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A Study on Crash Reduction of a Signalized Intersection Converted to a Multi-Lane Roundabout

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Converted to a Multi-Lane Roundabout

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Honors Research Project

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Abstract

The study outlined in this paper investigated the effect of changing the intersection of E. Main Street, Haymaker Parkway, and N. Willow Street to a two-lane roundabout. The goal of the study was to measure what the proposed design would do to predicted car accident numbers. After calculating the crash reduction factors (CMFs) for each classification of incident, the study proved that the proposed changes would be an improvement. The construction of a roundabout to replace the signalized intersection at this location would produce enough value to pay itself off in just over two years.

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Section 1: Site Description

The Site that was studied is located at the intersection of E. Main Street, Haymaker Parkway, and N. Willow Street. This location is a five-leg intersection with two major arteries. The intersection is at the northwest corner of Kent State University. The location includes a five-lane leg from the east, a two-lane leg from the north, a four-lane leg from the west, a four-lane leg from the southwest, and a two-lane leg from the south. Figure 1 below shows the site location.

Figure 1: This figure shows the intersection location for this project.

Section 2: Background

This location is part of a traffic study and improvement program currently being worked on by Arcadis, US. The study being conducted by Arcadis includes a stretch of the road beginning west of this intersection and continuing past horning road to the east. Their study considered crash counts and modification factors for the project in its entirety. This study is meant to be a deeper dive into what might be the most concerning location within that project scope. During the study of this location, it was noted that many near misses took place. That is, there were nearly accidents at each site visit due to issues with the design. Issues include long signal waiting times, overstimulation due to extensive lighting and signage, high traffic flow, and irregular traffic patterns. The five-legged nature of this intersection is a concern because it requires added signal, signage, and pedestrian faculty complexity.

Section 3: Improvement Options

Improvement options for the structure of this intersection include altering Haymaker Parkway in order to create two separate intersections or converting the intersection to a five-leg roundabout. When converting an intersection into a roundabout, space is usually the major concern. Roundabouts require more space to service the same number of lanes when compared to intersections with signal control. However, in this case, the alternative improvement option would be to create an entirely new intersection to reduce the complexity of each intersection. The creation of a new intersection is not ideal because the intersection would require more space and would require tuning to ensure two signalized intersections could service the same amount of traffic in the given space. Also, this location is urban and the two-intersection plan would require

demolition of residential homes. The demolition, acquisition, and added complexity of two intersections is the reason that a roundabout design was chosen for study.

Section 4: Roundabout Design

The benefits come from the shape of the roundabout. At an intersection, vehicles are crossing in front of each other. The crossing points of the vehicle movement paths are defined as conflict points. Conflict points are classified into crossing points, merging points, and diverging points. Reducing conflict points at an intersection can reduce the possibility of crashes significantly, and reducing crossing points can reduce severe crashes greatly. Within the intersection of East Main Street and Haymaker Parkway angle crashes, left turn crashes, and rear end crashes occurred often. A typical 4-leg intersection has 32 conflict points. The proposed roundabout at the intersection of East Main Street and Haymaker Parkway will reduce the number of conflict points from 43 to 12 (6 merging points and 6 diverging points). Figure 2 below shows a comparison between conflict points for a standard four leg signalized intersection and for a roundabout servicing the same traffic lane count.

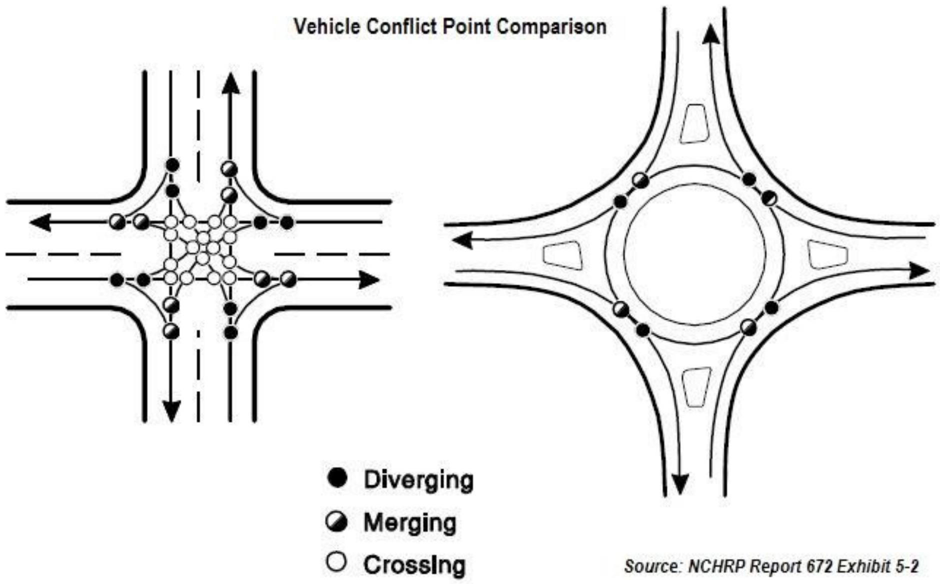

Figure 2: This figure shows the conflict points for a four-leg signalized intersection and for a roundabout designed for the same traffic lane count.

