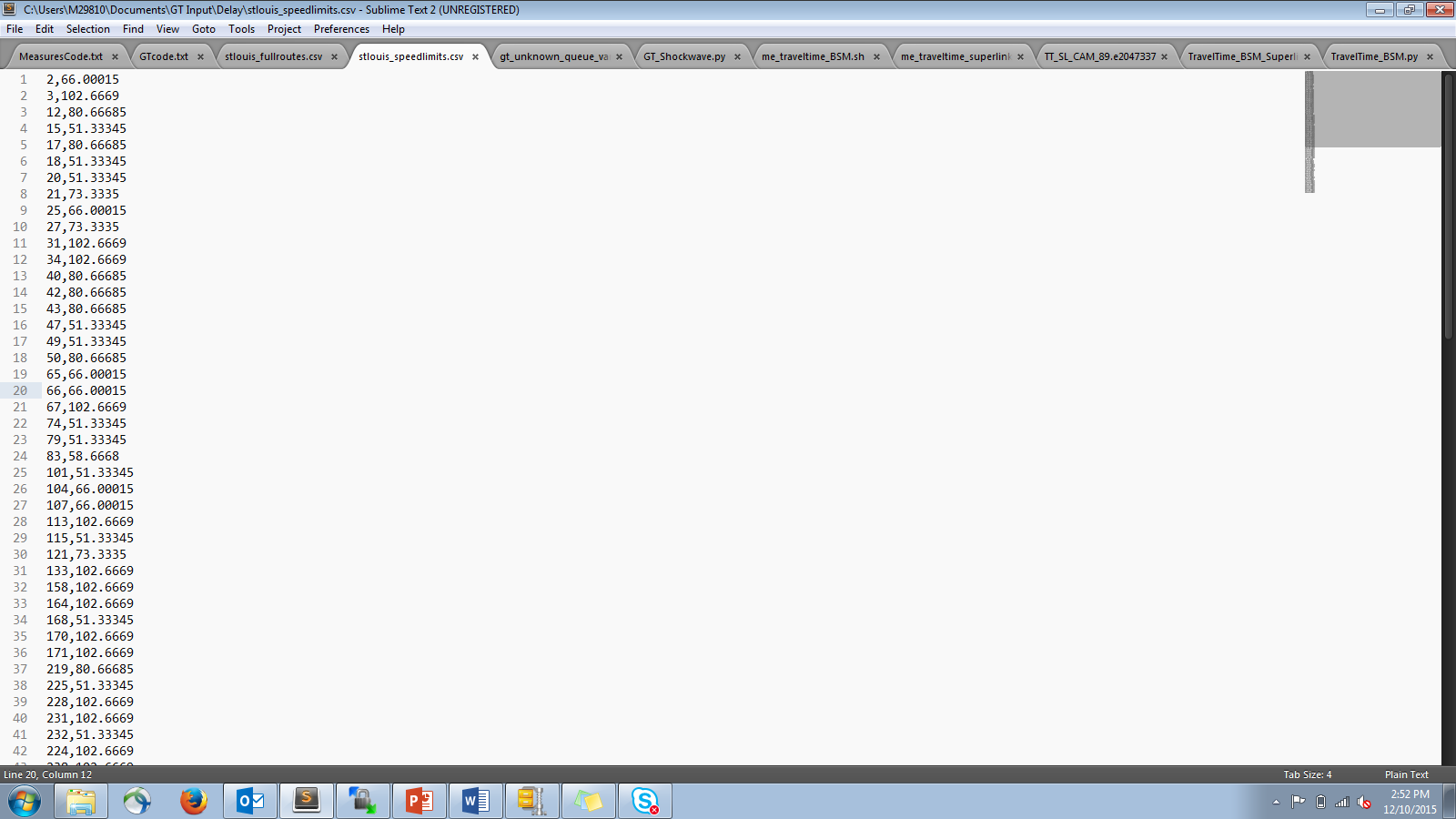


Figure ‑: Speed Limits File example

## Full Travel Time Superlinks File

Like the Travel Time Routes and Superlinks files, this is identical to the Full Routes file but for Travel Time superlinks. The Full Travel Time Superlinks file has the structure outlined in Table 3-12 and an example is shown in Figure 3‑12.

