

## Activity #36: Determining the Passage Time (Design)

### Purpose

- The purpose of this activity is to determine the maximum allowable headway (MAH) and passage time for your intersection.

### Learning Objectives

- Select an MAH.
- Select a passage time.

### Required Resources

- VISSIM input file created in Activity #28.
- Phase Termination Analysis Excel template (A28.xlsx).

### Information

The maximum allowable headway (MAH) is the largest headway that you will tolerate in a departing queue before the phase should terminate. The choice of this headway involves balancing two conflicting and competing issues: if the headway that you select is too small, then you run the risk of terminating the phase too soon and not serving all of the vehicles in the queue that formed during red. However, if the headway that you select is too large, then you run the risk of allowing the phase to extend too long, serving not just the initial queue but also vehicles that arrive after the initial queue has cleared.

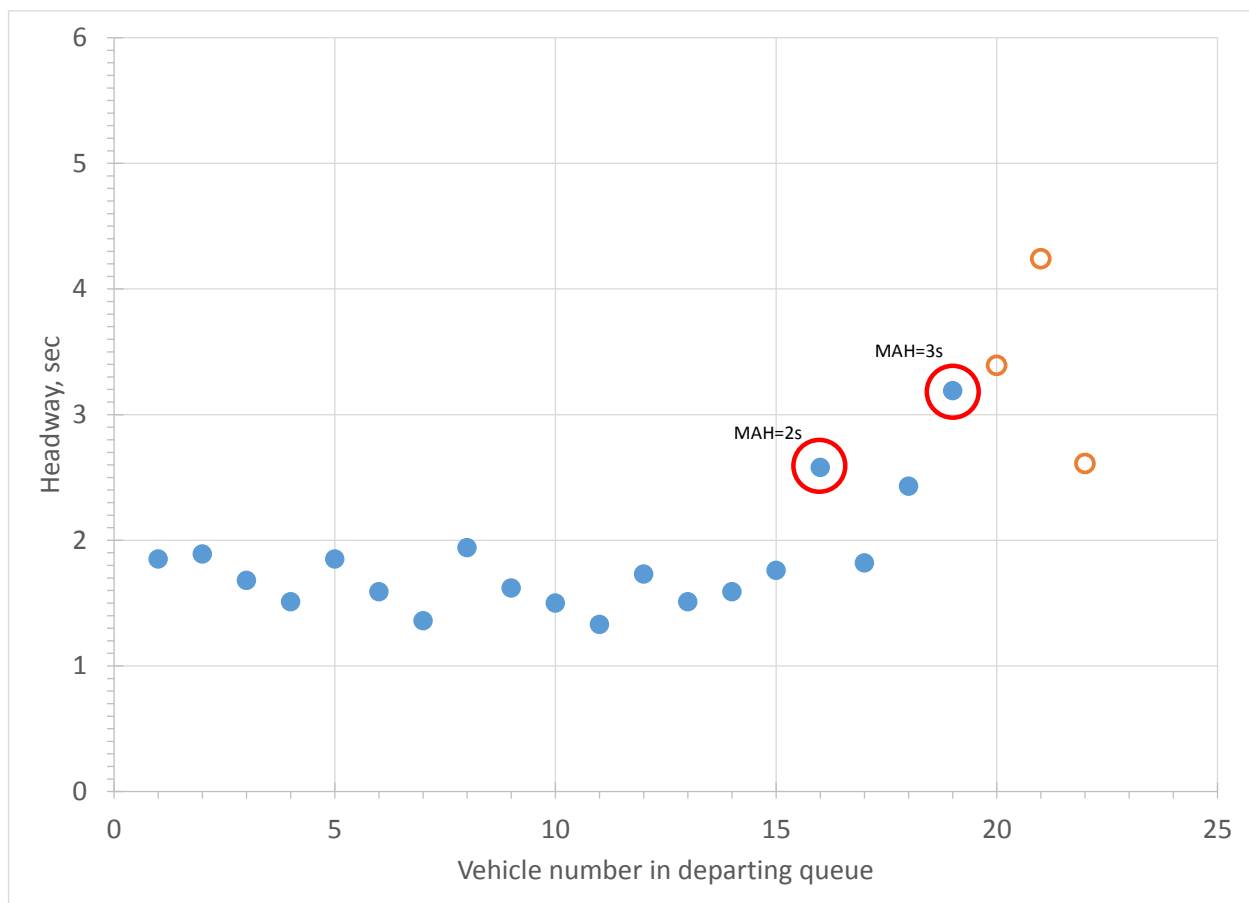
One problem comes in recognizing that some of the headways that you observe after the queue has cleared might be in the same range as those that you observed during the queue clearance. Conversely, a slowly reacting driver in a vehicle that is part of a departing queue will result in a headway that is longer than the normal saturation headway. The choice that you make in the value of the MAH will have some risk of both conditions:

- Type 1 termination, or phase failure, when not all of the initial queue is served or
- Type 2 termination, an inefficient extension of the green, resulting in longer delays on the other approaches.

