Project #1

Highway Design and Traffic Operations

Preliminary Alignment Design and Evaluation

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Team:

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Statement of Problem

The project aims to develop an alternative route for US Trunk Highway (USTH) 12 to bypass the city of Cokato, addressing the challenge of increasing traffic demands that the existing route through downtown cannot accommodate. The initiative explores two potential bypass routes: a southern path utilizing the existing right of way along 60th Street, and a northern route circumventing the city. The evaluation process includes a preliminary review of both options, with considerations for design specifications such as speed, curvature, grade, visibility, and environmental obstacles.

An initial visualization of the proposed routes is provided (referenced as Figure 1), facilitating further analysis through aerial imagery and land use mapping. This analysis aims to assess the potential impacts, lengths, intersections, and financial implications of each option. The project concludes with a comprehensive evaluation, weighing both quantitative and qualitative aspects to recommend the most viable bypass route.

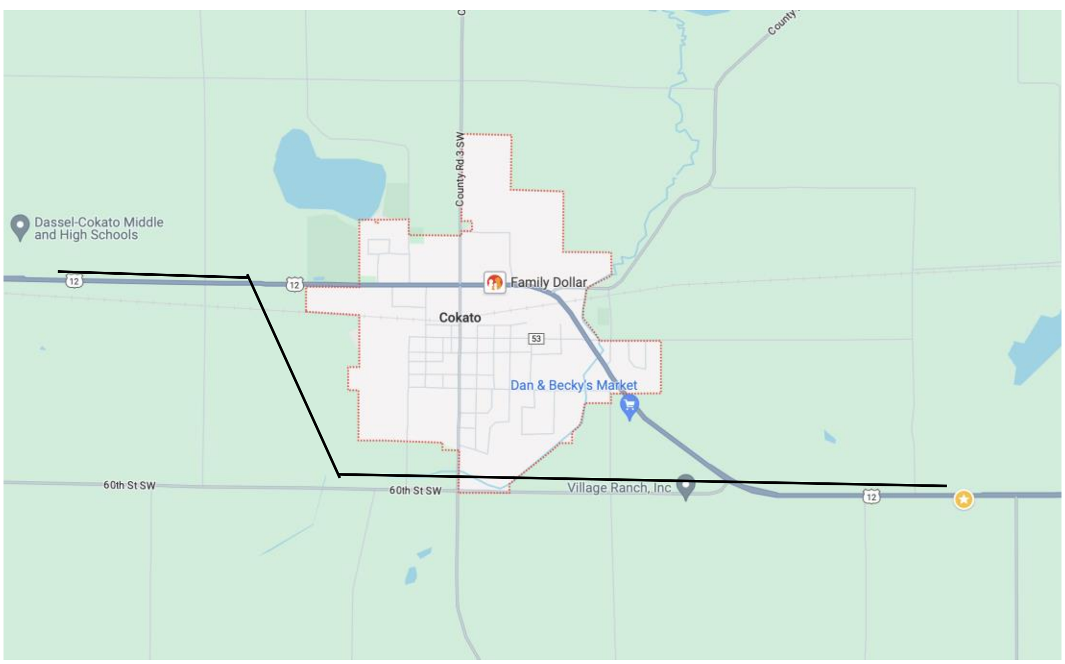


Figure 1: Preliminary draft of the two alignment options

Methodology

To divert US Trunk Highway 12 around Cokato, two alternatives were evaluated for their feasibility, and impact on society and the environment, leading to a recommendation.

Alternative A proposes a northern bypass starting near Dassel-Cokato schools, using the right of way (ROW) of 40th St SW, and reconnecting east of Cokato. This route, designed with an around 2500-foot radius for driver comfort, avoids natural and man-made obstacles like Brocks Lake and a solar farm. It incorporates minimal property relocations and earthwork but necessitates the rerouting of homes and construction of additional roads. Challenges include crossing wetlands and a pond, building a short railroad overpass, and modifying local roads for perpendicular intersections with USTH 12.

Alternative B suggests a southern route, also beginning near the schools but using the ROW of 60th St SW, and rejoining USTH 12 on the east side of Cokato. It features a railroad overpass constructed on a tangent to minimize relocations and adapt to the terrain's gradient. This alternative requires partial reconstruction of 60th St SW and Johnson Ave SW to meet the highway correctly, along with the need to reroute driveways and homes. Unlike Alternative A, this option would necessitate industrial relocations for a smooth integration with the existing highway.