As in Figure 2, the five-leg roundabout at our location will have two conflict points per leg for the minor roads. There will be three for the east leg of East Main Street and the Haymaker Parkway due to the increase in lanes. Figure 3 below is a technical drawing of the intersection as proposed by Arcadis, US.

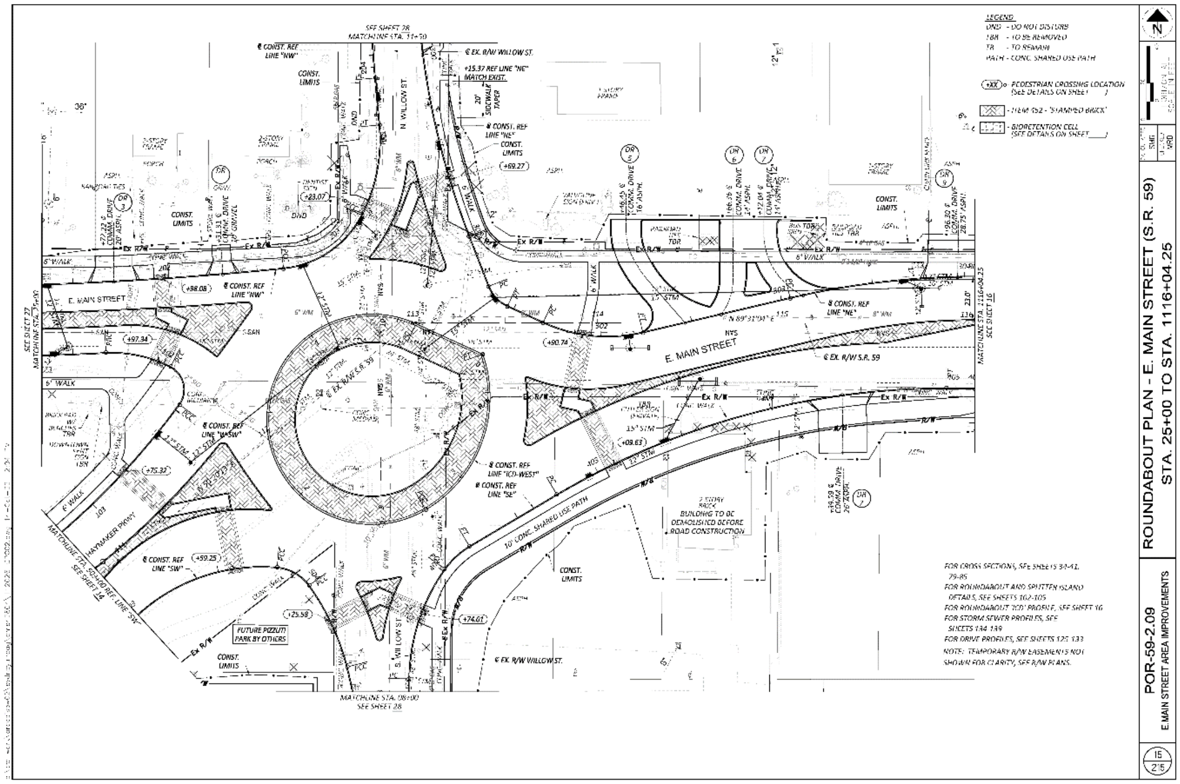

Figure 3: This figure shows the proposed design for the roundabout at our location as of 10/14/2022. Note: The intersection may go through some changes at the discretion of Arcadis, US and The City of Kent.

Section 5: Methodology

The first action that had to be taken was to find the existing crash data for this intersection. These can be found by going to the Ohio Department of Public Safety website and searching for the incidents that occurred in the area. Data for each leg of the intersection was taken from 2016 to 2018 because this was the period after the current improvements were made. The data is automatically found between log points framing the intersection between its neighboring intersections. After crash data is collected, the information should be inserted into the Economic Crash Analysis Tool (ECAT). ECAT is a program written within Microsoft Excel for the Ohio Department of Transportation (ODOT). The program aids in compiling crash data

and modifying it using crash modification factors. The program will then produce tables and graphs that might be beneficial. The program requires that the user input Site information, crash modification factors, any time related variables, and any data associated with accidents. An ECAT file will need to be created for the existing conditions and then another will be made for the proposed condition. The existing condition ECAT is used to create graphs for current expected and predicted accident rates. Those rates are then taken and multiplied by their KABCO values to create a figure detailing the cost of the incidents that happen in a year.