While the ideal goal is to achieve a Type 3 termination (when the phase terminates just after the queue has cleared) each time a phase terminates, your challenge is to find a MAH that balances the risks of the Type 1 and Type 2 terminations.

So what is a phase termination analysis? A phase termination analysis is a tool that looks at the headway data generated by a simulation model from a stream of vehicles departing from an intersection and, given a value of the MAH, classifies each phase termination into one of the three types described above.

Let's consider three examples showing how a phase termination analysis can help you determine the MAH. The first example shows the headways for a stream of 22 vehicles departing from an intersection approach after the start of green. The vehicles that were a part of the queue (19 vehicles) are shown with the solid dots in Figure 1. The three vehicles that arrived after the queue cleared are shown with hollow dots in the figure. If we set the MAH to 2 seconds, the ideal value of the saturation headway, the phase will terminate after serving the 16<sup>th</sup> vehicle, leaving three queued vehicles unserved. This is a Type 1 termination and is often called a phase failure. However, if we set the MAH to 3 seconds, to account for the normal variation in driver behavior, the phase will terminate after serving vehicle #19, the last vehicle in the original queue. This is called a Type 3 termination in which the entire queue is served and then the phase terminates. It is the "Goldilocks Zone", just long enough but not too long.



**Figure 1. Example headways from departing vehicle queue**

The second example (Figure 2) also shows the headways from a stream of 22 departing vehicles after the start of green. Again, 19 vehicles were a part of the queue, while three vehicles arrived after the queue had cleared. If we set the MAH to 2 seconds, the phase could terminate after serving the first vehicle (depending on the value set for the minimum green time). And even if the MAH is set to 3 seconds, the phase will terminate after serving vehicle #13, with six queued vehicles still unserved. It is not possible with this vehicle stream to achieve a Type 3 termination. Rather, a Type 1 termination results.

