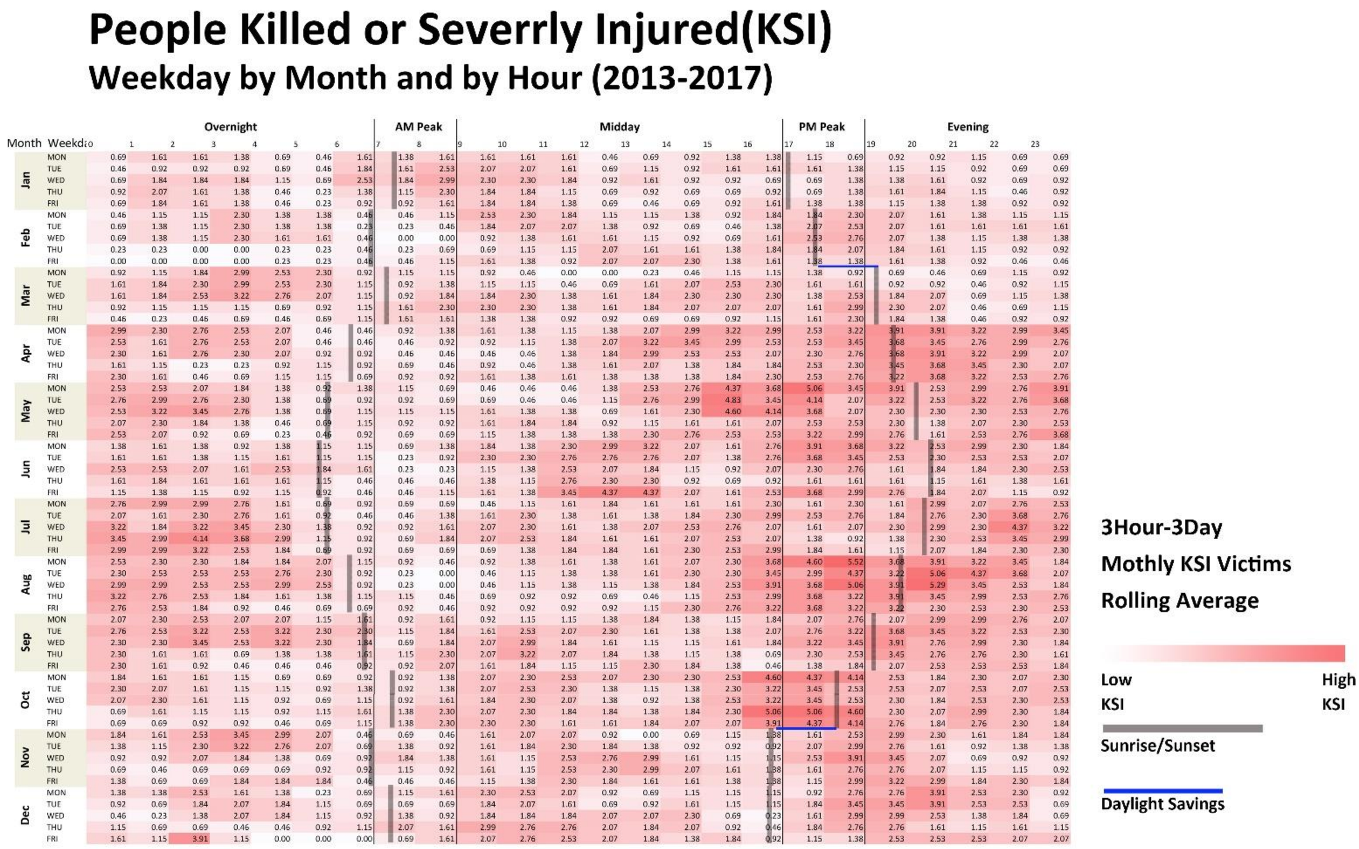
When Analysis:

Although it is known that speed of vehicles influences the severity of crashes, there are lots of time-related factors that also threaten the traffic safety. For example, it is harder for drivers to clearly identify road signs during the night. High school drivers usually drive their cars to and from their schools during the morning and evening peaks, and they are inexperienced in coping with complicated road conditions during peak hours. Besides, there are many influential factors that are implicitly related to time, such as icy/snow-slush roads, street light. The "WHEN" part of analysis focuses on exploring the relationship between KSI crashes (killed and severe injury crash) with time and those time-related factors. Based on the time of day investigation of KSI crash victims, we select two noticeable periods that have larger number of victims in KSI crashes as our study periods to conduct comprehensive analysis on. The two periods include peak hour and nighttime.

