RWR 4013

Digital Twins for Smart Cities

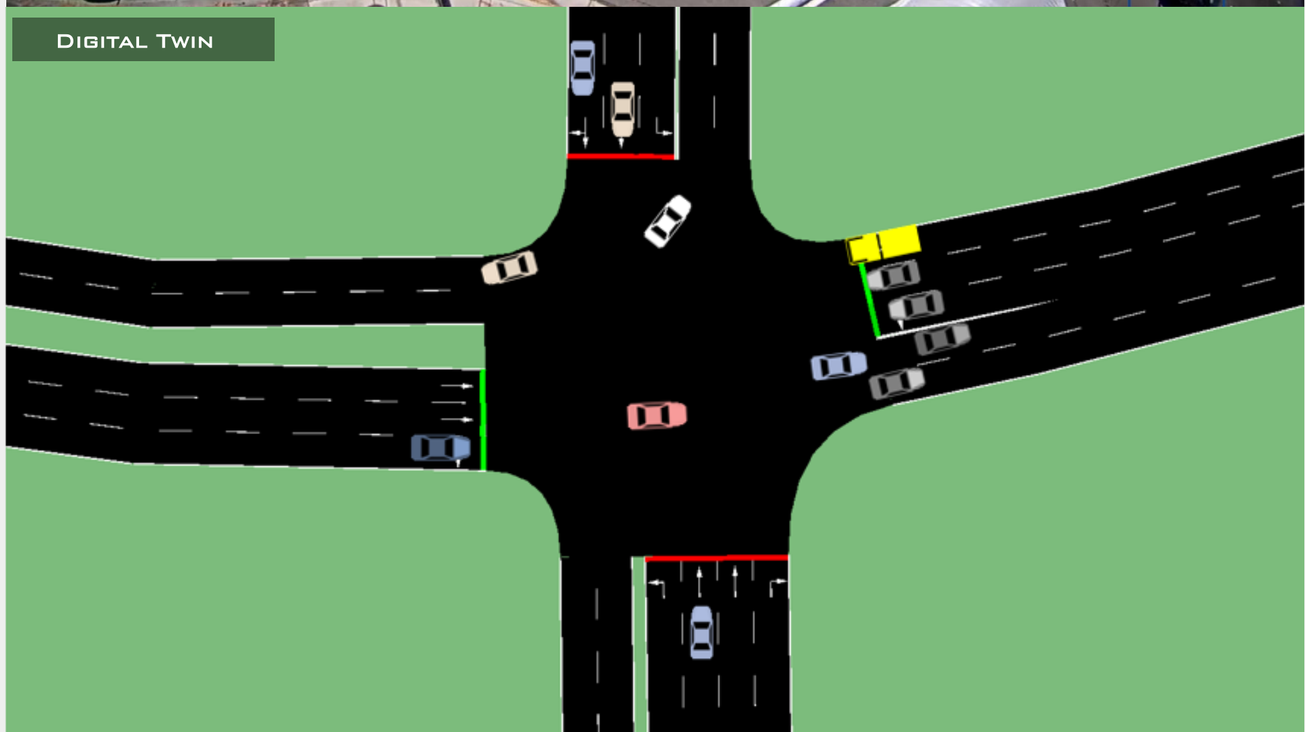
Dr. Ahmad Mohammadi

Week 10 | Session 1:
Decision
(Communication & Presentation I)