Table ‑: Full Travel Time Superlinks file fields

| Element | Description | Values |
| --- | --- | --- |
| superlink\_route\_group | A unique identifier for all superlink routes along the same roadway. | Character String |
| superlink\_route\_num | A unique identifier for each individual superlink route in the group.  NOTE: Each superlink\_route\_group/superlink\_route\_num combination should be unique and each should have a unique origin/destination combination. | Character String |
| origin\_link | The roadway segment where the superlink route starts. | Integer |
| link | Each roadway segment that makes up the superlink route between origin\_link and destination\_link.  NOTE: This is repeated for each link until the destination\_link is reached. | Integer |
| destination\_link | The roadway segment where the superlink route ends. | Integer |

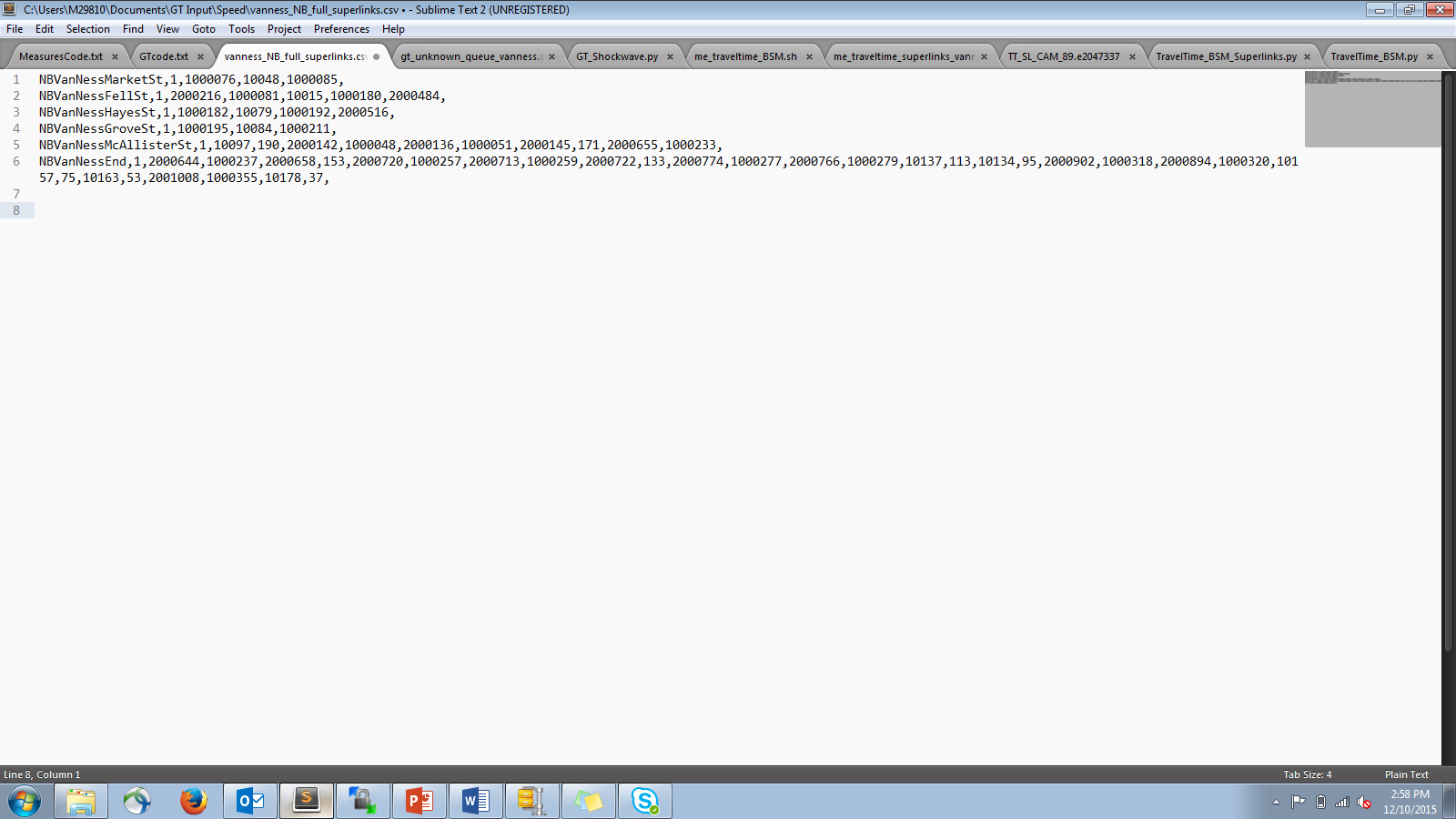


Figure ‑: Full Travel Time Superlinks File example

## Downstream Superlinks File

This file just lists the superlink that is directly downstream of the current superlink. The last superlink should be set as its own downstream superlink to prevent errors. The Downstream Superlinks file has the structure outlined in Table 3-13 and an example is shown in Figure 3-13.