1. **Time of Day Investigation(Kefan)**

   There are 1649 crashes in Philadelphia city that include at least one fatality or one major injury, and 1845 victims in these crashes have lost their life or get severely injured. Latest data from PennDOT showed that KSI death has decreased in 2017, so has the number of severe injuries. However, the Vision Zero one year update predicts that current trend of fatality decrease will not achieve ultimate goal of eliminating traffic-related death by 2030. While Philadelphia admits that "not every crash can be prevented", the city comes up with a list of proposals that aim to reduce the severity of crashes. Our when analysis helps the city understand when KSI crashes are most likely to happen and when are these crashes causing more fatalities or severe injuries.



To make this analysis clear, we analyze KSI crash data from 2013 to 2017 and summarize the rolling average of person that are killed or severely injured by month, weekday and hour. The final table is colored by white-to-red scale.

In the summary chart, lighter areas mainly distributed on am peak and midday period. This means generally fewer people are killed or severely injured during these two periods. Victims rise a little in the afternoon from June to September due to the fatigue caused by temperature.

Difference before and after 4 pm is obvious. After 4 pm, there are more “red” areas, which means more people are killed or are severely injured in KSI crashes, especially from April to October. There are more vehicles on the roads, and it is hard for inexperienced drivers to cope with complicated traffic in Philadelphia, such as changing driving lane on time, choosing the right time to drive into an arterial road or crossing a sign-controlled intersection. Nighttime period also has a very higher of KSI victims, even though pm peak has passed. Red areas distributed on the evening period, especially after March.

After we combine the average sunrise/sunset line with victim chart, we can see that KSI victims decrease after the sunrise line. The rise of victims after the sunset is also obvious, which gives us an early guess that visibility may be an issue in nighttime KSI crashes.

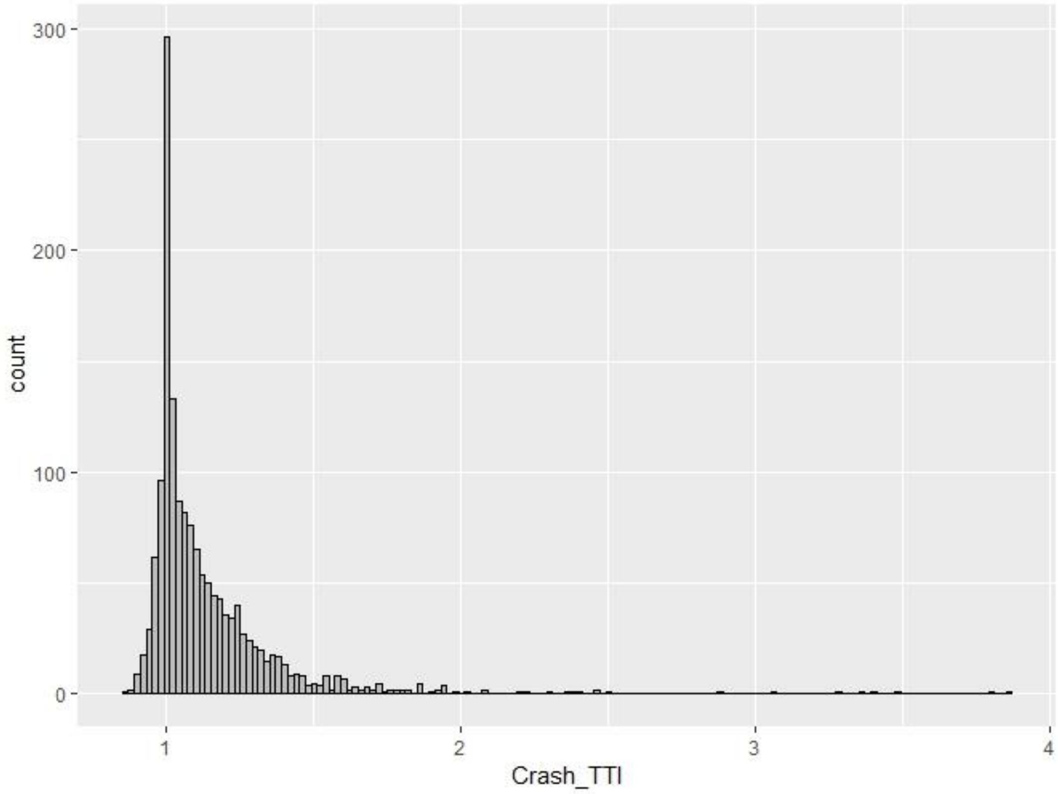
Based on the chart, we decide to focus mainly on analyzing crashes after 4 pm and divide the period into pm peak and evening and conduct analysis respectively. In peak hour analysis, we also include am peak to find if there are common characteristics between am peak and pm peak crashes. For nighttime analysis, we will investigate visibility issue, as well as other factors that influence KSI crashes.