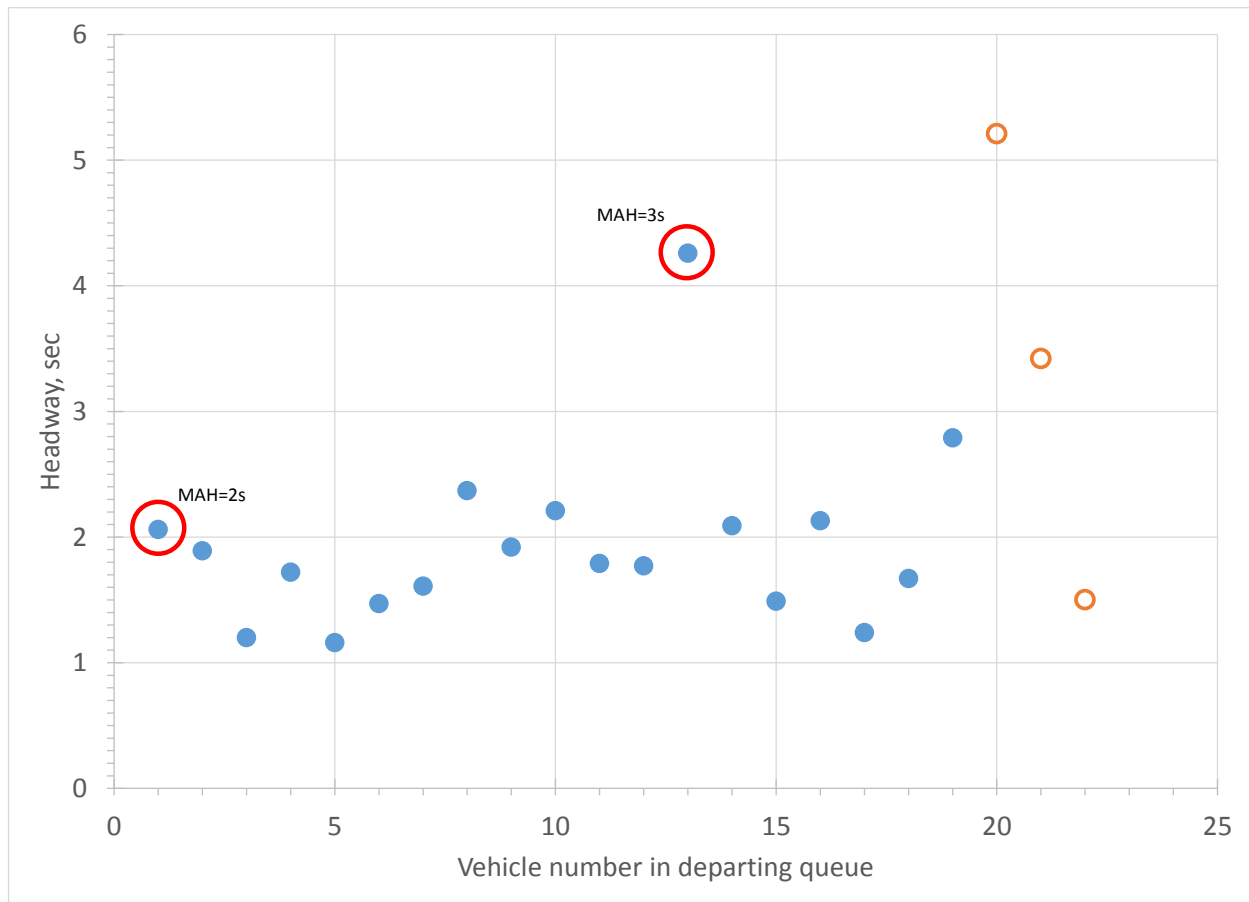
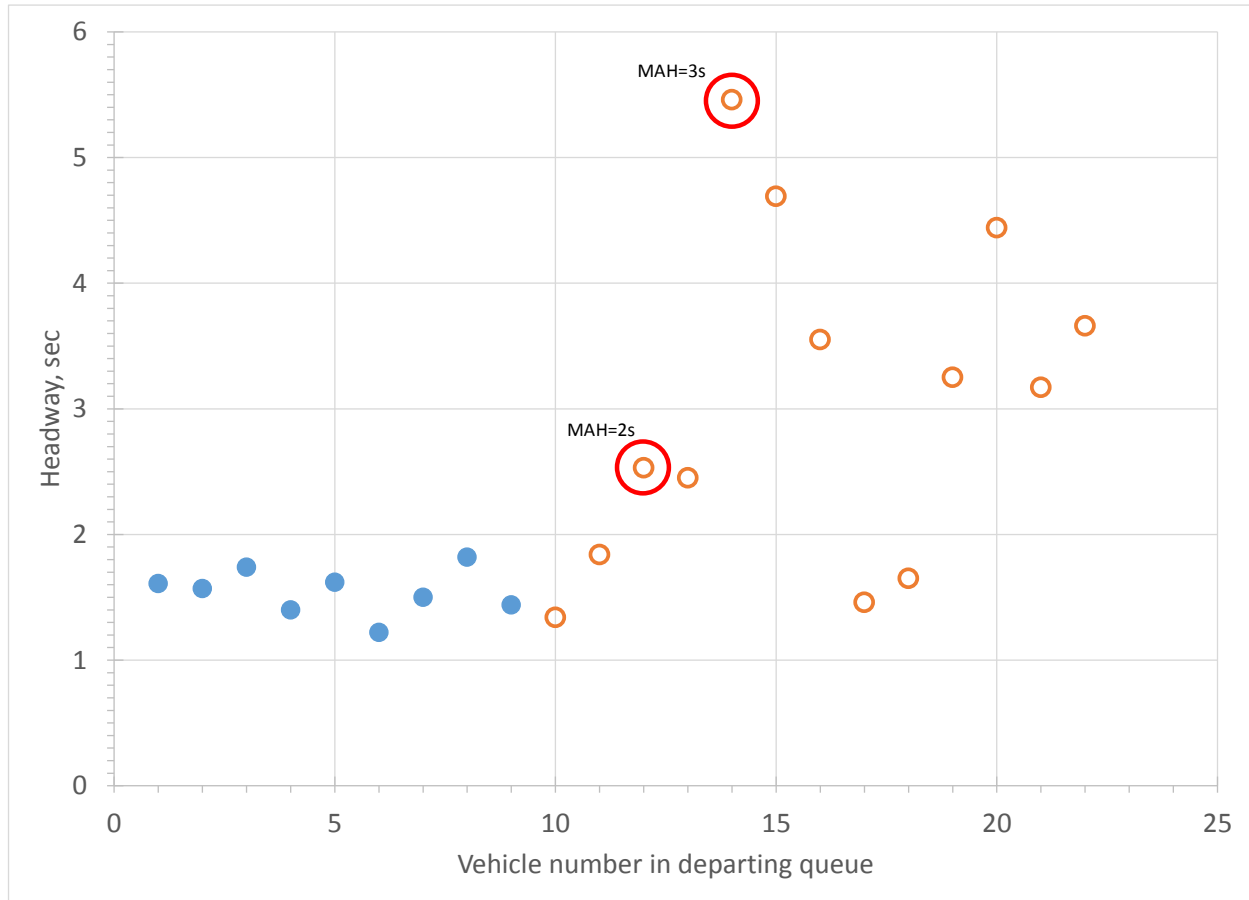