Both options emphasize minimizing environmental disruption, property relocations, and ensuring safe, perpendicular junctions with the existing highway.

Quantitative Summary

The quantitative analysis of the two proposed routes for rerouting US Trunk Highway 12 around Cokato reveals distinct challenges and requirements for each option:

- **Northern Route (Option A):** This option is significantly longer, necessitating about twice the new right of way compared to the southern option. It demands more acquisition of existing right of way. The route encounters steep grades up to 5% over short distances and requires the removal of 4 acres of wetlands, indicating considerable environmental impact.

- **Southern Route (Option B):** While shorter, this route faces challenges related to its proximity to industrial areas, resulting in more total relocations, predominantly industrial. The steepest grade encountered is 2.38%, slightly less steep than the northern route but still notable.

Final Recommendation

Considering the evaluation parameters such as cost, safety, traffic management, and the impact on local communities and environments, the **Southern Alternative (B)** emerges as the more favorable option. This conclusion is drawn based on its overall lower environmental impact, despite the challenges posed by its proximity to residential areas and the complexities involved in constructing the elevated railroad crossing. The choice favors efficient traffic flow, minimal relocations, and the strategic consideration of local amenities and natural features.

Design Conditions and Features

The plan development for rerouting US Trunk Highway 12 around Cokato is detailed in AutoCAD, adhering to specific project specifications and scales. The design process encompasses three primary aspects: horizontal alignment, cross-section, and vertical alignment, each tailored to integrate seamlessly within the specified environment and project constraints.

Horizontal Alignment (Southern Route):

- Chosen for its minimal impact on Cokato and ease of land acquisition along the 60th St SW.
- Features curves with radii significantly exceeding the minimum requirement of 1500 feet, enhancing drivability and alignment with the terrain.

- Curve angles are optimized to closely follow the natural landscape, reducing road deviation.

Cross-Section Design:

- Utilizes standard values from design manuals, aligned with terrain profiles to determine cut-and-fill requirements.
- Cross-sections are provided at frequent intervals and critical points to ensure a balance between safety, particularly in runoff distances, and minimizing earthwork.

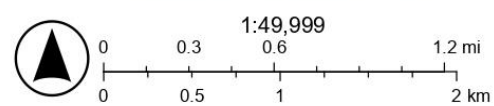
Vertical Alignment:

- Incorporates long grades to enhance driving comfort, constrained by specific intersection elevations and structures like railroad bridges.
- The design adheres to a maximum of 3% vertical grade change.
- The planning faced challenges in maintaining terrain congruence, with vertical curve lengths determined according to the MNDOT Road Design Manual and rounded for practicality.

The coordination between vertical and horizontal designs, while complex, prioritizes practical and environmental considerations. This meticulous approach ensures the project's alignment with both technical requirements and the goal of minimizing impact on the surrounding landscape and community.

Cokato alignment

3/24/2024



Esri, CGIAR, USGS, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, USFWS

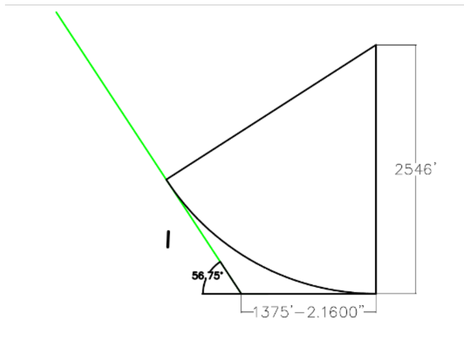
Description of Horizontal Curves:

Both curves had deflection angle, Δ = 56.75˚

Curves of radius, R = 2546’ were chosen.

Thus, Curve Length = 2521.75’

Tangent Length =1375.18’



PI#1: sta. 133+38.75		PI#2: sta. 194+85.5	
PC#1: sta. 119+63.57	PC#2: sta. 181+10.32	PT#2: sta. 206+32.07	PT#1: sta. 144+85.32

For Radius 2546’, from MNDoT RDM, a superelevation of 0.048 is necessary.