The Proposed ECAT file will use crash modification factors (CMF) from the clearinghouse website to create the graphs for the proposed improvements. These graphs will include crash reduction, initial cost reduction, predicted crash counts by type, and time to make up the cost of construction. These values will then be used to compare with the existing and prove whether the proposed changes would be beneficial. Figure 3 below has the loose schedule for the methodology.

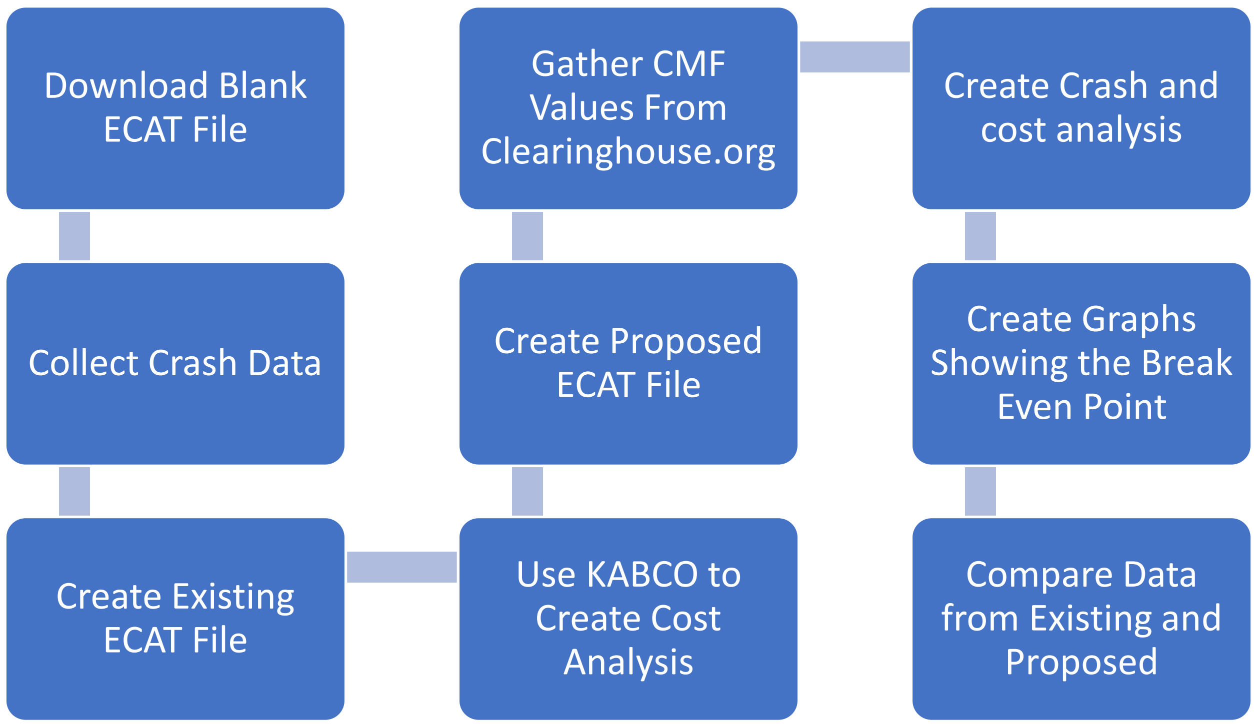

Figure 3: This figure shows the order in which tasks should be completed for this type of project.

Section 6: Data

The car crash data for this paper comes from the Ohio Department of Public Safety (ODPS) and is from the period of 2016 to 2018. The accident data does not go back further due to minor changes to the design of this intersection that were put into place in 2015. The crash reports were found by searching the streets that connect to the intersection and setting a boundary to the nearest crossing road. The CMF values were taken from the clearinghouse website because they take the values from scholarly papers and grade them based on peer review. Values for the roundabout were only considered at above a four-star rating and only if they applied to multi-lane roundabouts. CMF values were also taken for raised islands that would

channelize incoming and outflowing traffic while supplying a place for pedestrians to stop while walking. Another CMF was taken for the Pavement resurfacing that would need to occur. The combined CMF and CRF values can be found in Table 5 in the appendix. These combined values were found by using ECAT to calculate the expected accidents by type based on the collected data and the CMF values found on clearinghouse.org. The percentage change in accidents is the CRF. Then the following equation can be used to convert CRF to CMF

$$1 - \frac{CRF}{100}$$

These values can be compared with other CMF values to determine if there are safer alternatives.

Section 7: Results from Data

Existing

The results of the data manipulation include the accident counts per year for the existing intersection which can be found in Figure 4 below.