Methodology:

1. Use 2013-2017 Philadelphia crash shapefile (multiple points) and select crashes that involves at least one traffic fatality and severe injury. (Severe injury is recorded as “MAJ_INJ_NO”, which is usually defined as incapacitating.)
2. Relate KSI crash shapefile to the corresponding “crash person” table using CRN field. (Each recorded crash has its unique CRN number.)
3. Select all points on KSI crash shapefile and select the relate table, export the selected columns in crash person table.
4. Select the table and keep the crashes whose “INJ_SEVRITY” columns equal to 1 or 2. (1 refers to fatal injury, 2 refers to suspected serious injury. Not all people that get involved in KSI crashes will get killed or severely injured.)
5. Add the table to the layer and join KSI crash shapefile to this table.(Since one KSI crash may have multiple victims, we should select one to many.)
6. Export the joined table, so each victim of KSI crashes will have information of crash time and other information that is recorded.
7. Summarize data table based on month-weekday-hour.
8. Calculate rolling average of KSI victims based on three-day-three-hour average.

2. Peak Hour Analysis(Kefan)

Before we conduct peak hour analysis, we need to look at how road congestion level is related to KSI crashes in Philadelphia. A good measurement of average congestion level for roads is TTI, which refers to travel time index. This index measures the



ratio of actual travel time and free flow time by hour(image002).

The joined data for 1649 KSI crashes has shown that the closer TTI is to 1, the more KSI crashes. It is reasonable because speed of vehicle is positively related to the severity of crash victims[1]. Lower TTI means the driver could drive through the road more quickly, and the average speed of driving is higher, which increases the danger of fatal injuries.

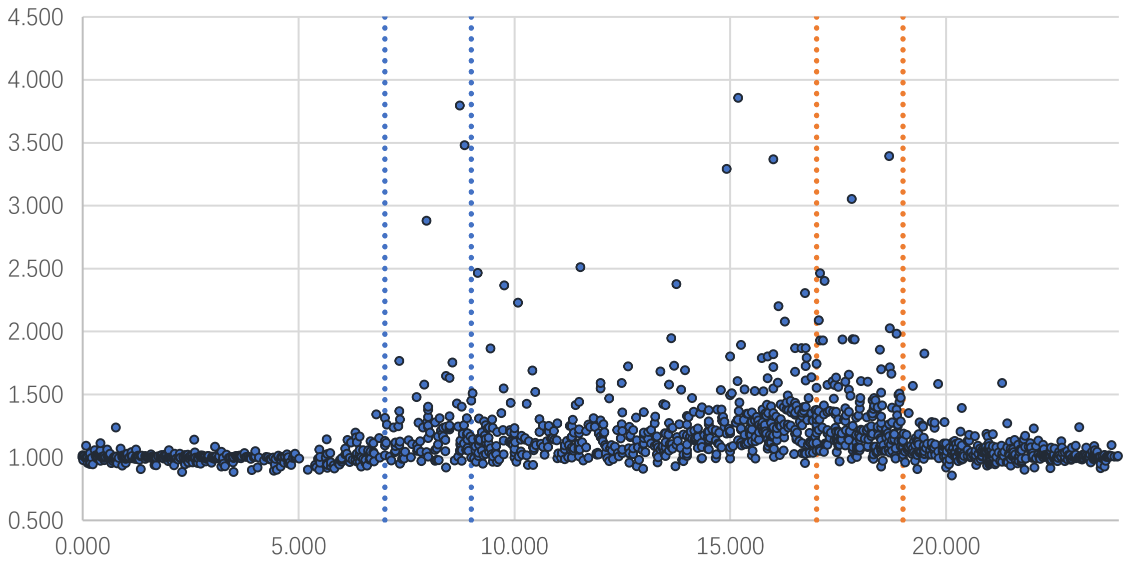
To find out if peak hour KSI crashes and KSI crashes in other periods differs in TTIs, we did t-tests. We select 7-8am as am peak and 5-6pm as pm peak and compared TTIs of KSI crashes during these two periods with that of KSI crashes during midday. The results are shown as following:

AM peak T-test		**PM peak T-test**	
Sample mean		Sample mean	
x-(Am peak)	1.239	x-(pm peak)	1.302
y-(midday)	1.236	y-(midday)	1.236
Sample S.D.		Sample S.D.	
x-(Am peak)	0.426224316	x-(pm peak)	0.322084138
y-(midday)	0.293870745	y-(midday)	0.293870745
Sample Size		Sample Size	
am peak	97	pm peak	196
midday	489	midday	489
Numerator:	0.003	Numerator:	0.065
Denominator:	0.045270992	Denominator:	0.026568437
T	0.065103199	T	2.452250825
P-Value	0.474102931	P-Value	0.007355446

[1] Philadelphia vision zero action plan. http://visionzerophl.com/uploads/attachments/cjo6byxt40hfcs3d6bv9eixws-file-2018-vision-zero-update-sm.pdf

Formula:	TDIST(0.0651,114,1)	Formula:	TDIST(2.4522,332,1)
Numerator:	4.2003E-06	Numerator:	4.98269E-07
Denominator:	3.66014E-08	Denominator:	1.5005E-09
DF ν:	114	DF ν:	332

The t-test of am peak and midday has a p-value of 0.47, which means we can not reject the null hypothesis that the average TTIs of am peak KSI crash and midday KSI crash are the same. The insignificant result shows that even though there are more vehicles during am peak, it is not related to the distribution of KSI crashes. The t-test of pm peak and midday has a p-value of 0.007, which means we can reject the null hypothesis that average TTIs of pm KSI crash and midday KSI crash are the same for the alternative hypothesis that pm KSI crash has a higher average TTIs than midday KSI crash. There are two possible explanations. One is that there are several KSI crashes happened in extremely congested roads and raise the average TTIs, the other is there are other factors that increase the severity of KSI crashes besides speed.



The distribution of KSI crashes by hour in the chart above shows that compared to midday, not many points are "outliers" during pm peak. The first possible explanation is not supportive. Therefore, we look at the other explanation. We compared the flag tables of pm peak KSI crashes and midday KSI crashes and select out factors that pm peak crashes have a higher proportion.

Flag	PM peak	Midday	PM/MIDDAY
ILLUMINA_1	37.8%	0.6%	64.27861
ALCOHOL_RE	9.0%	2.4%	3.80597
DRINKING_D	5.0%	1.8%	2.819237
ICY_ROAD	1.0%	0.4%	2.537313
HIT_GDRAIL	2.0%	1.2%	1.691542
MOTORCYC_1	19.9%	12.2%	1.636976
RUNNING_ST	2.5%	1.6%	1.585821
TAILGATING	3.0%	2.0%	1.522388
PEDESTRIAN	39.8%	29.4%	1.353234
FATIGUE_AS	0.5%	0.4%	1.268657
UNLICENSED	3.5%	2.9%	1.18408
NON_INTE_1	81.1%	70.0%	1.158493

UNSIGNALIZ	20.9%	18.4%	1.133693
DRIVER_19Y	2.0%	1.8%	1.127695
LOCAL_ROAD	69.2%	62.5%	1.105601
INTERSECTI	55.2%	50.0%	1.104478
SIGNALIZED	34.3%	31.6%	1.08742
LOCAL_RO_1	38.3%	35.9%	1.067613
DRIVER_18Y	1.0%	1.0%	1.014925

It is astonishing that around 38 percent of KSI crashes that happened during pm peak are reported as "crash scene lighting was dark"[2], while only 0.6% percent of midday KSI crashes are reported as dark. There are 76 KSI crashes happened during pm peaks, and most of these crashes happened from November to February when the city is already dark.