Thus, distance from normal crown to reach 1/3 full superelevation = 249.6’ [using S=1/400]

Distance from PC to to full superelevation = 76.8’

Description of Vertical Curves:

PVI#1: 103+92.12

G_1: 0.5% G_2: 0.29%   thus, A=0.21 $L_s = 570'$ or k=136

Thus, Length of curve: 1107.44’ = 108’   PVC=103+38.12 and PVT= 104+46.12

Offset at PVI = $(G_2 - G_1)/(2 \times L_c) \times x2$ = 0.11’ and $x_m =$ 68.35’ from PVT

Elevation of PVT = 1030.27’   Elevation of PVT = 1030.16’   Low point elevation = 1029.65’

PVI#2: 163+60.72

G_1: 2.38% G_2: 0.5% thus, A=1.88 $L_s = 570\ or\ k = 136$

Thus, Length of curve: 255.68’ = 256’ PVC= 162+32.27 and PVT= 164+88.27

Offset at PVI = (G2-G1)/(2*Lc)×x2 = 0.60’ and x_m = low point located at PVT

Elevation of PVC = 1063.04’ Elevation of PVT = 1059.36’

PVI#3: 188+83.212

G_1: 1.33% G_2: 2.38% thus, A= 3.71 $L_s = 570$ or k=151

Thus, Length of curve: 560.21’ = 562’ PVC= 186+02.212 and PVT= 191+64.212

Offset at PVI = (G2-G1)/(2*Lc)×x2 = 2.61’ and $x_m = G_1 \times L_c/(G_1 - G_2)$= 201.47’ from PVT

Elevation of PVC = 1113.57’ Elevation of PVT = 1116’ Elevation of high point = 1118.3’

Evaluation of Vertical and Horizontal Curve Coordination:

The First Horizontal Curve is on a constant Upgrade, but the second horizontal curve has a crest vertical curve in the middle. This will be disorienting for the drivers. However, rerouting would have resulted in the demolition of schools and ended up in more earthwork, thus resulting in more cost.

Horizontal and Vertical Curve Passing Sight Distance:

PSD

PVI#1: 103+92.12

G1: 0.5% G2: 0.29%, A=0.21, Ls= 75' or k= 357

For start of no passing zone,

S= 857.57 ft, no passing zone before this.

Start of no- passing zone = Station of PVC – S = 119+63 – 8+60 = 11103 ft

For end of no-passing zone,

S1= 2399.02 ft,

Station of end no-pass = Station of PVT – (S-S1) = 129+46.3

PVI#2:

G1: 2.38% G2: 0.5% thus, A=1.88, Ls = 671.24

For start of no passing zone,

S= 12.31 ft, no passing zone before this

Start of no- passing zone = Station of PVC – S = 181+10.32 – 12.31 = 17+98.01

For end of no- passing zone

S1= 767.29

End No-Pass Zone = Station of PVT – (S-S1) = 206+32.07 – 0.0038 = 206+32.066

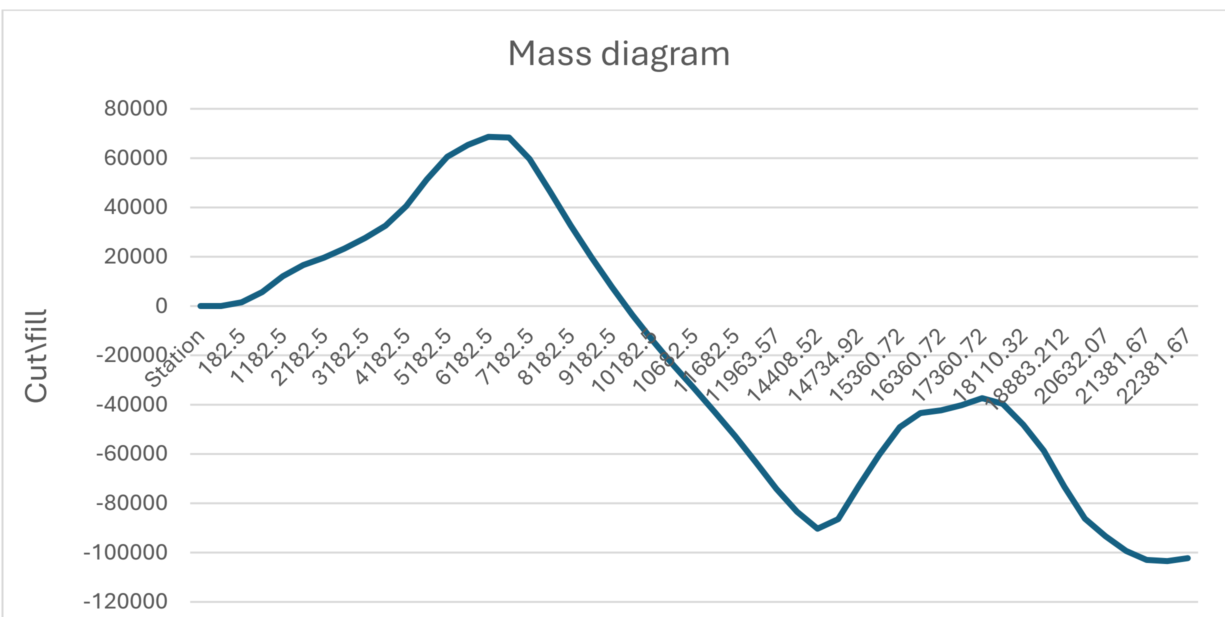
Truck Climbing Lane Calculation/Justification

