DEPARTMENT OF TRANSPORTATION

Estimation of Metro Freeway System Reliability and Resilience: Appendices

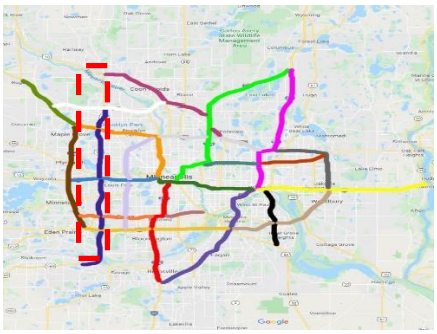
Eil Kwon, Principal Investigator
Department of Civil Engineering
University of Minnesota Duluth

FEBRUARY 2022

Research Report
Final Report 2022-01

APPENDIX A: TRAVEL-TIME RELIABILITY TRENDS ANALYSIS FOR INDIVIDUAL CORRIDORS UNDER DIFFERENT OPERATIONAL CONDITION

A.1 US-169 CORRIDOR (NORTHBOUND/SOUTHBOUND)

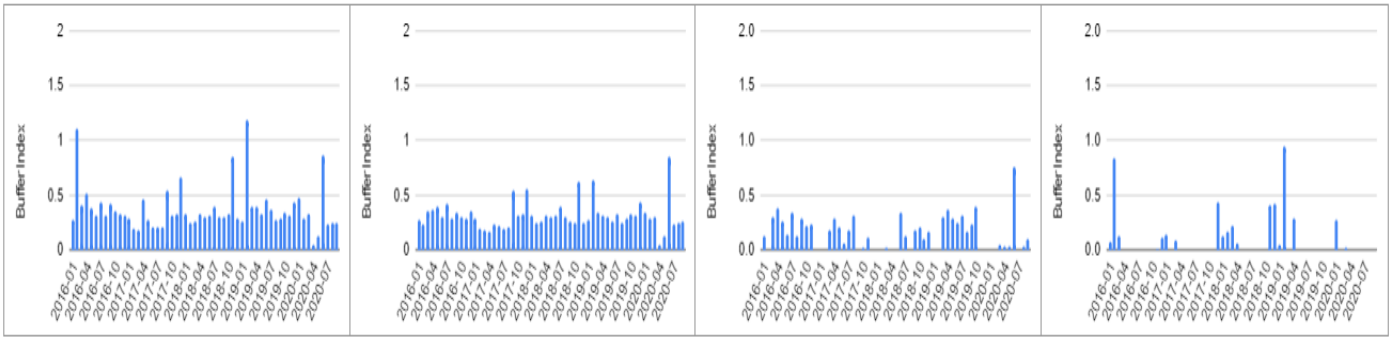


A.1.1 169 Northbound Route (Afternoon Peak Period)

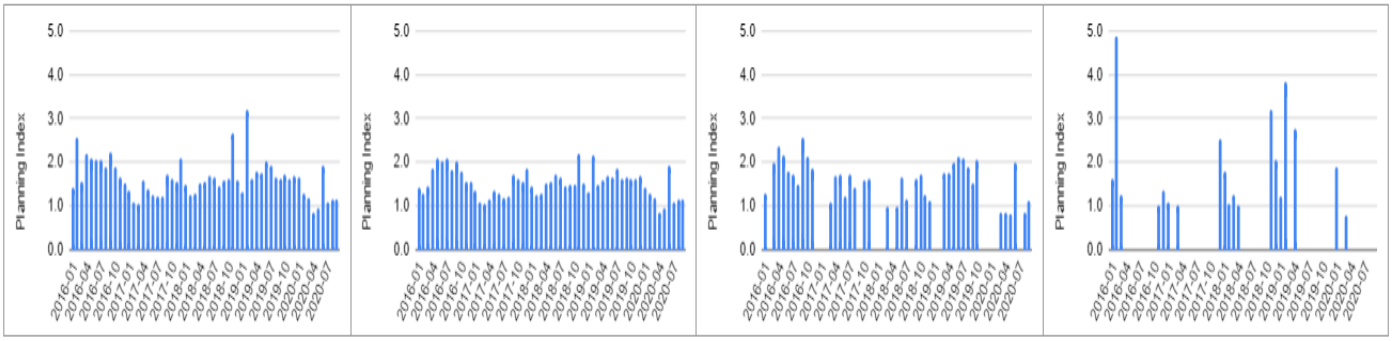
A.1.1.1 Effects of Weather conditions on Travel-Time Reliability

All Dry Rain Snow

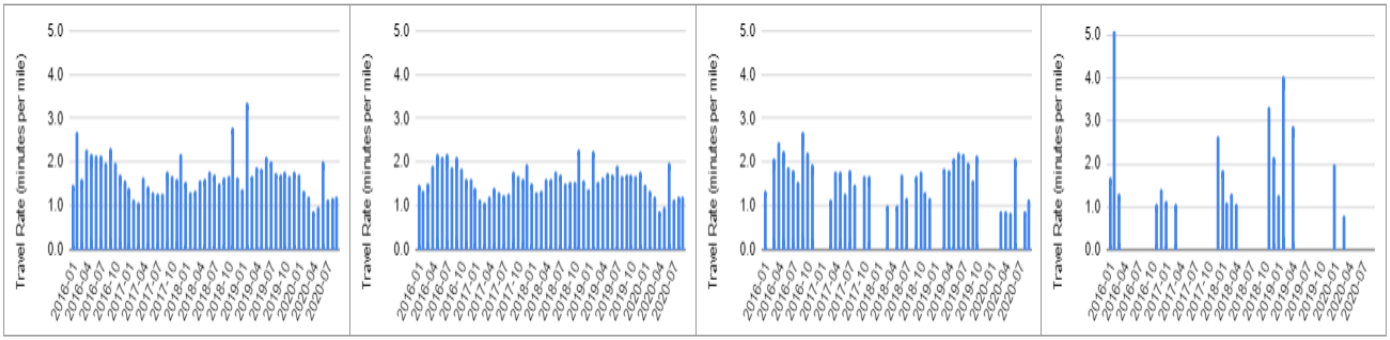
Buffer Index



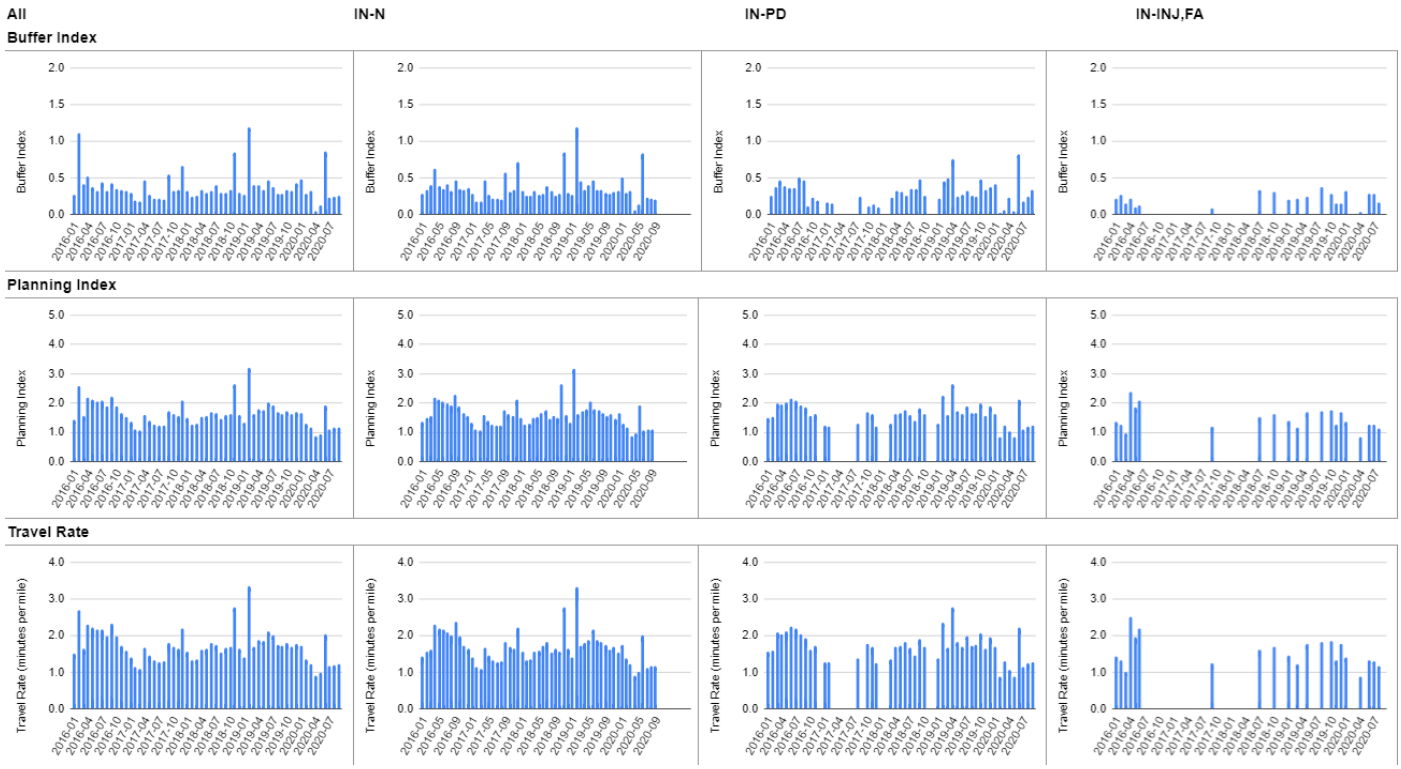
Planning Index



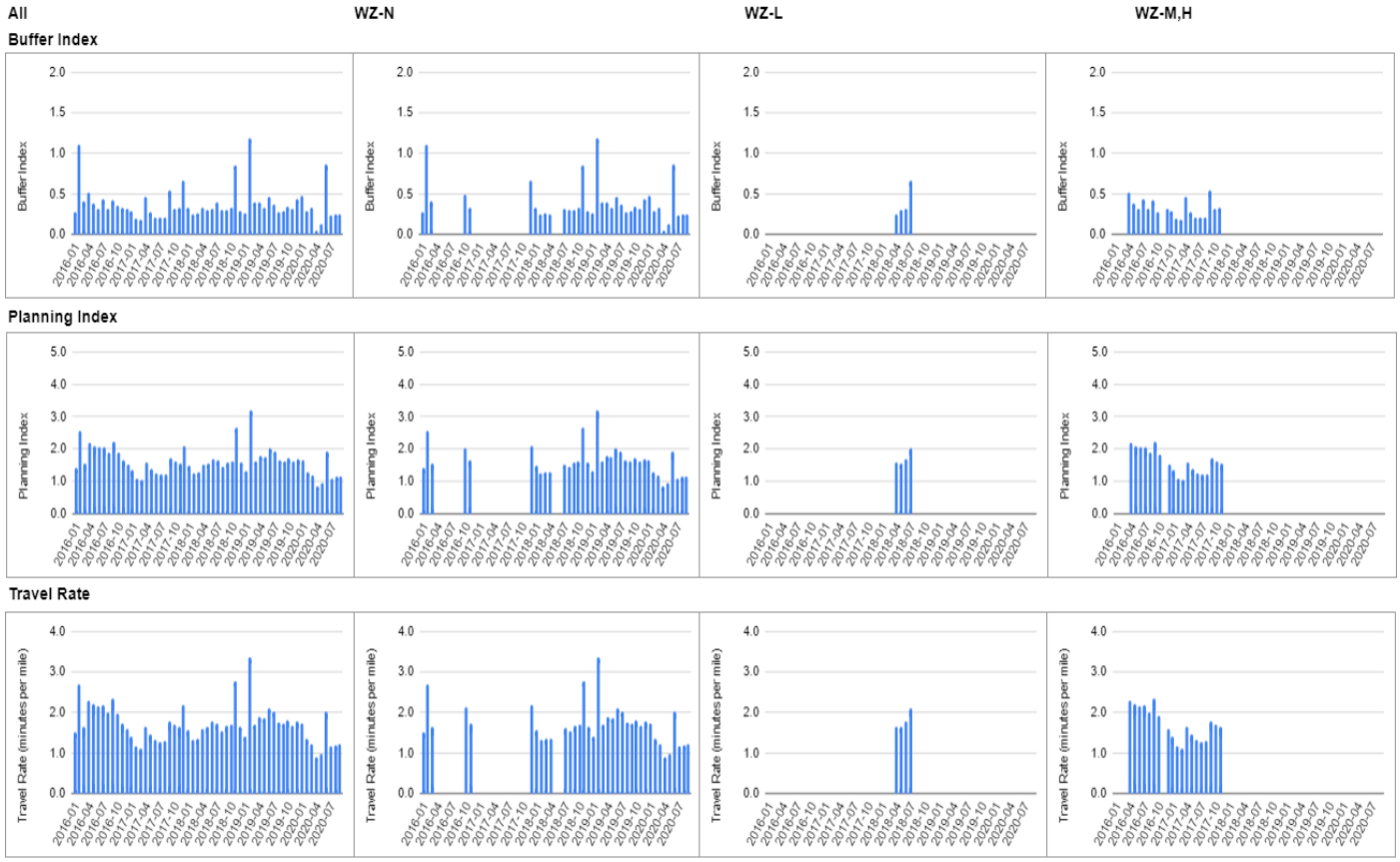
Travel Rate



A.1.1.2 Effects of Incidents

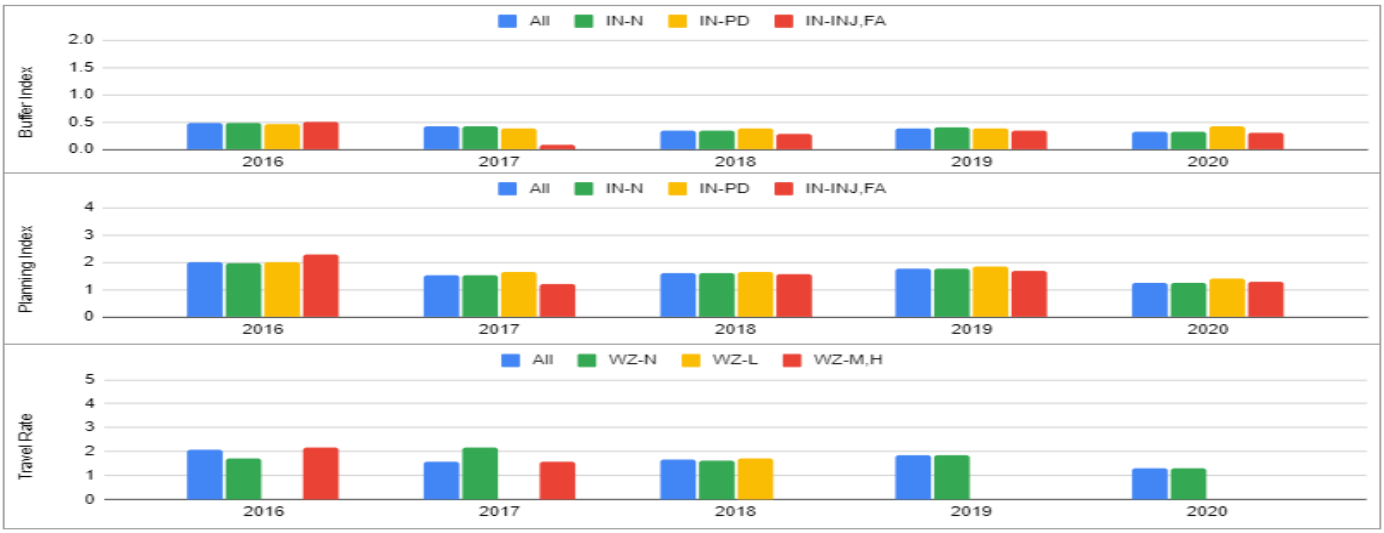


A.1.1.3 Effects of Work Zones



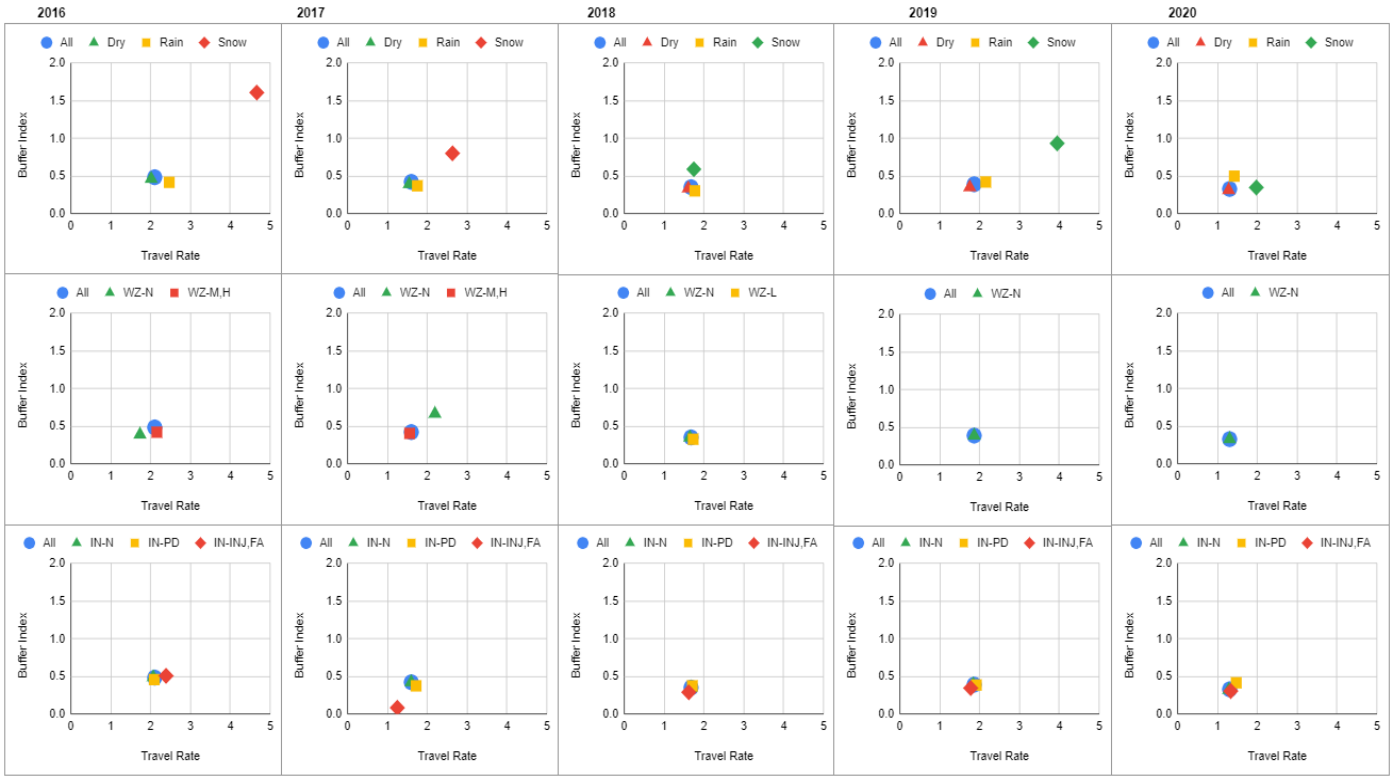
A.1.1.4 Yearly Variations - Weather Effects

A.1.1.5 Incident Effects



A.1.1.6 Work-Zone Effects

A.1.1.7 Yearly Variations of Combined Index



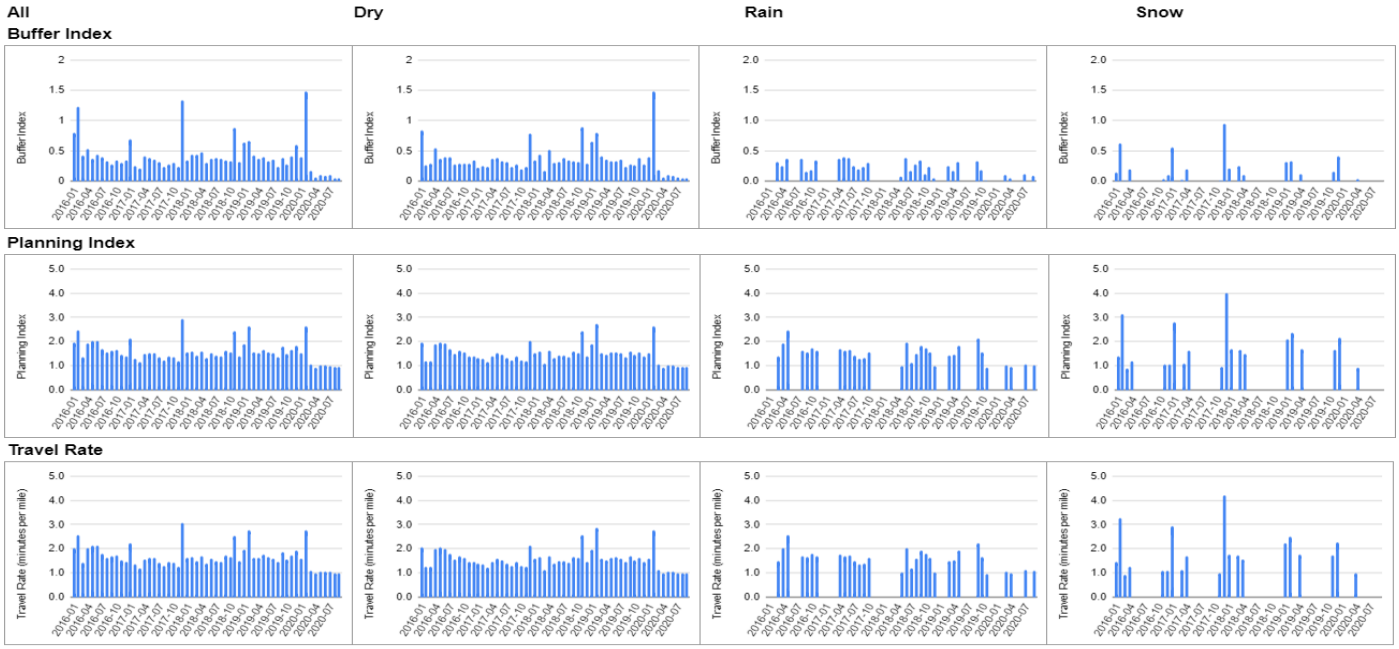
A.1.1.8 Variations of Traffic-Flow Measures

A.1.1.9 Trends Summary (169 Northbound Route)

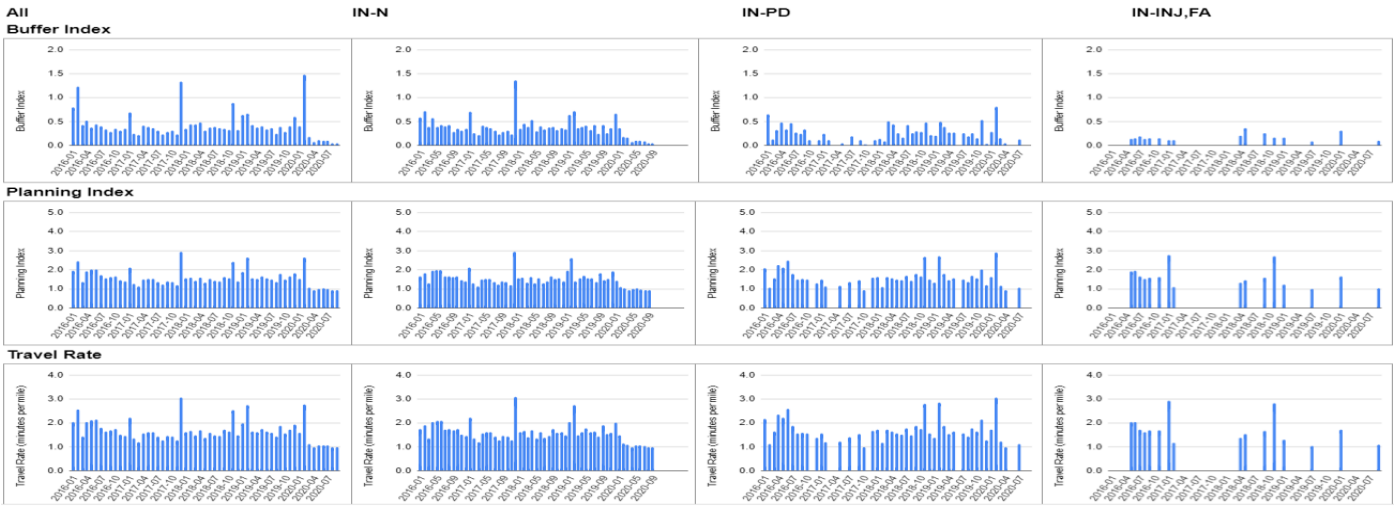
- The planning and travel-rate indices show consistently ascending trend from 2017 until the end of 2019, indicating the congestion level on this route had been rising before the pandemic, as also indicated on the variations on VMT, VHT and DVH.
- The effects of snow were significantly higher than those from rain on this route through years, while incidents had not made much differences on the reliability values.