Figure 2. Example headways from departing vehicle queue

The third example (Figure 3) again shows the headways from a stream of 22 departing vehicles. The queue clears with the 9<sup>th</sup> vehicle. But the headways for the next two vehicles are under 2 seconds and the headways for the subsequent two vehicles are under 3 seconds. With MAH values of 2 and 3 seconds, the phase would continue to time after the queue clears and we would have an inefficient Type 2 termination.



**Figure 3. Example headways from departing vehicle queue**

The point of these three examples is there is a balance to achieve: you will have to allow some Type 1 terminations in order to not have too many Type 2 terminations. This is the risk that you will try to minimize when selecting your value of MAH.

Here are the three parts of the phase termination analysis that you will conduct:

- The first part of the analysis involves the headways for the departing vehicles, with the stream separated into vehicles that were a part of the queue and those that arrived after the queue had cleared. An example of the headway data are shown in the first two columns of Figure 4. Note that when you collect your headway data in this activity, the passage time is set to 5 seconds so that you can observe a sufficient sample of both queued and non-queued vehicles and their resulting headways departing after the beginning of green. This high passage time provides you with enough vehicles (and resulting headways) to allow you to study different values of MAH and their effects on phase termination.
- The next step in the analysis involves superimposing a value for the MAH that determines when the display would change from green to red. The display would continue as green as long as the headway in the data stream is less than the MAH, but would change to red when a headway exceeds this value. The “Ideal Signal Display”, column 3 in Figure 4, shows the display that would result from the MAH that has been selected: the green would be displayed until a headway occurs that is greater than the MAH, in this case 3 seconds. The “Change Occurs” column (column 4) shows when the change from green to red would occur.
- The third part of the analysis, the “Termination Outcomes”, determines whether this display change occurs when queued vehicles are still being served (a Type 1 termination) or whether the green would continue to be displayed even when non-queued vehicles would be served (a Type 2 termination). In this example, the two queued vehicles are served, but the first three non-queued vehicles are served as well. The display doesn’t change to red until the sixth headway (7.79 seconds), which is the first headway in this example to exceed the MAH of 3.0 seconds.

MAH	Percentile										
3.0	98.2%										
Headway (sec)		Signal Information		Termination Outcomes			Outcome Distribution				
Queued	NonQueued	Ideal Signal Display	Change Occurs	Type 1	Type 3	Type 2	Type 1 Termination	Type 3 Termination	Type 2 Termination		
1.15		Green					3	5	9		
1.96		Green									
	1.15	Green					<b>Results of Phase Termination Analysis</b>				
	1.3	Green									
	1.91	Green					Headway	1.5	2.0	2.5	3.0
	7.79	Red	Change			1	Percentile	32.0%	76.4%	95.9%	98.2%
	8.03	Red					Type 1 Termination	17	14	6	3
	5.14	Red					Type 3 Termination	0	1	6	5
							Type 2 Termination	0	2	5	9

**Figure 4. Example phase termination analysis results**

Looking a little more closely at Figure 4, we can make the following observations:

- The current value of the MAH (3.0 seconds) is shown in the upper left of the figure.
- The Signal Information shows the Ideal Signal Display based on the value of the MAH. The Change Occurs column shows when the displays changes from green to red, showing the ending of that phase. The Termination Outcome shows whether a Type 1, Type 2, or Type 3 termination results. The “1” indicates the resulting termination type, in this case Type 2.
- The Outcome Distribution shows the number of each termination type for the value of the MAH selected. In this example there are three Type 1, five Type 3, and nine Type 2 terminations, when the MAH equals 3 seconds.
- The Percentile is the percentage of vehicles with headways that are less than the MAH (in this example, 98.2%).