Truck climbing lanes are required only when the truck's speed is reduced to a minimum of 10 mph. Here, in our design the road alignment did not require a truck climbing lane.

Cut/Fill Calculation

Station	cut	fill	Cut Volume	Fill Volume	Shrinkage	Total Fill	Net Fill(-)/Cut(+)	Mass diagram	
0	244.34	64.11	1523.89	118.72	17.81	136.53	1387.36	0	
182.5	578.56		4283.93	0.00	0.00	0.00	4283.93	1523.89	
682.5	1734.76		6425.04	0.00	0.00	0.00	6425.04	5671.28	
1182.5	1734.76		4543.59	0.00	0.00	0.00	4543.59	12096.32	
1682.5	718.78		2992.43	0.00	0.00	0.00	2992.43	16639.91	15% shrinkage assumed
2182.5	897.13		3652.98	0.00	0.00	0.00	3652.98	19632.34	
2682.5	1075.48		4313.54	0.00	0.00	0.00	4313.54	23285.32	
3182.5	1253.83		4974.09	0.00	0.00	0.00	4974.09	27598.86	
3682.5	1432.18		7912.43	0.00	0.00	0.00	7912.43	32572.95	
4182.5	2840.53		10850.76	0.00	0.00	0.00	10850.76	40485.38	
4682.5	3018.88		9233.54	0.00	0.00	0.00	9233.54	51336.14	
5182.5	1967.23		4789.59	0.00	0.00	0.00	4789.59	60569.67	
5682.5	619.15		3281.70	0.00	0.00	0.00	3281.70	65359.27	
6182.5	1152.97		2135.13	2112.93	316.94	2429.86	-294.74	68640.97	
6682.5		1140.98	0.00	7558.24	1133.74	8691.98	-8691.98	68346.23	
7182.5		2940.47	0.00	11539.80	1730.97	13270.77	-13270.77	59654.26	
7682.5		3291.02	0.00	11858.69	1778.80	13637.49	-13637.49	46383.49	
8182.5		3112.67	0.00	11198.13	1679.72	12877.85	-12877.85	32746.00	
8682.5		2934.32	0.00	10537.57	1580.64	12118.21	-12118.21	19868.15	
9182.5		2755.97	0.00	9877.02	1481.55	11358.57	-11358.57	7749.94	
9682.5		2577.62	0.00	9216.46	1382.47	10598.93	-10598.93	-3608.63	
10182.5		2399.27	0.00	8555.91	1283.39	9839.29	-9839.29	-14207.56	
10392.12		2220.92	0.00	8111.74	1216.76	9328.50	-9328.50	-24046.85	
10682.5		2159.42	0.00	8307.63	1246.14	9553.77	-9553.77	-33375.35	
11182.5		2326.7	0.00	8567.30	1285.09	9852.39	-9852.39	-42929.13	
11682.5		2299.64	0.00	9148.13	1372.22	10520.35	-10520.35	-52781.52	
11713.97		2640.35	0.00	9446.52	1416.98	10863.50	-10863.50	-63301.87	
11963.57		2460.77	0.00	8061.63	1209.24	9270.87	-9270.87	-74165.36	
12040.37		1892.51	0.00	5968.35	895.25	6863.60	-6863.60	-83436.24	
14408.52		1330.4	6729.41	2463.70	369.56	2833.26	3896.15	-90299.84	
14485.32	3633.88		13369.98	0.00	0.00	0.00	13369.98	-86403.70	
14734.92	3585.91		12793.70	0.00	0.00	0.00	12793.70	-73033.71	
14860.72	3322.69		11126.37	0.00	0.00	0.00	11126.37	-60240.01	
15360.72	2685.55		5718.93	0.00	0.00	0.00	5718.93	-49113.64	
15860.72	402.67		1158.81	30.98	4.65	35.63	1123.19	-43394.71	
16360.72	223.09	16.73	2058.54	30.98	4.65	35.63	2022.91	-42271.53	
16860.72	888.52		2880.81	0.00	0.00	0.00	2880.81	-40248.62	
17360.72	667.12		1235.41	3021.76	453.26	3475.02	-2239.62	-37367.80	
17860.72		1631.75	0.00	7396.52	1109.48	8506.00	-8506.00	-39607.42	
18110.32		2362.37	0.00	9164.07	1374.61	10538.69	-10538.69	-48113.42	
18187.12		2586.23	0.00	12756.13	1913.42	14669.55	-14669.55	-58652.10	
18883.21		4302.08	0.00	11220.91	1683.14	12904.04	-12904.04	-73321.65	
20555.27		1757.21	0.00	6212.07	931.81	7143.89	-7143.89	-86225.69	
20632.07		1597.31	0.00	5187.07	778.06	5965.14	-5965.14	-93369.58	
20881.67		1203.71	0.00	3166.69	475.00	3641.69	-3641.69	-99334.71	
21381.67		506.3	611.30	937.59	140.64	1078.23	-466.94	-102976.40	
21881.67	330.1		1161.09	0.00	0.00	0.00	1161.09	-103443.34	
22381.67	296.89		549.80	0.00	0.00	0.00	549.80	-102282.25	