A.1.2 169 Southbound Route (Morning Peak Period)

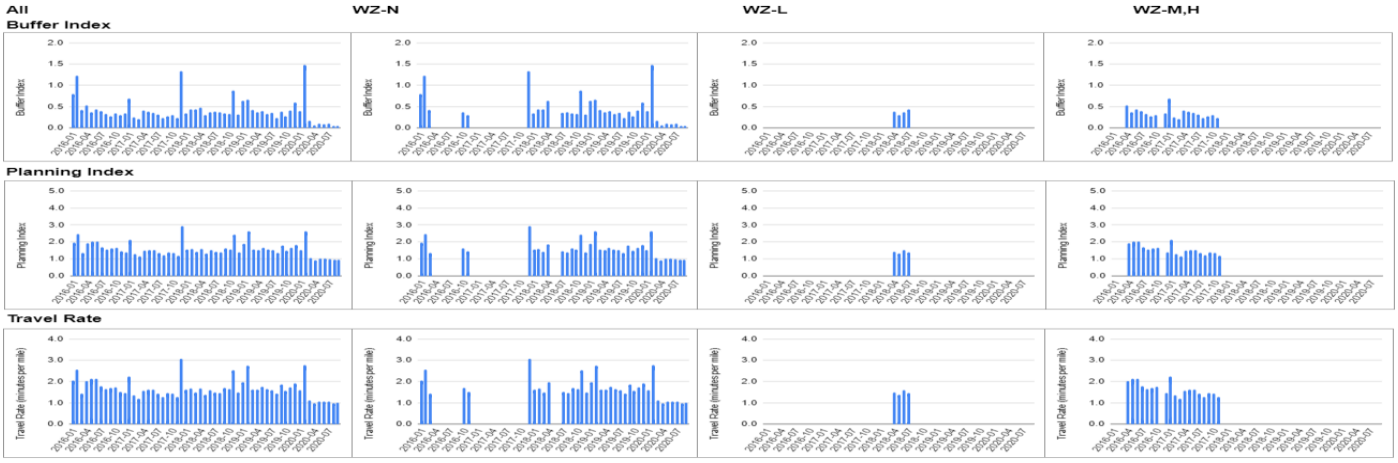
A.1.2.1 Effects of Weather



A.1.2.2 Effects of Incidents



A.1.2.3 Effects of Work Zone

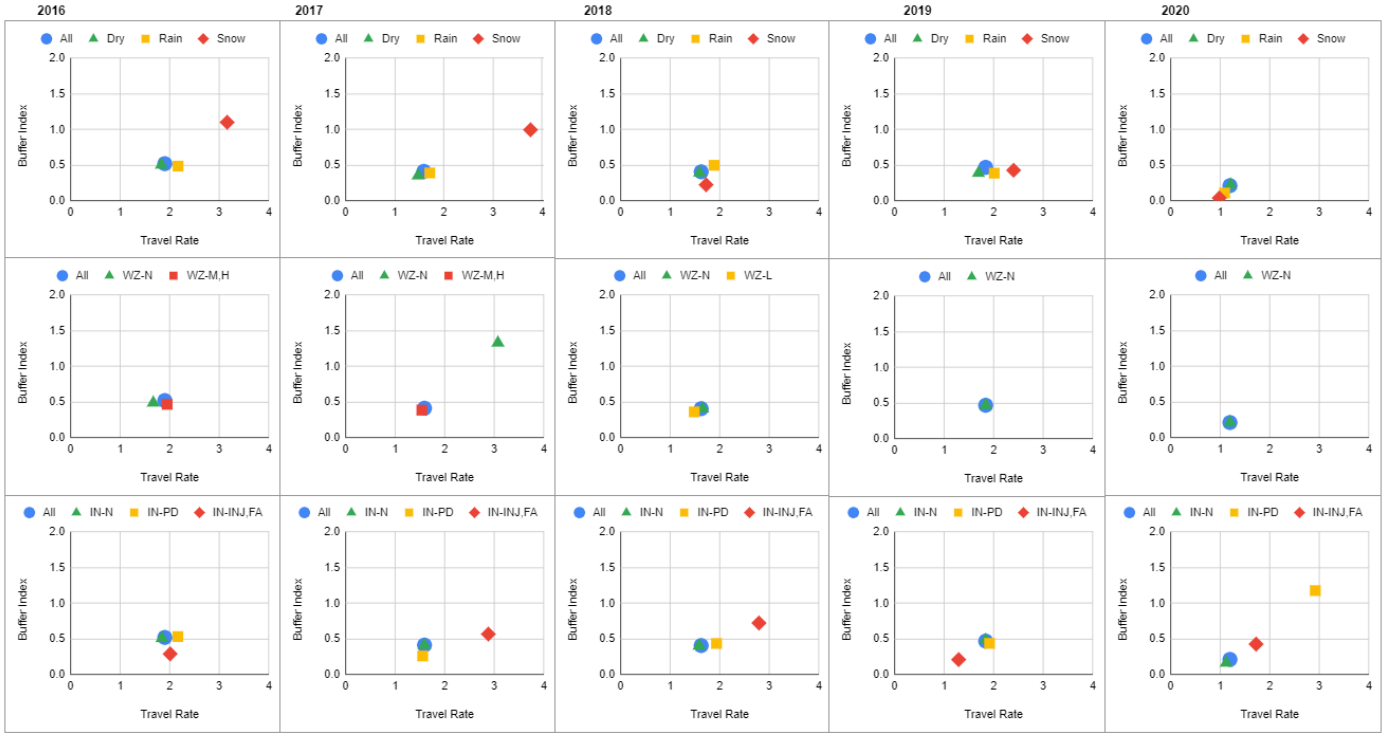


A.1.2.4 Yearly Variations - Weather

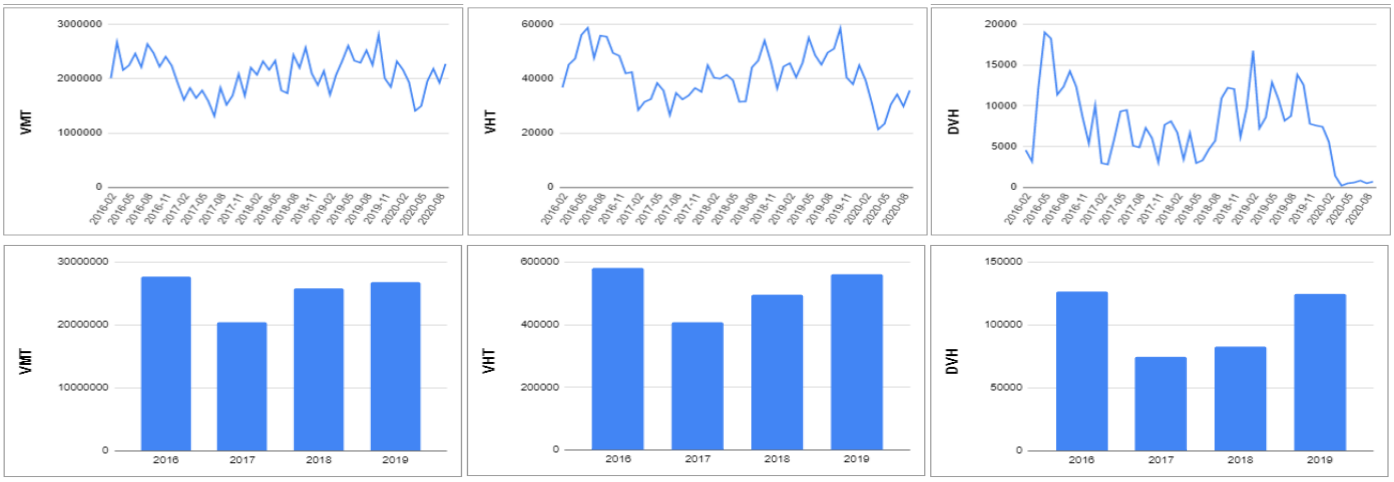
A.1.2.5 Yearly Variations – Incidents

A.1.2.6 Yearly Variations – Work Zone

A.1.2.7 Yearly Variations of Combined Index



A.1.2.8 Variations on Traffic-Flow Measures

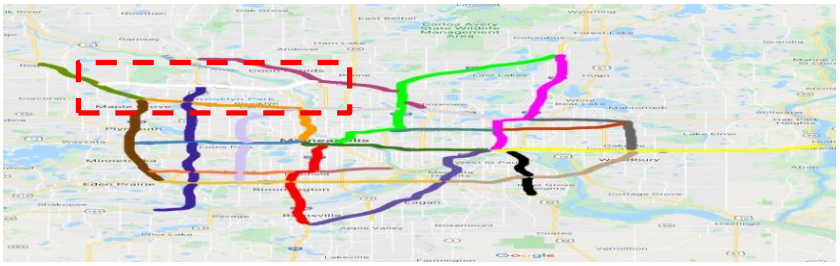


A.1.2.9 Trends Summary (169 Southbound Route)

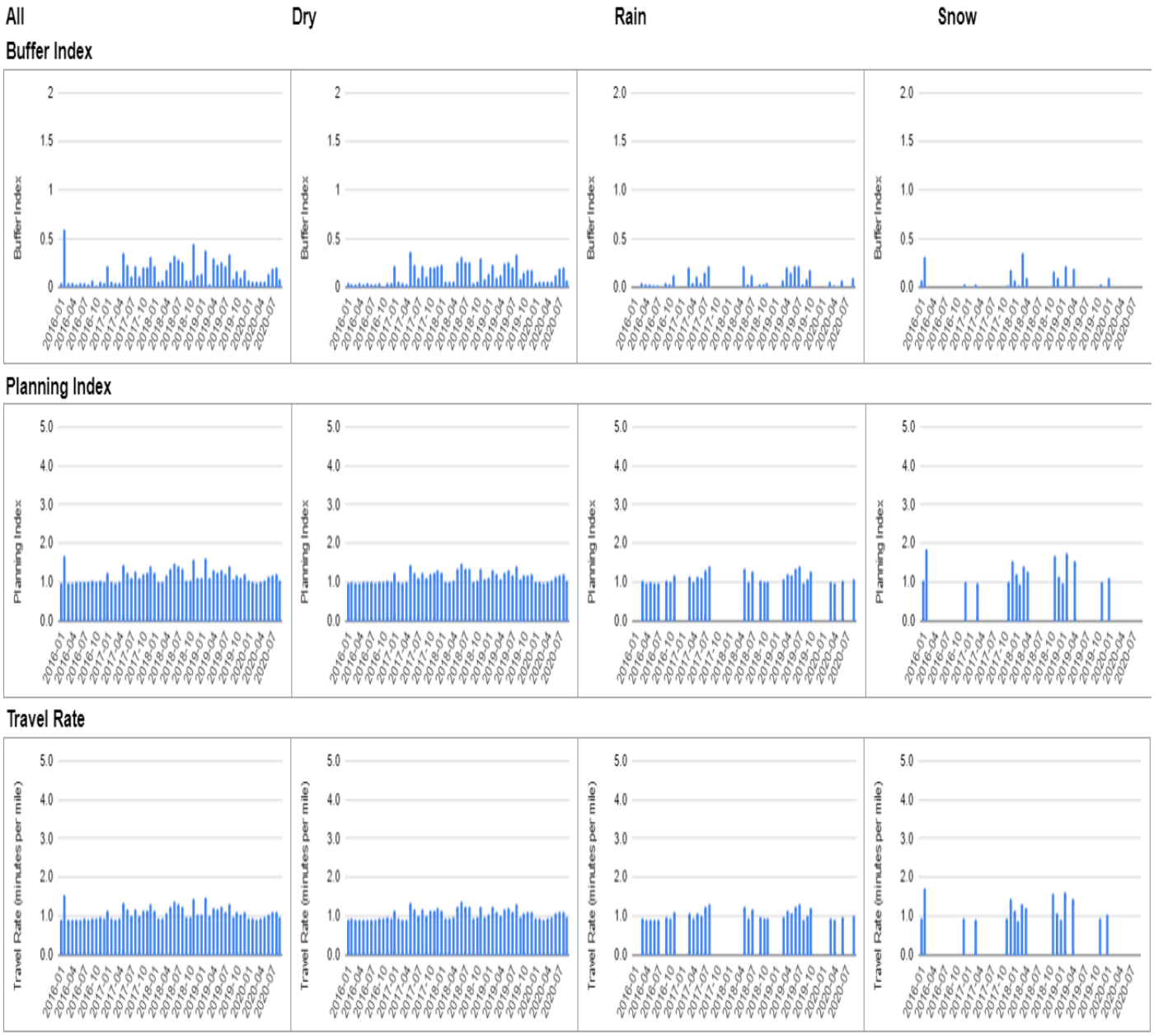
- Similar to the 169 NORTHBOUND route, the Planning and Travel-Rate indices of the 169 SOUTHBOUND route indicate a slight, but consistently upward trend from 2017 until 2019 before the pandemic started, i.e., the congestion level had been increasing as also shown in the traffic-flow measures.
- The effects of snow on reliability were improved in 2018 and 2019 compared to those in 2016 and 2017.
- The property-damage only incidents had the most significant effects on the reliability in 2020, and it may be attributed to the reduced traffic flows during the pandemic.

A.2 TH-610 CORRIDOR (EASTBOUND/WESTBOUND)

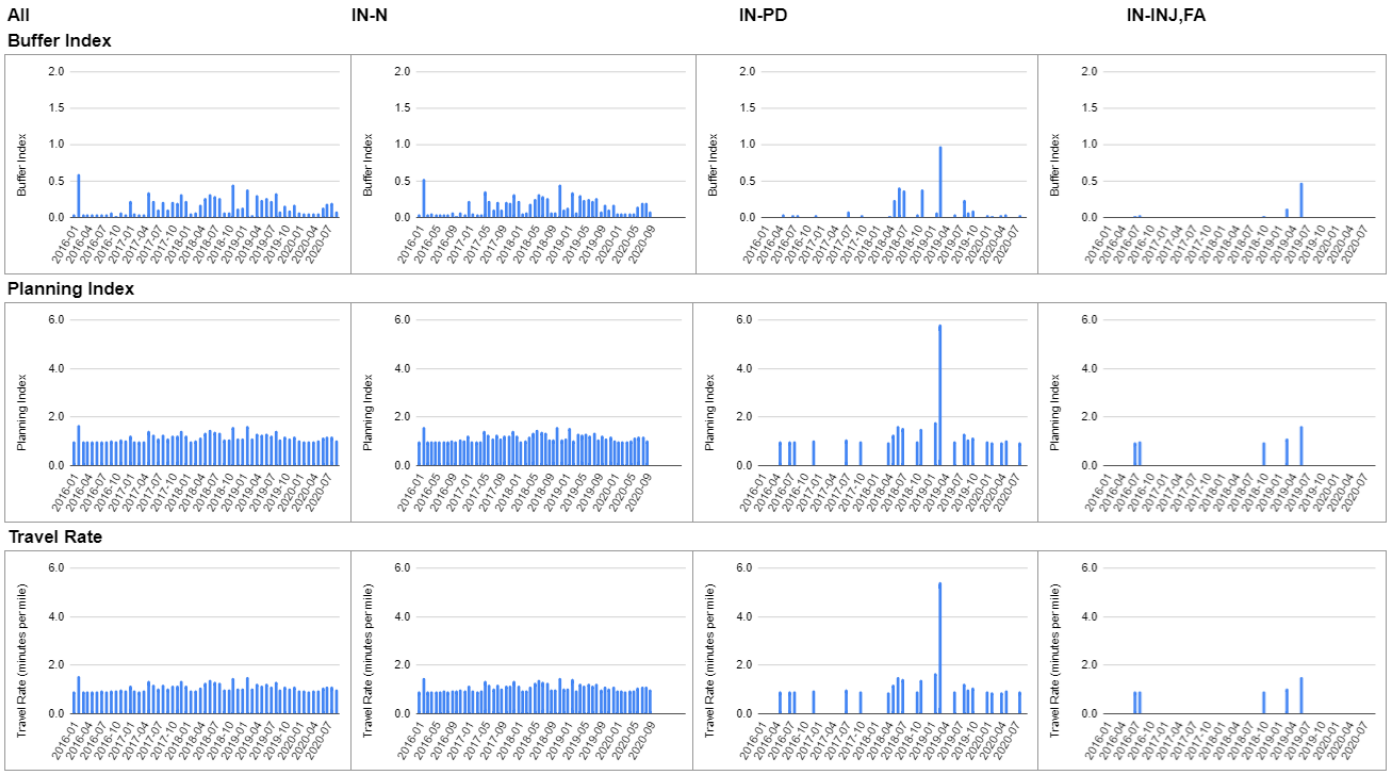
A.2.1 TH-610 Westbound Route (Afternoon Peak Period)