Month	KSI Crash Amount
JAN	9
FEB	10
MAR	4
APR	1
SEP	1
OCT	3
NOV	25
DEC	23
Sum	76

Beside darkness, behavioral factors in pm crashes also has a larger proportion, such as alcohol use, drinking driving, tailgating, fatigue and asleep. Pm peak KSI crashes also involve in more vulnerable users, such as pedestrians, motorcyclists and young drivers. Road condition also matters, including icy road, unsignalized or signalized intersections and mid-block area.

Flag	AM peak	Midday	AM/MIDDAY
ILLUMINA_1	6.12%	0.59%	10.408
DRINKING_D	7.14%	1.76%	4.048
HIT_GDRAIL	4.08%	1.18%	3.469
HIT_GDRA_1	2.04%	0.59%	3.469
ALCOHOL_RE	7.14%	2.35%	3.036
HIT_TREE_S	7.14%	2.55%	2.802
ICY_ROAD	1.02%	0.39%	2.602
RUNNING_ST	4.08%	1.57%	2.602
HIT_FIXED_	17.35%	9.61%	1.805
SNOW_SLUSH	1.02%	0.59%	1.735
HIT_BARRIE	7.14%	4.12%	1.735
CURVE_DVR_	3.06%	1.76%	1.735
CURVED_ROA	13.27%	7.84%	1.691
HIT_POLE	5.10%	3.14%	1.626
MODERATE_I	14.29%	8.82%	1.619
IMPAIRED_D	8.16%	5.10%	1.601

[2] Crash data dictionary and field constraints table, PennDOT

INTERSTATE	12.24%	8.04%	1.523
SCHOOL_ZON	2.04%	1.37%	1.487
SPEEDING_R	21.43%	15.69%	1.366
PSP_REPORT	12.24%	9.41%	1.301
DRIVER_75P	8.16%	6.47%	1.262
STOP_CONTR	12.24%	10.00%	1.224
UNSIGNALIZ	22.45%	18.43%	1.218
AGGRESSIVE	54.08%	45.10%	1.199
LOCAL_RO_1	40.82%	35.88%	1.138
NO_CLEARAN	4.08%	3.73%	1.096
DRUGGED_DR	4.08%	3.73%	1.096
INTERSECTI	54.08%	50.00%	1.082
DRIVER_50_	32.65%	30.78%	1.061
SPEEDING	9.18%	8.82%	1.041
HO_OPPDIR_	8.16%	7.84%	1.041
BICYCLE	7.14%	6.86%	1.041
DRIVER_18Y	1.02%	0.98%	1.041
WET_ROAD	12.24%	11.96%	1.024
UNBELTED	21.43%	20.98%	1.021

To make peak hour analysis more thorough, we also compare am KSI crashes with midday KSI crashes. "ILLUMINATION" also ranks the highest in terms of proportion. Beside factors that are included in pm peak table, am peak involves in more school zone crashes, speeding crashes and aggressive driving crashes.

3. Strategies

a. Short-term Strategy

1. School bus enforcement during peak hour

School bus safety is a high priority in Pennsylvania. Although Pennsylvania has come up with clear and strict law of school bus stopping law to keep children safe on and around the school bus, school bus injuries are still high.[3] In Philadelphia, 7-8 am peak has seen 2 times more school bus and school zone injuries than 6-and-9 am. Around 4 children everyday are reported to be involved in traffic crashes.[4] Enforce the school bus right on the road during peak hour, especially am peak, will improve the awareness of bus drivers and other vehicle drivers.

The enforcement proposal includes raising the penalty of violation during the peak hour, installing cameras on school bus to monitor blind spot and enforcing stopping signals.

a. Raise penalty of peak hour violation

(picture)

Currently, a driver will receive all of the following penalties:

- 60-Day Driver's License Suspension
- Five (5) points on your driving record

[3] School bus safety, PennDOT. https://www.penndot.gov/TravelInPA/Safety/TrafficSafetyAndDriverTopics/Pages/School-Bus-Safety.aspx

[4]

- $250 Fine

We are proposing a raised penalty could be applied during peak hours. For example, a 50 percent raised penalty during peak hour will make drivers think twice when they are on the edge. The government could also require drivers to make up for their misbehaviors of violating stop laws, such as volunteering on children's safety in the nearest school bus stop.