Mass Diagram



Clear Zone Calculation

In assessing the clear zone (CZ) for road design, it is imperative to factor in key parameters such as the design speed and the Annual Average Daily Traffic (AADT). For instance, with a design speed of 60 mph and an AADT of 10,000 vehicles, the clear zone should be meticulously calculated to ensure safety and minimize risks. By analyzing the cut/fill section of each segment of the road, engineers can determine the necessary width of the recoverable clear zone. This zone serves as a buffer, free of hazards, and sufficiently wide to accommodate vehicles that may deviate from the roadway under normal driving conditions. By incorporating these considerations into the design process, road planners can enhance safety and mitigate potential accidents, thereby promoting smoother traffic flow and safeguarding motorists and pedestrians alike. Here is a part of the calculation:

			Clear Zone (ft)		Assumptions	
Station	cut	fill	cut	fill	Speed	AADT
0	244.34	64.11	27.5	35	60	10k
182.5	578.56		27.5			
682.5	1734.76		27.5			
1182.5	1734.76		27.5			
1682.5	718.78		27.5			
2182.5	897.13		27.5			
2682.5	1075.48		27.5			
3182.5	1253.83		27.5			
3682.5	1432.18		29			
4182.5	2840.53		29			
4682.5	3018.88		29			
5182.5	1967.23		26			
5682.5	619.15		27.5			
6182.5	1152.97		26			
6682.5		1140.98		75.5		
7182.5		2940.47		75.5		
7682.5		3291.02		75.5		
8182.5		3112.67		75.5		
8682.5		2934.32		75.5		
9182.5		2755.97		75.5		
9682.5		2577.62		75.5		
10182.5		2399.27		75.5		
10392.12		2220.92		75.5		
10682.5		2159.42		75.5		
11182.5		2326.7		75.5		
11682.5		2299.64		75.5		
11713.97		2640.35		75.5		
11963.57		2460.77		55.25		
12040.37		1892.51		35		
14408.52		1330.4		35		
14485.32	3633.88		29			
14734.92	3585.91		29			
14860.72	3322.69		29			
15360.72	2685.55		29			
15860.72	402.67		26			
16360.72	223.09	16.73	27.5	35		
16860.72	888.52		27.5			
17360.72	667.12		27.5			
17860.72		1631.75		35		
18110.32		2362.37		75.5		
18187.12		2586.23		75.5		
18883.21		4302.08		75.5		
20555.27		1757.21		55.25		
20632.07		1597.31		35		
20881.67		1203.71		35		
21381.67		506.3		35		
21881.67	330.1		27.5			
22381.67	296.89		27.5			

The results have been attached in the Excel file.

Impact Assessment

Length (feet)	22381.67
Right of Way (acres)	64.224
New	70.55
Along Existing	52.66
Residential Relocations	5
Industrial Relocations	0
Farmland (acres)	69.12
Wetland (acres)	0.06
Recreational (acres)	1.44
Stream crossings	2
At-grade intersections	2
Overpasses/Underpasses	1
Maximum Grade	2.38%
Superelevation Pass/Fail	Pass