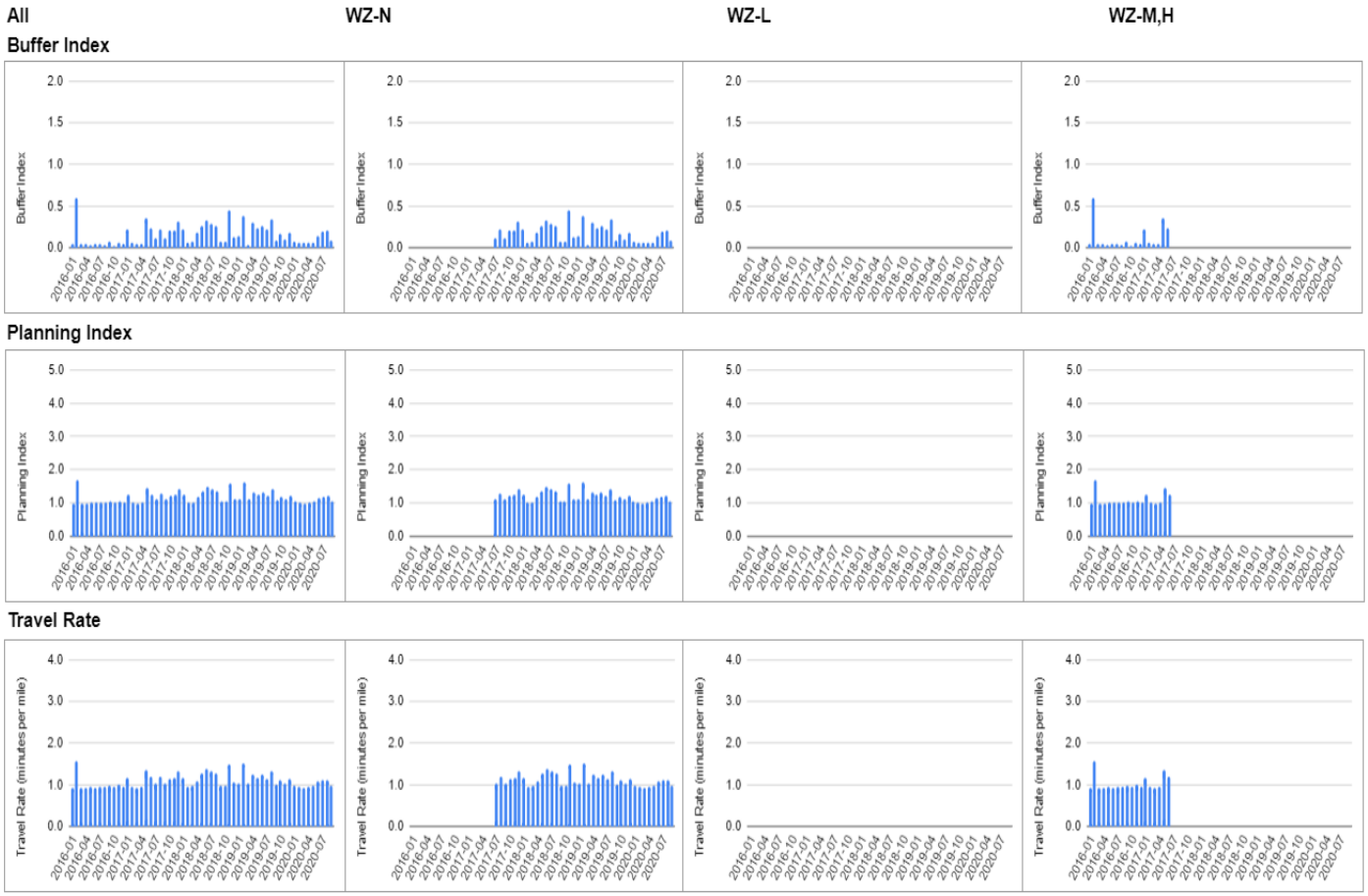
A.2.1.1 Effects of Weather



A.2.1.2 Effects of Incidents



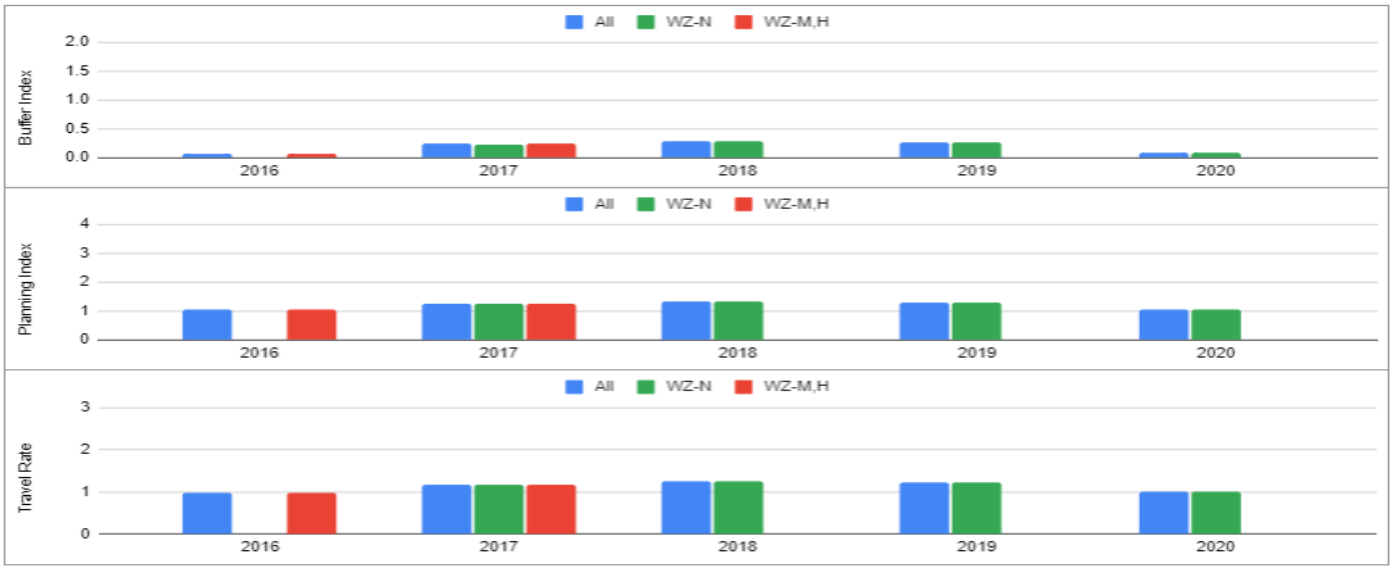
A.2.1.3 Effects of Work Zone



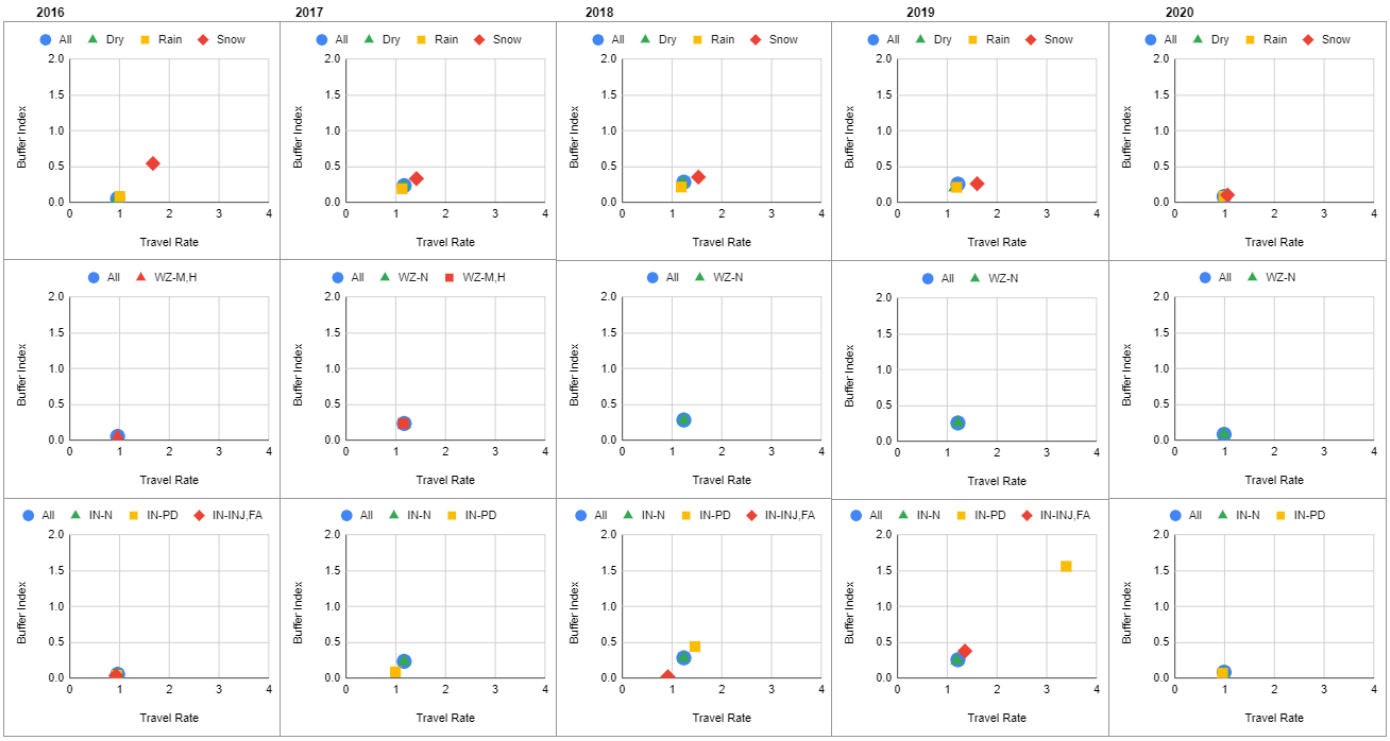
A.2.1.4 Yearly Variations - Weather

A.2.1.5 Yearly Variations – Incidents

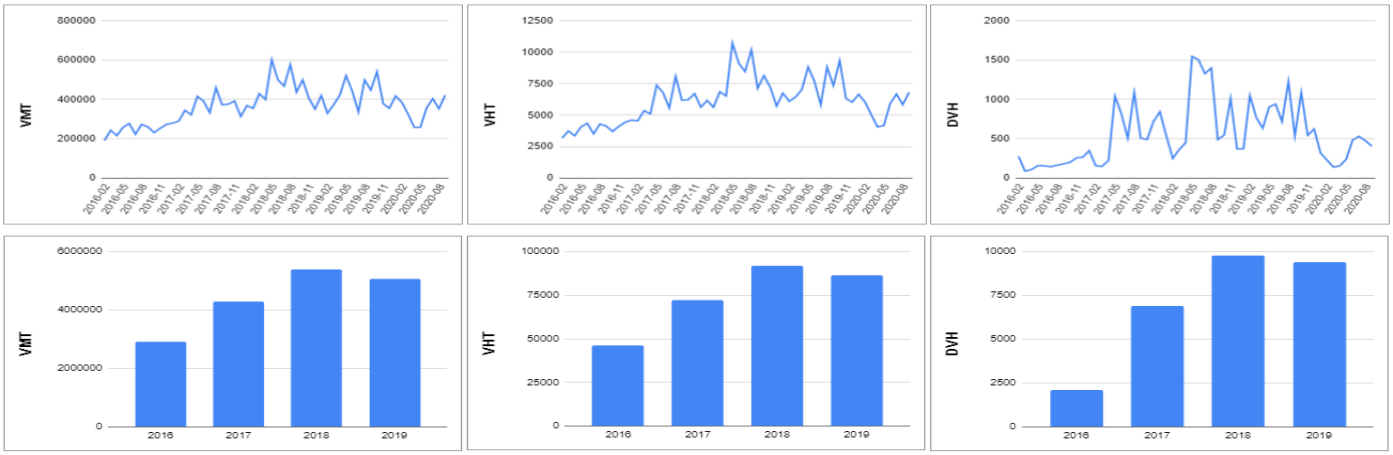
A.2.1.6 Yearly Variations – Work Zones



A.2.1.7 Yearly Variations of Combined Index



A.2.1.8 Variation Trends for Traffic-Flow Measures

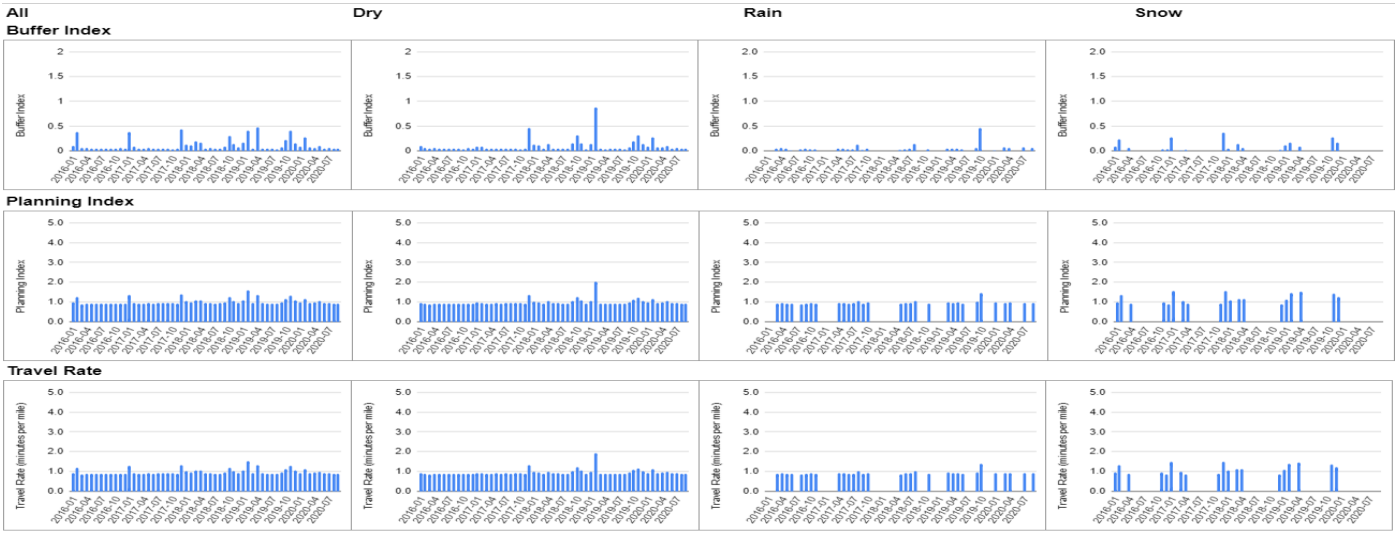


A.2.1.9 Trends Summary

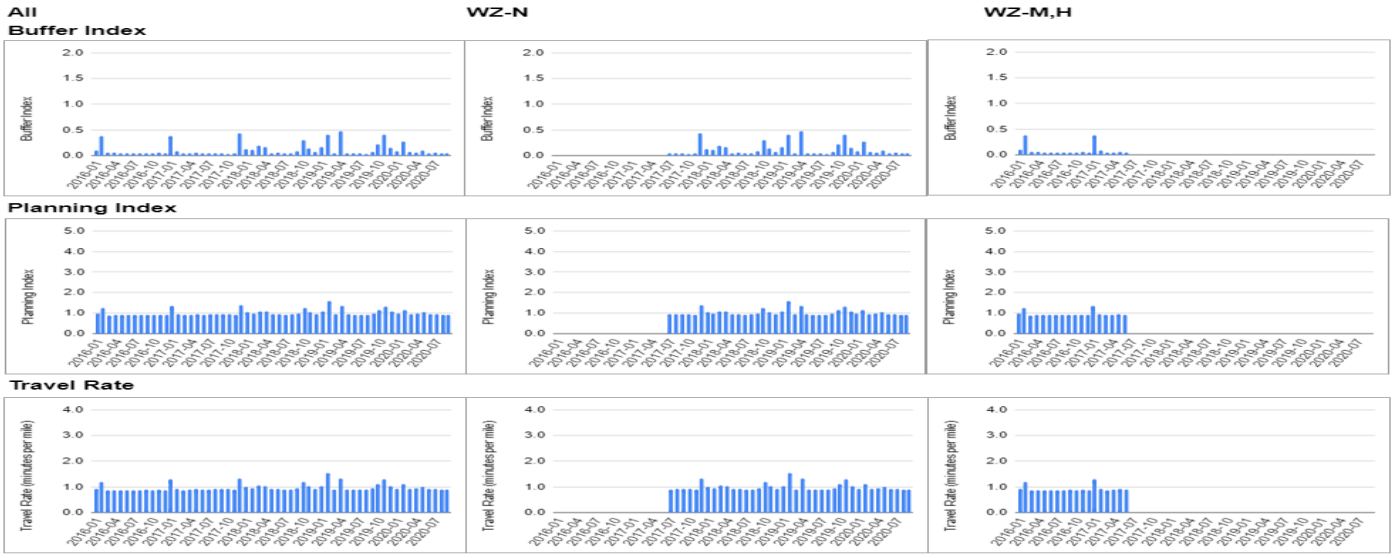
- All the traffic-flow measures, i.e., VMT, VHT and DVH, have increased from 2016 to 2018 with a slight decrease in 2019. However, all the travel-time reliability measures have remained relatively stable during the same period.
- The property-damage incidents in 2019 significantly made the travel-time reliability worse than other years.
- The effects of snow on the travel-time reliability are still consistently higher than those from rain, while the differences are not very significant.

A.2.2 TH-610 Eastbound Route (Morning Peak Period)

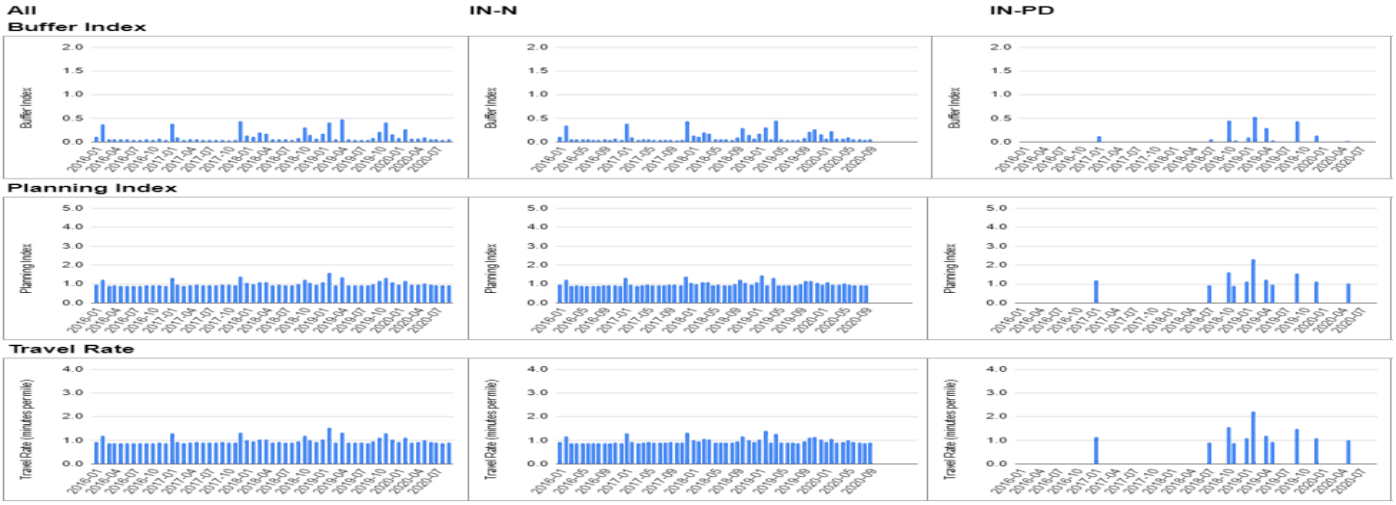
A.2.2.1 Effects of Weather



A.2.2.2 Effects of Work Zones



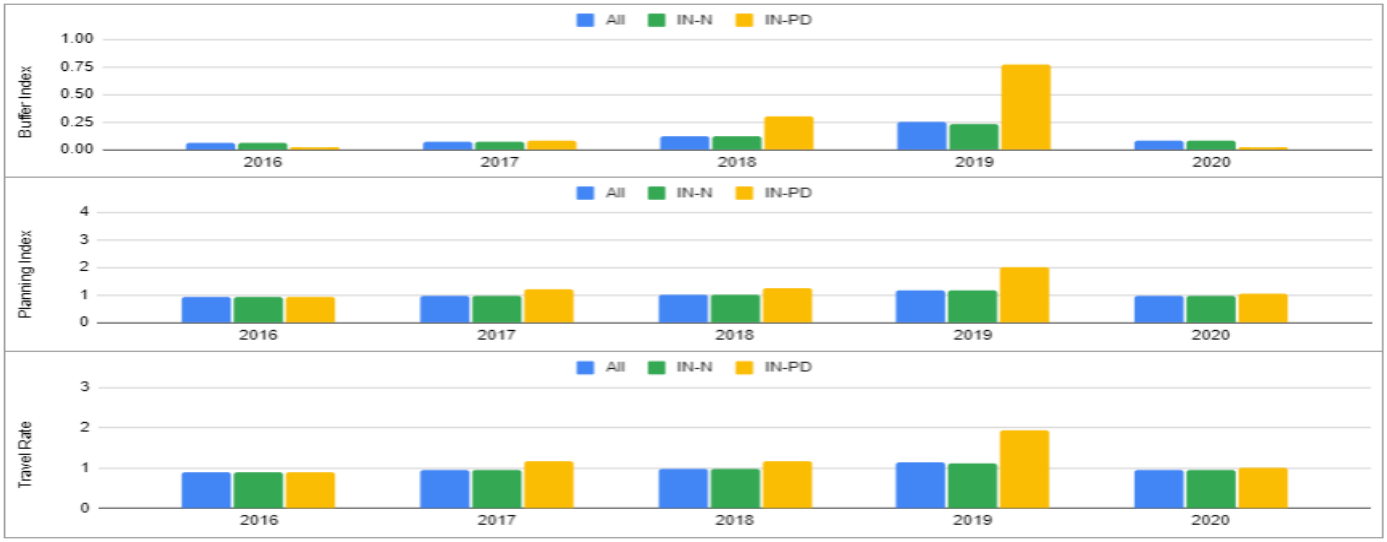
A.2.2.3 Effects of Incidents



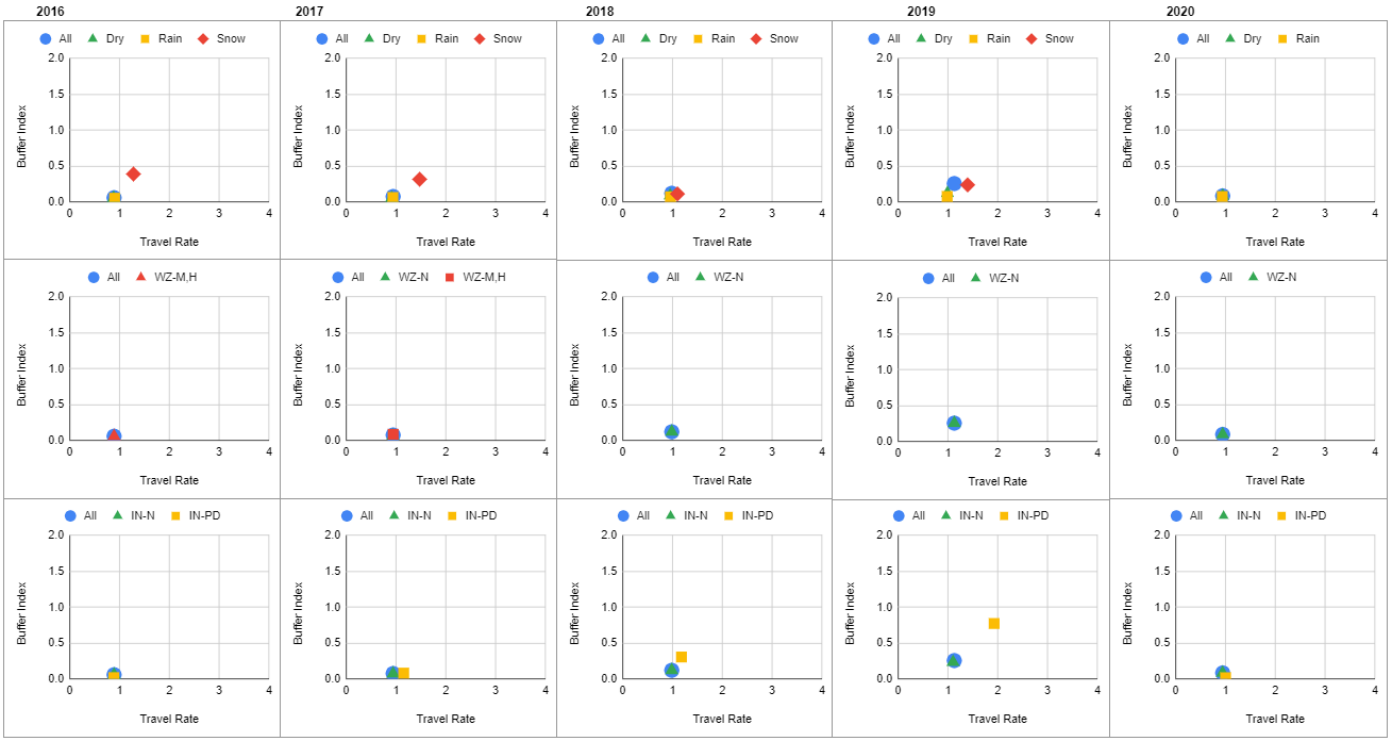
A.2.2.4 Yearly Variations - Weather

A.2.2.5 Yearly Variations – Work Zones

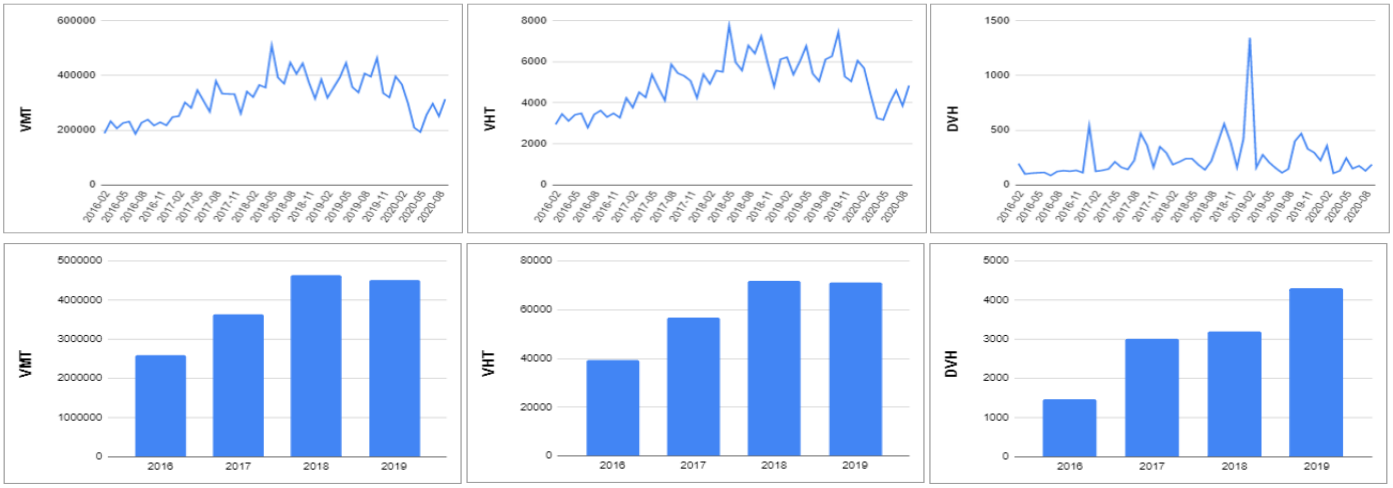
A.2.2.6 Yearly Variations – Incidents



A.2.2.7 Yearly Variations of Combined Index



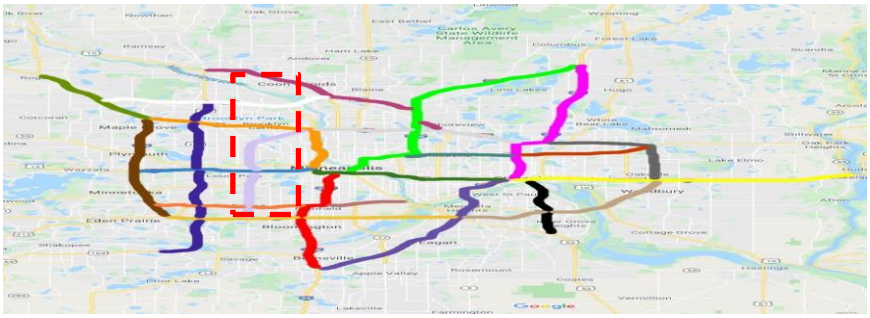
A.2.2.8 Variations of Traffic-Flow Measures



A.2.2.9 Trends Summary

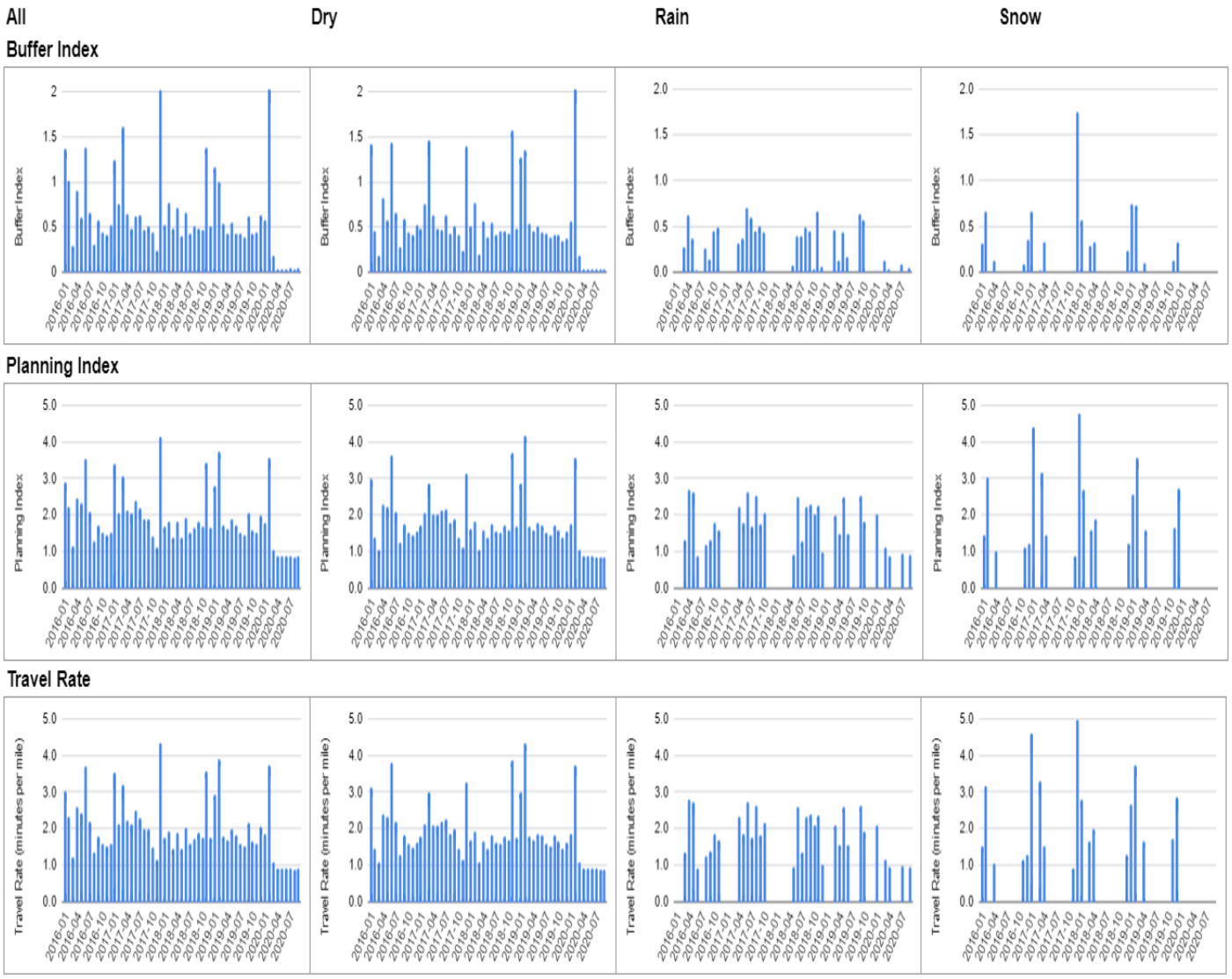
- The traffic-flow in the 610 EASTBOUND route show continuously increasing trends from 2016 to 2018, while the flow measures in 2019 indicate a slightly downward pattern. However, the travel-time reliability indices on this route had remained stable during the same period.
- The effects of property-damage only incidents on the reliability have been the single most important factor since 2017.

A.3 TH-100 CORRIDOR (NORTHBOUND/SOUTHBOUND)

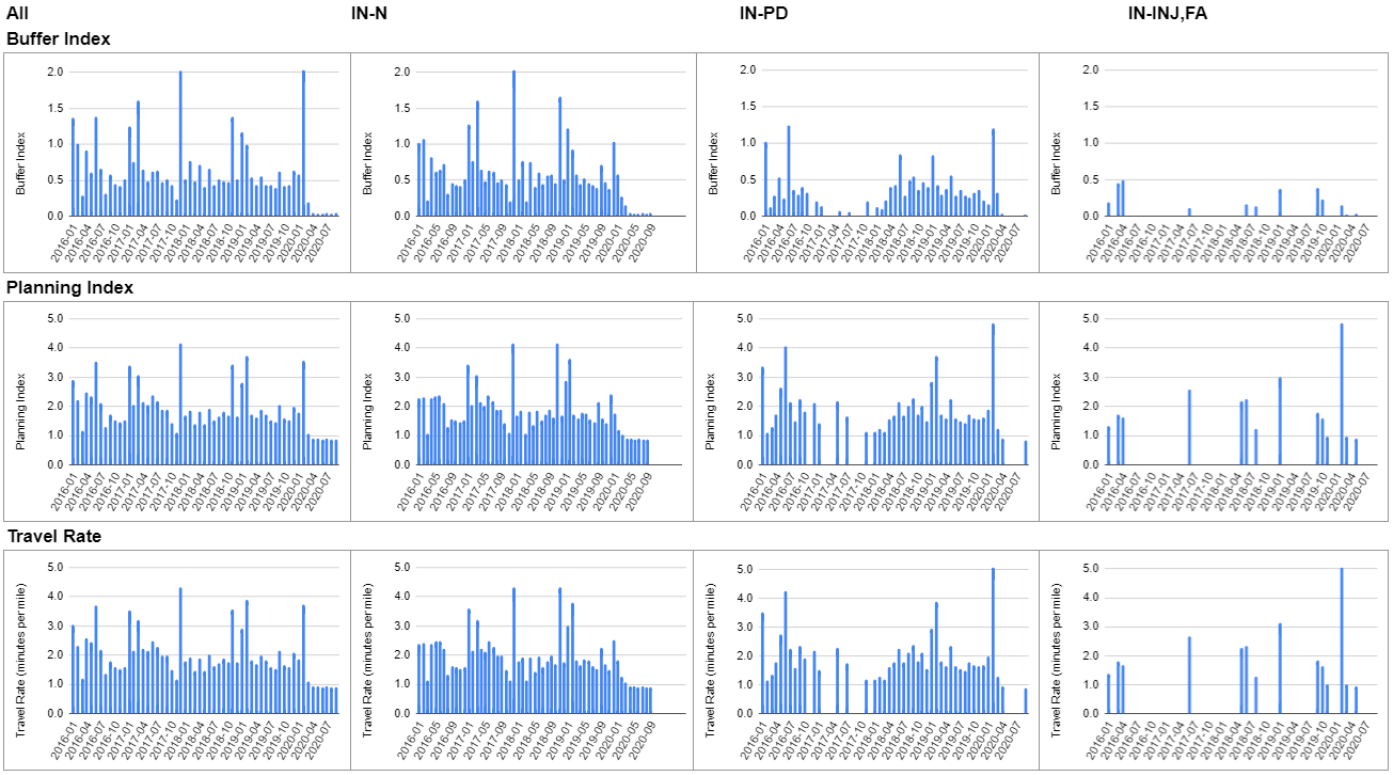


A.3.1 100 SOUTHBOUND Route (Morning Peak)