Our proposes bus stopping laws are as follows:

- 60-Day Driver's License Suspension
- Five (5) points on your driving record
- $250 Fine
- Violation during 7am-9am and 5-6pm will raise the penalty by 50 percent
- Drivers who violate the stopping law need to volunteer on the nearest school bust stop to keep children's safety during school commuting time.

b. Monitoring school bus blind spot

(Photoshop before/after)

Lots of school buses installed blind spot mirror to avoid injuries on the rear right and rear left that are unable to be seen from side mirrors. However, the vision provided by blind spot mirrors is narrow and limited. Pennsylvania has approved bill to install cameras school bus that automatically photograph and ticket drivers who pass a school bus as it picks up or drops off passengers.[5] These cameras can also be used to shoot rest of blind spots and transmit real-time monitoring data to help school bus driver to confirm the safety of driving.

c. Enforce stopping signals

(Photoshop before/after)

When driving beside a running school bus, it is usually hard for vehicle driver to anticipate when the bus is going to stop. It is also confusing when a vehicle driver when he is driving behind a slow school bus and want to overtake it. An enforced signal system could be added to school bus so that school bus driver can send a message to surrounding cars before it is going to stop for picking-up/drop-off.

2. Travel Demand Management (TDM) strategies

(pictures)

TDM strategies provides many benefits for both commuting and non-commuting trips. Their inherent flexibility provides better transportation accessibility, predictability, more route choices, better utilization of transportation system and performance.[6] Since congestion has related to the distribution of KSI crashes during the pm peak, it is reasonable to implement TDM strategies to calm down peak hour traffic.

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[5] https://triblive.com/news/education/safety/13576399-74/bill-advances-allowing-automated-cameras-on-school-buses-to-catch-illegal-passing

[6] https://www.mdt.mt.gov/pubinvolve/hamilton/docs/final_chap7.pdf

TDM has be used by many communities and their strategies include:

- Flextime
- Alternate Work Schedule
- Compressed Work Week
- Partly Telecommuting
- Ride Sharing
- Vanpooling
- Public Transit
- Ramp Metering
- Transit Subsidy
- Transit Oriented Development (TOD)
- Alternating Directions of Travel Lane

b. Medium-term Strategy

1. Road function transition during peak hour (school vehicles only around schools during peak hour) (before/after renderings)

   Transition of road function during peak hour have be implemented and proven to be a good way of solving problems such as school drop-off chaos.[7] In the middle term, we are thinking changing road functions in certain segment so that problem with peak hour could be solved or eased. There are two useful transitions.

   - School streets. School Streets could be marked with signs indicating the restricted hours. Fifteen minutes before school begins and for 15 minutes after it lets out, “school guides” could be put at the street segment intersection to block traffic and keep children safe. This strategy could also encourage the use of public transit, and is proven to increase the air quality around schools.
   - Narrow commuting streets. There are narrow streets in Philadelphia where lots of office buildings are opened to. During the commuting time, these streets are usually among the most congested. Their traffic flow even influence traffic of surrounding streets. We are proposing turning these streets to “walk only” during peak hours, so that the high concentration of drop-offs/pick-ups on these streets can be dispersed.

2. After School Program Safety Enforcement

   More and more students are enrolled in after-school programming in Philadelphia and most programs will put these students on streets during the dusk or night. Although Philadelphia has required that these programs present clearly about how they will keep the student safe during the program time, students’ safety on the road to and from after-school programs is not clearly mentioned. An enforcement of safety requirement could be addressed to late programs

[7] https://usa.streetsblog.org/2018/11/27/the-european-answer-to-school-drop-off-chaos/

as well as weekend programs. The requirements could include:

- Late program must make sure every students have at least one public route to get back
- Weekend program should pay for transportation regulation during pick-up/drop-off periods
- Large program must possess at least one night bus line to drop off students until 10 pm.

c. Long-term Strategy

1. Citywide alert system / Waze for city.

Leverage operations centers. Grows as vehicles get more connected. Perhaps partner with a vendor like Waze. To make people more aware during times when crashes are higher.

2. New road materials to encourage snow/ice melt