- The “Results” summarizes these Percentiles and the number of terminations for each type for four MAH values (ranging from 1.5 seconds to 3.0 seconds). For example, when the MAH was selected to be 2.0 seconds, there were 14 Type 1 terminations and only 2 Type 2 terminations.

Once you determine the MAH, you can then select the passage time based on the unoccupancy time that is calculated as a function of the detection zone length, the mean vehicle speed, and the mean vehicle length. The passage time is set equal to the unoccupancy time,  $t_u$ .

$$t_u = MAH - \frac{L_d + L_v}{v}$$

where

$L_d$  = detection zone length

$L_v$  = vehicle length

$v$  = vehicle speed

## Tasks

### Task 1: Excel template preparation.

- Download the file A36.xlsx from the Companion Web Site. Note that the template page that you will use for the phase termination analysis is labeled “Tab 4”.
- Create new tabs: Tab 1, Tab 2, Tab 3, Tab 5, Tab 6, and Tab 7. Place these tabs in order before and after the existing Tab 4.

### Task 2: VISSIM preparation.

- Make a copy of the folder that includes your VISSIM data files from Activity #28. Name this new folder “A36”. Use these VISSIM files as the basis for your analysis and design of the passage time.
- Select one approach on one of the major streets of your intersection for your headway study.
- Increase the volume on this link to produce “beginning of green” queue lengths of 10 to 15 vehicles per cycle per lane. Remember to note the original volume as you will need this for Task 8.
- Verify that the passage time is set to 5.0 seconds on the approach that you have selected.
- Establish a “data collection” point (data collector) just downstream of the signal head (but within the link, not the connector) for the lane on the approach that you selected above.
- Select and configure the “Data Collection (raw data)” evaluation file. Set the collection time from 300 to 3600 seconds.

### Task 3: Headway data.

- Run VISSIM.
- Open and parse the MER file into Tab 2 of your A36 Excel template.
- Copy the parsed data to Tab 3 of your Excel file. Keep only five columns:
  - t(Exit)
  - VehNo
  - v[mph]
  - tQueue
  - VehLength[ft]
- Delete the other columns.
- Figure 5 shows the layout of the MER file after it has been opened in Excel and parsed. The five columns noted above are shown in boxes.

Measurement	t(Entry)	t(Exit)	VehNo	Vehicle type	Line	v[mph]	b[ft/s <sup>2</sup> ]	Occ	Pers	tQueue	VehLength[ft]
1	304.79	-1	298	100	0	29.8	0.51	0.01	1	0	14.76
1	-1	305.12	298	100	0	29.9	0.51	0.02	1	0	14.76
1	312.56	-1	303	100	0	33.7	0.78	0.04	1	0	14.76
1	-1	312.86	303	100	0	33.9	0.78	0.06	1	0	14.76
1	388.35	-1	305	100	0	8.4	10.37	0.05	1	69.5	14.76
1	-1	389.23	305	100	0	14.3	9.36	0.03	1	69.5	14.76
1	390.81	-1	307	100	0	14.7	7.25	0.09	1	69	14.76
1	-1	391.43	307	100	0	17.7	6.84	0.03	1	69	14.76
1	392.52	-1	313	100	0	21.9	9.3	0.08	1	57.6	14.76
1	-1	392.95	313	100	0	24.3	6.92	0.05	1	57.6	14.76
1	394.27	-1	318	100	0	24.1	7.76	0.03	1	53.3	14.76
1	-1	394.67	318	100	0	26.2	7.5	0.07	1	53.3	14.76
1	396.37	-1	319	100	0	24	5.79	0.03	1	51.6	14.76
1	-1	396.78	319	100	0	25.6	5.63	0.08	1	51.6	14.76