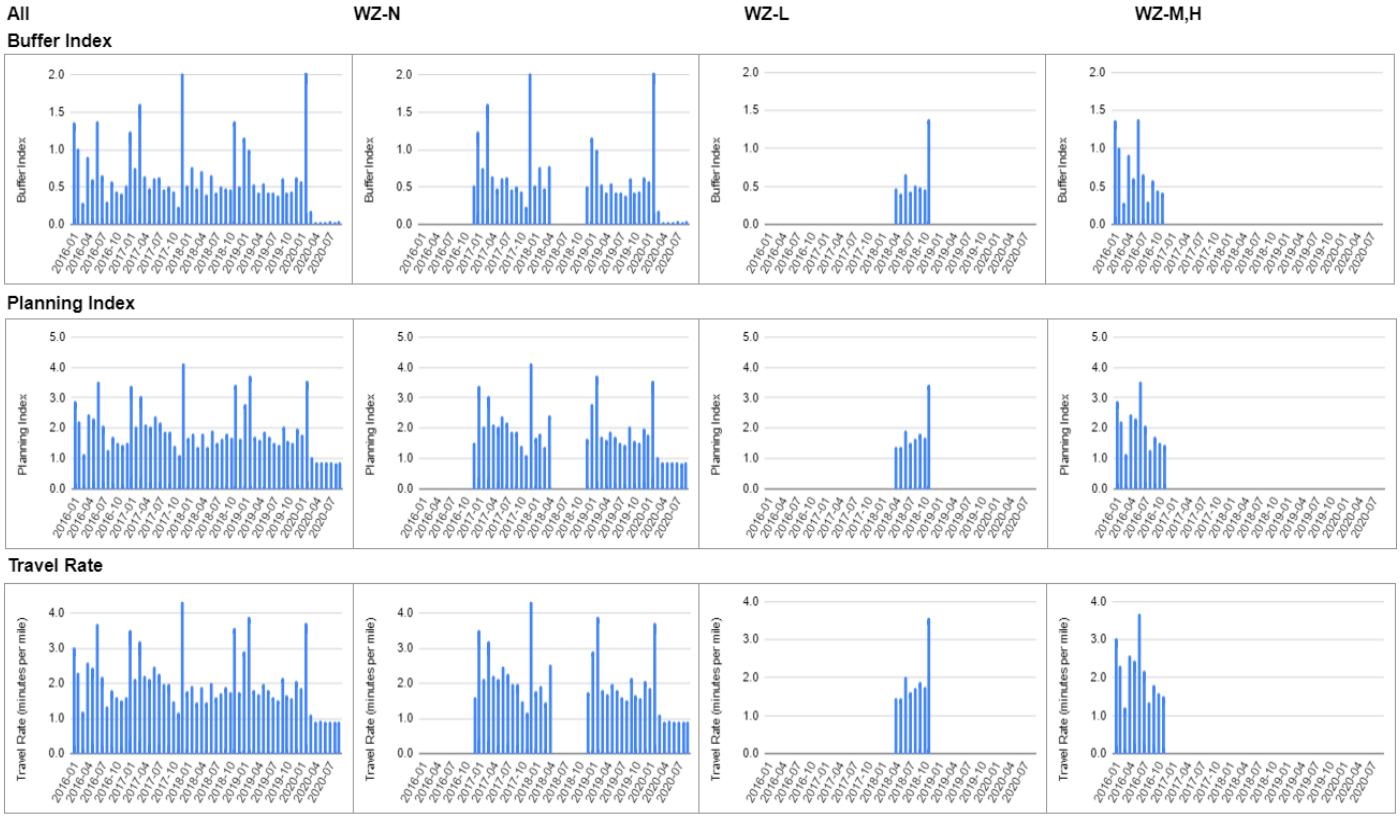
A.3.1.1 Effects of Weather



A.3.1.2 Effects of Incidents

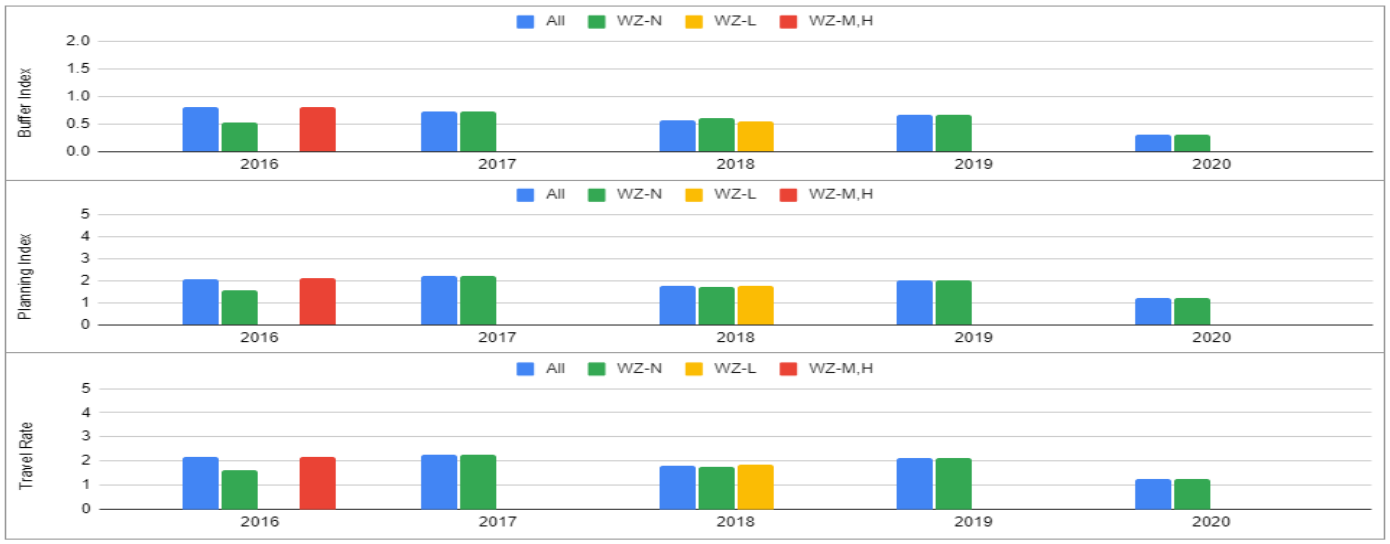


A.3.1.3 Effects of Work Zones



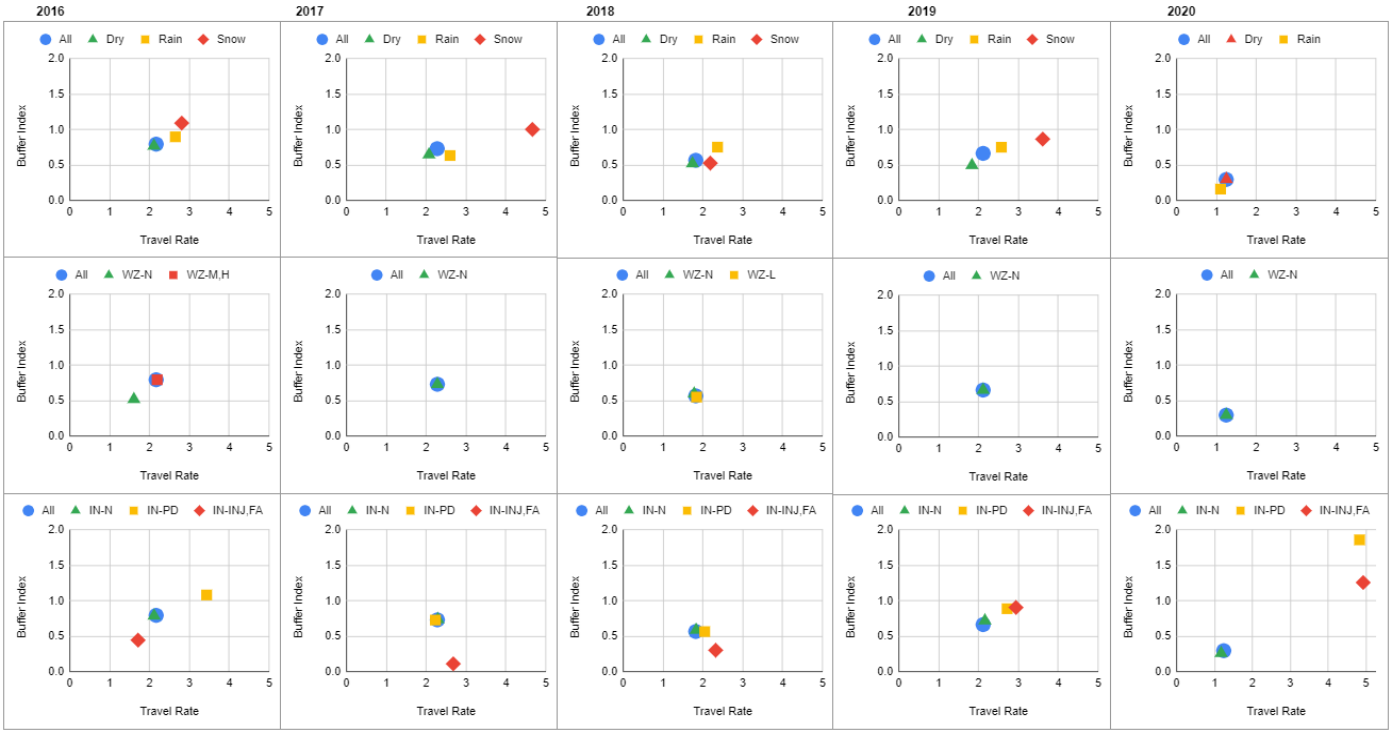
A.3.1.4 Yearly Variations – Weather

A.3.1.5 Work Zones

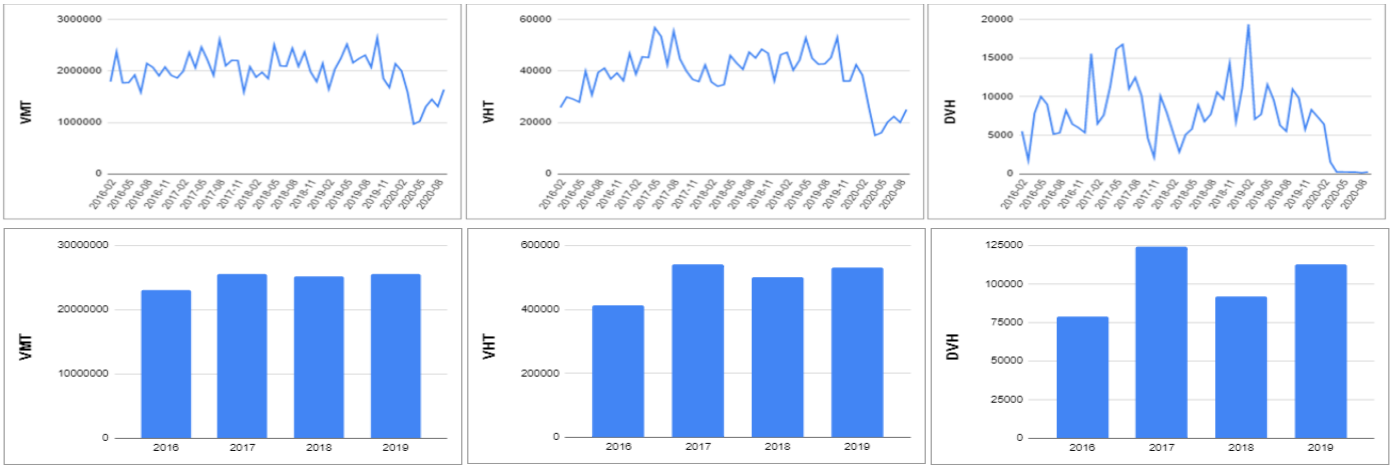


A.3.1.6 Incidents

A.3.1.7 Yearly Variations of Combined Index



A.3.1.8 Variations of Traffic-Flow Measures

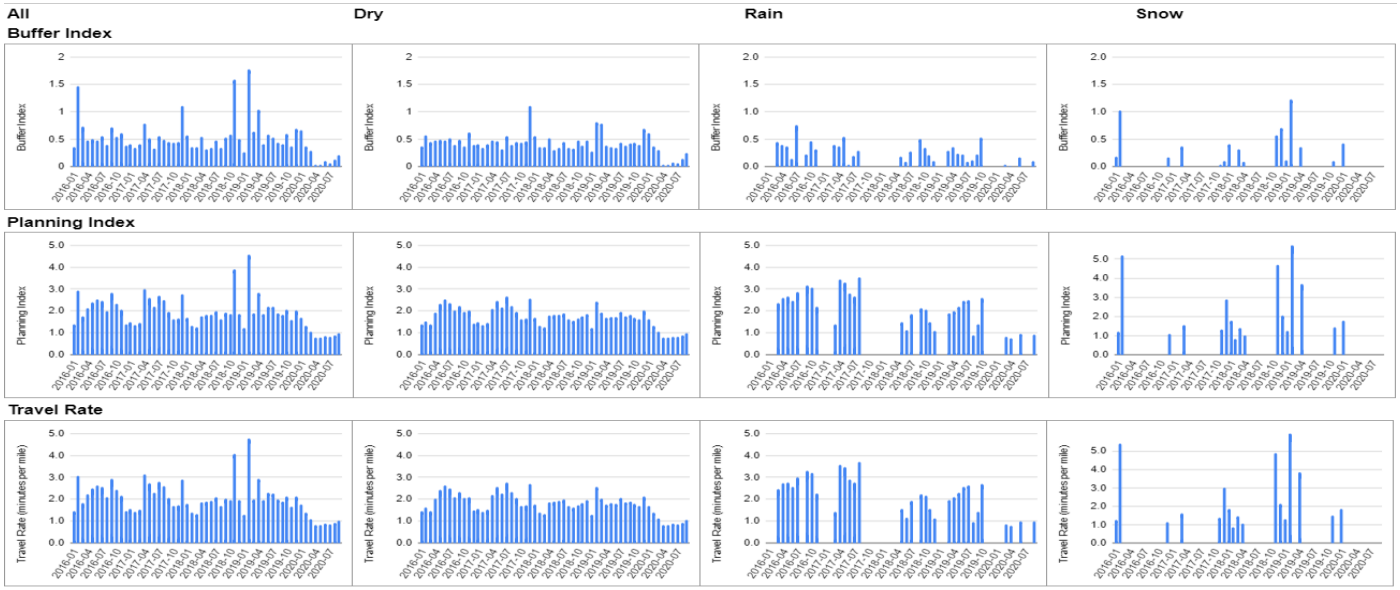


A.3.1.9 Trends Summary

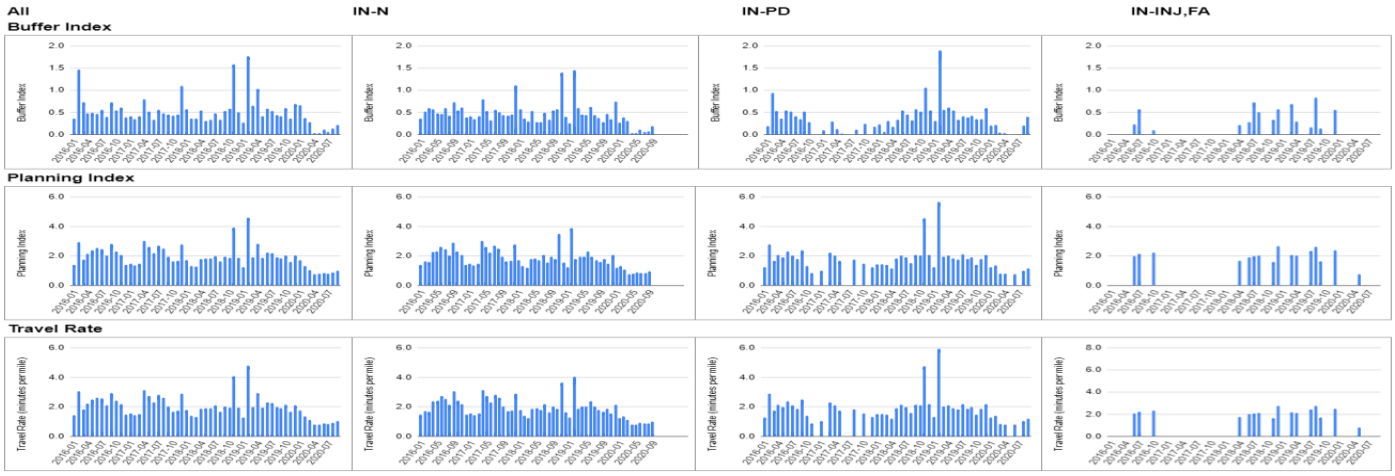
- The monthly fluctuating patterns of both buffer and planning indices indicate large variations in travel times with high-level of congestion have been prevailing. The delayed-vehicle hours also show a significantly upward trend, while the VMT values have a very slight increase.
- Snow has been a consistent factor affecting the reliability, which has also been increasingly affected by incidents.

A.3.2 100 NORTHBOUND Route (Afternoon Peak Period)

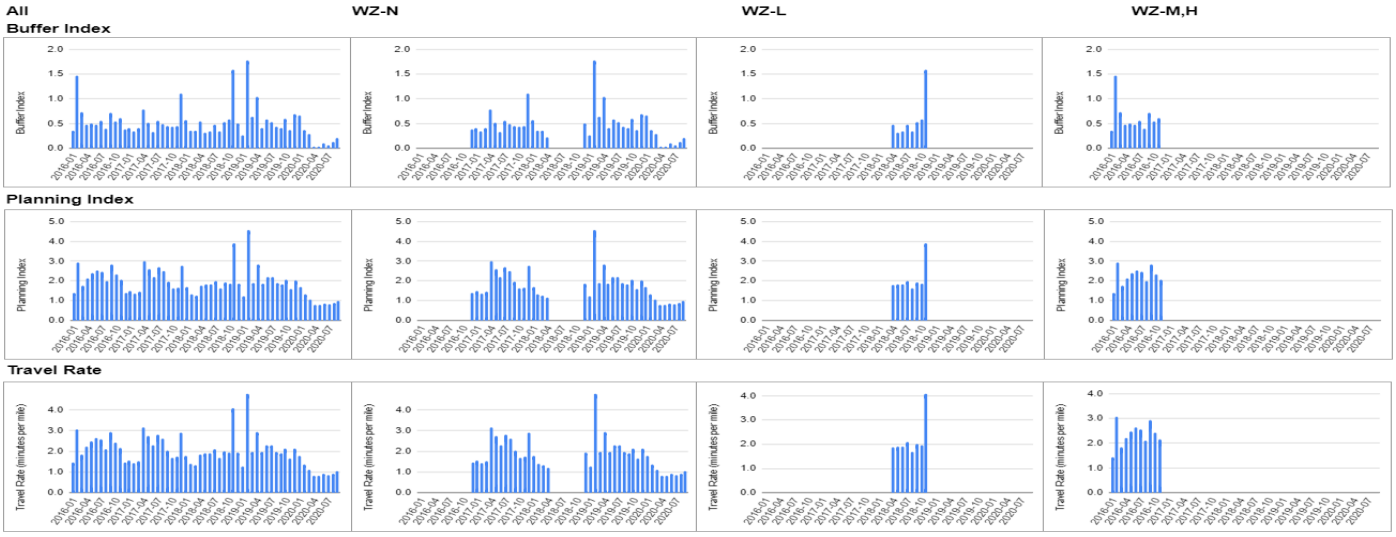
A.3.2.1 Effects of Weather



A.3.2.2 Effects of Incidents

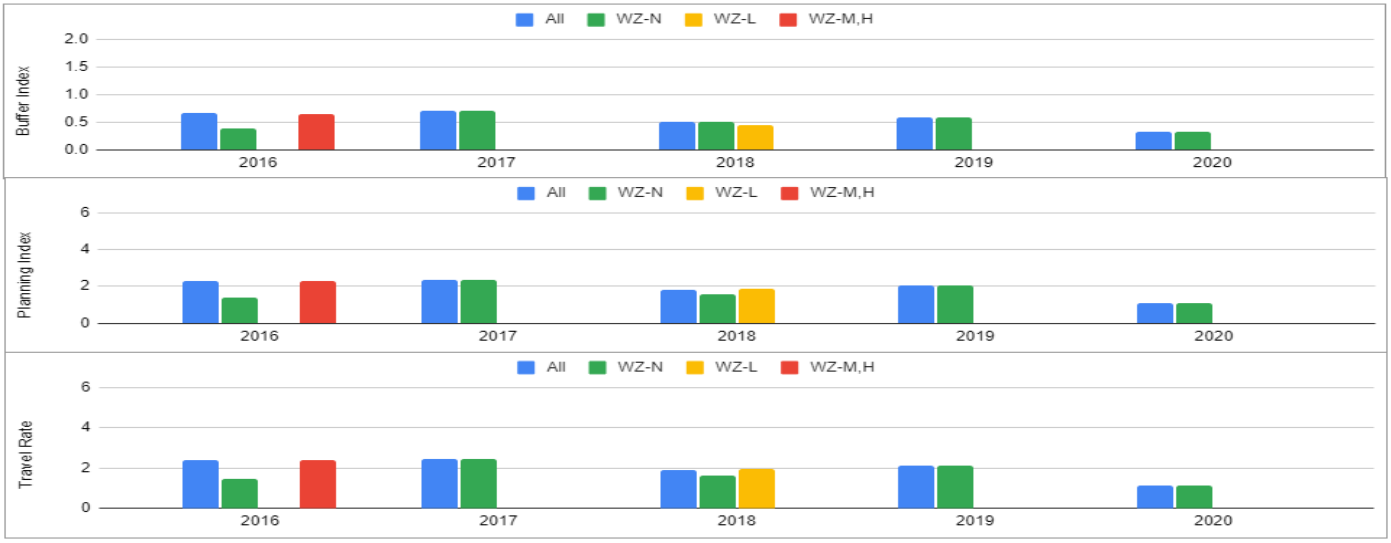


A.3.2.3 Effects of Work Zones



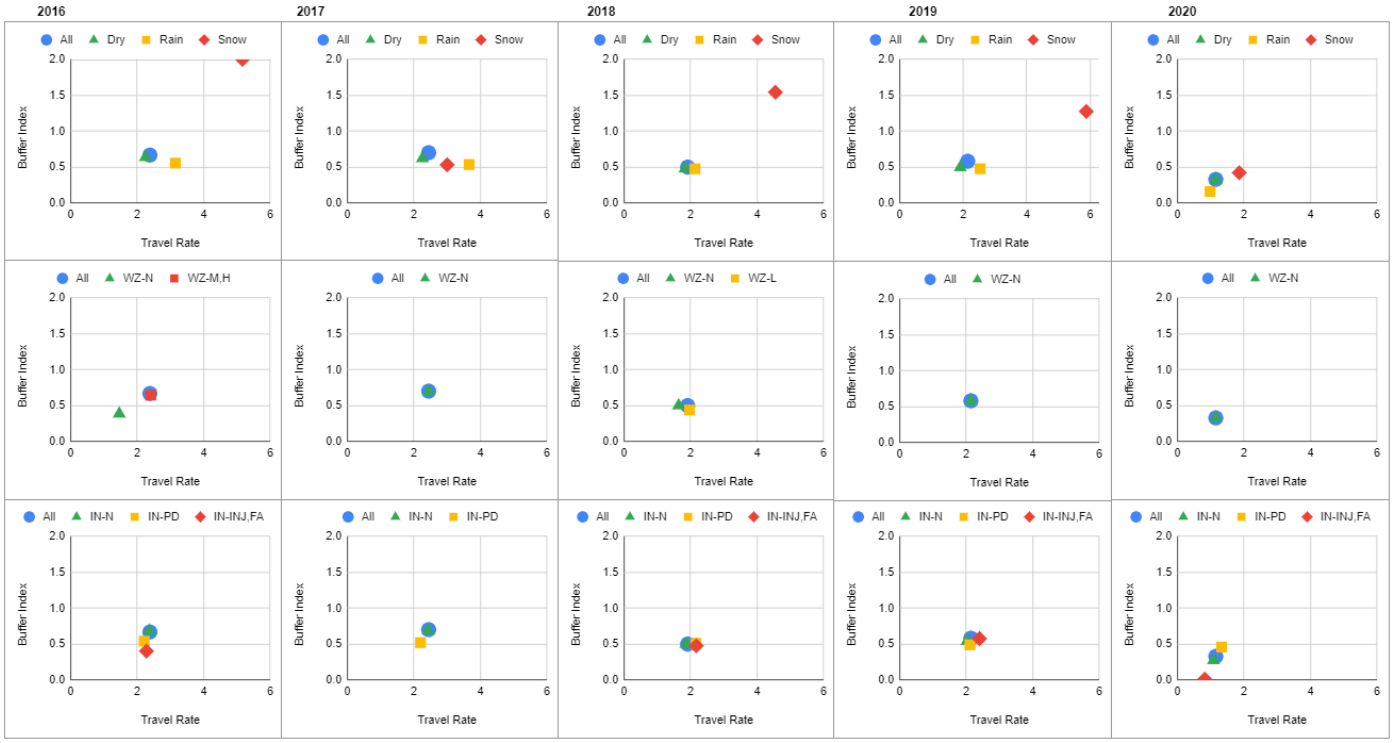
A.3.2.4 Yearly Variations - Weather

A.3.2.5 Yearly Variations – Work Zones

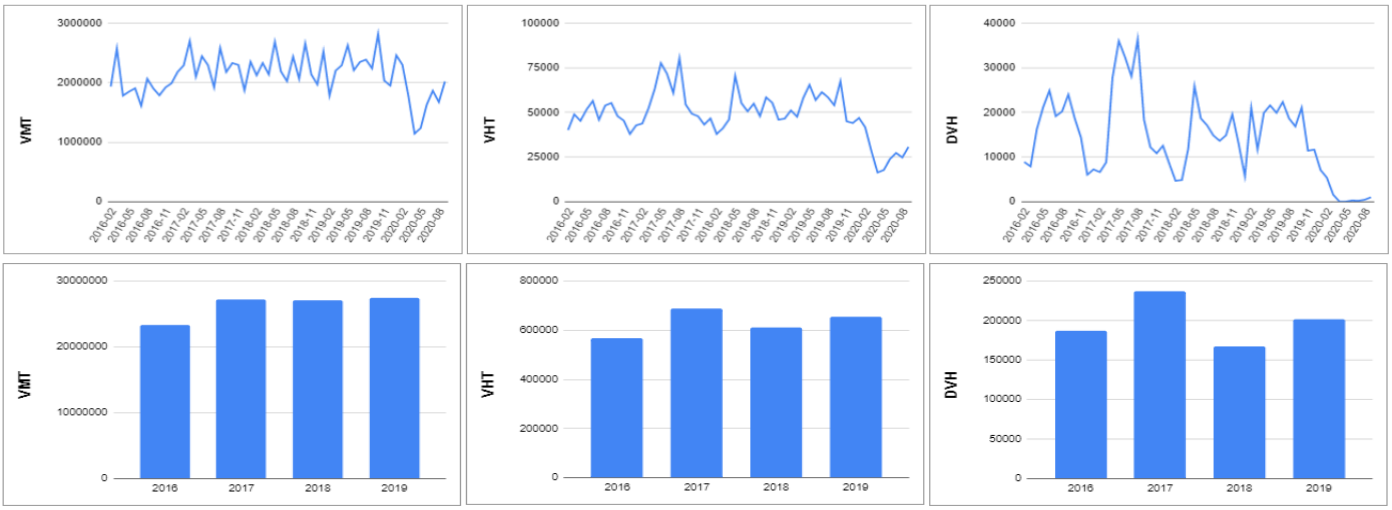


A.3.2.6 Yearly Variations – Incidents

A.3.2.7 Yearly Variations – Combined Index



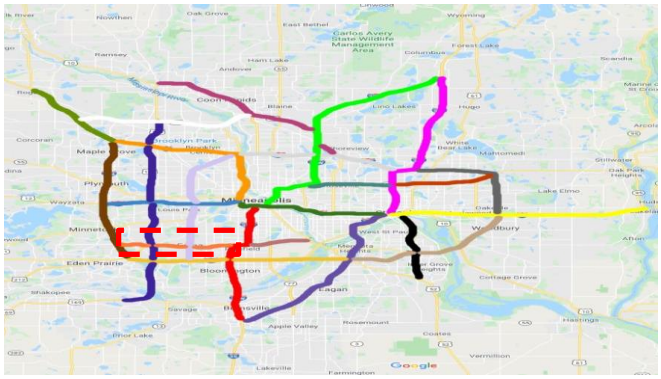
A.3.2.8 Variations of the Traffic-Flow Measures



A.3.2.9 Trends Summary

- The monthly variations of both buffer and planning indices show relatively stable patterns in travel-time variability and congestion level.
- Snow has been the main contributing factor to the variations of the reliability measures.