Table 3‑13: Full Travel Time Superlinks file fields

| Element | Description | Values |
| --- | --- | --- |
| superlink\_route\_group | A unique identifier for all superlink routes along the same roadway. | Character String |
| superlink\_route\_num | A unique identifier for each individual superlink route in the group.  NOTE: Each superlink\_route\_group/superlink\_route\_num combination should be unique and each should have a unique origin/destination combination. | Character String |
| downstream\_superlink\_route\_group | A unique identifier for the superlink route directly downstream of superlink\_route\_group. | Character String |
| downstream\_superlink\_route\_num | A unique identifier for the superlink route directly downstream of superlink\_route\_num. | Character String |

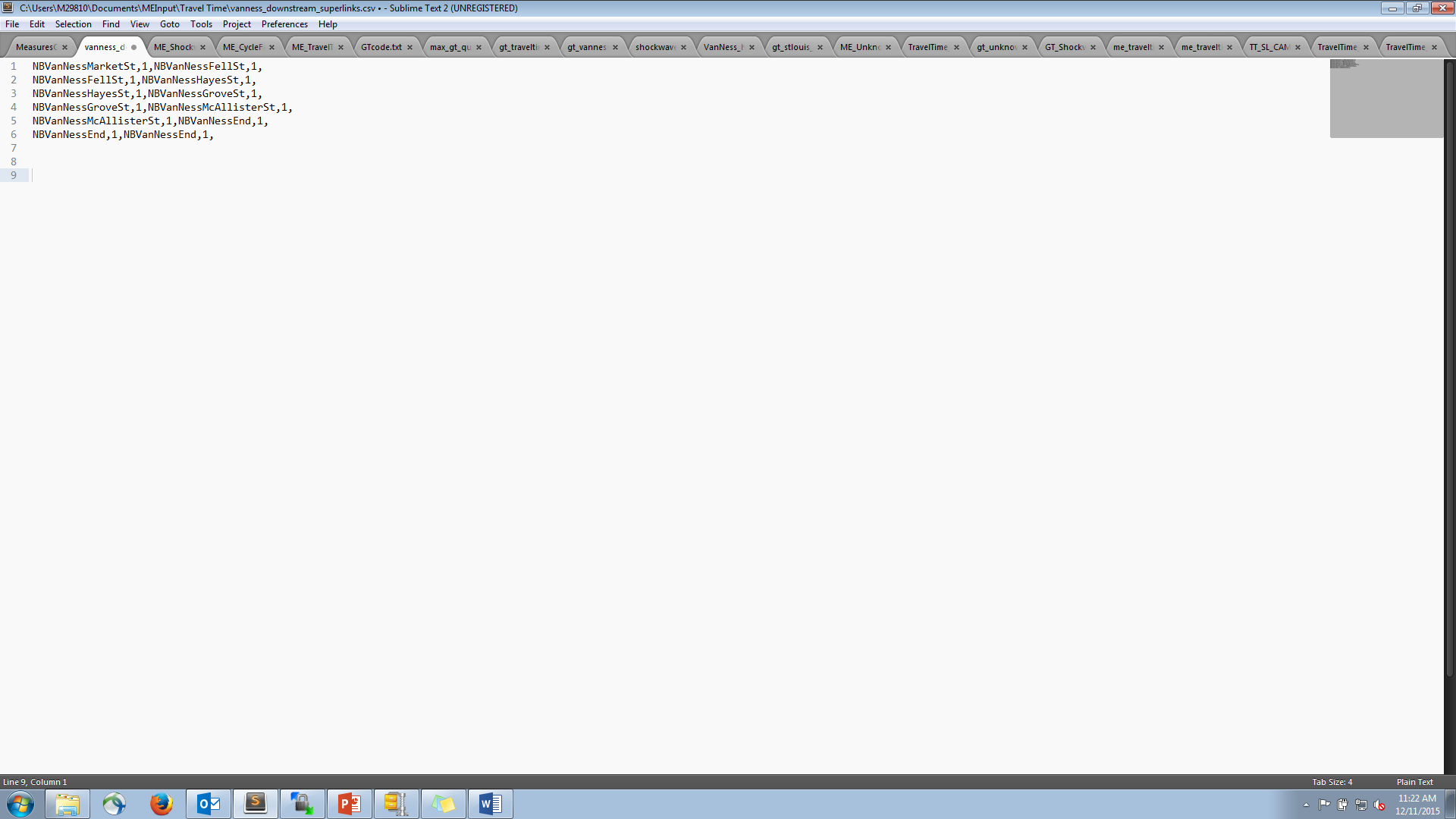


Figure 3‑13: Downstream Superlinks File example

# Output Files

## Queue Output File

The Queue output file is a csv that reports queues formed at every known bottleneck location (or at any variable location) for each time step. The file contains the items from Table 4‑1an example is shown in Figure 4‑1.