Figure 5. VISSIM MER file in Excel

- Sort the file by t(Exit) with the largest time sorted first.
- Eliminate all rows in which t(Exit) equals “-1”.
- Resort the file by t(Exit) with the lowest time sorted first.
- Add a new column identifying whether the vehicle was a part of the queue or not. This can be done by putting a Q or NQ in the cell adjacent to the tQueue data. Figure 6 shows an example of the determination of Q or NQ based on whether tQueue is zero or greater than zero using an Excel logic function.

t(Exit)	VehNo	v[mph]	tQueue	VehLength[ft]	Q/NQ
305.12	298	29.9	0	14.76	NQ
312.86	303	33.9	0	14.76	NQ
389.23	305	14.3	69.5	14.76	Q
391.43	307	17.7	69	14.76	Q
392.95	313	24.3	57.6	14.76	Q
394.67	318	26.2	53.3	14.76	Q
396.78	319	25.6	51.6	14.76	Q
399.11	323	24.6	49.1	14.76	Q
400.45	334	27.2	38.6	14.76	Q

If(tQueue>0,"Q","NQ")

**Figure 6. Example determination whether a vehicle is in a queue or not (Q or NQ)**

- In a new column, compute the headway between each vehicle pair as shown in Figure 7.

	t(Exit)	VehNo	v[mph]	tQueue	VehLength[ft]	Q/NQ	Headway
11							
12	305.12	298	29.9	0	14.76	NQ	
13	312.86	303	33.9	0	14.76	NQ	7.74
14	389.23	305	14.3	69.5	14.76	Q	76.37
15	391.43	307	17.7	69	14.76	Q	2.20
16	392.95	313	24.3	57.6	14.76	Q	1.52
17	394.67	318	26.2	53.3	14.76	Q	1.72
18	396.78	319	25.6	51.6	14.76	Q	2.11
19	399.11	323	24.6	49.1	14.76	Q	2.33
20	400.45	334	27.2	38.6	14.76	Q	1.34

**Figure 7. Example calculation of headway based on the “exit” times of two consecutive vehicles**



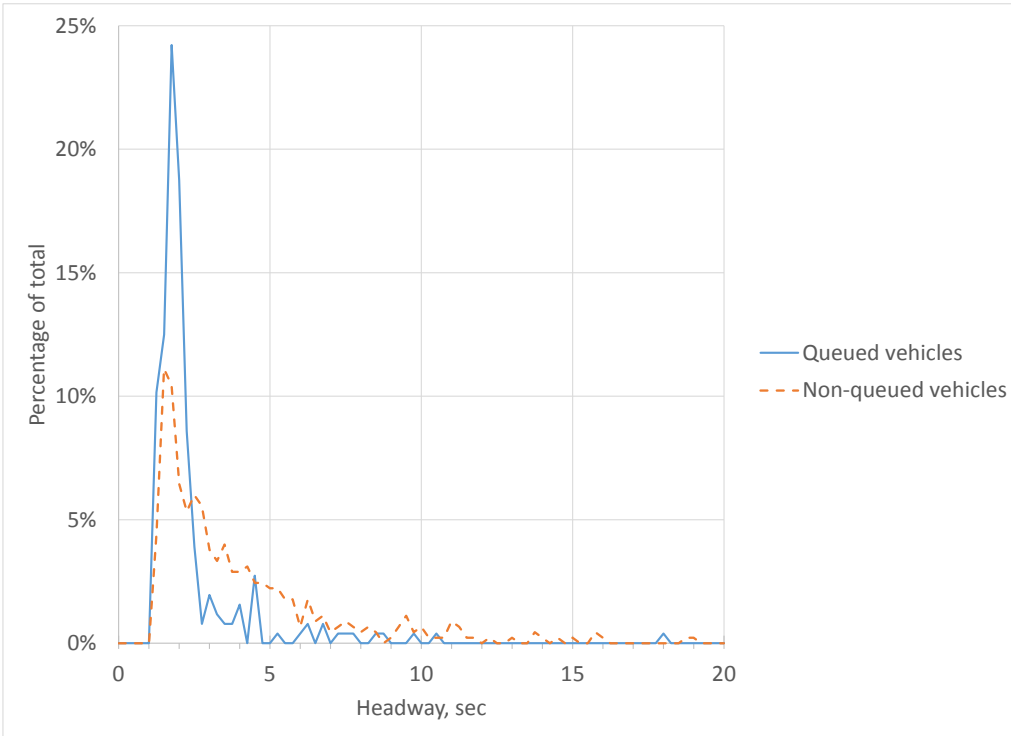
**Task 4: Headway distribution analysis.**

- Using the headway data created in Task 3, create frequency (histogram) and cumulative frequency plots in Tab 3 of the spreadsheet. The bin range should be from 0 to 20 seconds in 0.25 increments. Figure 8 shows an example of the data used to create the frequency and cumulative frequency plots including (for headway bins from 0.00 to 4.00 seconds) the frequency (number) and the percent frequency for the queued data.