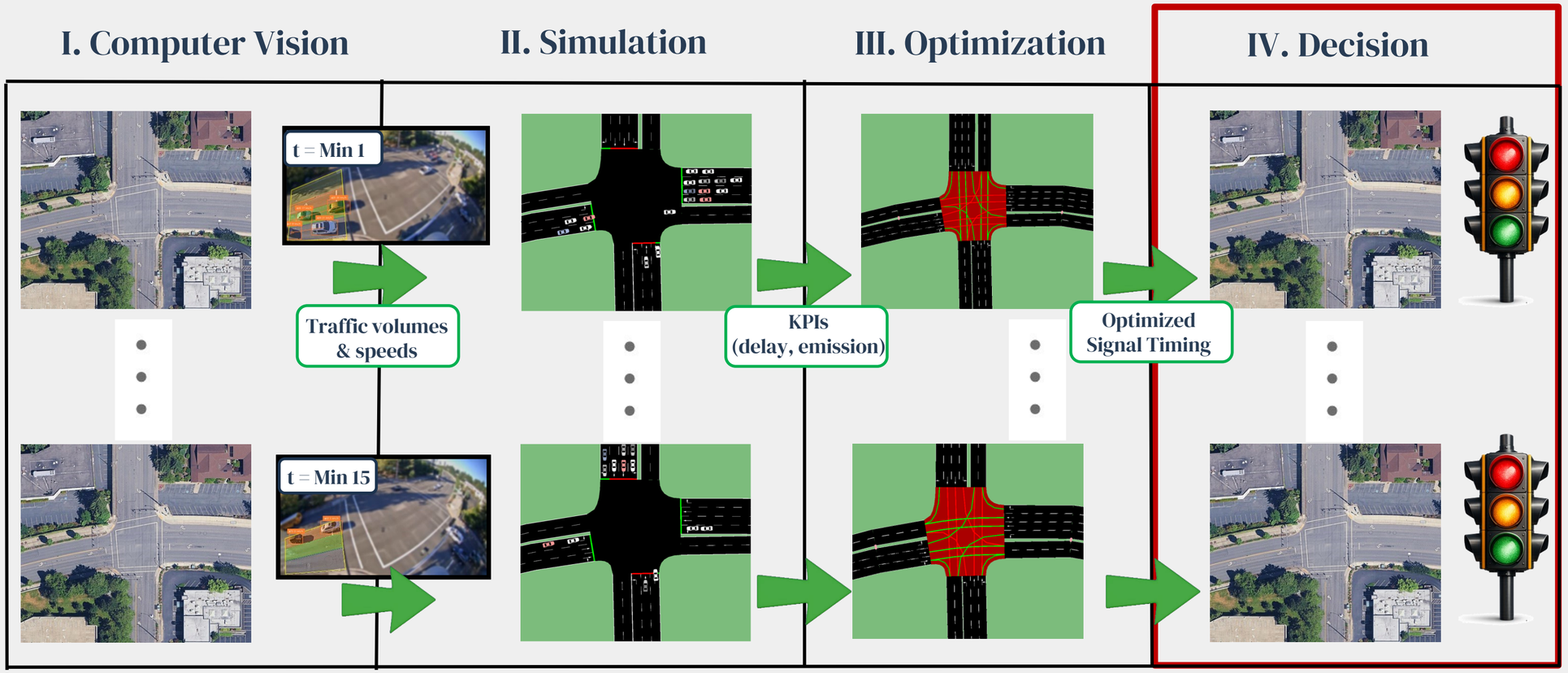
Fall 2026

RoadwayVR

roadwayvr.github.io/DigitalTwinsforSmartCities



Overview of Course Syllabus in One Shot



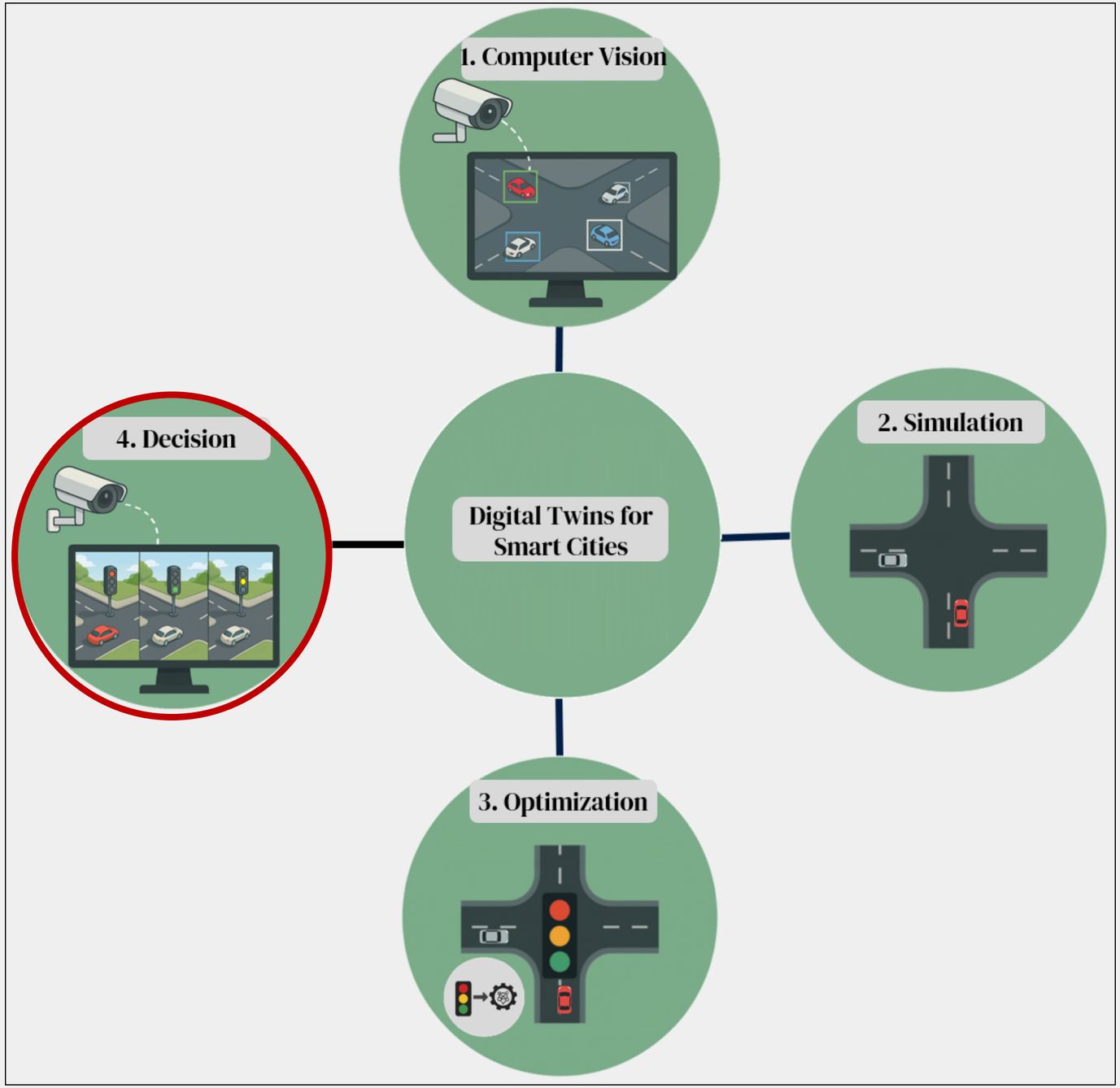
Agenda

1. Select Best Signal Timing Strategy

- ❑ Result Interpretation: KPIs
- ❑ Result Interpretation: Signal Timing

2. Create a Professional Presentation

- ❑ Visualization of Results
- ❑ Presentation Preparation



Result Interpretation: KPIs

Typical values (FHWA):

- ❑ **Upstream functional area (30 mph / 48 km/h): 395 ft (120 m)**
- ❑ **Downstream functional area (30 mph / 48 km/h): 200 ft (61 m)**

Existing Condition Result

	A	B	C	D	E	F	G	H	I
1	Minute	lane_id	edge_id	approach	avg_delay_s	vg_stopped_delay_	throughput	emission_co2_mg	los
2	all	E0_0	E0	EB	9.56	5.69	41	1780881.06	A
3	all	E0_1	E0	EB	5.95	1.28	80	5513512.48	A
4	all	E0_2	E0	EB	8.51	3.75	20	1172333.21	A
5	all	E2_0	E2	WB	3.81	2.19	25	266267.39	A
6	all	E2_1	E2	WB	3.07	1.84	114	1611076.94	A
7	all	E2_2	E2	WB	11.59	7.77	15	337890.35	B
8	all	E2_3	E2	WB	4.25	3	24	302868.69	A
9	all	E3_0	E3	NB	21.04	15.6	71	3775700.32	C
10	all	E3_1	E3	NB	16.45	9.67	91	10817603.93	B
11	all	E3_2	E3	NB	32.93	24.34	30	2940771.51	C
12	all	E7_0	E7	SB	11.3	9.21	24	522100.82	B
13	all	E7_1	E7	SB	12.53	10.01	83	3530998.04	B
14	all	E7_2	E7	SB	18.91	14.45	71	2287767.05	B
15	all	E7_3	E7	SB	15.84	13.42	22	566687.55	B
16	all	all	all	all	12.55	8.73	711	35426459.34	B

Digital Twin Result

	A	B	C	D	E	F	G	H	I
1	Minute	lane_id	edge_id	approach	avg_delay_s	avg_stopped_delay_s	throughput	emission_co2_mg	los
2	all	E0_0	E0	EB	6.67	3.37	63	7486293.46	A
3	all	E0_1	E0	EB	5.54	3.82	53	1013760.54	A
4	all	E0_2	E0	EB	3.81	2.1	20	897102.39	A
5	all	E2_0	E2	WB	4.66	3.03	25	384187.14	A
6	all	E2_1	E2	WB	4.75	3.54	92	2069526.37	A
7	all	E2_2	E2	WB	8.68	6.02	31	874084.03	A
8	all	E2_3	E2	WB	4.45	3.55	23	385166.02	A
9	all	E3_0	E3	NB	7.49	3.76	101	10565380.45	A
10	all	E3_1	E3	NB	7.81	5.04	58	1660796.91	A
11	all	E3_2	E3	NB	15.19	11.08	30	1863242.21	B
12	all	E7_0	E7	SB	8.54	6.67	24	391935.86	A
13	all	E7_1	E7	SB	6.23	4.61	99	2501243.34	A
14	all	E7_2	E7	SB	12.47	8.84	53	1150719.08	B
15	all	E7_3	E7	SB	17.08	14.68	22	581374.59	B
16	all	all	all	all	8.1	5.72	694	31824812.39	A

Result Interpretation: Signal Timing

Typical values (FHWA):

- ❑ **Upstream functional area (30 mph / 48 km/h): 395 ft (120 m)**
- ❑ **Downstream functional area (30 mph / 48 km/h): 200 ft (61 m)**

Existing Condition Result

	A	B	C
1	Minute	Green_EW	Green_NS
2	all	39	15
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

Digital Twin Result

	A	B	C
1	Minute	Green_EW	Green_NS
2	1	18.4	35.6
3	2	22.9	31.1
4	3	29.2	24.8
5	4	31	23
6	5	26	28
7	6	30.1	23.9
8	7	30.6	23.4
9	8	26.5	27.5
10	9	30.7	23.3
11	10	34.3	19.7
12	11	28.5	25.5
13	12	28.7	25.3
14	13	33.8	20.2
15	14	27.5	26.5
16	15	27	27
17	all	28.3	25.7

Visualization of Results

“The simple graph has brought more information to the data analyst’s mind than any other device.” John Tukey

Exercise - Per Approach

Download CSV data from Slide 2

Part A) Submit Two csv files as bellow, you need aggregate the previous excel and provide below excells

Hint, Average Delays and Stopped are averaged
Thoughput and Emmissions are summed
LOS is calculated using The Average Delay and comapring with threshold as we discuses in Week8

	A	B	C	D	E	F	G
1	Minute	approach	avg_delay_s	avg_stopped_delay	throughput	emission_co2_mg	los
2	all	EB					
3	all	WB					
4	all	NB					
5	all	SB					

	A	B	C	D	E	F	G
1	Minute	approach	avg_delay_s	avg_stopped_delay	throughput	emission_co2_mg	los
2	all	EB					
3	all	WB					
4	all	NB					
5	all	SB					

Part B) Compare the two csv by visualizing and creating charts (You can use Excell or Python)

Part C) Write two paragraphs discussion about which method generated better result in each approach using each KPI

Part D) Write which approach generated better result in overall

Part E) please compare the signal timings and explain whats the difference between signal timing changes in two methods?

Exercise

- ❑ Create an excell
- ❑ Copy and paste the two developed csv side by side

Existing

Digital Twin

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Minute	approach	avg_delay_	avg_stopped_delay	throughput	emission_c	los			Minute	approach	avg_delay_	avg_stoppe	throughput	emission_c	los
2	all	EB	8.006667	3.573333333	141	8466727	A			all	EB	5.34	3.096667	136	9397156	A
3	all	WB	5.68	3.7	178	2518103	A			all	WB	5.635	4.035	171	3712964	A
4	all	NB	23.47333	16.53666667	192	17534076	C			all	NB	10.16333	6.626667	189	14089420	B
5	all	SB	14.645	11.7725	200	6907553	B			all	SB	11.08	8.7	198	4625273	B

Exercise

- Select the first metric column

Existing

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Minute	approach	avg_delay_	avg_stopped_delay	throughput	emission_c	los			Minute	approach	avg_delay_	avg_stoppe	throughput	emission_c	los
2	all	EB	8.006667	3.573333333	141	8466727	A			all	EB	5.34	3.096667	136	9397156	A
3	all	WB	5.68	3.7	178	2518103	A			all	WB	5.635	4.035	171	3712964	A
4	all	NB	23.47333	16.53666667	192	17534076	C			all	NB	10.16333	6.626667	189	14089420	B
5	all	SB	14.645	11.7725	200	6907553	B			all	SB	11.08	8.7	198	4625273	B