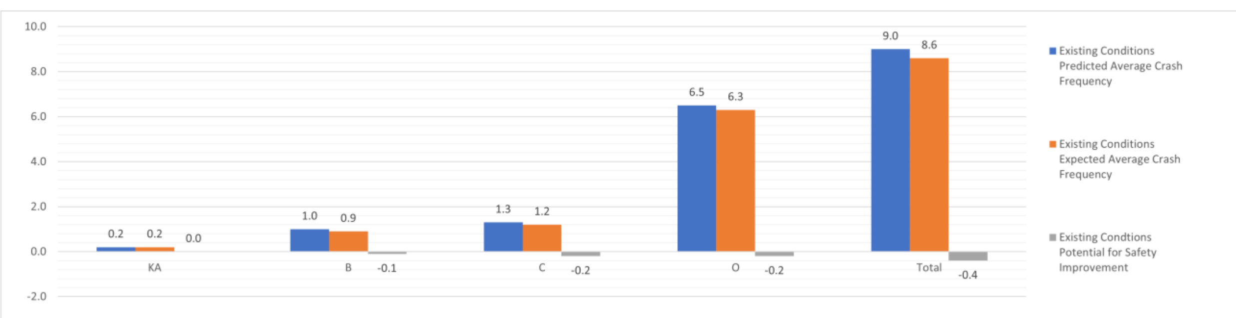

Figure 4: This figure compares the number of accidents predicted in a year given the type of intersection compared to the expected number of accidents in a year given the crash data. The grey bar indicated the difference and the negative value indicated that the intersection is performing better than anticipated for its design.
Note: The information in this figure can be found in Table 1 in the appendix.

This data shows that the current accident rate at this intersection is lower than the predicted amount. This means that the intersection cannot reasonably be changed to be safer

without reconstruction. The predicted value being within half a point of the expected also indicates that the accidents are not due to non-compliance in most cases. The data displayed in Figure 4 can then be multiplied by the corresponding value for KABCO cost, found in Table 2 to create Figure 5, which can be found below.

Figure 5: This figure shows the total codified cost of the accidents for the year by KABCO type. The table also shows the total value of all accidents based on expected and predicted accidents.
Note: The values in this figure can also be found in Table 3 and the KABCO values are in Table 2.

The data above shows the cost of each type of accident per year with the current design. Figure 5 is important because although Figure 4 shows only 0.2 K-type accidents a year, or 1 accident for every 5 years, The value of incidents resulting in death from a cost perspective is much higher than the others. Accidents resulting in death account for 82.47% of the perceived cost of this intersections car crashes. Also, Figure 5 shows the total cost of the accidents in a year to amount to over a million dollars despite averaging about 9 accidents a year. These numbers assist in validating if there is an issue that needs to be addressed.

Proposed

After confirming that there is a problem with the current roadway structure at this intersection, CMF data must be found and the sum of each improvement will be used to edit the predicted crash values at this location. This series of information allows for the creation of Figure 6 below.

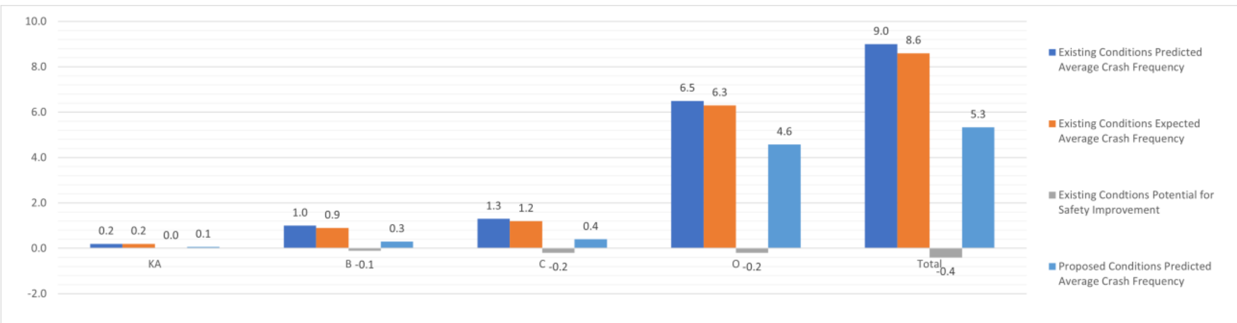

Figure 6: This figure compares the existing predicted and expected accident counts compared to the proposed predicted accident counts.
Note: These values can be found in table 4

Figure 6 indicates that the number of accidents resulting in altered life status or death will be cut in half by these improvements. This is due to rounding. The proposed number of accidents of this type to be expected in a year is actually 0.0631, from Table 4, which is 1 KA- type accident every 15.85 years the other types of accidents also see reductions leading to a total yearly accident count of 5.3 for this intersection. When using an expected average annual daily traffic (AADT) value of 18,000 vehicles, the value for city arterials of this size, approximately 0.000081% of vehicles will be in accidents after the improvements compared to 0.00014% for the existing. Figure 7 below shows the monetary value of each crash type including the expected proposed numbers.