<i>Q/NQ</i>	<i>Headway</i>	<i>Bin</i>	<i>Frequency</i>	<i>%Frequency</i>
Q	76.37	0.00	0	0.0%
Q	2.2	0.25	0	0.0%
Q	1.52	0.50	0	0.0%
Q	1.72	0.75	0	0.0%
Q	2.11	1.00	0	0.0%
Q	2.33	1.25	26	10.2%
Q	1.34	1.50	32	12.5%
Q	1.11	1.75	62	24.2%
Q	1.56	2.00	48	18.8%
Q	1.3	2.25	22	8.6%
Q	1.68	2.50	10	3.9%
Q	1.31	2.75	2	0.8%
Q	2.44	3.00	5	2.0%
Q	1.04	3.25	3	1.2%
Q	2.07	3.50	2	0.8%
Q	1.12	3.75	2	0.8%
Q	2.5	4.00	4	1.6%

**Figure 8. Example frequency and cumulative frequency headway data for queued vehicles**

- Figure 9 shows the resulting frequency plot based on the frequency data shown in Figure 8. Note that the queued vehicles have a more focused distribution around the mean of 2.2 seconds. The non-queued vehicles have a similar focus (the mean is 4.0 seconds), but also include a number of headway values that are much higher than the mean.



**Figure 9. Headway frequency plot for queue and non-queued vehicles**

**Task 5: Phase termination analysis.**

- Create the data that you will need for the phase termination analysis in Tab 3. Figure 10 shows two columns that have been created that place the queued (QData) and non-queued (NQData) headway data in the two columns on the right.

t(Exit)	VehNo	v[mph]	tQueue	VehLength[ft]	Q/NQ	Headway	Headway (sec)	
							QData	NQData
305.12	298	29.9	0	14.76	NQ			
312.86	303	33.9	0	14.76	NQ	7.74		7.74
389.23	305	14.3	69.5	14.76	Q	76.37	76.37	
391.43	307	17.7	69	14.76	Q	2.20	2.2	
392.95	313	24.3	57.6	14.76	Q	1.52	1.52	
394.67	318	26.2	53.3	14.76	Q	1.72	1.72	
396.78	319	25.6	51.6	14.76	Q	2.11	2.11	
399.11	323	24.6	49.1	14.76	Q	2.33	2.33	
400.45	334	27.2	38.6	14.76	Q	1.34	1.34	
401.56	339	28.6	34.6	14.76	Q	1.11	1.11	
403.12	341	29.5	32.1	14.76	Q	1.56	1.56	
404.42	344	31.1	30.4	14.76	Q	1.30	1.3	
406.1	348	30.3	29.5	14.76	Q	1.68	1.68	
407.41	364	31.2	22.3	14.76	Q	1.31	1.31	
409.85	366	30.5	22.2	14.76	Q	2.44	2.44	
410.89	372	30.8	20.7	14.76	Q	1.04	1.04	
412.96	374	30	16.1	14.76	Q	2.07	2.07	

**Figure 10. Creation of input data for phase termination analysis**

- Copy the headways for the queued and non-queued vehicles from Tab 3 into the two input columns in the phase termination analysis template on Tab 4 of your spreadsheet. The data should be pasted as “values”. Figure 11 shows the headway data that have been pasted into the first two columns of the phase termination analysis template for this example. The Signal Information and Termination Outcomes are calculated based on these input data.