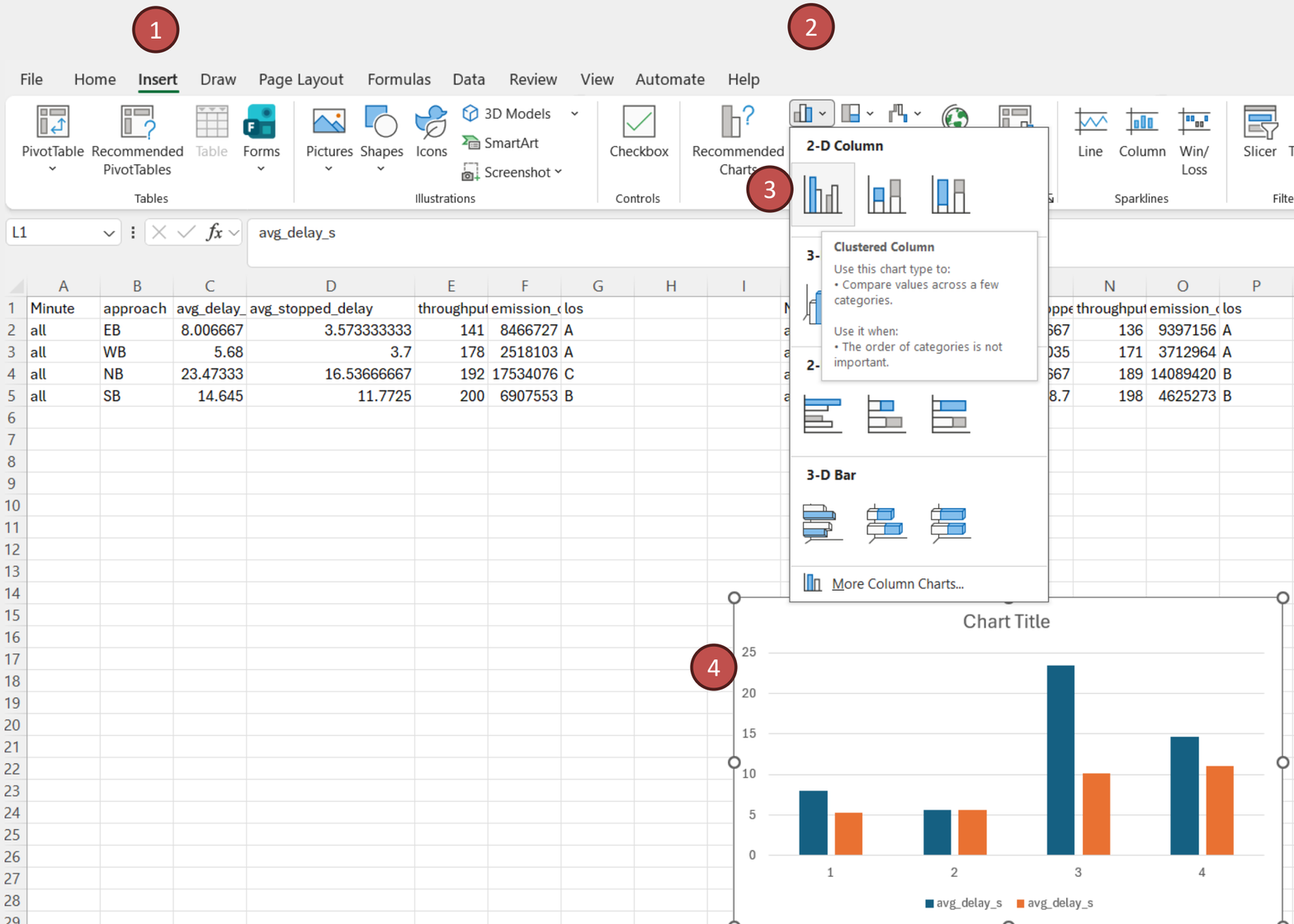
Hold ctrl and Select the Same metric in the Digital Twin

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Minute	approach	avg_delay_	avg_stopped_delay	throughput	emission_c	los			Minute	approach	avg_delay_	avg_stoppe	throughput	emission_c	los
2	all	EB	8.006667	3.573333333	141	8466727	A			all	EB	5.34	3.096667	136	9397156	A
3	all	WB	5.68	3.7	178	2518103	A			all	WB	5.635	4.035	171	3712964	A
4	all	NB	23.47333	16.53666667	192	17534076	C			all	NB	10.16333	6.626667	189	14089420	B
5	all	SB	14.645	11.7725	200	6907553	B			all	SB	11.08	8.7	198	4625273	B

Exercise

❑ Insert → 2-D column Clustered Column

→ See the Chart

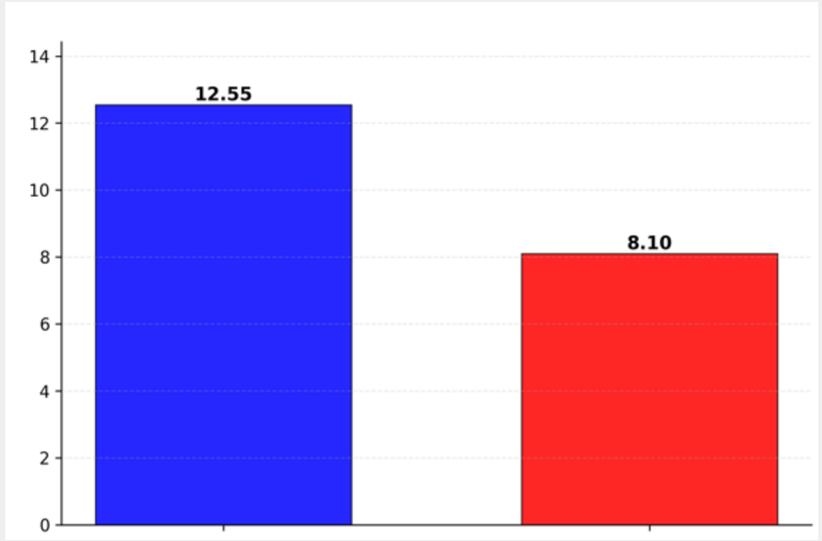


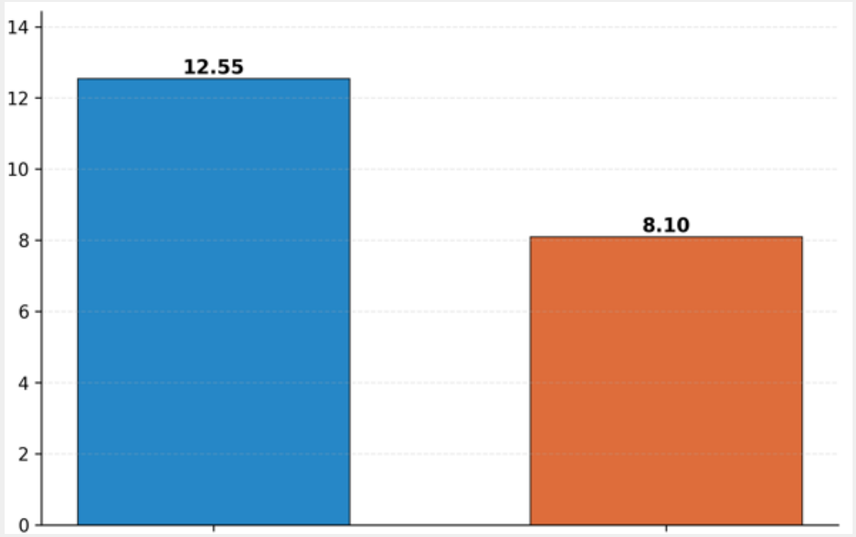
	A	B	C	D	E	F	G
1	Minute	approach	avg_delay_	avg_stopped_delay	throughput	emission_c	los
2	all	EB	8.006667	3.573333333	141	8466727	A
3	all	WB	5.68	3.7	178	2518103	A
4	all	NB	23.47333	16.53666667	192	17534076	C
5	all	SB	14.645	11.7725	200	6907553	B

	N	O	P
1	throughput	emission_c	los
2	136	9397156	A
3	171	3712964	A
4	189	14089420	B
5	198	4625273	B