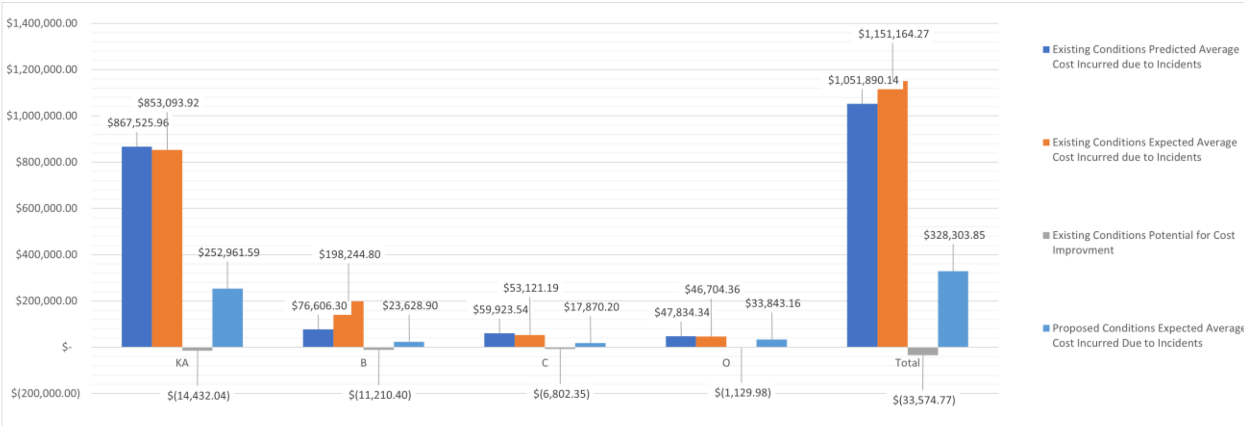

Figure 7: This figure expands upon the values of figure 3. It includes the predicted value of the accidents in the proposed design. Higher values are higher perceived costs to the city.
Note: these values can be found in table 6

As can be seen in Figure 7, the improvements decrease the cost of operation due to car accidents in the intersection by 822,860.42 dollars. The majority of this improvement comes from the KA-type accidents which account for 600,132.33 dollars. O-type accidents, accidents with no reported injury, are reduced the least by percentage. Figure 8 below shows how the accidents occur based on accident counts, expected accidents for the current road structure, and the expected accidents for the proposed build.