MAH	Percentile					
4.0	90.8%					
Headway (sec)		Signal Information		Termination Outcomes		
Queued	NonQueued	Ideal Signal Display	Change Occurs	Type 1	Type 3	Type 2
	7.74	Red				
		Green				
2.2		Green				
1.52		Green				
1.72		Green				
2.11		Green				
2.33		Green				
1.34		Green				
1.11		Green				
1.56		Green				
1.3		Green				
1.68		Green				
1.31		Green				
2.44		Green				
1.04		Green				
2.07		Green				
1.12		Green				
2.5		Green				
3.31		Green				
1.52		Green				
2.85		Green				
	4.26	Red	Change		1	
	3.14	Red				
8.29		Red				
	1.94	Red				

Figure 11. Outcomes for phase termination analysis showing type 1 termination

- Delete the values in the Queued headway data column that are “large”. These large values are usually greater than 20 seconds and occur following a non-zero value of a Non-Queued headway. These large values represent the headway between the last vehicle that leaves at the end of green and the first vehicle that leaves at the beginning of the following green. For example, in Figure 12, you would delete the value of 76.37 seconds as it is a large value (exceeding 20 sec) and it follows a non-zero NonQueued headway value.

Headway (sec)		Signal Information		Termination Outcomes		
Queued	NonQueued	Ideal Signal Display	Change Occurs	Type 1	Type 3	Type 2
	7.74	Green				
76.37		Red	Change		1	
2.2		Red				
1.52		Red				
1.72		Red				
2.11		Red				
2.33		Red				
1.34		Red				
1.11		Red				
1.56		Red				

Figure 12. Logic for eliminating large Queued headway values

- Use the Phase Termination Analysis template to determine the Termination Outcomes for a range of possible MAH. Enter a value MAH (cell A7) and record the resulting number of Types 1, 2, and 3 terminations in the “Results” section of the template. Each time you enter a new value for the MAH, a new set of outcomes will be calculated. Figure 13 shows the results of a phase termination analysis for six MAH cases, ranging from 1.5 seconds to 4.0 seconds. When the MAH is set to 1.5 seconds, the phase would terminate before the queue had cleared for all 15 phases; only 22.9 percent of the vehicles would be served. At the other extreme, if the MAH is set to 4.0 seconds, while 90.8 percent of the vehicles would be served, the phase would extend past the time the queue had cleared in 7 of the 17 cases (Type 2 terminations).

		Outcome Distribution					
		Type 1 Termination	5				
		Type 3 Termination	3				
		Type 2 Termination	7				
Results of Phase Termination Analysis							
Headway	1.5	2.0	2.5	3.0	3.5	4.0	
Percentile	22.9%	70.2%	83.3%	86.4%	88.5%	90.8%	
Type 1 Termination	15	12	7	6	5	5	
Type 3 Termination	0	1	3	2	3	3	
Type 2 Termination	0	2	5	7	7	7	

Figure 13. Phase termination analysis results for four example maximum allowable headways

**Task 6: Select the MAH.**

- Select your MAH based on your desire to emphasize gap outs as the most desired way to end the phase using your results on Type 1 and Type 2 terminations.

**Task 7: Compute the passage time.**

- Using the data from Tab 3, determine the mean speed for non-queued (NQ) vehicles.
- Compute the passage time using the MAH value from Task 6 and the mean speed that you computed for non-queued vehicles. Assume an average vehicle length of 20 feet and a detection zone length of 22 feet.

**Task 8: Observe VISSIM simulation using new values of passage time.**

- Set the passage times that you selected in Task 7 into your VISSIM network for all phases in your intersection.
- Verify that the detection zone length is set to 22 feet and the minimum green time is set to 5 seconds.
- Reduce the volume on the link that you've just studied back to its original value.
- Run VISSIM.
- Collect the performance data (average vehicle delay and average queue length) and summarize these data for the individual approaches and for the intersection. Compare these performance data with the base case from Activity #28. What has changed?
- Observe the simulated operation of your intersection and make conclusions about what you see. Compare these observations with those from Activity #28. What has changed?

**Deliverable**

- Submit an Excel spreadsheet that includes the phase termination analysis results and data analysis outcomes, as well as the network performance evaluation. The Excel workbook should follow the structure outlined below:
  - Tab 1: Title page with activity number and title, authors, and date completed.
  - Tab 2: Raw data from the MER file.
  - Tab 3: Parsed data, headway data, and frequency data and plot.
  - Tab 4: Phase termination analysis using template including a summary table containing the number of occurrences of each termination type.
  - Tab 5: Evaluation of phase termination analysis including discussion of your results from Task 5, selection of and justification for the MAH, and determination of passage time.
  - Tab 6: Performance data from VISSIM.
  - Tab 7: Analysis and summary of VISSIM performance data including comparison of your new data and observations with the results from the base case (Activity #28).