A.4 TH-62 CORRIDOR 1 (I-494 – I-35W, EASTBOUND/WESTBOUND)

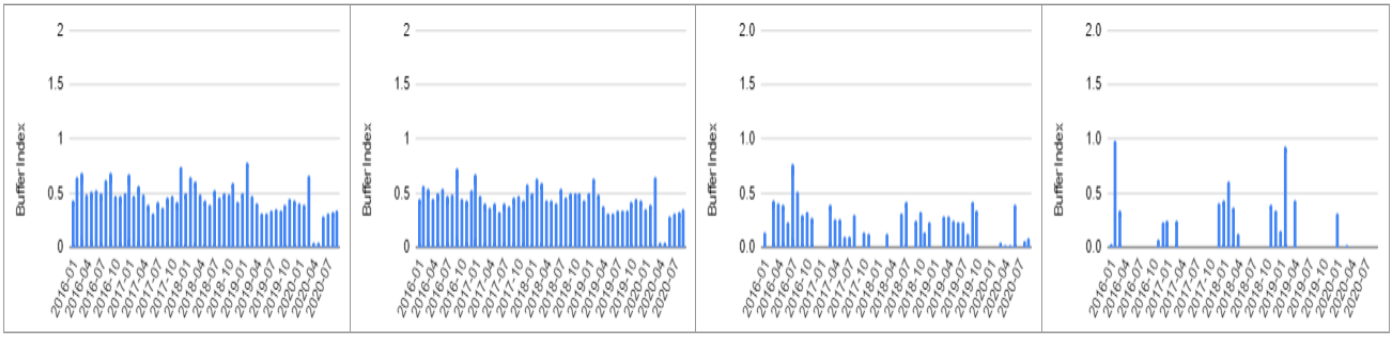


A.4.1 TH-62 EASTBOUND Route 1 (I-494 -> I-35W: Afternoon Peak)

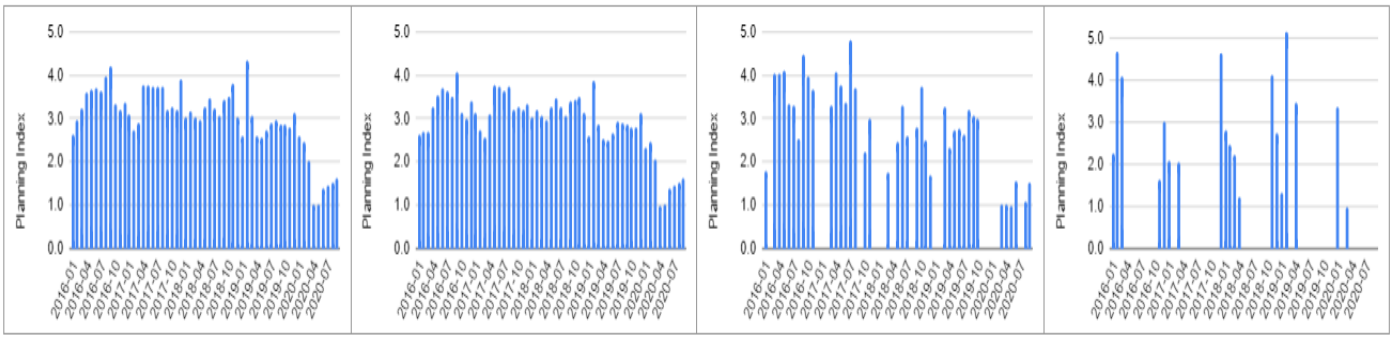
A.4.1.1 Effects of Weather

All Dry Rain Snow

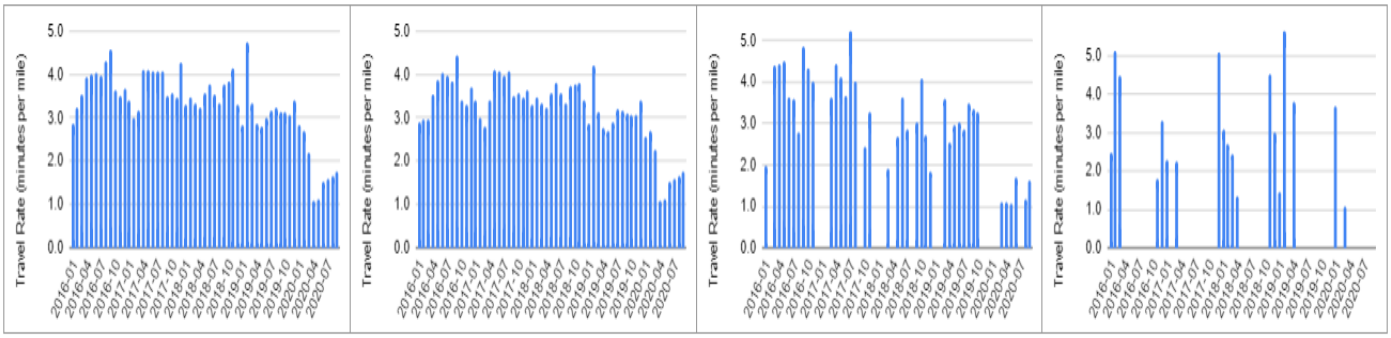
Buffer Index



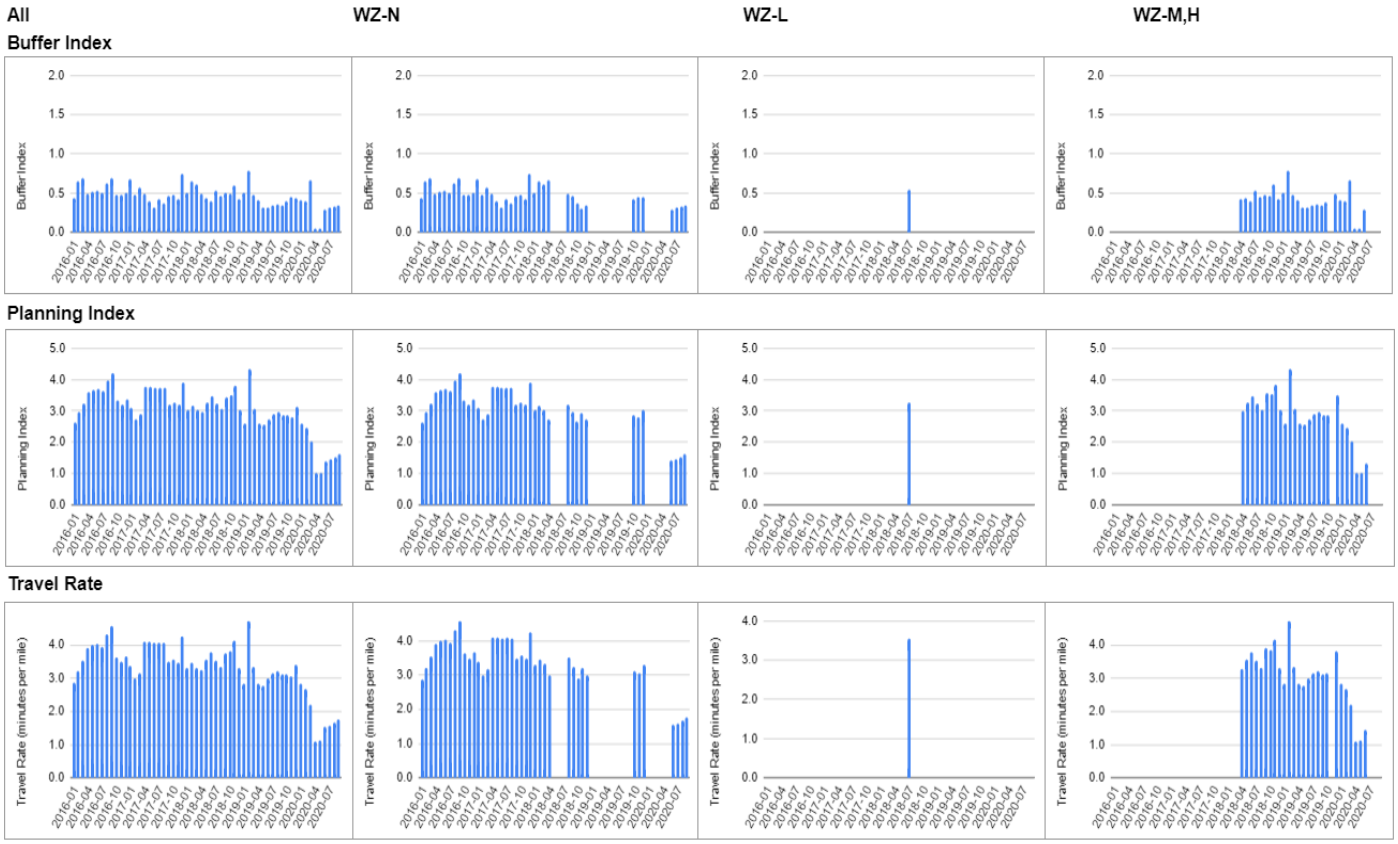
Planning Index



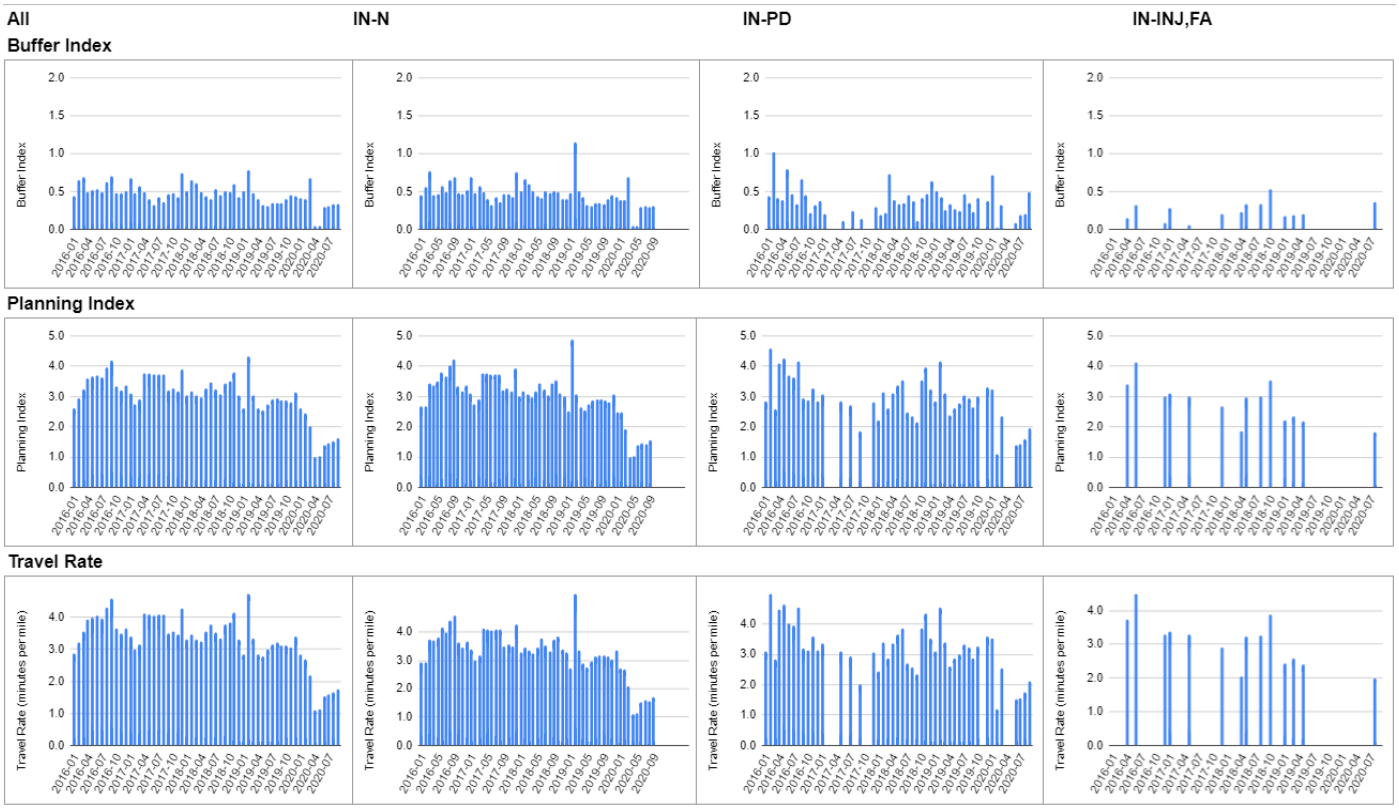
Travel Rate



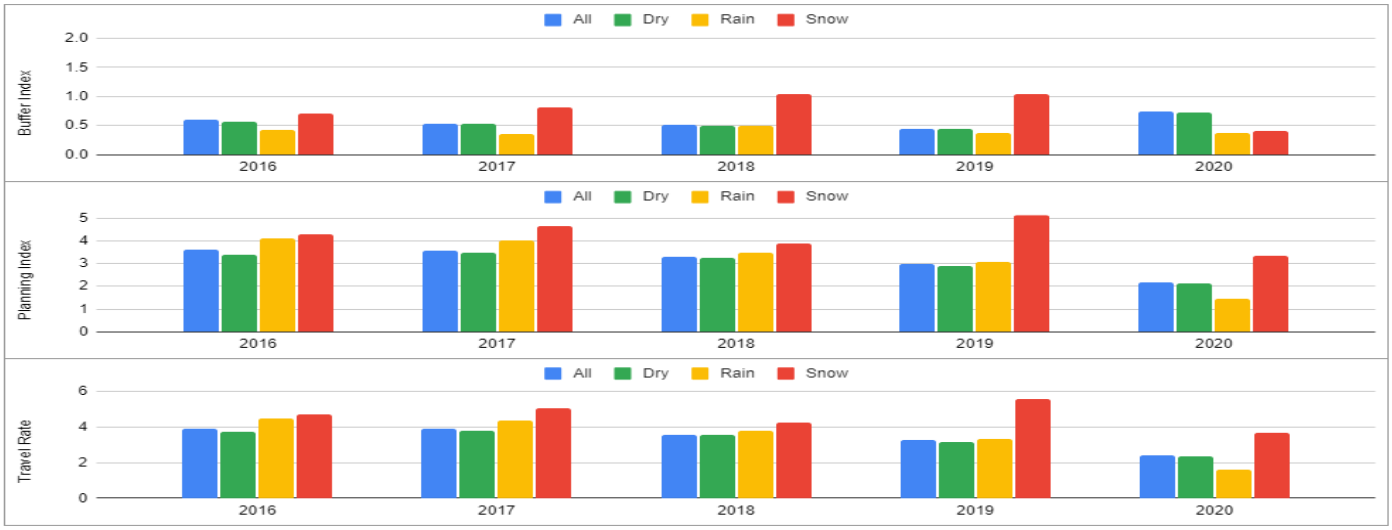
A.4.1.2 Effects of Work Zones



A.4.1.3 Effects of Incidents



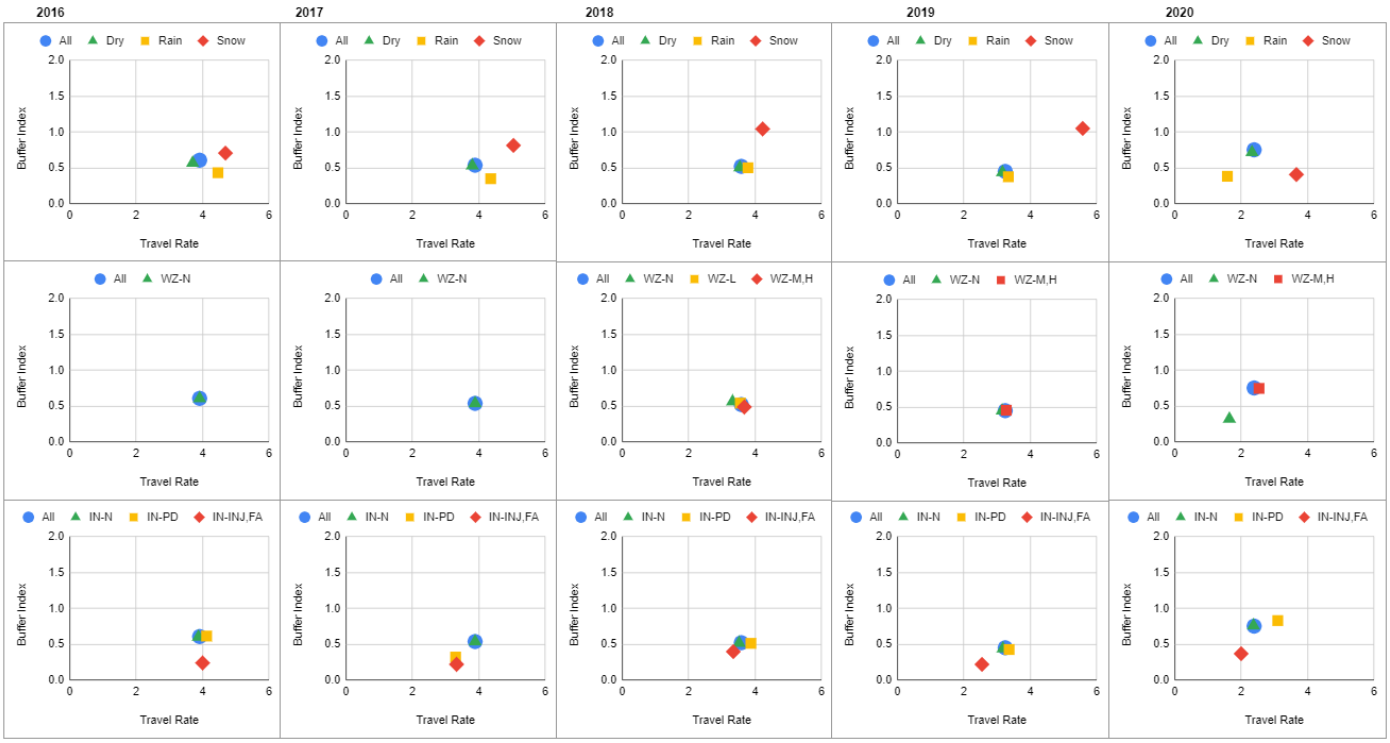
A.4.1.4 Yearly Variations



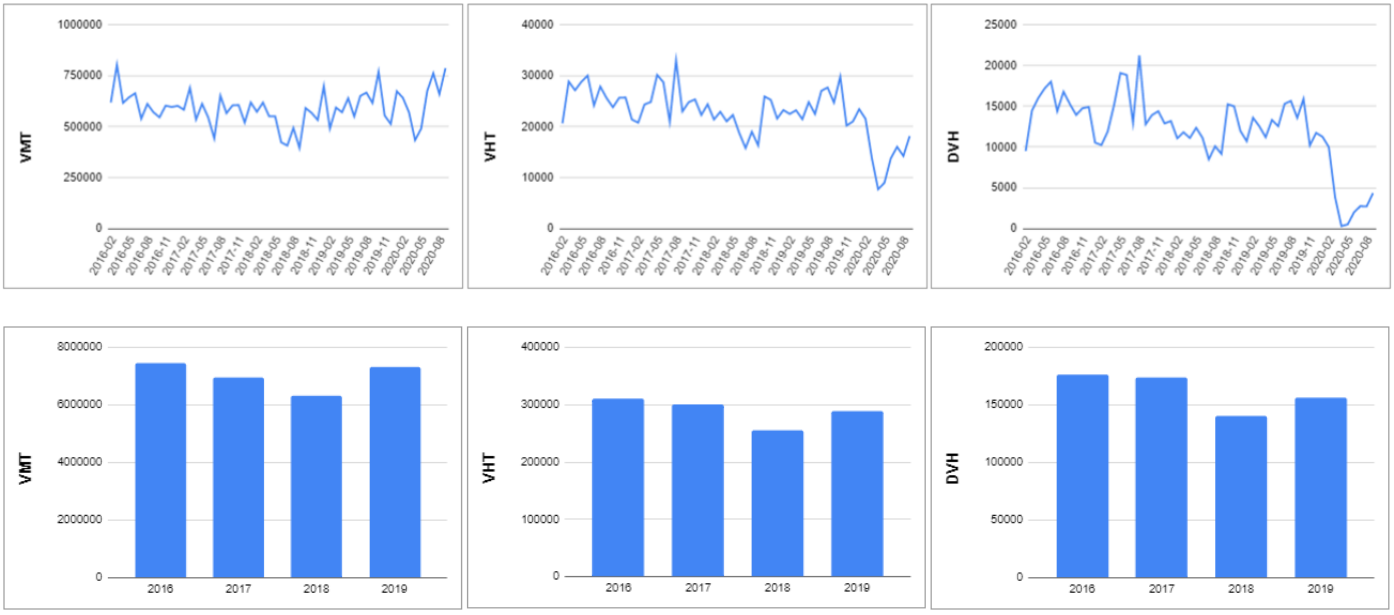

All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
6
4
2
0
2016
2017
2018
2019
2020


All
WZ-N
WZ-L
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
6
4
2
0
2016
2017
2018
2019
2020

A.4.1.5 Yearly Variations of Combined Index



A.4.1.6 Variations of Traffic-Flow Measures

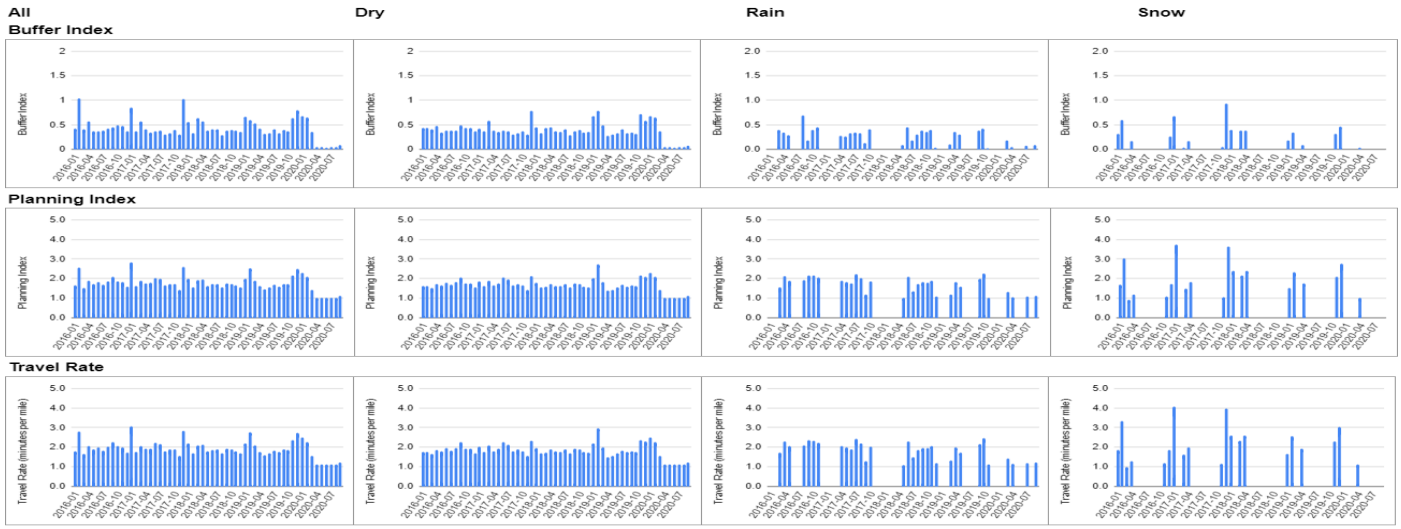


A.4.1.7 Trends Summary

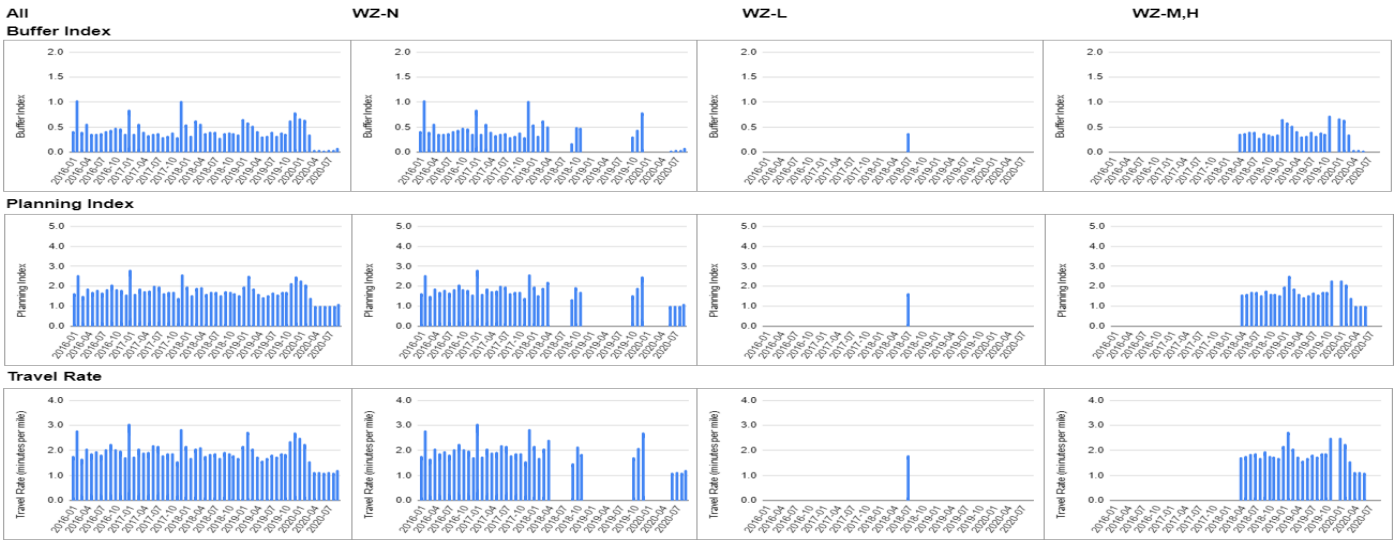
- Very high level of congestion has been fluctuating through time, while the traffic-flow patterns indicate a gradually decreasing trend in vehicle delays.
- Snow has been the main factor affecting the variability of travel times.