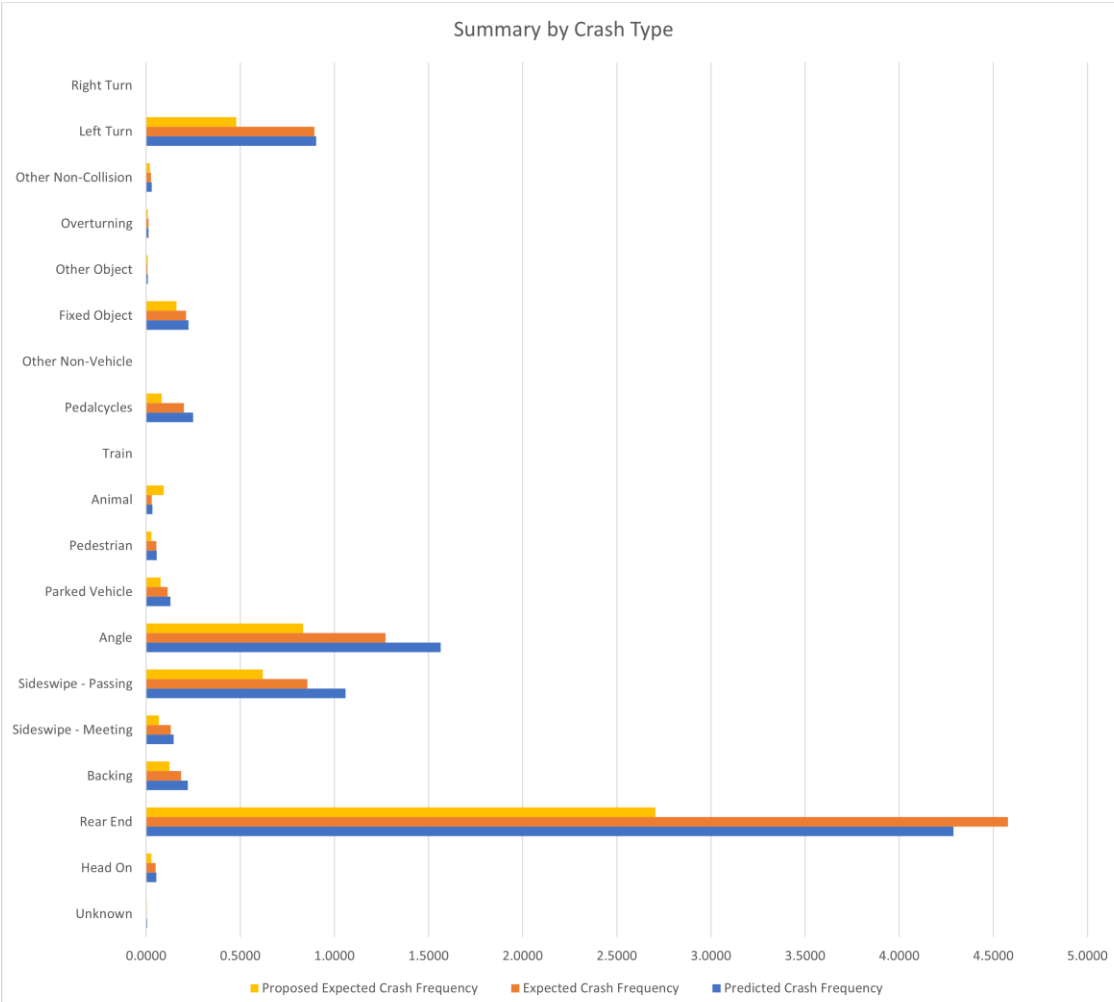

Figure 8: This figure has the data for the predicted and expected accidents by type. This includes the values predicted for the proposed design.
Note: These values can be found in table 7

The data in Figure 8 shows the current expected crash frequency based on accident records in blue, the current predicted crash frequency based on the intersection type in orange, and the predicted proposed crash frequency for our design in yellow. All crash types show reductions except for animal accidents. Animal accidents are expected to increase because animals tend to have a hard time understanding how to exit a roundabout once they enter. This is unfortunate; however, the other results seem very promising. Accidents such as left turn and

backing should not occur in the intersection but may happen in the surrounding areas due to high business traffic. The fiscal benefit by year is located in Figure 9 below.

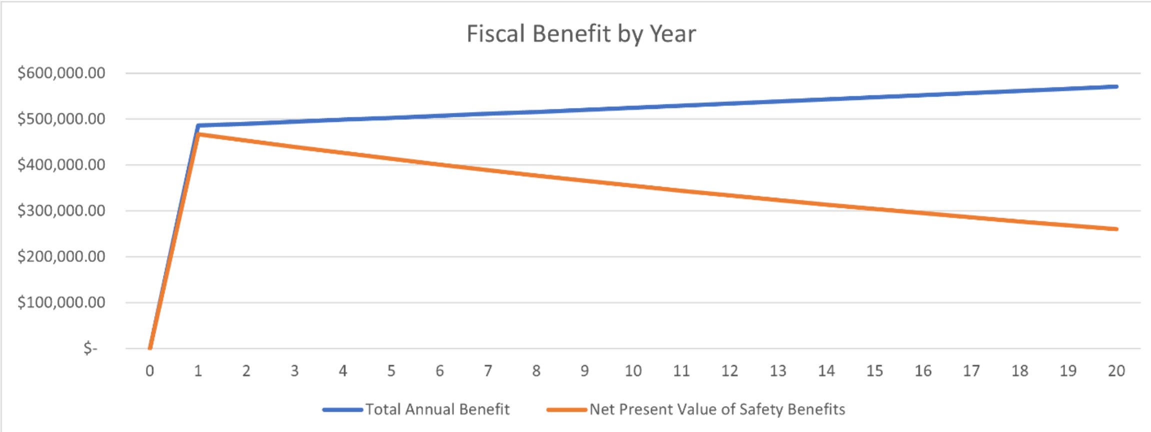

Figure 9: This graph shows the annual benefit in dollars per year as well as the net present value.
Note: These values are calculated in table 8.
Note: The net present value declines due to normal wear on the roadway structures.

Figure 9 visualizes the total annual benefit and the net present value of the proposed intersection. As can be seen, the net present value of the proposed intersection decreases over time due to wear on the structure and based on expected increase in traffic volume. Traffic volume will eventually lead to a change in the design to accommodate more vehicles. Arguably, the more important data point here is total annual benefit. The importance in total annual benefit is that it dictates if the intersection is fiscally benefitting the municipality or not due to safety. As we can see in Figure 9, the value of this intersection is expected to continue to increase as the next twenty years pass. Figure 10 below shows the most important metric for a government to decide to fund a safety project.