Exercise

- ❑ **Which Colors are Better (raise your hand)?**



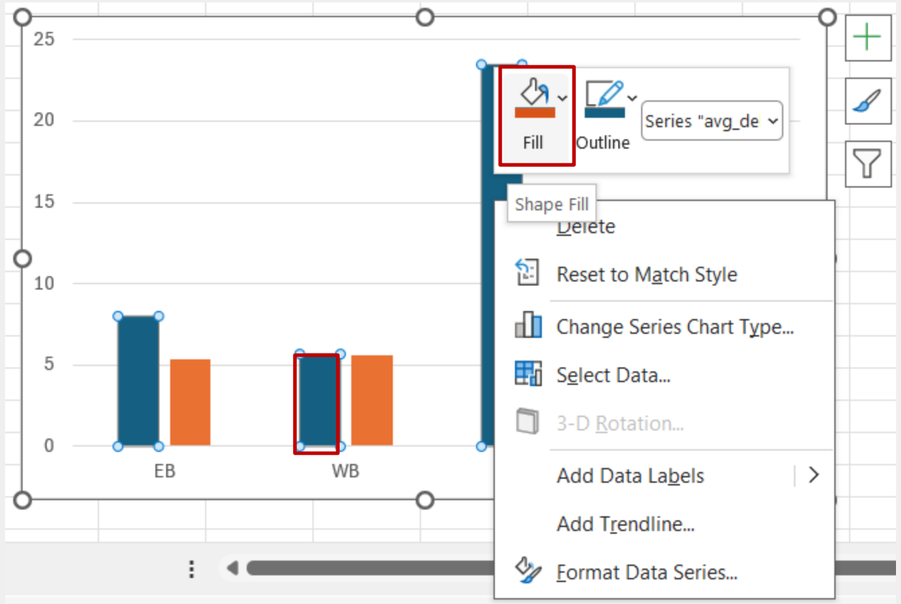


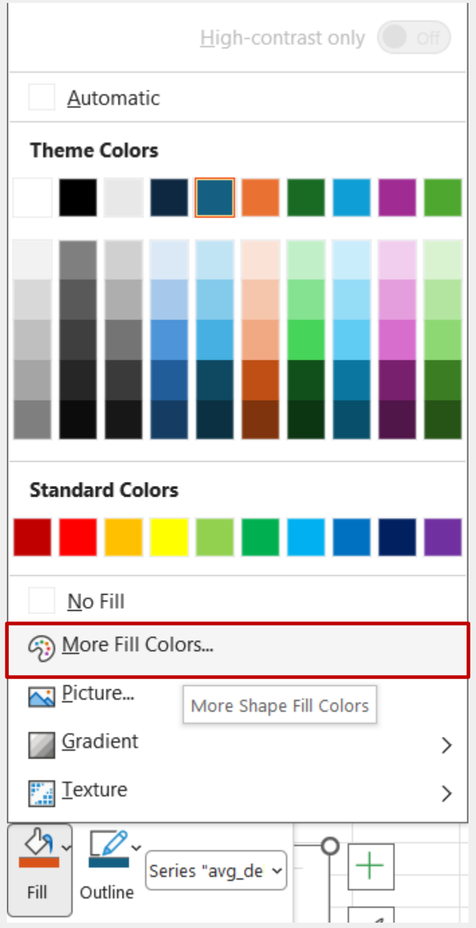
Exercise

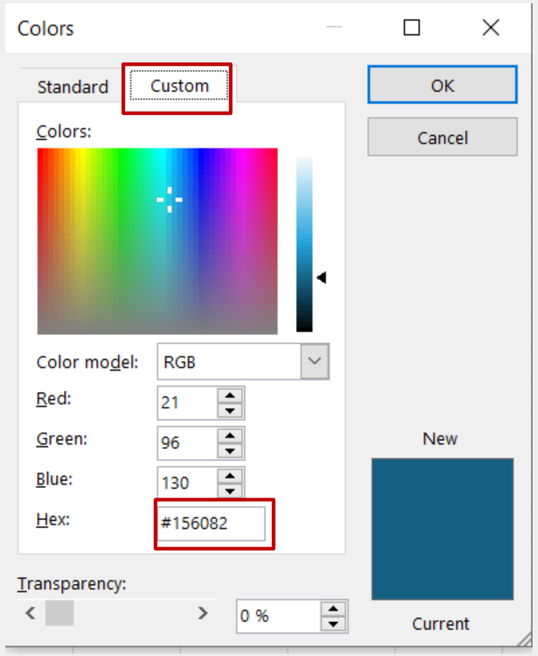
- Color Codes

Exercise

- ❑ Select the Bars
- ❑ Right Click on it
- ❑ Select Fill
- ❑ More Fill Colors → Custom → Hex → Copy and paste preferred color code there

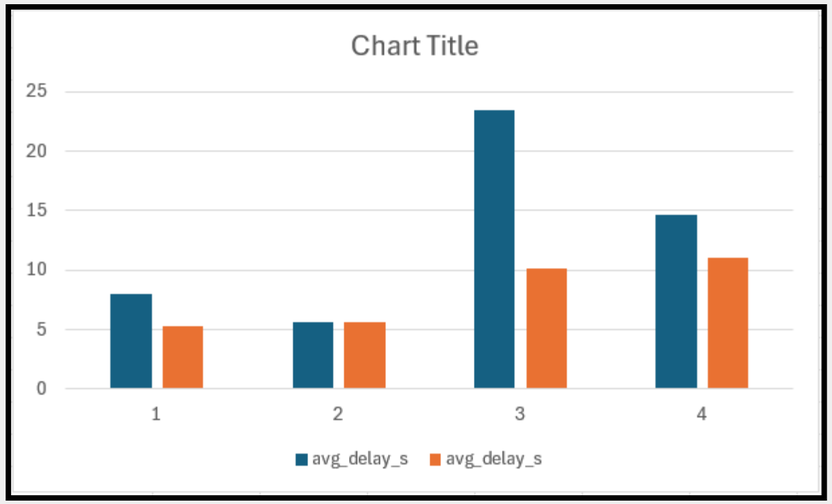


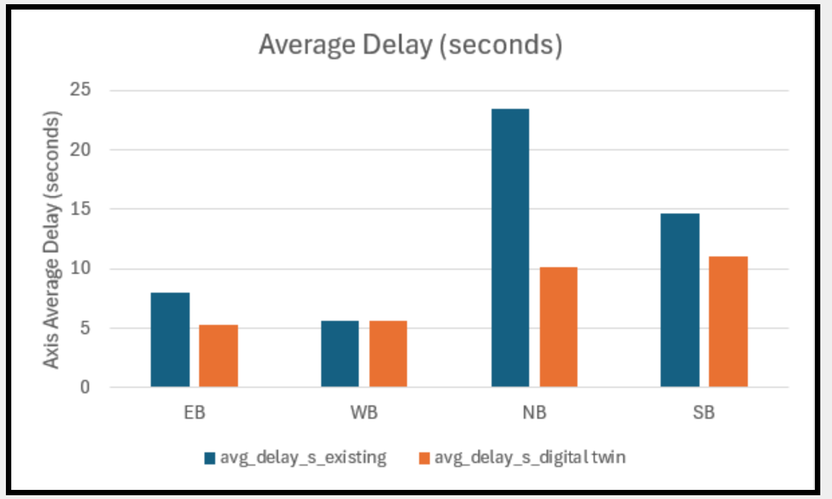




Exercise

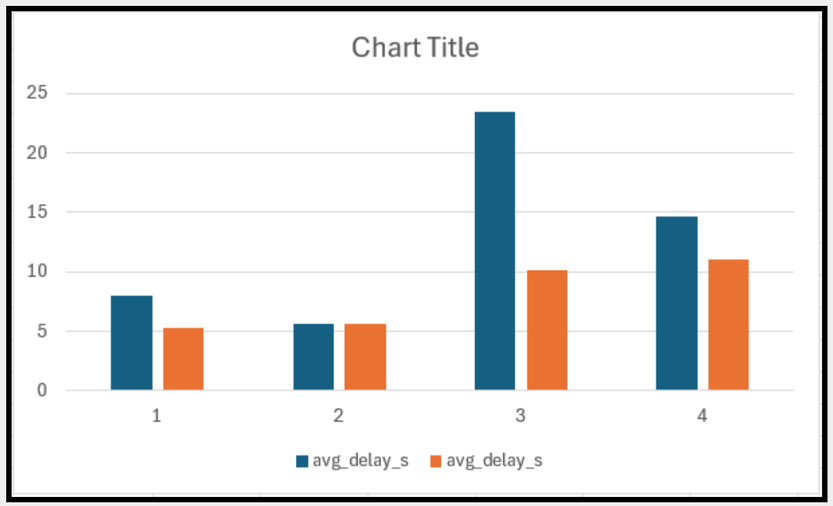
- ❑ The Final Goal is to change chart 1 to a complete chart 2
- ❑ Name the differences?

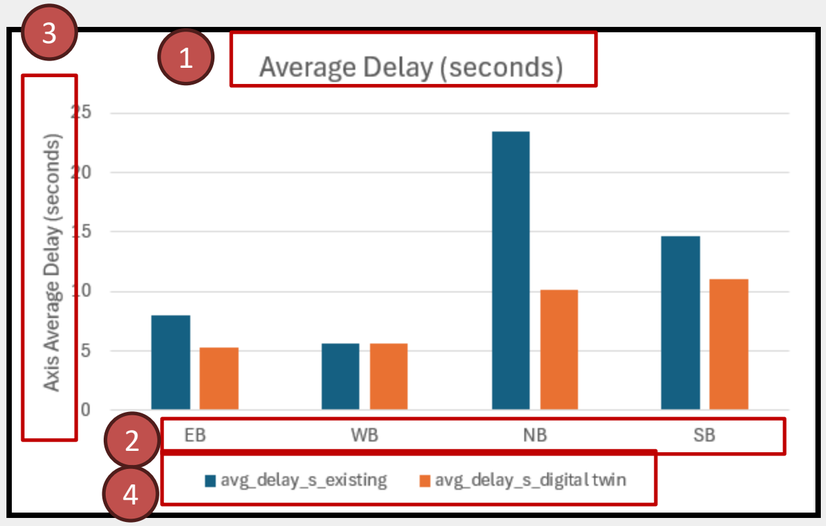




Exercise

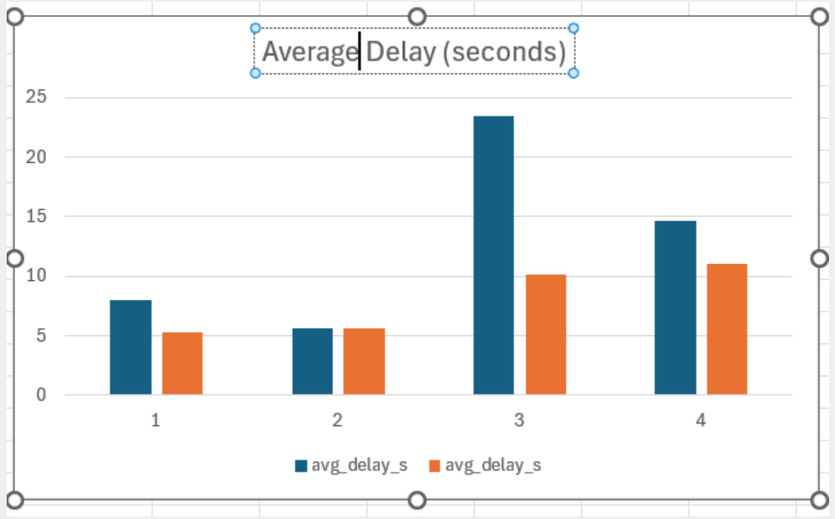
1. Title
2. X Axis (unit)
3. Y Axis (unit)
4. Chart Legend