Table ‑. Queue file fields

|  |  |  |
| --- | --- | --- |
| Column | Description | |
| time | The time of the queue |
| superlink\_name | From the Bottlenecks input |
| lane\_group | From the Bottlenecks input |
| queue\_count | The number of vehicles in queue |
| queue\_length | The length of the queue in feet |

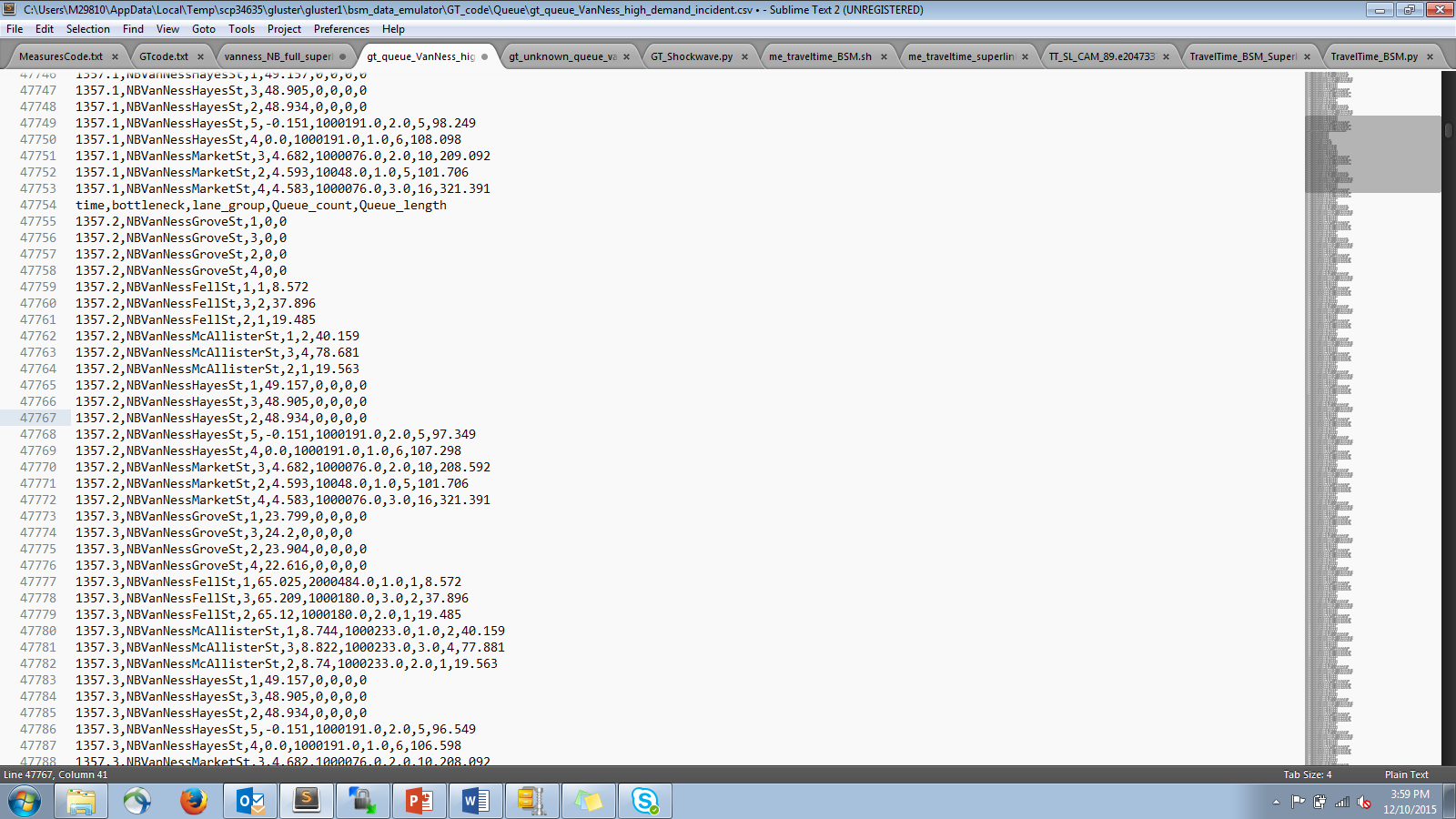


Figure ‑. Queue file example excerpt

## Max Queues File

The Max Queues file is a comma delimited file that has the maximum queue for each bottleneck or variable queue location for a predetermined interval (default of 2 minutes). The Max Queue file contains the data elements from Table 4‑2.