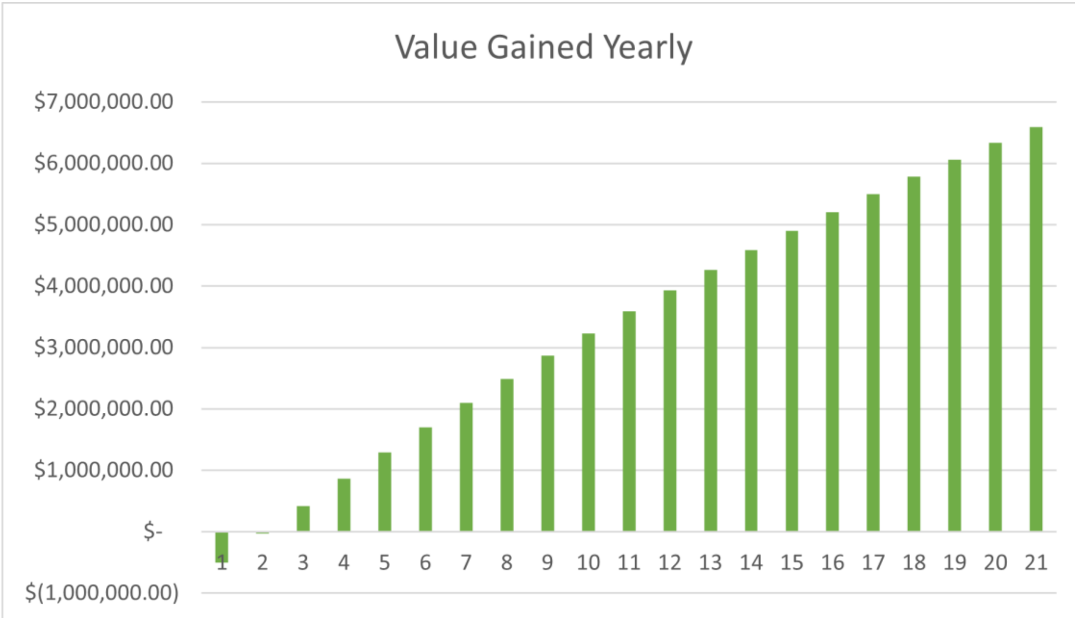

Figure 10: This graph shows the net revenue brought on by the safety improvements in dollars per year. Note: These improvements are expected to reach the break-even point just after the second year of implementation assuming a 500,000-dollar cost for the roundabout based on a conservative estimate.

Figure 10 shows the actual actionable increase in value generated by the improvements outlined in the proposed build. This project looks very profitable because just after the second year mark the roundabout would reach the break-even point and the project would have paid for itself based on KABCO crash cost estimates.

<u>Section 8: Meaning of Results</u>

Based on the results this project looks to be a very profitable one for the City of Kent. Almost all metrics show a decrease in the number of accidents. The reductions in figures 6 through 8 show that less accidents are expected to occur in the year following construction, which will result in a cost reduction for the city. Not only will this benefit the city but the data in figures 9 and 10 show that the proposed intersection will continue to save the city money in the coming twenty years.

Section 9: Appendix

Project Summary Results (Without Animal Crashes)							
			KA	B	C	O	Total
Npredicted - Existing Conditions			0.216	0.970	1.335	6.464	8.985
Nexpected - Existing Conditions			0.213	0.918	1.183	6.311	8.625
Npotential for improvement - Existing Conditions			-0.004	-0.052	-0.152	-0.153	-0.360

Table 1: This table indicates the numerical value for the number of accidents expected to occur by KABCO value and measured in accidents per year. Expected conditions are based upon accident data that was gathered between 2016 to 2018. The predicted values are based on expected crash factors for an intersection of this type.

Ohio KABCO Values and Meanings			Cost by severity from FHWA manual	
2012 to present				
5-Fatal	K	Any injury that results in death within a 30-day period after the crash occurred.	$	4,008,900.00
4-Incapacitating	A	Any injury, other than a fatal injury, which prevents the injured person from walking, driving or normally continuing the activities the person was capable of performing before the injury	$	216,000.00
3- Non-incapacitating	B	Any injury, other than a fatal injury or an incapacitating injury, which is evident to observers at the scene. Examples: contusions (bruises); lacerations; bloody nose.	$	79,000.00
2-Possible	C	Complaint of pain without visible injury. Examples: whiplash; headache.	$	44,900.00
1-No injury reported	O	When there is no information about an individual being injured (i.e., a hit-skip driver) there would be no “reported” injury and this would be the appropriate selection.	$	7,400.00
	K/A/B	additional injurious crashes simultaneously, value is added to the value of the most damaging inci	$	158,200.00

Table 2: This table details the KABCO accident scale and the given value for each type of accident based on Ohio standards. The blue portion of the table comes from the Federal Highway Administration (FHWA) manual and the yellow portion is from the Ohio Department of Transportation (ODOT) website.

Project Summary Results In Dollars (Without Animal Crashes)							
			KA	B	C	O	Total
$predicted - Existing Conditions			$ 867,525.96	$ 76,606.30	$ 59,923.54	$ 47,834.34	$ 1,051,890.14
$expected - Existing Conditions			$ 853,093.92	$ 198,244.80	$ 53,121.19	$ 46,704.36	$ 1,151,164.27
$potential for improvement - Existing Conditions			$ (14,432.04)	$ (11,210.40)	$ (6,802.35)	$ (1,129.98)	$ (33,574.77)

Table 3: This table has the cost of each accident type by KABCO value expected in a year.