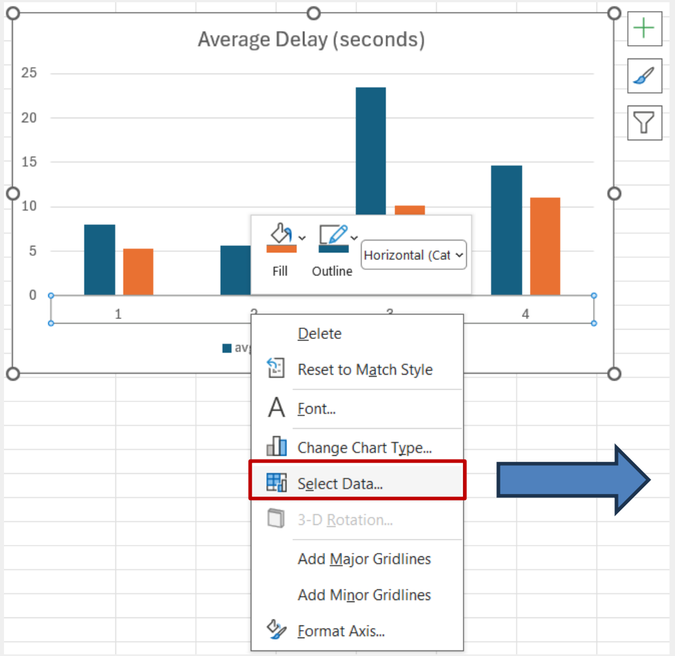


Title

1 **Click on Title and Modify the Name to The Specific Metric + add unit in parenthesis**



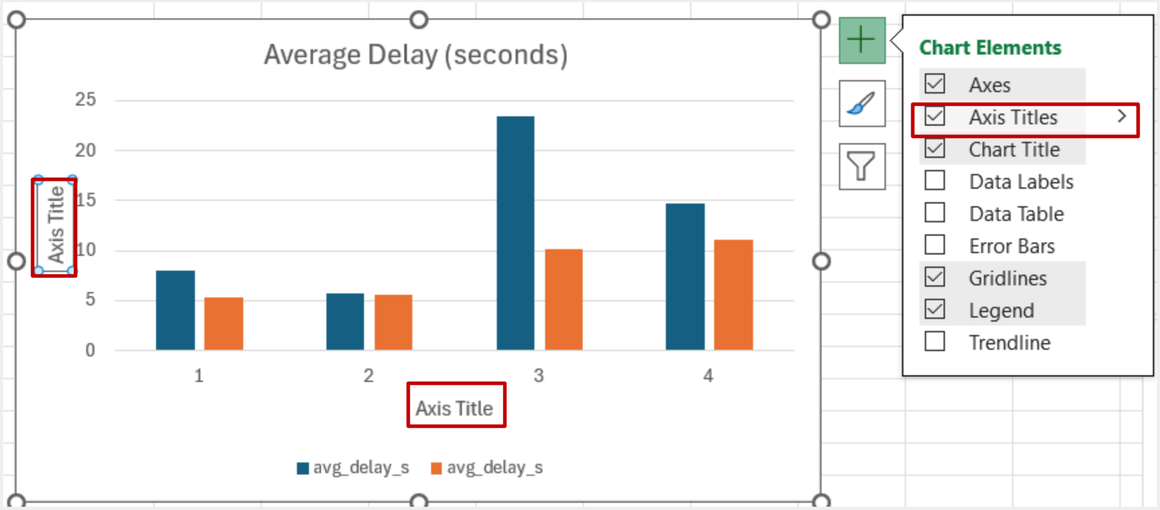
2



3

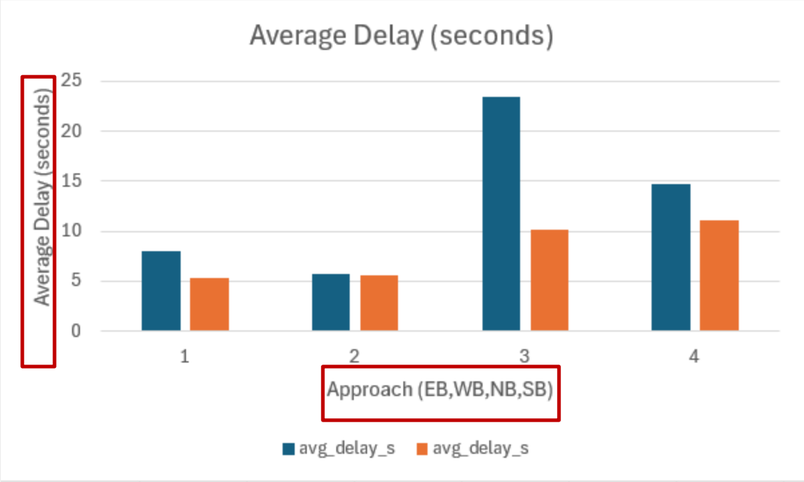
4

Add Axis Title



Add Axis Title

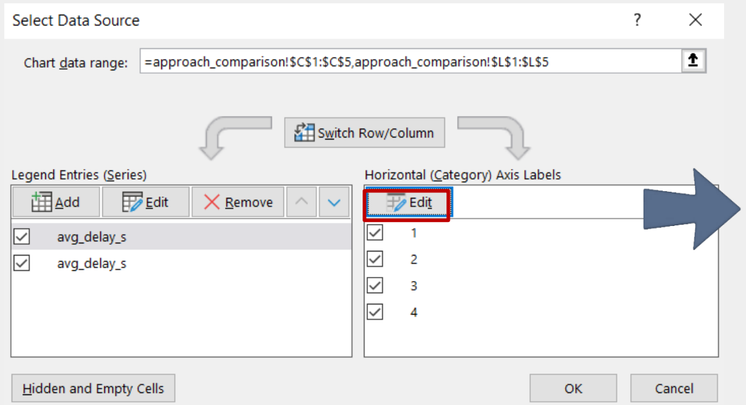
- ❑ Add X Axis (title and unit)
- ❑ Add Y Axis (title and Unit)

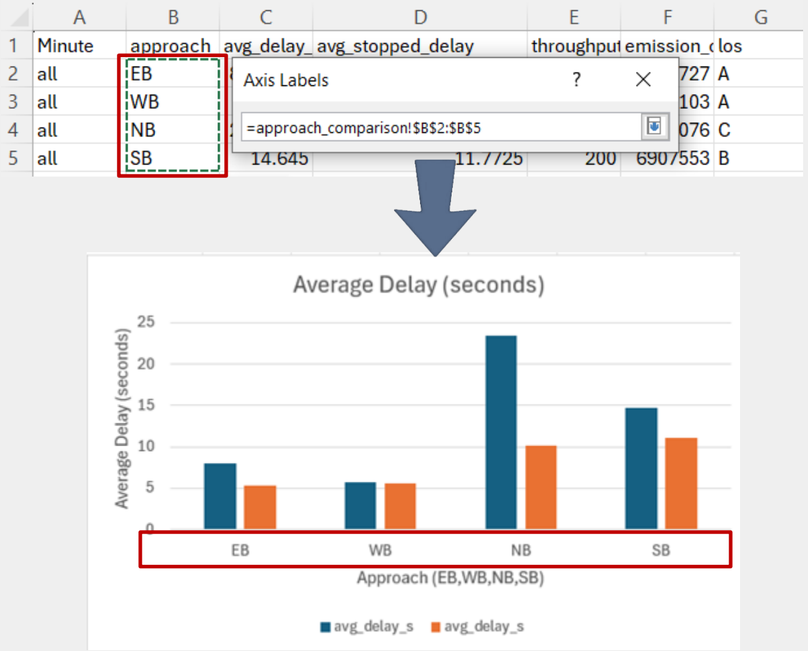


X Axis

❑ Update X Ais values → X Axis → Right Click → Select Data → Select Approach

2





Update Legend

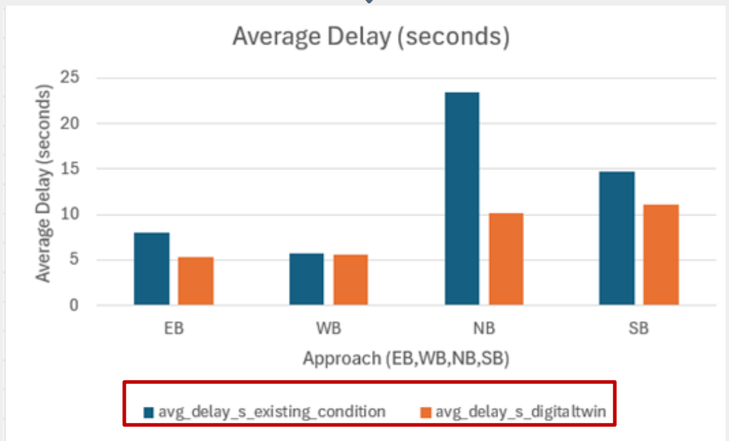
❑ Select Y Axis → Right Click → Select Data → Select Approach