A.4.2 TH 62 WESTBOUND Route 1 (I-35W -> I-494, Morning Peak)

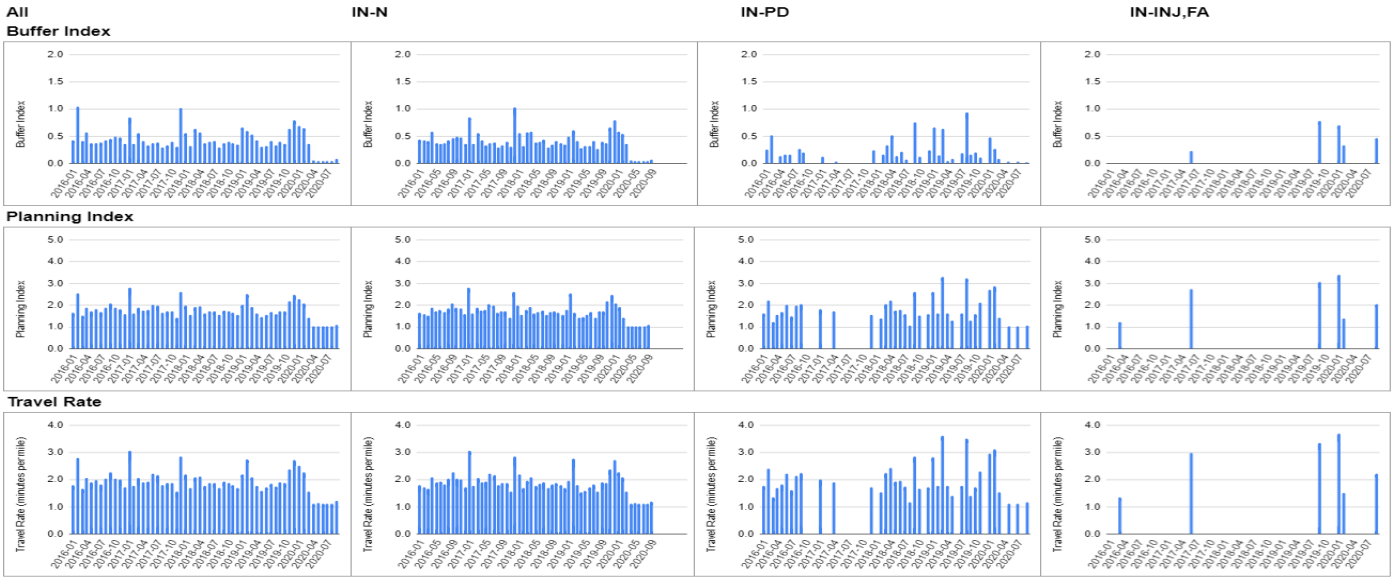
A.4.2.1 Effects of Weather



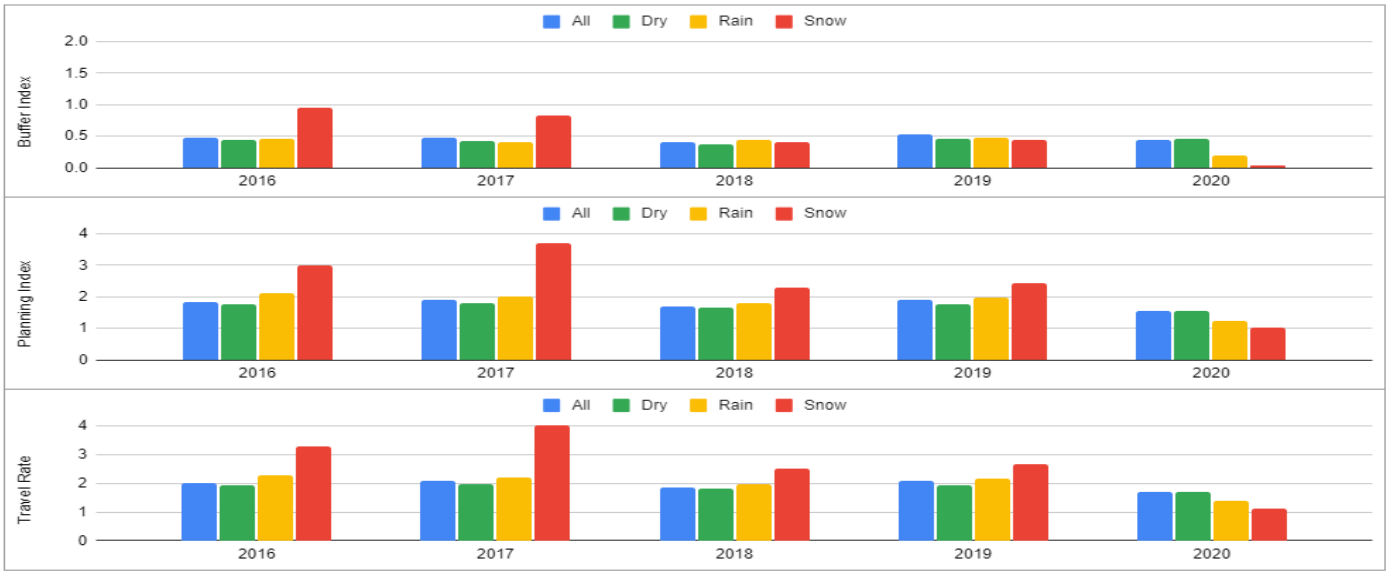
A.4.2.2 Effects of Work Zones



A.4.2.3 Effects of Incidents



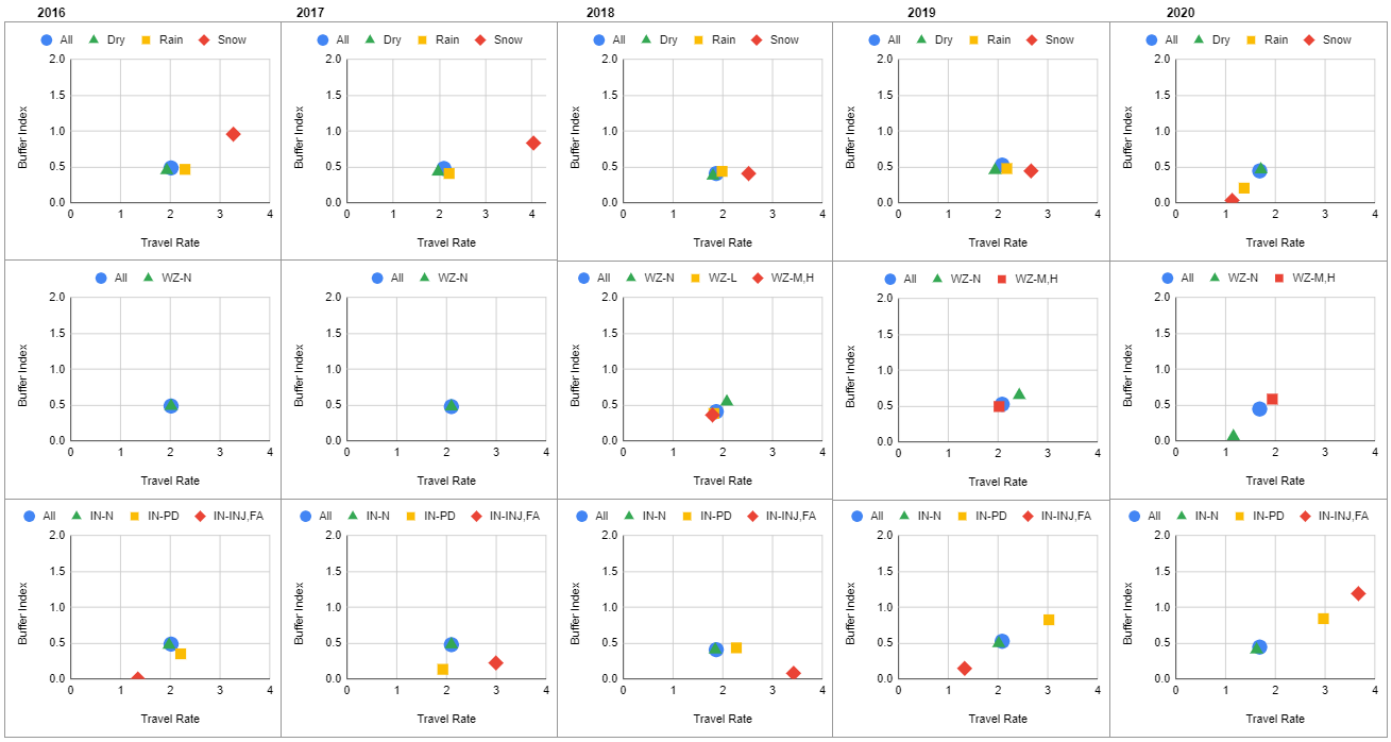
A.4.2.4 Yearly Variations




All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
WZ-N
WZ-L
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.4.2.5 Yearly Variations of Combined Index



A.4.2.6 Variations of Traffic-Flow Measures

A.4.2.7 Trends Summary

- Traffic-flow measures indicate gradually decreasing patterns in both VMT and delays.
- The monthly/yearly variations of the reliability measures also show a stable pattern.
- The reliability on this route has been significantly affected by both snow and incidents.

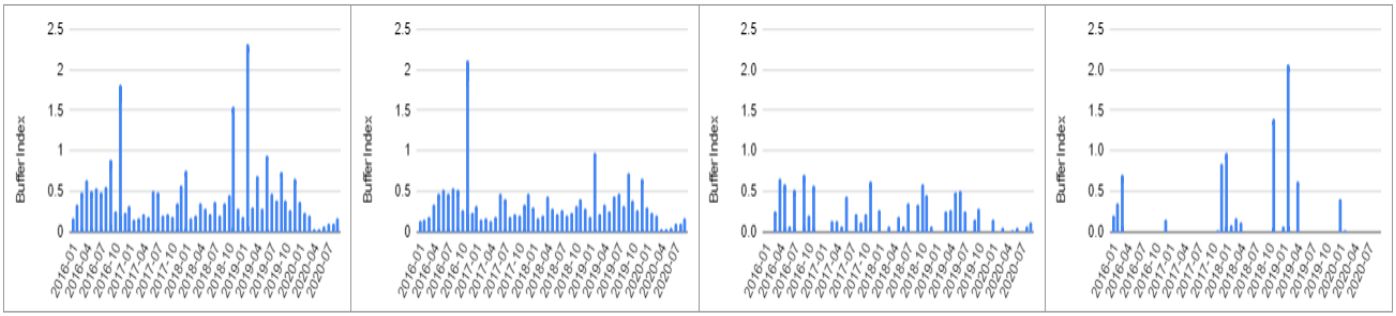
A.5 TH-62 CORRIDOR 2 (I-35W – TH 55, EASTBOUND/WESTBOUND)

A.5.1 TH 62 EASTBOUND Route 2 (I-35W -> TH 55, Afternoon Peak)

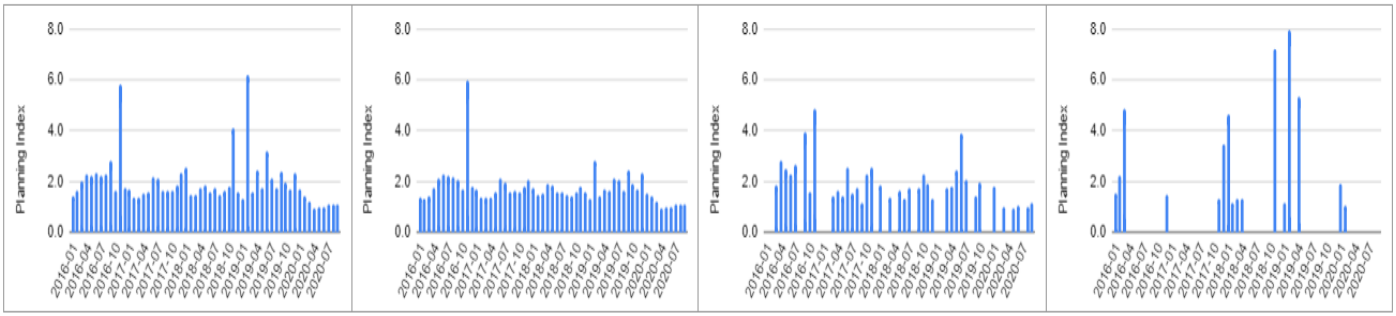
A.5.1.1 Effects of Weather

All | Dry | Rain | Snow

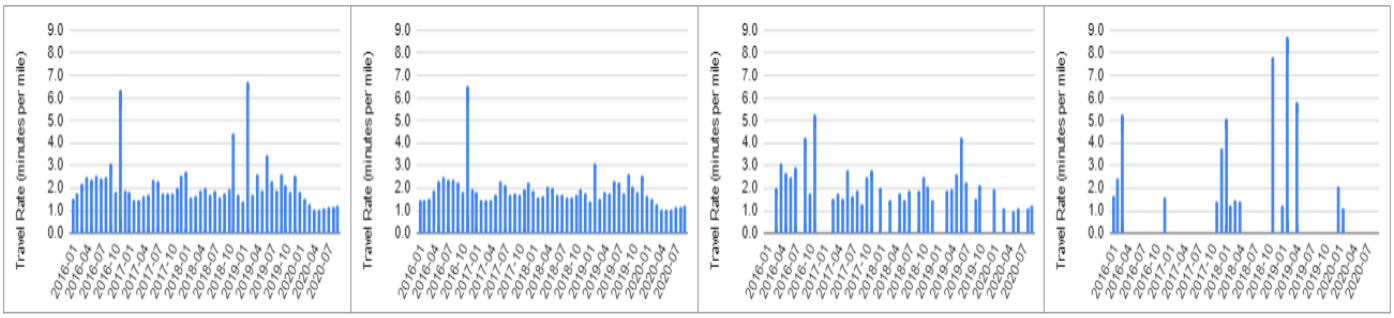
Buffer Index



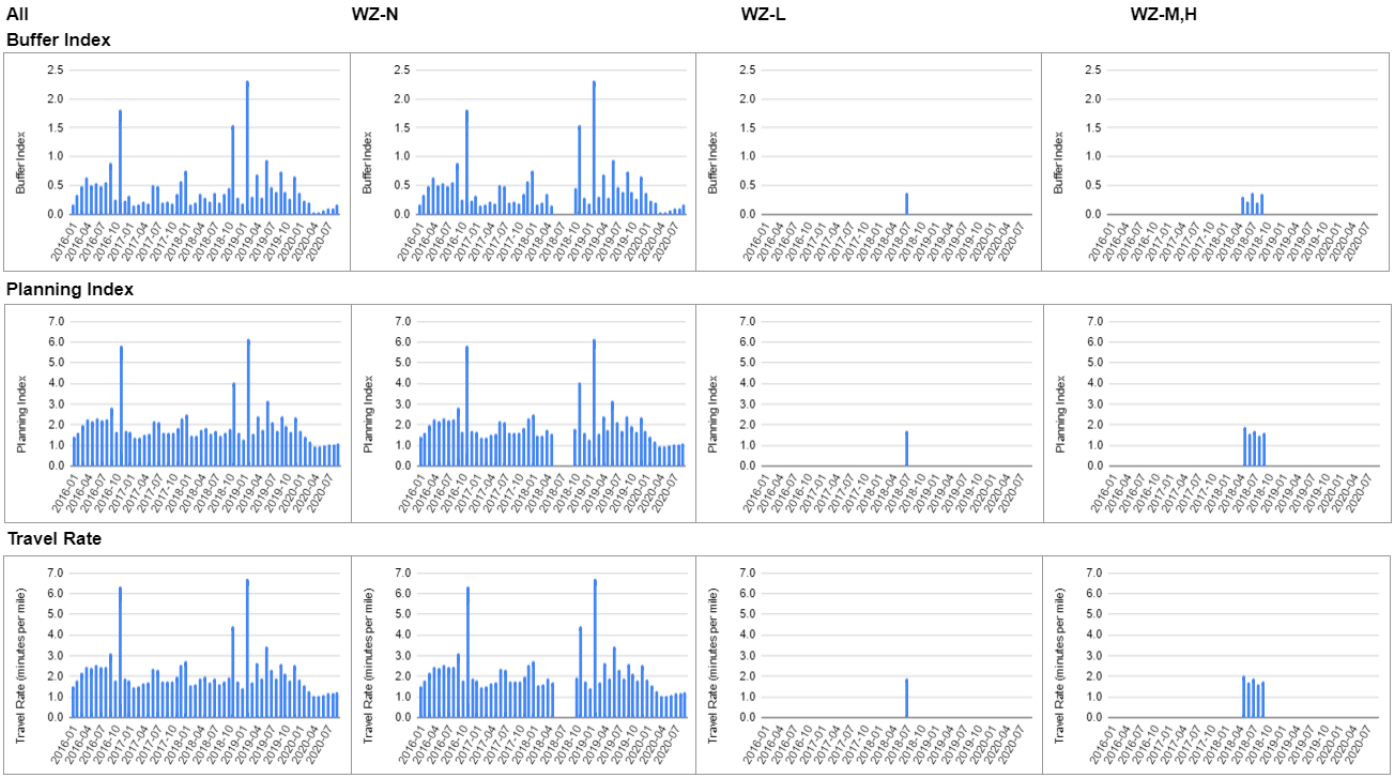
Planning Index



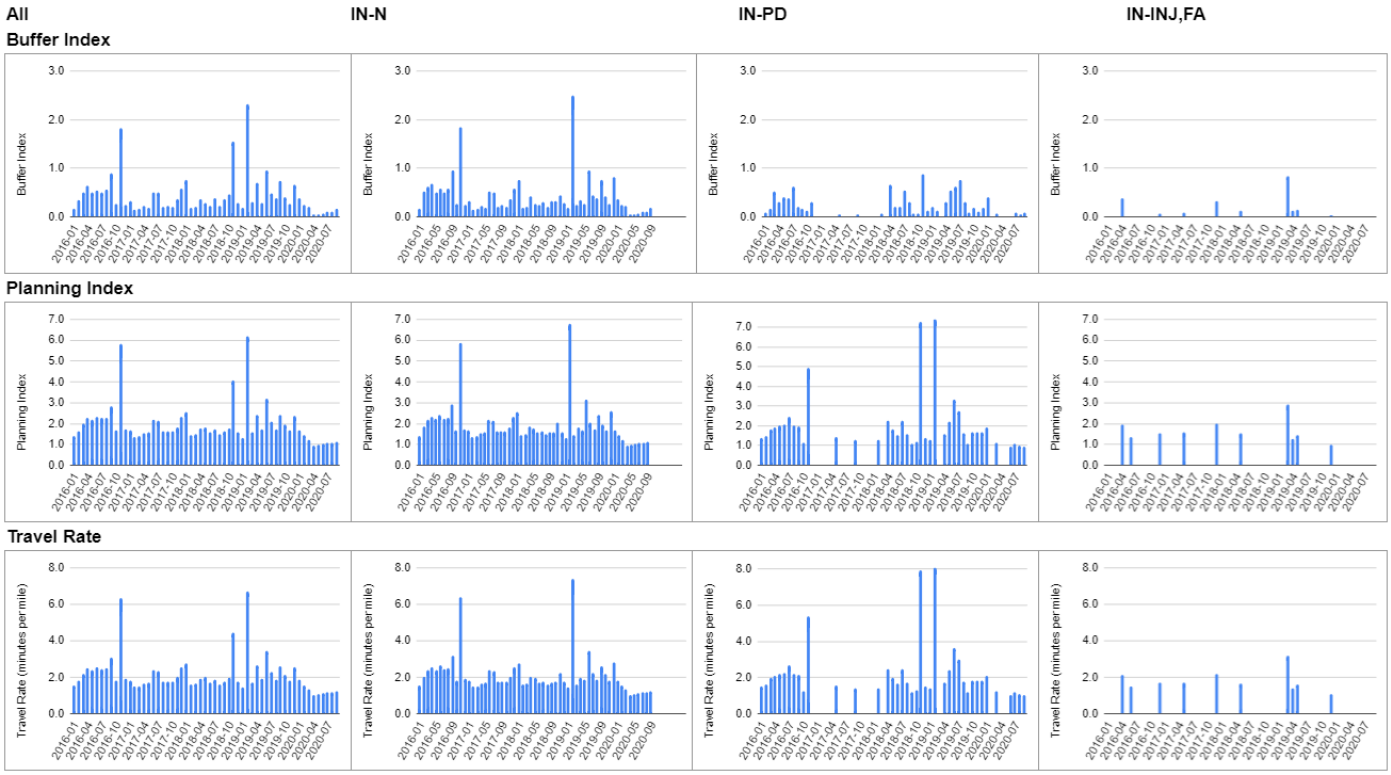
Travel Rate



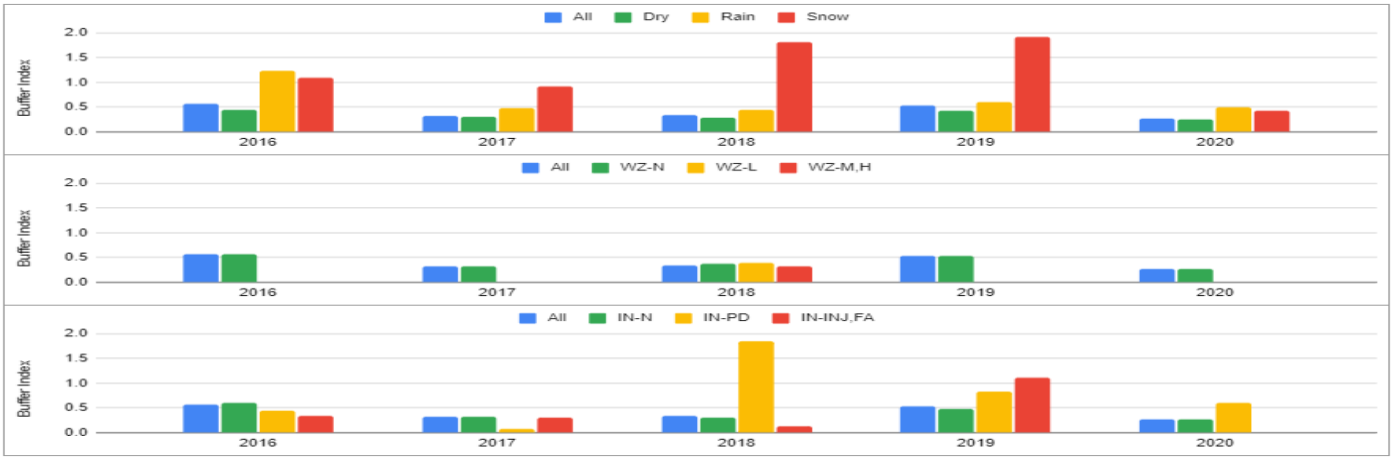
A.5.1.2 Effects of Work Zones



A.5.1.3 Effects of Incidents



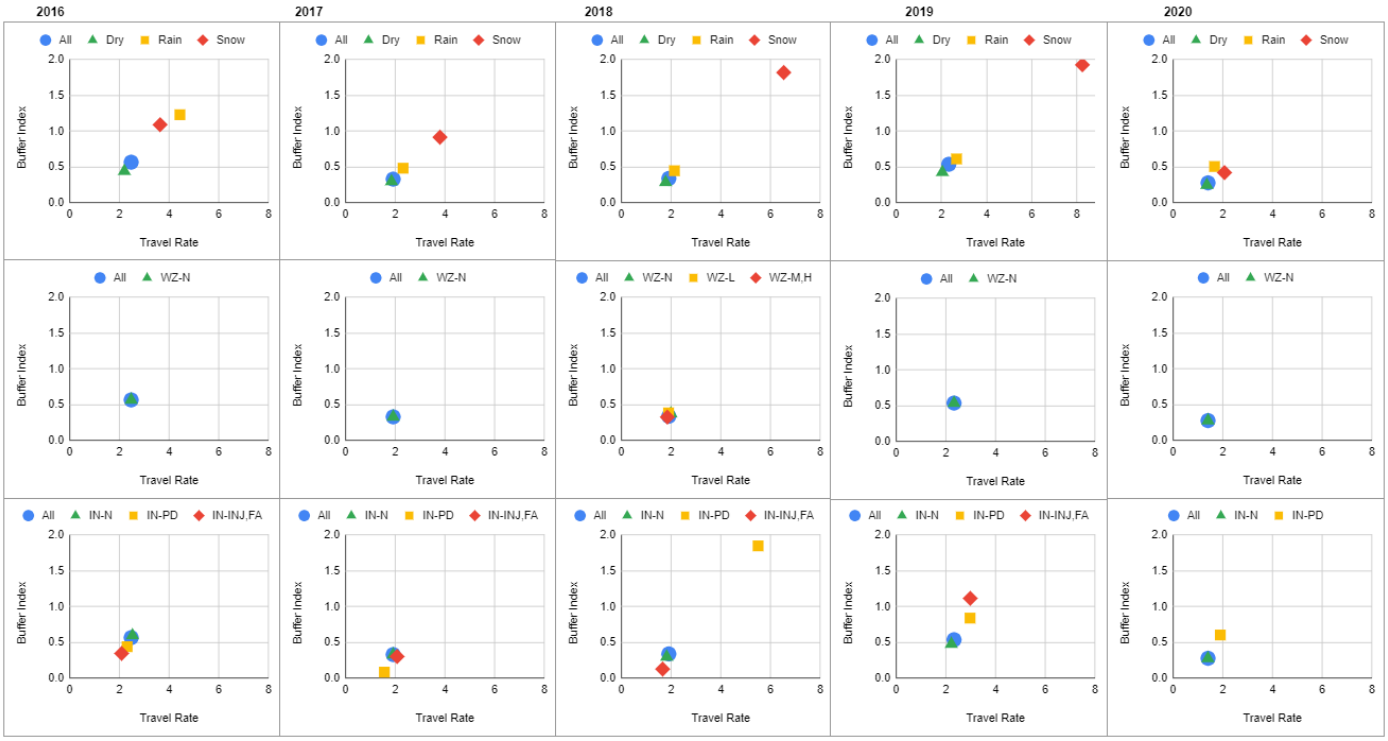
A.5.1.4 Yearly Variations



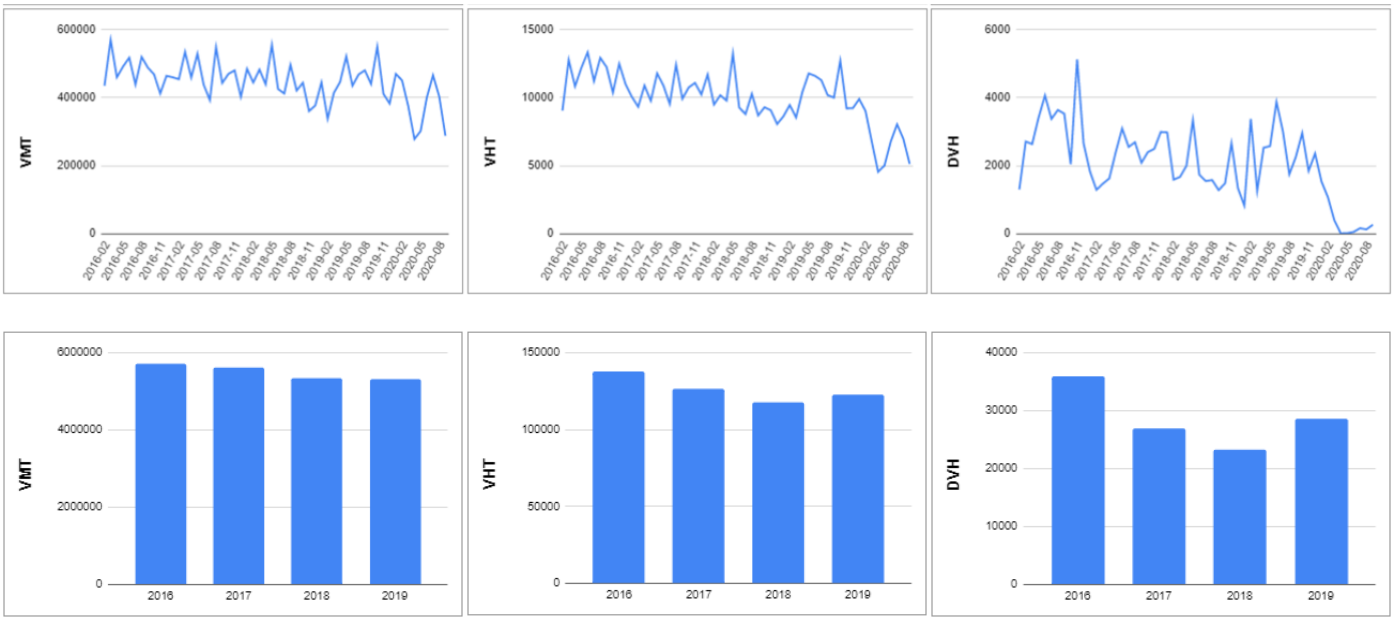

All
Dry
Rain
Snow
Planning Index
8
6
4
2
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
All
IN-N
IN-PD
IN-INJ,FA
Planning Index


All
Dry
Rain
Snow
Travel Rate
8
6
4
2
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate

A.5.1.5 Yearly Variations of Combined Index



A.5.1.6 Variations of Traffic-Flow Measures

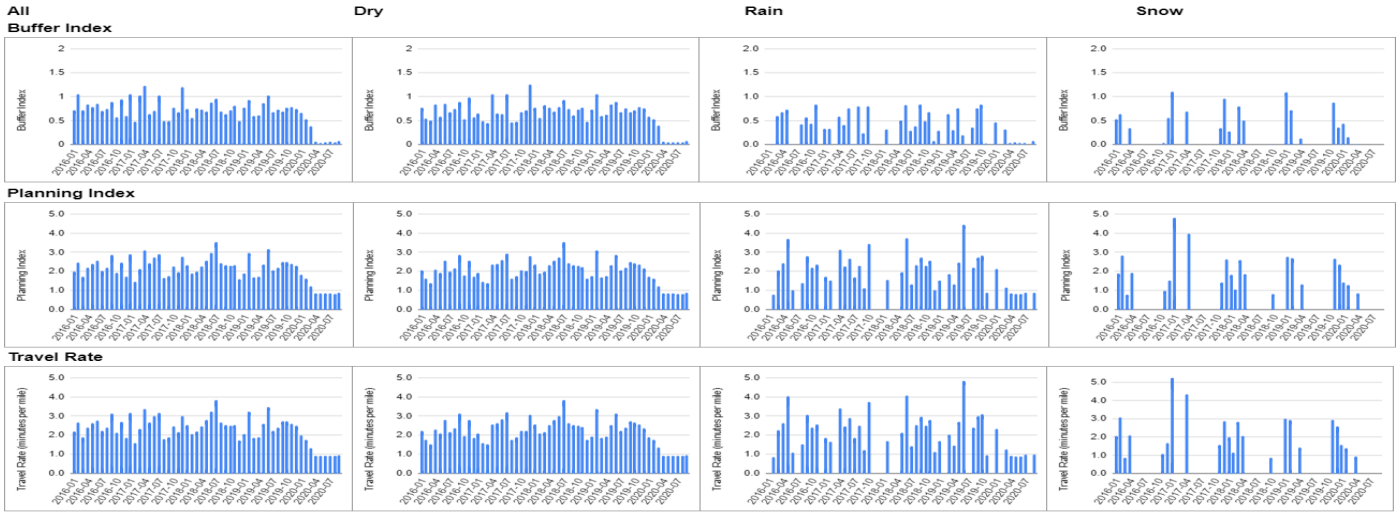


A.5.1.7 Trends Summary

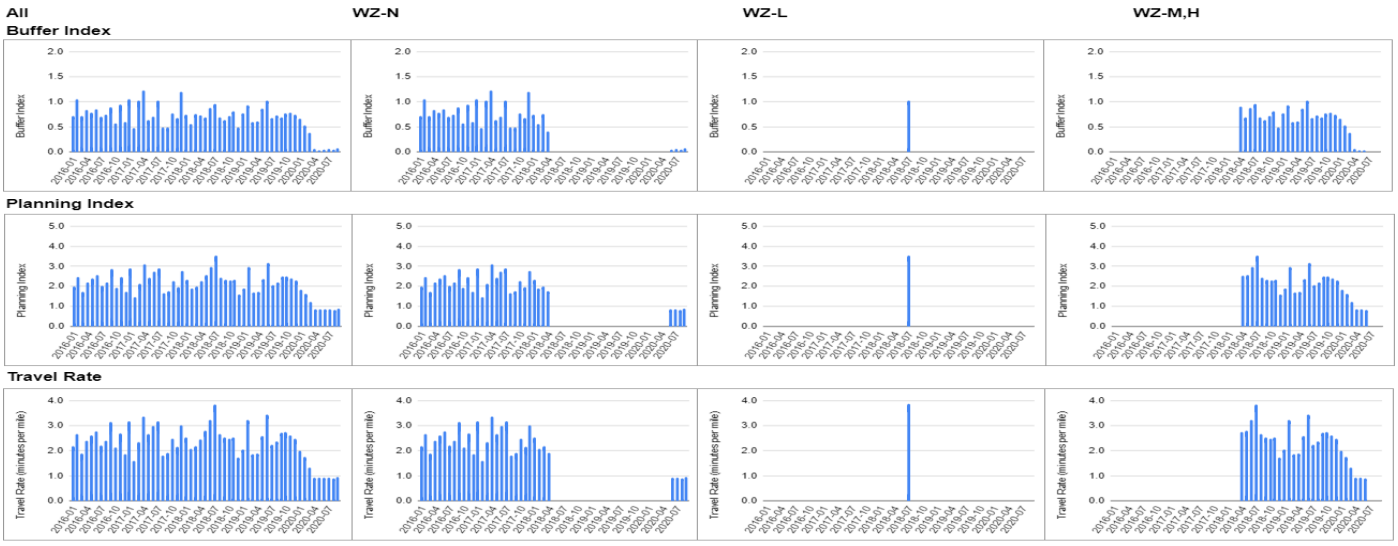
- Both VMT and delays have been decreasing and the over-all reliability trends show stable patterns.
- Snow has been the main factor contributing to the variability of travel times, while the effects of incidents on the reliability have also been increasing since 2017.

A.5.2 TH 62 WESTBOUND Route 2 (TH 55 -> I-35W, Morning Peak)

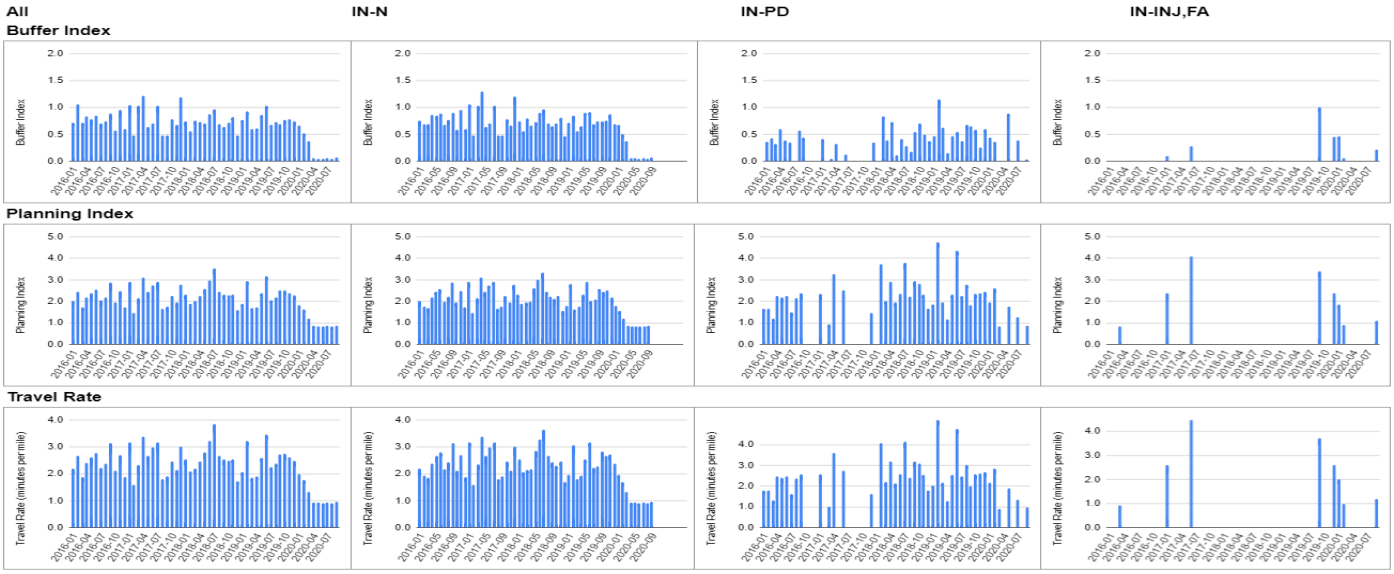
A.5.2.1 Effects of Weather



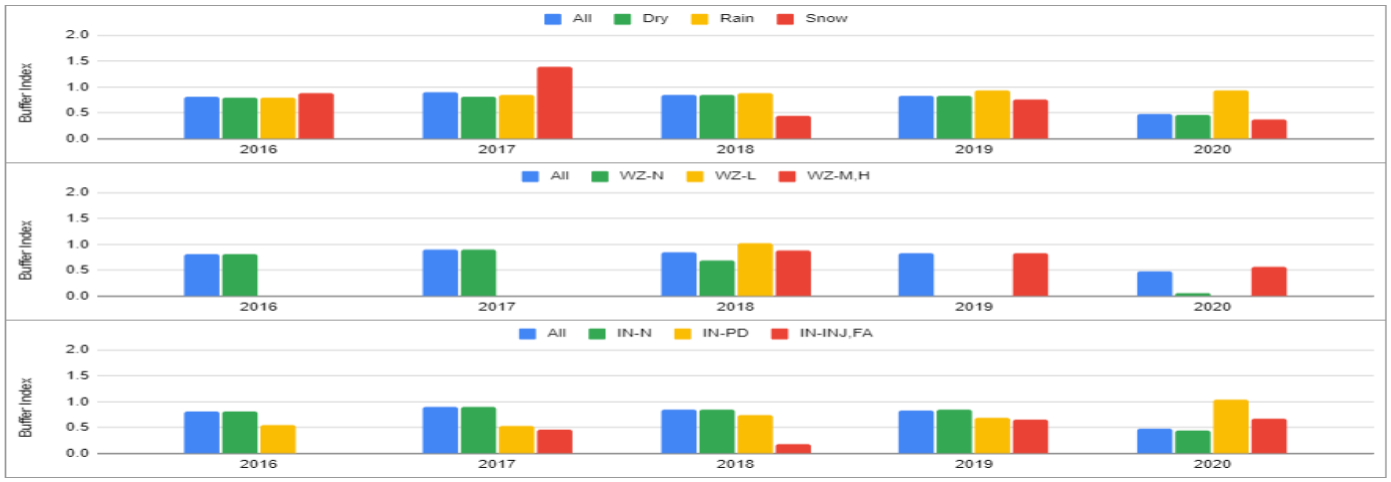
A.5.2.2 Effects of Work Zones

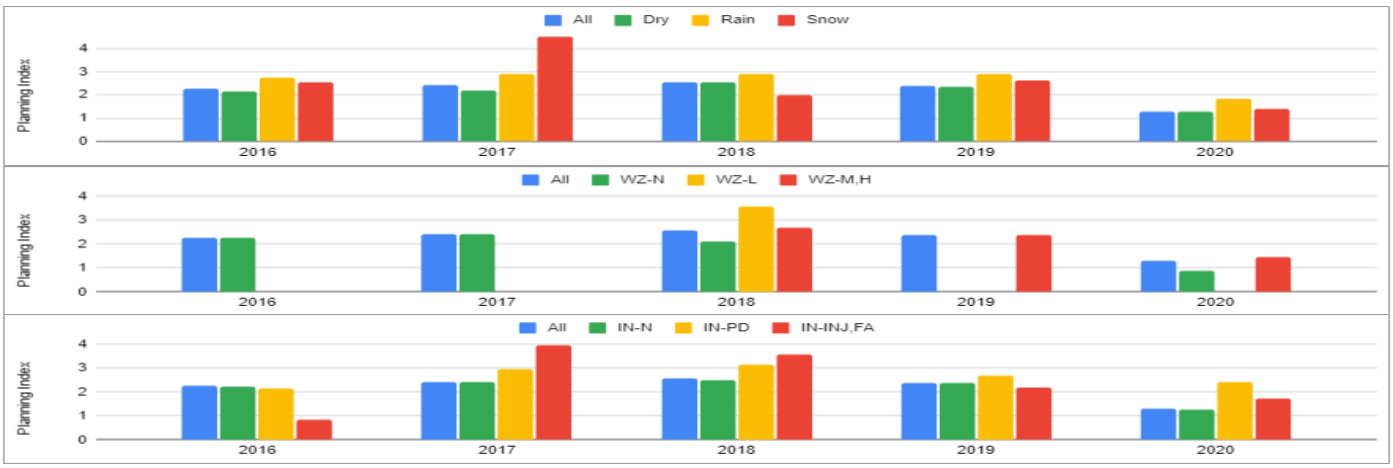


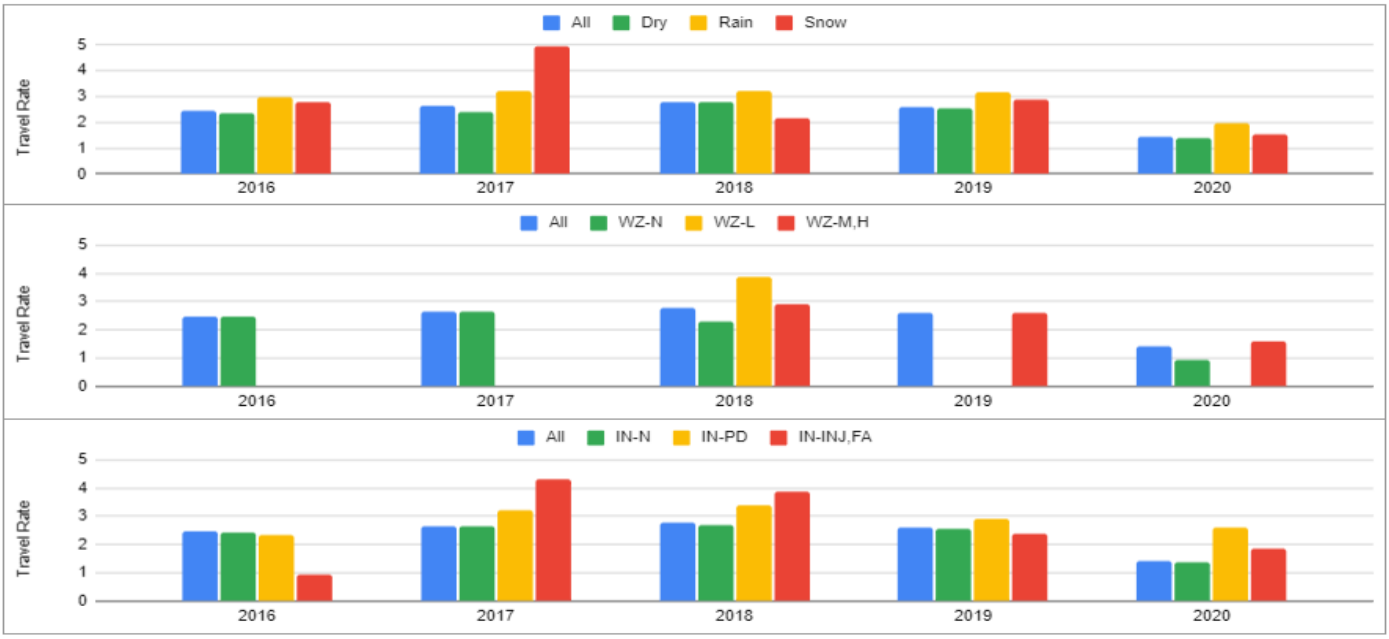
A.5.2.3 Effects of Incidents



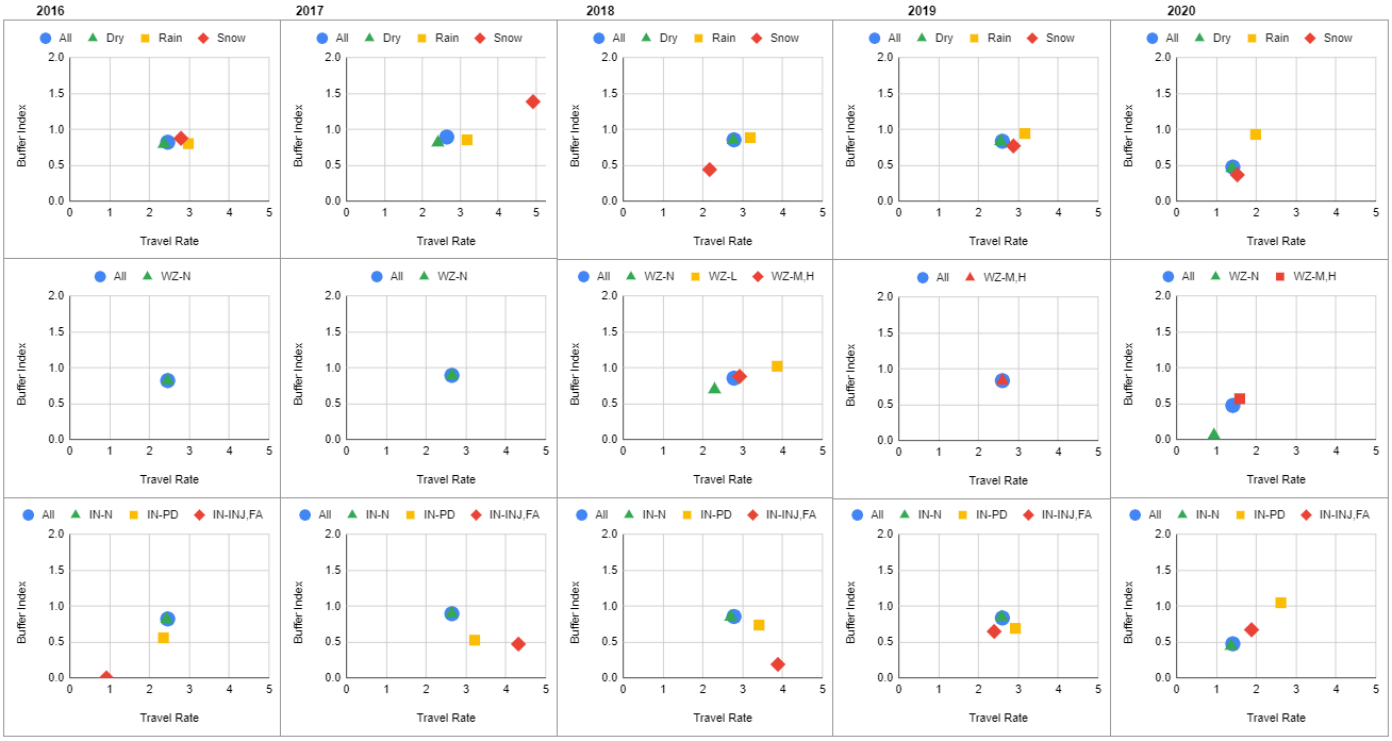
A.5.2.4 Yearly Variations







A.5.2.5 Yearly Variations of Combined Index

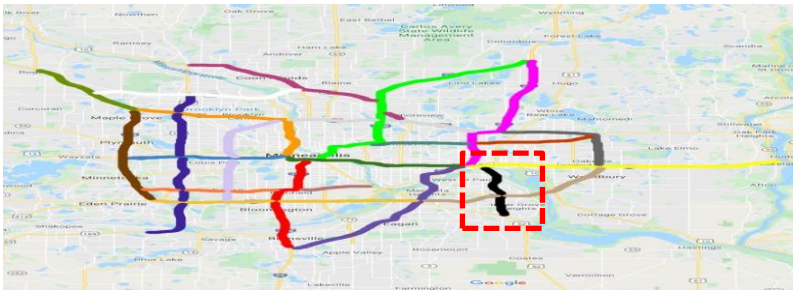


A.5.2.6 Variations of Traffic-Flow Measures

A.5.2.7 Trends Summary

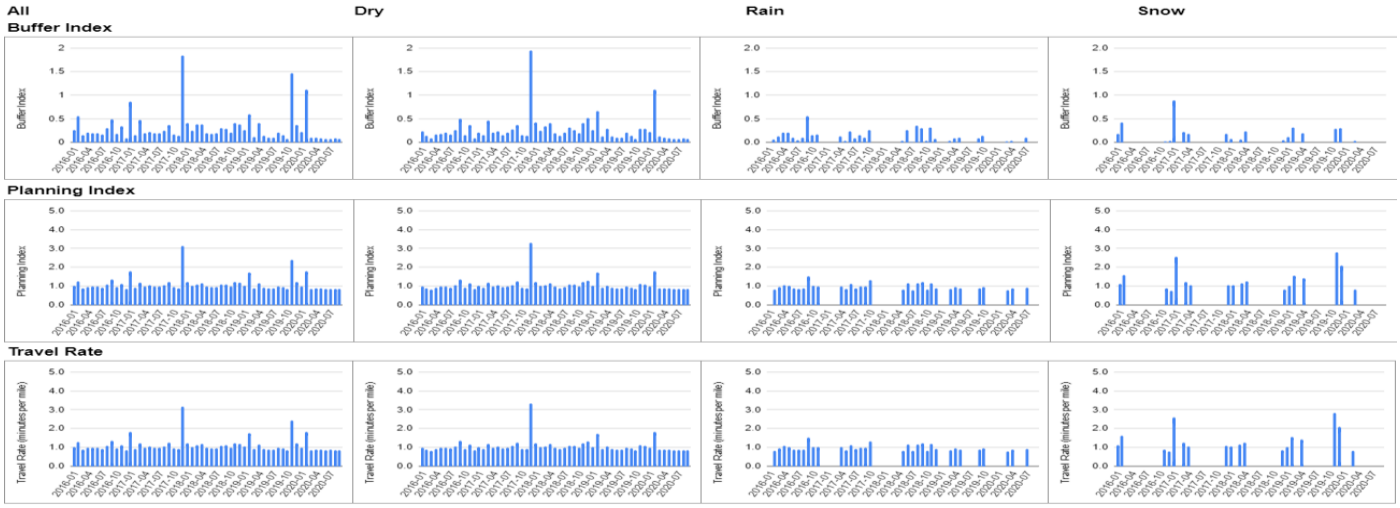
- The monthly/yearly traffic-flow measures do not show significant changes though time, while a high level of congestion with large variability in travel times can be observed from the variation patterns of the reliability measures.
- Incidents have been a main contributing factor affecting the reliability of this route, while snow does not appear to be the major factor.

A.6 TH-52 CORRIDOR (NORTHBOUND/SOUTHBOUND)

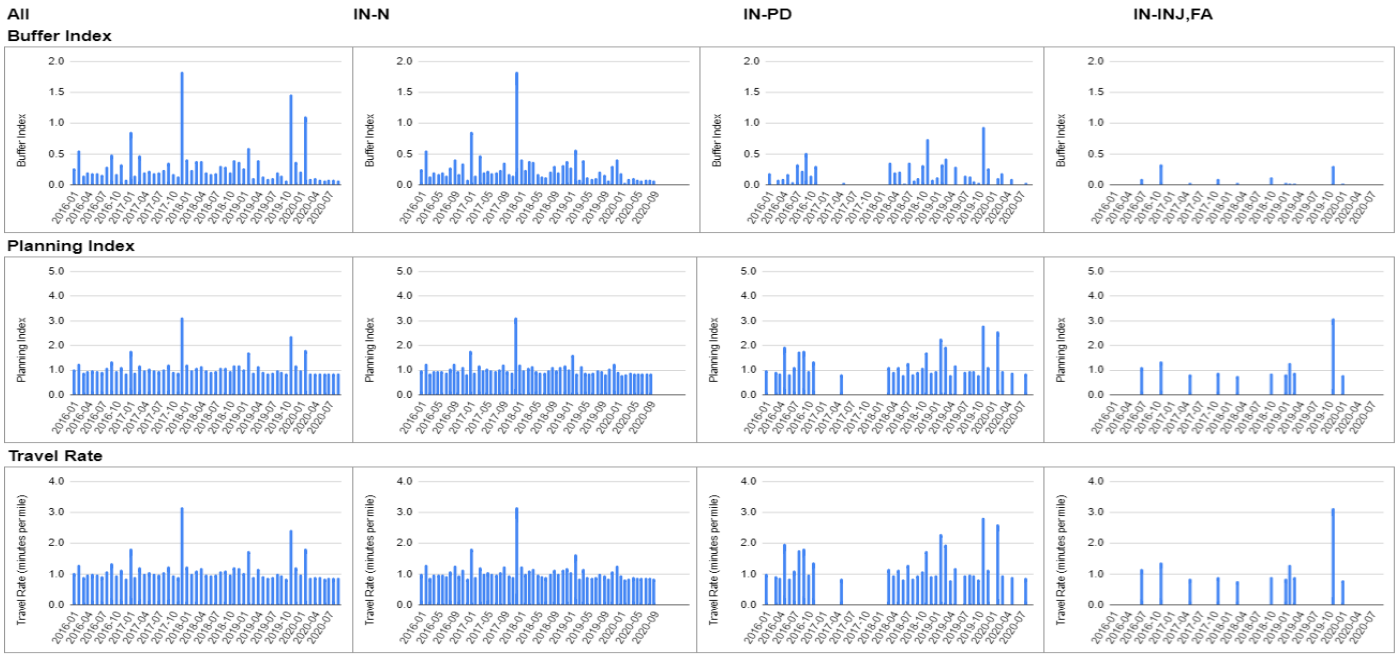


A.6.1 TH-52 NORTHBOUND Route (Morning Peak Period)