Table ‑: Max Queue file fields

| Name | Description |
| --- | --- |
| time | Interval time the max queue was observed over. |
| superlink\_name | From Bottlenecks file |
| lane\_group | From Bottlenecks file |
| max\_queue\_length | Length of max queue |
| max\_queue\_count | Number of vehicles in max queue |
| time\_of\_queue | Actual local time when queue occurred |

## Travel Time Output

The Travel Time file is a comma delimited file that has average Travel Time by routes or superlinks over a predetermined interval (default of five minutes). The Travel Time file has the fields listed in Table 4‑3.

Table ‑: Travel Time file fields

|  |  |
| --- | --- |
| Name | Description |
| route\_group | From Routes file |
| route\_num | From Routes file |
| simulation\_time | Local time interval start that average travel time is taken for |
| average\_travel\_time | Average travel time for that interval over given route in seconds |

## Cycle Failure File

The Cycle Failure output file is a comma delimited file that contains one of four statuses for each cycle phase indicating either failure or no failure. The Cycle Failure file contains the data elements from Table 4‑4 on each line.

Table ‑: Cycle Failure file fields

| Name | Description |
| --- | --- |
| superlink\_name | From Bottlenecks file |
| lane\_group | From Bottlenecks file |
| green\_starttime | When green phase began for the cycle |
| next\_greentime | The greentime that will come after the phase |
| status | Can be either:  Failure – Certain or Failure – Uncertain OR  No Failure – Certain or No Failure – Uncertain or No Queue Found |

## Consolidated Shockwave File

The consolidated shockwave file is a comma delimited file that contains all shockwaves over the network after the consolidation process. The consolidated shockwave file contains the data elements from Table 4‑5 on each line.

Table ‑: Shockwave file fields

| Name | Description |
| --- | --- |
| time | Time shockwave began |
| superlink\_name | Superlink shockwave occurred on |
| lane\_group | From superlinks file  NOTE: Shockwaves do not resolve to lane detail |
| start\_location\_x | Distance from end of superlink where shockwave started in ft |
| shockwave\_length | Length of the shockwave in ft |
| end\_time | Time when shockwave ended |
| end\_x | Distance from end of superlink where shockwave ended in ft |
| shockwave\_type | 4 if Queued  3 if Highly Congested with Rapid Deceleration  2 if Rapid Deceleration  1 if Deceleration |
| shockwave\_propogation\_speed | Propogation speed of shockwave |
| shockwave\_count | Number of vehicles in shockwave |
| significant\_shockwave | If shockwave type is 4 and number of vehicles in shockwave is greater than or equal to 5 |

## Delay File

The Delay file is a comma delimited file that contains the delay compared to free flow travel time for each average travel time found for each route. The Delay file contains the data elements from Table 4‑6 on each line.

Table ‑: Delay file fields

| Name | Description |
| --- | --- |
| route\_group | From Travel Time Output |
| route | From Travel Time Output |
| time | Local time |
| average\_delay | The actual travel time minus the free flow speed |
| average\_travel\_time | From Travel Time Output |
| free\_flow\_travel\_time | Travel Time as calculated by traversing the route at posted speed limits |

## Space Mean Speed File

The Space Mean Speed file is a comma delimited file that contains the average speed over a given superlink. The Space Mean Speed file contains the data elements from Table 4‑7.

Table ‑: Space Mean Speed file fields

| Name | Description |
| --- | --- |
| time | Start time of average travel time interval |
| roadway | From Travel Time Superlinks file |
| lane | From Travel Time Superlinks file (NOTE: This is a unique identifier, not the actual lane. Travel time is not resolved to lane level.) |
| space\_mean\_speed | The average speed over the superlink in miles per hour |
| roadway\_length | The length of the superlink in feet |

U.S. Department of Transportation  
ITS Joint Program Office-HOIT  
1200 New Jersey Avenue, SE  
Washington, DC 20590  
  
Toll-Free “Help Line” 866-367-7487  
[www.its.dot.gov](http://www.its.dot.gov)  
  
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