C1 | avg_delay_s_existing_condition

	A	B	C	D	E	F	G
1	Minute	approach	avg_delay_	avg_stopped_delay	throughput	emission_c	los
2	all	EB	8.006667	3.573333333	141	8466727	A
3	all	WB	5.68	3.7	178	2518103	A
4	all	NB	23.47333	16.53666667	192	17534076	C
5	all	SB	14.645	11.7725	200	6907553	B

L1 | avg_delay_s_digitaltwin

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Minute	approach	avg_delay_	avg_stopped_delay	throughput	emission_c	los			Minute	approach	avg_delay_	avg_stoppe	throughput	emission_c	los
2	all	EB	8.006667	3.573333333	141	8466727	A			all	EB	5.34	3.096667	136	9397156	A
3	all	WB	5.68	3.7	178	2518103	A			all	WB	5.635	4.035	171	3712964	A
4	all	NB	23.47333	16.53666667	192	17534076	C			all	NB	10.16333	6.626667	189	14089420	B
5	all	SB	14.645	11.7725	200	6907553	B			all	SB	11.08	8.7	198	4625273	B



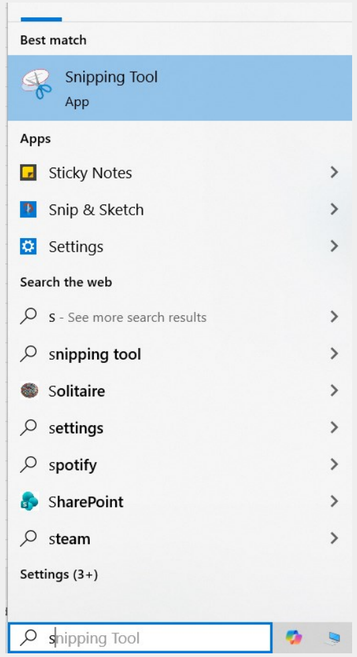
Update Legend

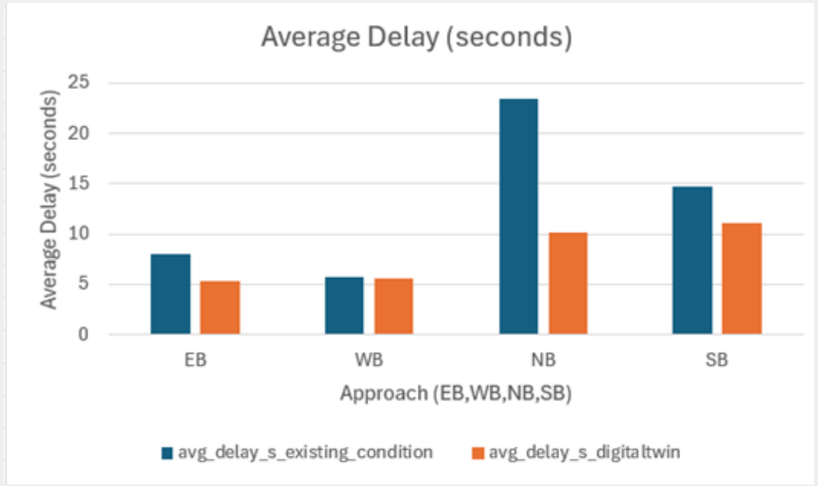
- ❑ Follow the Same process for other metrics including average stopped delay, throughput, and emission

Presentation Preparation

Presentation Preparation

- ❑ Take Image from Excel and Move it to PowerPoint
- ❑ In Windows → Use Snipe Tool
- ❑ Capture a very clean image of each chart in Excel
- ❑ Move it to PowerPoint



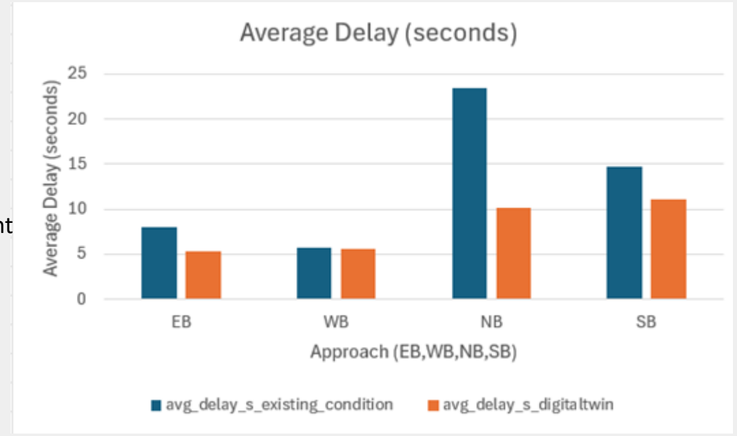


Powerpoint

1. Same Width and Height

✓Copy and paste Charts in Powerpoint

Height



Width

Chart 2

Height

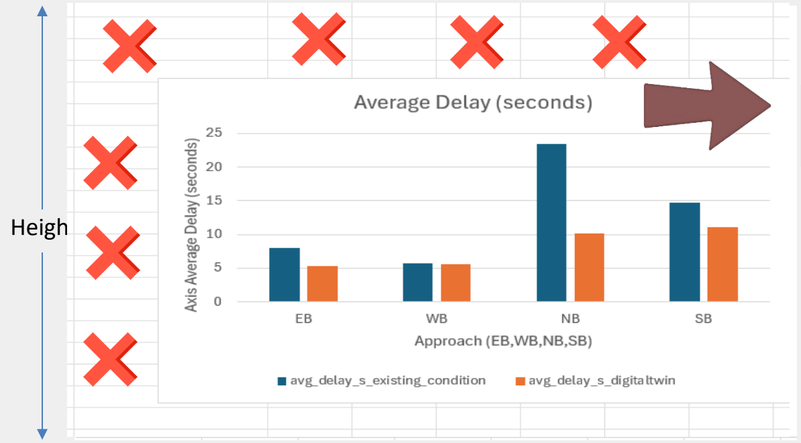
Chart 3

Chart 4

Width

2. Avoid Stretching out and redundant space

✓Below chart is Stretched out and has extra redundant space (shown with)



Heigh

Width

Chart is clearly stretched out to match the same width and height. Compare the text with texts with previous slide

Chart 2

Height

Chart 3

Chart 4

3. Avoid using Small Fonts

✓**Fonts are very small to read in** ✗

Chart 2

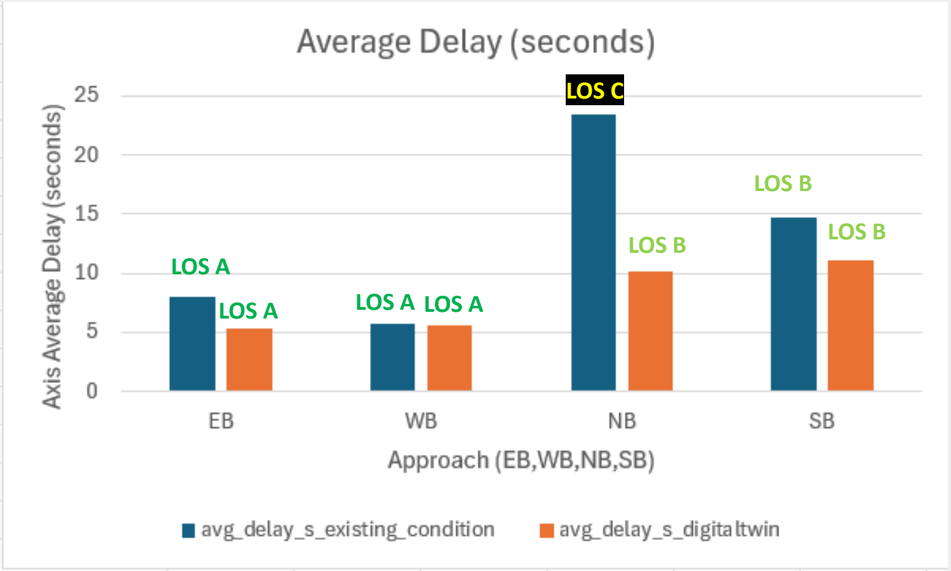
Height

Chart 3

Chart 4

Add Metric 5 (LOS)

- ❑ In Powerpoint, copy and paste Metric 1 chart and Add LOS levels on top of each bar (small fonts) → This is just for Chart 1
- ❑ A is Dark Green
- ❑ B is Light Green
- ❑ C is Yellow (with black background)
- ❑ D is Orange
- ❑ E is Light Red
- ❑ F is dark Red



Exercise – Overall

- ❑ Download CSV data from Slide 2
- ❑ Take the overall result (row of 16) and draw charts