Project Summary Results (Without Animal Crashes)					
	KA	B	C	O	Total
$N_{predicted}$ - Existing Conditions	0.2164	0.9697	1.3346	6.4641	8.9848
$N_{expected}$ - Existing Conditions	0.2128	0.9178	1.1831	6.3114	8.6251
$N_{potential\ for\ improvement}$ - Existing Conditions	-0.0036	-0.0519	-0.1515	-0.1527	-0.3597
$N_{predicted}$ - Proposed Conditions	0.0631	0.2991	0.3980	4.5734	5.3336

Table 4: This table expands on table 1 to include the predicted values for the proposed design.

	Factors			
	KA	**B**	**C**	**O**
CRF	29.65225564	32.5887993	33.64043614	72.46252812
CMF	0.703477444	0.674112007	0.663595639	0.275374719

Table 5: This table shows the crash reduction factors (CRF) and crash modification factors (CMF) for each KABCO value.

Project Summary Results In Dollars (Without Animal Crashes)							
			KA	B	C	O	Total
$predicted - Existing Conditions			$ 867,525.96	$ 76,606.30	$ 59,923.54	$ 47,834.34	$ 1,051,890.14
$expected - Existing Conditions			$ 853,093.92	$ 72,506.20	$ 53,121.19	$ 46,704.36	$ 1,025,425.67
$Potential for Improvement - Existing Conditions			$ (14,432.04)	$ (4,100.10)	$ (6,802.35)	$ (1,129.98)	$ (26,464.47)
$Predicted Improvement -Proposed Conditions			$ 252,961.59	$ 23,628.90	$ 17,870.20	$ 33,843.16	$ 328,303.85

Table 6: This table has the values for the expected and predicted cost values for the existing conditions as well as the predicted values for the cost of the accidents in the proposed design.

Summary by Crash Type				
	Existing			Proposed
Crash Type	Predicted Crash Frequency	Expected Crash Frequency	PSI	Proposed Expected Crash Frequency
Unknown	0.0045	0.0041	-0.0004	0.0029
Head On	0.0549	0.0499	-0.0050	0.0269
Rear End	4.2880	4.5781	0.2901	2.7043
Backing	0.2212	0.1847	-0.0364	0.1233
Sideswipe - Meeting	0.1454	0.1304	-0.0151	0.0664
Sideswipe - Passing	1.0596	0.8561	-0.2035	0.6192
Angle	1.5637	1.2710	-0.2927	0.8333
Parked Vehicle	0.1300	0.1135	-0.0165	0.0765
Pedestrian	0.0552	0.0540	-0.0012	0.0274
Animal	0.0333	0.0298	-0.0036	0.0944
Train	0.0002	0.0001	-0.0001	0.0001
Pedalcycles	0.2498	0.2006	-0.0492	0.0830
Other Non-Vehicle	0.0000	0.0000	0.0000	0.0000
Fixed Object	0.2246	0.2122	-0.0124	0.1602
Other Object	0.0087	0.0079	-0.0008	0.0082
Overturning	0.0129	0.0118	-0.0011	0.0090
Other Non-Collision	0.0294	0.0266	-0.0029	0.0205
Left Turn	0.9033	0.8945	-0.0089	0.4779
Right Turn	0.0000	0.0000	0.0000	0.0000

Table 7: This table shows the number of accidents per year by type for the existing and the proposed. The PSI value is the difference between the existing predicted and expected crash number.

Annual Benefits Summary By Crash Severity										
					Year					
Code	Severity		Avg Est Red	Present Value $	0	1	2	3	4	5
KA	Fatal &Incapacitating Injury Crash		0.703	$ 600,132.33	$ -	$ 425,768.08	$ 429,387.11	$ 433,036.90	$ 436,717.72	$ 440,429.82
B	Non-Incapacitating Injury Crash		0.674	$ 48,877.30	$ -	$ 33,228.84	$ 33,511.28	$ 33,796.13	$ 34,083.40	$ 34,373.11
C	Possible Injury Crash		0.664	$ 35,250.99	$ -	$ 23,591.24	$ 23,791.76	$ 23,993.99	$ 24,197.94	$ 24,403.63
O	Property Damage Crash		0.275	$ 12,861.20	$ -	$ 3,571.75	$ 3,602.11	$ 3,632.73	$ 3,663.61	$ 3,694.75
Total Annual Benefit					$ -	$ 486,159.91	$ 490,292.27	$ 494,459.76	$ 498,662.67	$ 502,901.30
Net Present Value of Safety Benefits					$ -	$ 467,461.46	$ 453,302.77	$ 439,572.92	$ 426,258.94	$ 413,348.21

Table 8: This table has the estimated reduction by KABCO value, the present cost of the improvement, and the annual benefit of the improvements. The net present value of safety benefits is the sum of costs and savings due to the improvements per year.

Note: The Discount rate for these improvements is 0.04% and the expected Traffic volume growth rate is 0.0085

<u>Note* a series of excel sheets with additional information can be provided at request.</u>

Section 10: References

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