	A	B	C	D	E	F	G	H	I
1	Minute	lane_id	edge_id	approach	avg_delay_	avg_stoppe	throughput	emission_(	los
2	all	E0_0	E0	EB	9.56	5.69	41	1780881	A
3	all	E0_1	E0	EB	5.95	1.28	80	5513512	A
4	all	E0_2	E0	EB	8.51	3.75	20	1172333	A
5	all	E2_0	E2	WB	3.81	2.19	25	266267.4	A
6	all	E2_1	E2	WB	3.07	1.84	114	1611077	A
7	all	E2_2	E2	WB	11.59	7.77	15	337890.4	B
8	all	E2_3	E2	WB	4.25	3	24	302868.7	A
9	all	E3_0	E3	NB	21.04	15.6	71	3775700	C
10	all	E3_1	E3	NB	16.45	9.67	91	10817604	B
11	all	E3_2	E3	NB	32.93	24.34	30	2940772	C
12	all	E7_0	E7	SB	11.3	9.21	24	522100.8	B
13	all	E7_1	E7	SB	12.53	10.01	83	3530998	B
14	all	E7_2	E7	SB	18.91	14.45	71	2287767	B
15	all	E7_3	E7	SB	15.84	13.42	22	566687.6	B
16	all	all	all	all	12.55	8.73	711	35426459	B

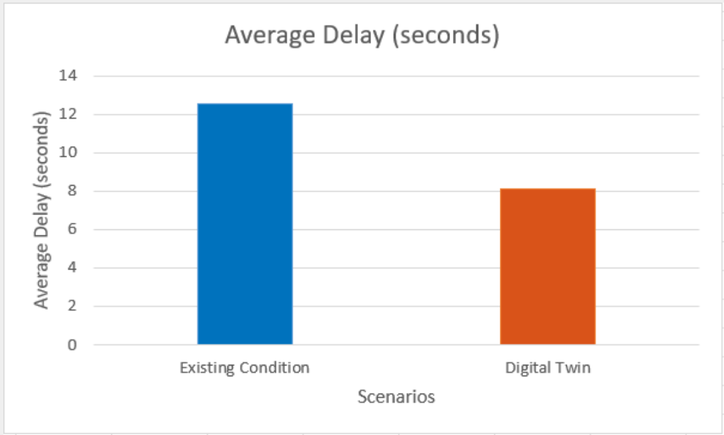
	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Minute	lane_id	edge_id	approach	avg_delay_	avg_stoppe	throughput	emission_(	los				
2	all	E0_0	E0	EB	6.67	3.37	63	7486293	A				
3	all	E0_1	E0	EB	5.54	3.82	53	1013761	A				
4	all	E0_2	E0	EB	3.81	2.1	20	897102.4	A				
5	all	E2_0	E2	WB	4.66	3.03	25	384187.1	A				
6	all	E2_1	E2	WB	4.75	3.54	92	2069526	A				
7	all	E2_2	E2	WB	8.68	6.02	31	874084	A				
8	all	E2_3	E2	WB	4.45	3.55	23	385166	A				
9	all	E3_0	E3	NB	7.49	3.76	101	10565380	A				
10	all	E3_1	E3	NB	7.81	5.04	58	1660797	A				
11	all	E3_2	E3	NB	15.19	11.08	30	1863242	B				
12	all	E7_0	E7	SB	8.54	6.67	24	391935.9	A				
13	all	E7_1	E7	SB	6.23	4.61	99	2501243	A				
14	all	E7_2	E7	SB	12.47	8.84	53	1150719	B				
15	all	E7_3	E7	SB	17.08	14.68	22	581374.6	B				
16	all	all	all	all	8.1	5.72	694	31824812	A				

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Existing Condition							Digital Twin					
2	approach	avg_delay_	avg_stopp	throughpu	emission_(	los		approach	avg_delay_	avg_stopp	throughpu	emission_(	los
3	all	12.55	8.73	711	35426459	B		all	8.1	5.72	694	31824812	A

Exercise – Overall

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Existing Condition							Digital Twin					
2	approach	avg_delay	avg_stopp	throughpu	emission_	los		approach	avg_delay	avg_stopp	throughpu	emission_	los
3	all	12.55	8.73	711	35426459	B		all	8.1	5.72	694	31824812	A

Average delay

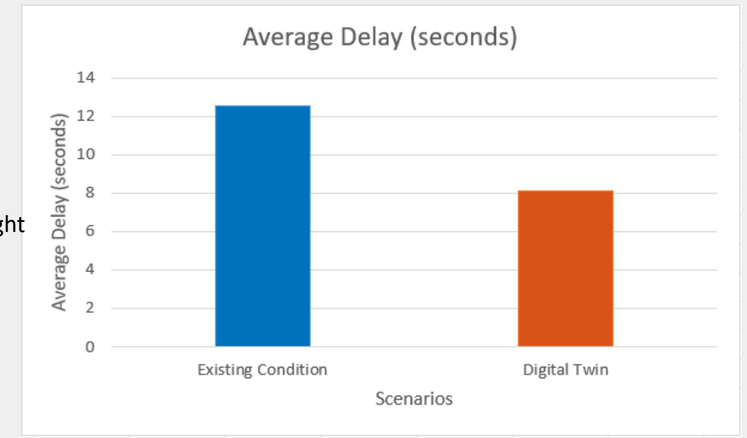


- Similarly, create the charts for the three other metrics

Create a Slide for Overall Result

✓**Copy and paste Charts from excell to PowerPoint**

Height



Width

Chart 2

Height

Chart 3

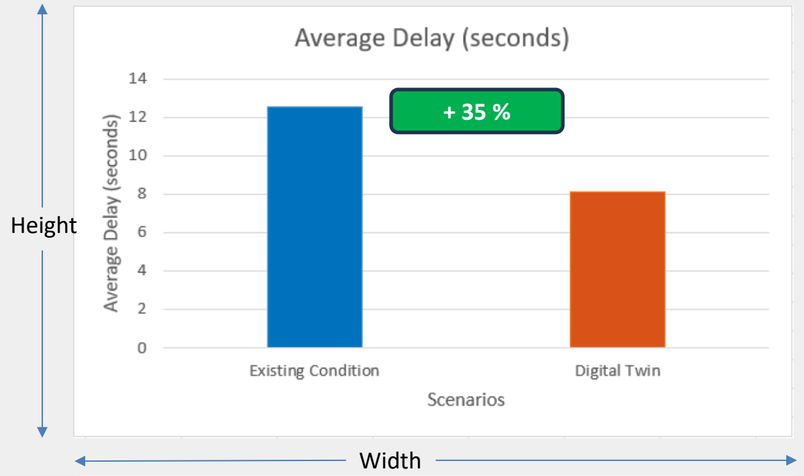
Chart 4

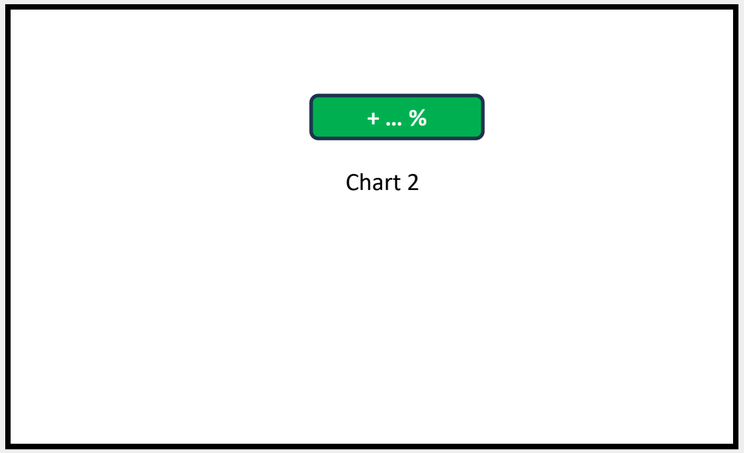
Width

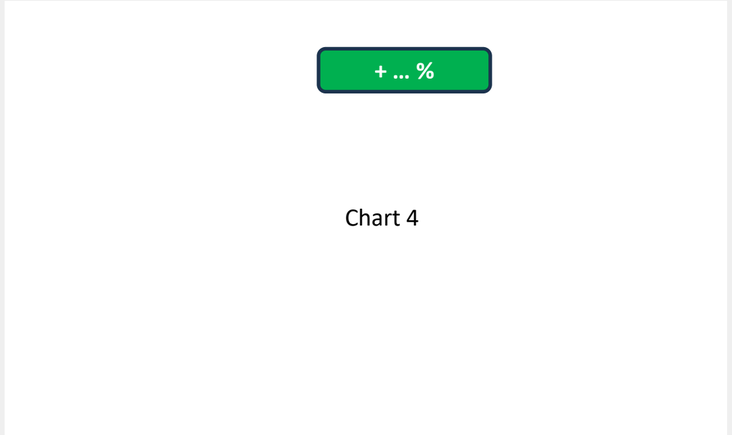
Add Additional Information

✓Add Percentage of Improvement or Degradation for each Chart for (overall result)

✓ For example, by dividing value of average delay in Digital Twin and Existing Condition, we achieve a 35% improvement







Results

Exercise – Overall

Download CSV data for existing green times

Existing Condition

	A	B	C
1	Minute	Green_EW	Green_NS
2	all	39	15

Digital Twin

	A	B	C
1	Minute	Green_EW	Green_NS
2	1	18.4	35.6
3	2	22.9	31.1
4	3	29.2	24.8
5	4	31	23
6	5	26	28
7	6	30.1	23.9
8	7	30.6	23.4
9	8	26.5	27.5
10	9	30.7	23.3
11	10	34.3	19.7
12	11	28.5	25.5
13	12	28.7	25.3
14	13	33.8	20.2
15	14	27.5	26.5
16	15	27	27
17	all	28.3	25.7

Exercise – Overall

Download CSV data for existing green times

Existing Condition

	A	B	C
1	Minute	Green_EW	Green_NS
2	all	39	15

Digital Twin

	A	B	C
1	Minute	Green_EW	Green_NS
2	1	18.4	35.6
3	2	22.9	31.1
4	3	29.2	24.8
5	4	31	23
6	5	26	28
7	6	30.1	23.9
8	7	30.6	23.4
9	8	26.5	27.5
10	9	30.7	23.3
11	10	34.3	19.7
12	11	28.5	25.5
13	12	28.7	25.3
14	13	33.8	20.2
15	14	27.5	26.5
16	15	27	27
17	all	28.3	25.7

Create Excel file like this

	A	B	C	D	E	F	G	H
1	Exisiting Condition					Digital Twin		
2	Minute	Green_EW	Green_NS			Minute	Green_EW	Green_NS
3	all	39	15			1	18.4	35.6
4						2	22.9	31.1
5						3	29.2	24.8
6						4	31	23
7						5	26	28
8						6	30.1	23.9
9						7	30.6	23.4
10						8	26.5	27.5
11						9	30.7	23.3
12						10	34.3	19.7
13						11	28.5	25.5
14						12	28.7	25.3
15						13	33.8	20.2
16						14	27.5	26.5
17						15	27	27
18						all	28.3	25.7

Exercise – Overall

Download CSV data for existing green times

	A	B	C	D	E	F	G	H
1	Exisiting Condition					Digital Twin		
2	Minute	Green_EW	Green_NS			Minute	Green_EW	Green_NS
3	all	39	15			1	18.4	35.6
4						2	22.9	31.1
5						3	29.2	24.8
6						4	31	23
7						5	26	28
8						6	30.1	23.9
9						7	30.6	23.4
10						8	26.5	27.5
11						9	30.7	23.3
12						10	34.3	19.7
13						11	28.5	25.5
14						12	28.7	25.3
15						13	33.8	20.2
16						14	27.5	26.5
17						15	27	27
18						all	28.3	25.7

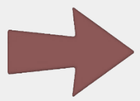
Repeat the rows → because it's the same

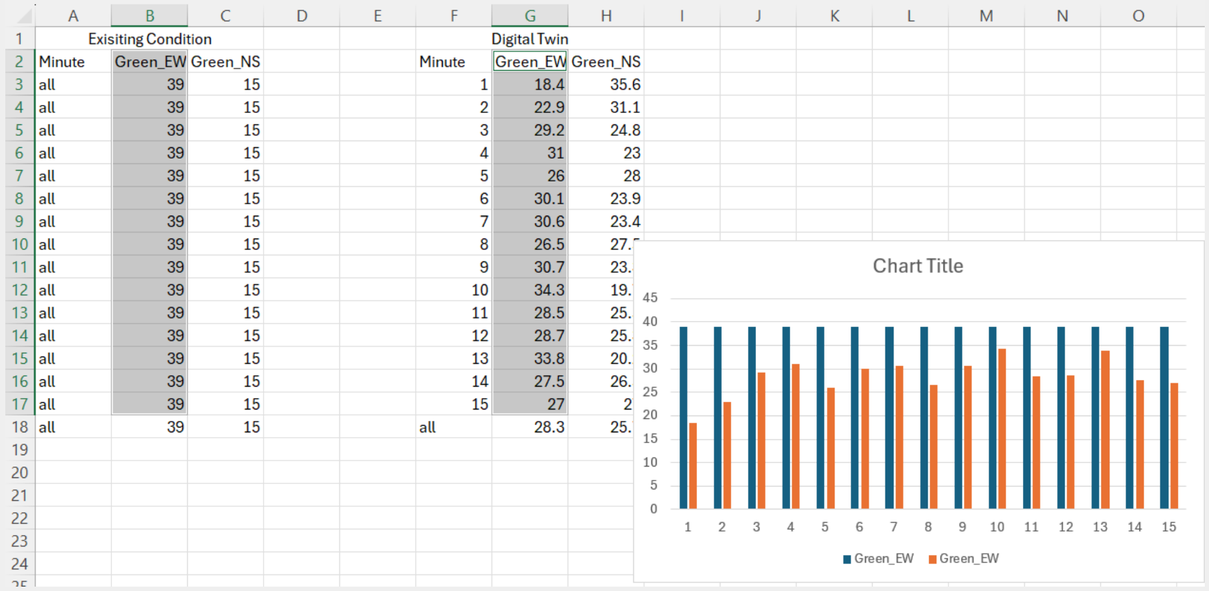
	A	B	C	D	E	F	G	H
1	Exisiting Condition					Digital Twin		
2	Minute	Green_EW	Green_NS			Minute	Green_EW	Green_NS
3	all	39	15			1	18.4	35.6
4	all	39	15			2	22.9	31.1
5	all	39	15			3	29.2	24.8
6	all	39	15			4	31	23
7	all	39	15			5	26	28
8	all	39	15			6	30.1	23.9
9	all	39	15			7	30.6	23.4
10	all	39	15			8	26.5	27.5
11	all	39	15			9	30.7	23.3
12	all	39	15			10	34.3	19.7
13	all	39	15			11	28.5	25.5
14	all	39	15			12	28.7	25.3
15	all	39	15			13	33.8	20.2
16	all	39	15			14	27.5	26.5
17	all	39	15			15	27	27
18	all	39	15			all	28.3	25.7

Exercise – Overall

Draw Charts for 15 Min for EW and NS

	A	B	C	D	E	F	G	H
1	Exisiting Condition					Digital Twin		
2	Minute	Green_EW	Green_NS			Minute	Green_EW	Green_NS
3	all	39	15			1	18.4	35.6
4	all	39	15			2	22.9	31.1
5	all	39	15			3	29.2	24.8
6	all	39	15			4	31	23
7	all	39	15			5	26	28
8	all	39	15			6	30.1	23.9
9	all	39	15			7	30.6	23.4
10	all	39	15			8	26.5	27.5
11	all	39	15			9	30.7	23.3
12	all	39	15			10	34.3	19.7
13	all	39	15			11	28.5	25.5
14	all	39	15			12	28.7	25.3
15	all	39	15			13	33.8	20.2
16	all	39	15			14	27.5	26.5
17	all	39	15			15	27	27
18	all	39	15			all	28.3	25.7



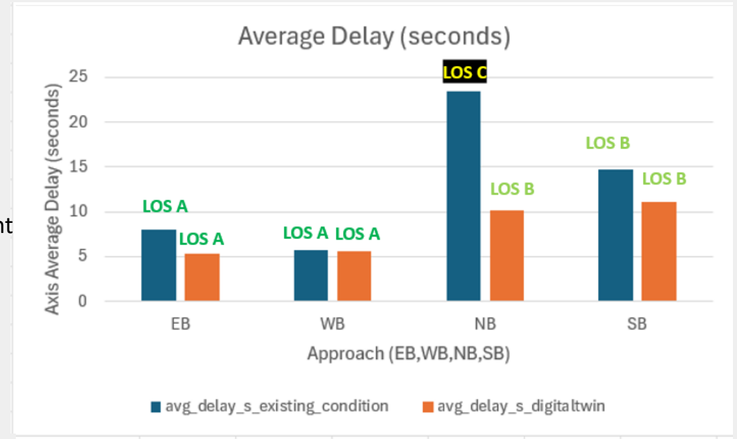


Final Results

- Per approach
- Overall
- Signal Timing

Per Approach

Height



Width

Chart 2

Height

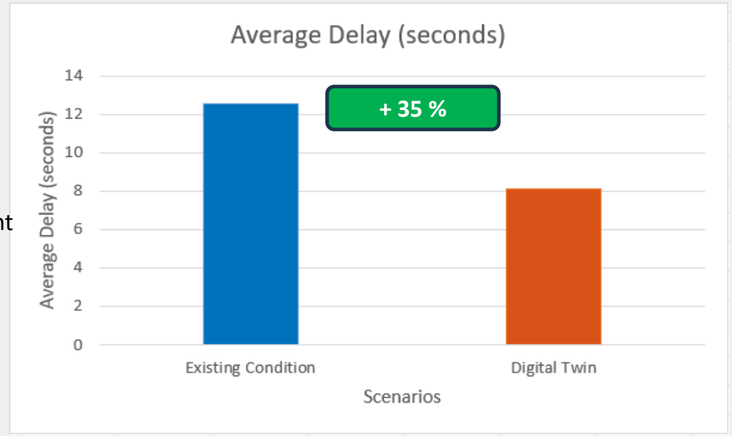
Chart 3

Chart 4

Width

Overall

Height



Width

+ ... %

Chart 2

Height

- ... %

Chart 3

+ ... %

Chart 4

Width

Signal Timing