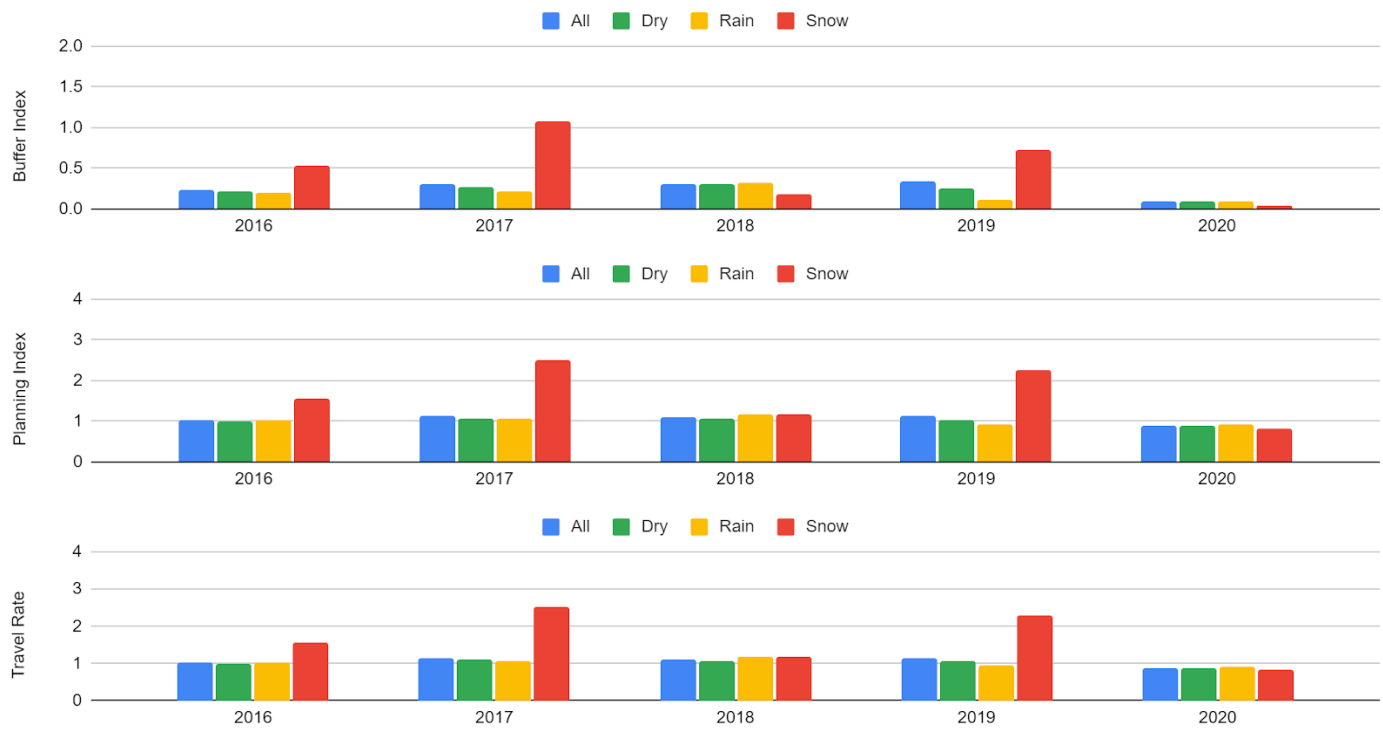
A.6.1.1 Effects of Weather



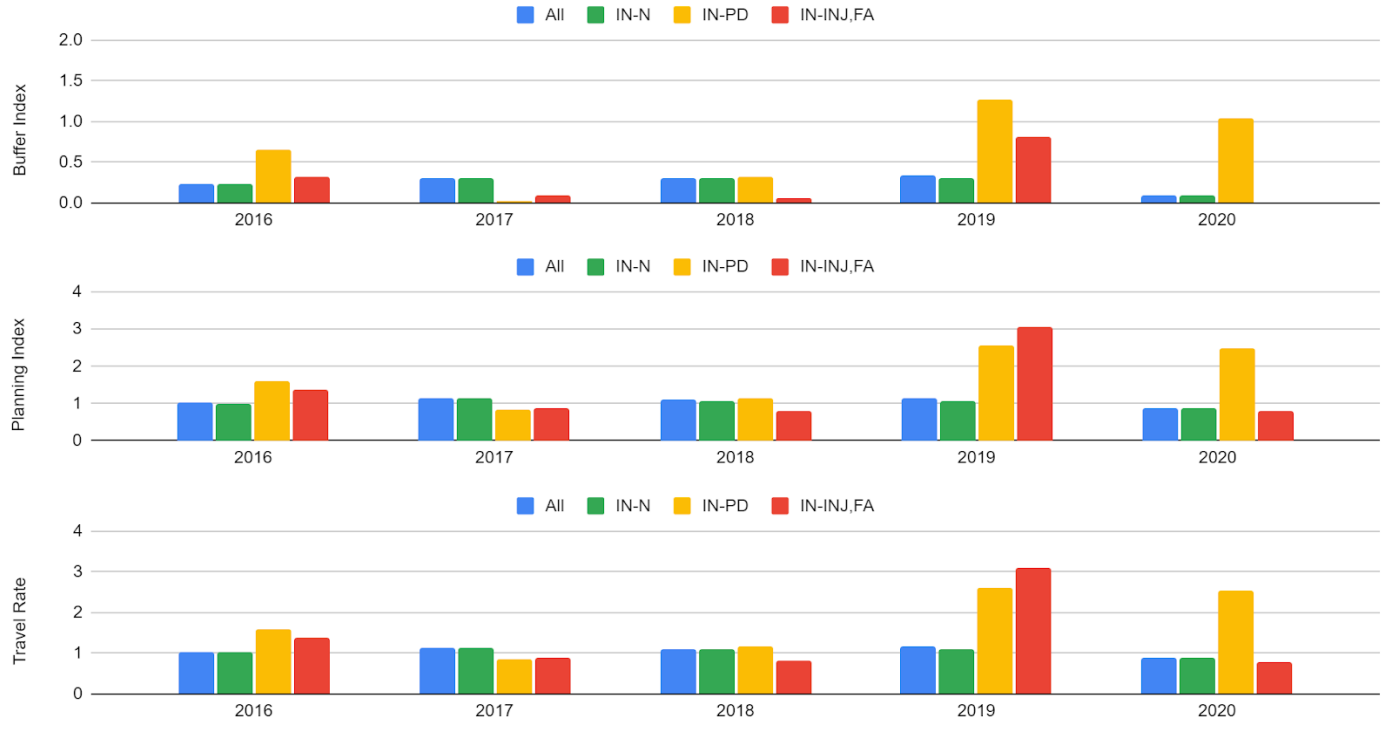
A.6.1.2 Effects of Incidents



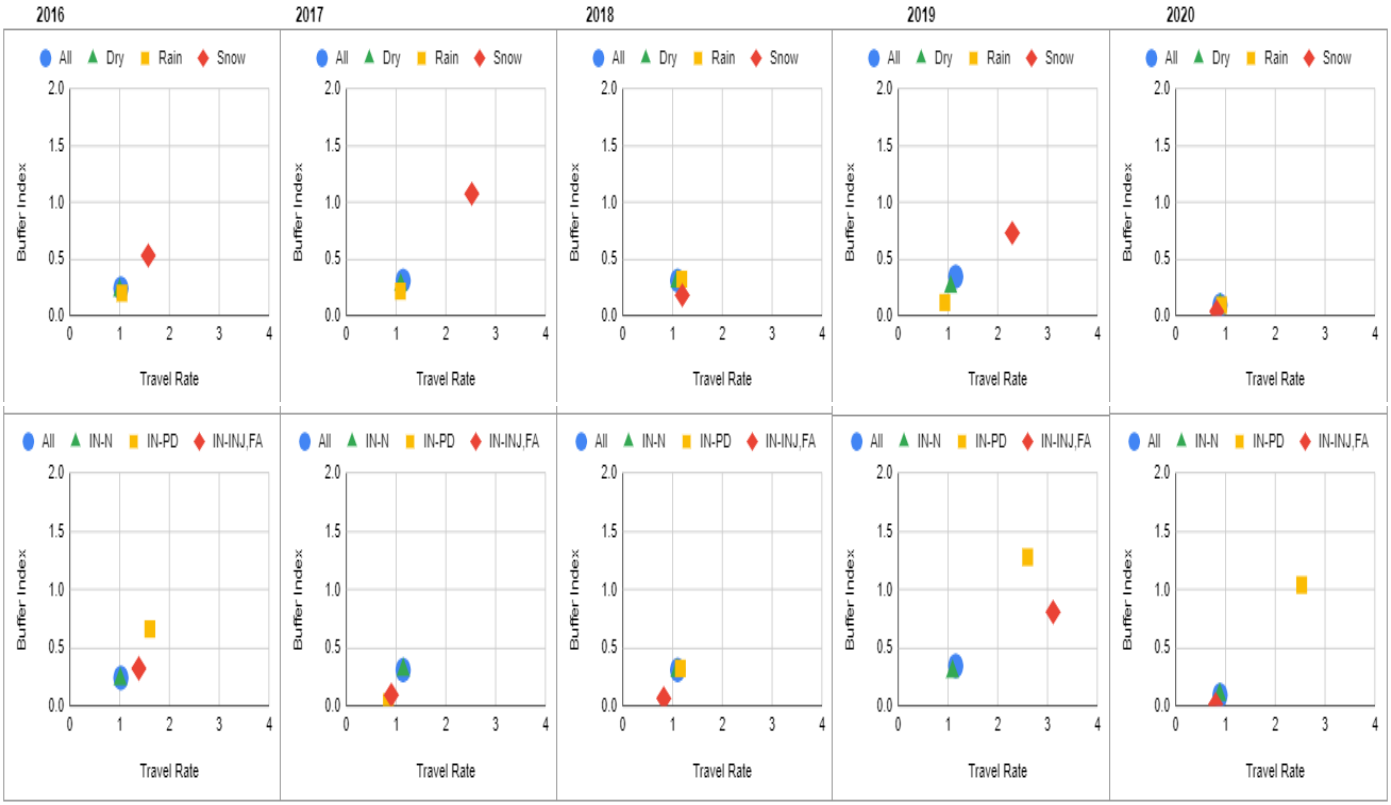
A.6.1.3 Yearly Variations – Weather



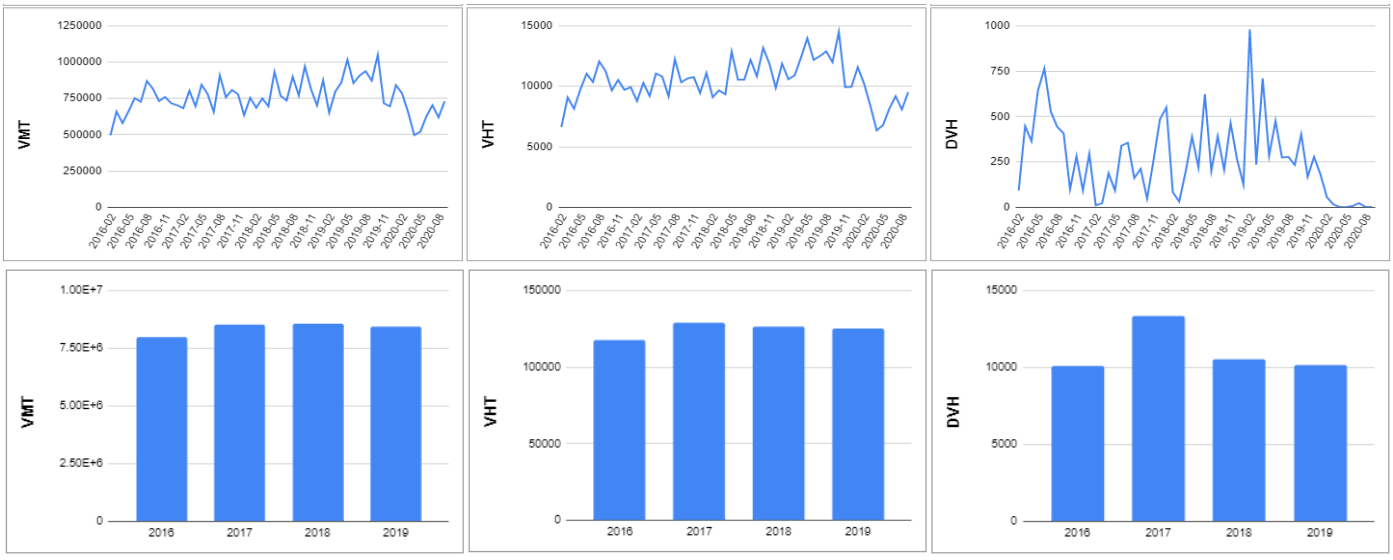
A.6.1.4 Yearly Variations - Incidents



A.6.1.5 Yearly Variations of Combined Index



A.6.1.6 Variations of Traffic-Flow Measures

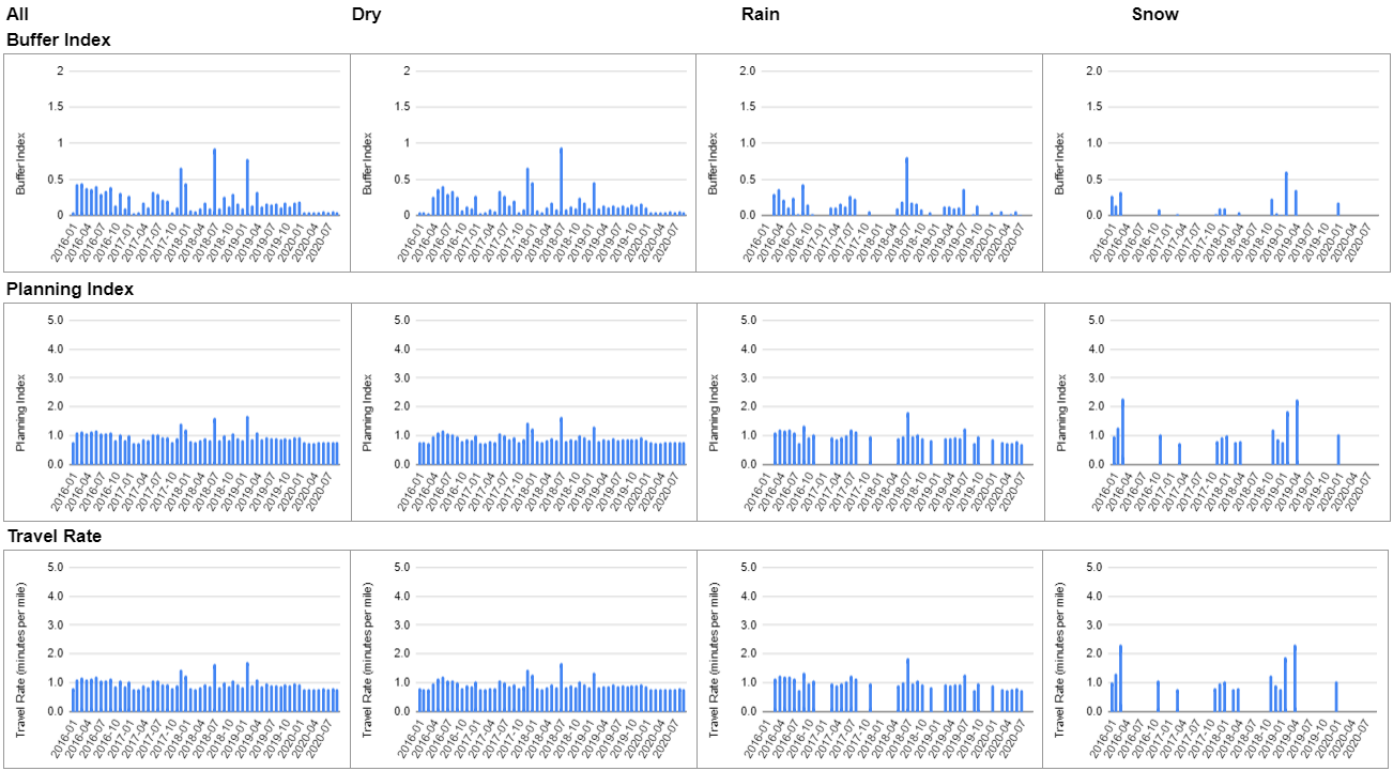


A.6.1.7 Trends Summary

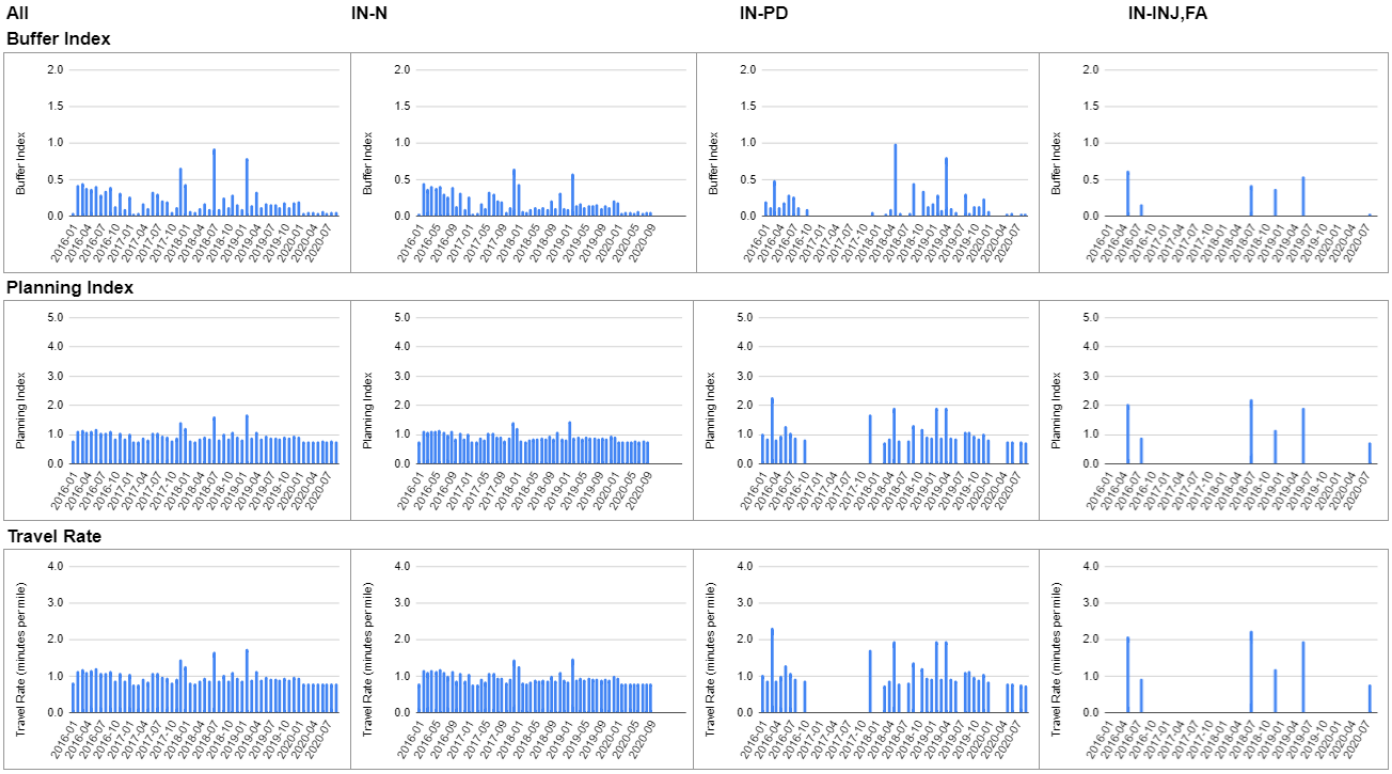
- Both VMT and DVH, delayed-vehicle hours, have been continuously increasing since 2016, while the 95th %-ile travel time has remained relatively stable during the same period.
- All the travel-time reliability measures show significantly decreased performance levels during winter seasons, indicating the coupled effects of snow and incidents on the reliability.

A.6.2 TH 52 SOUTHBOUND Route (Afternoon Peak)

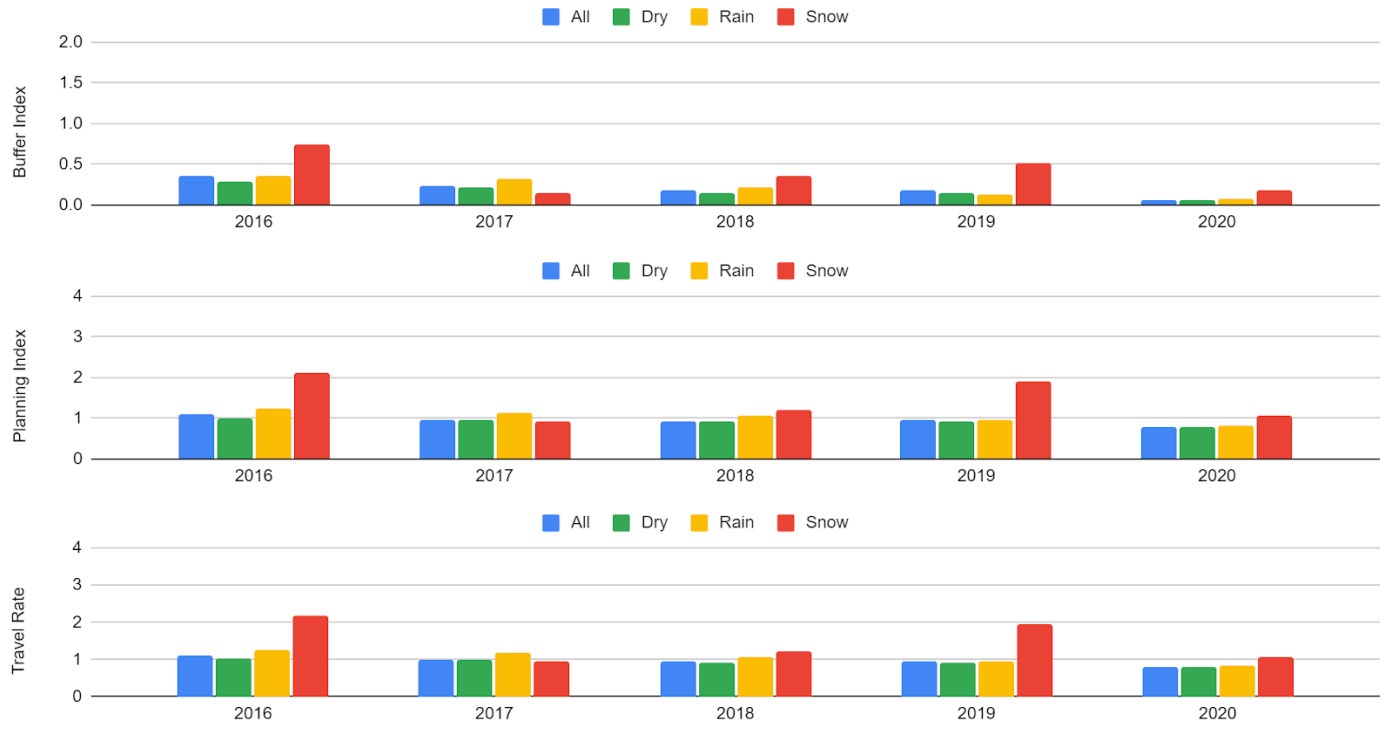
A.6.2.1 Effects of Weather



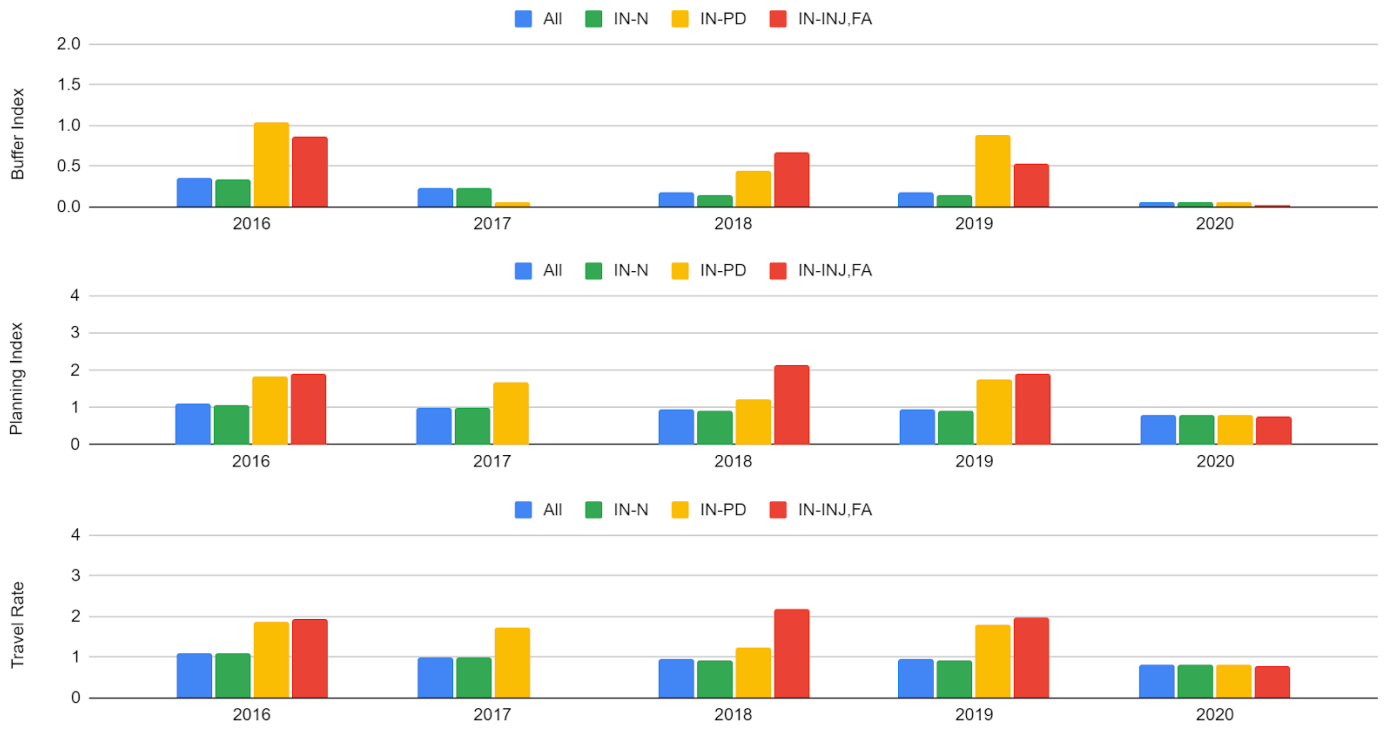
A.6.2.2 Effects of Incidents



A.6.2.3 Yearly Variations - Weather

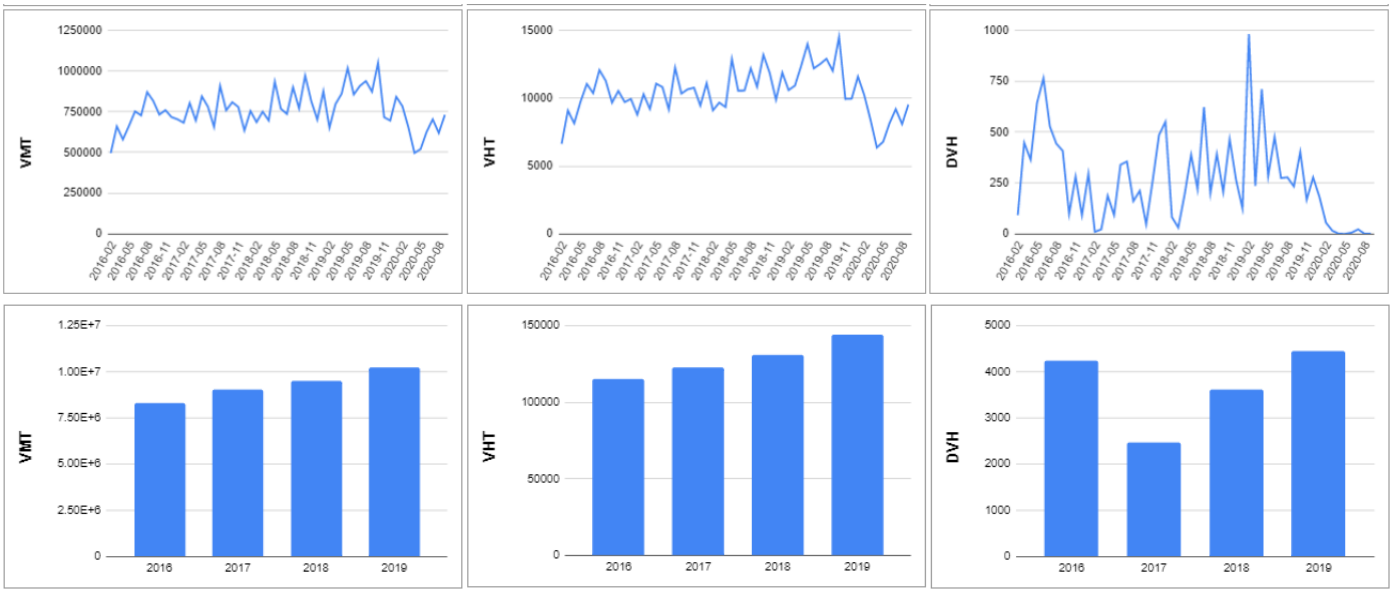


A.6.2.4 Yearly Variations - Incidents



A.6.2.5 Yearly Variations of Combined Effects

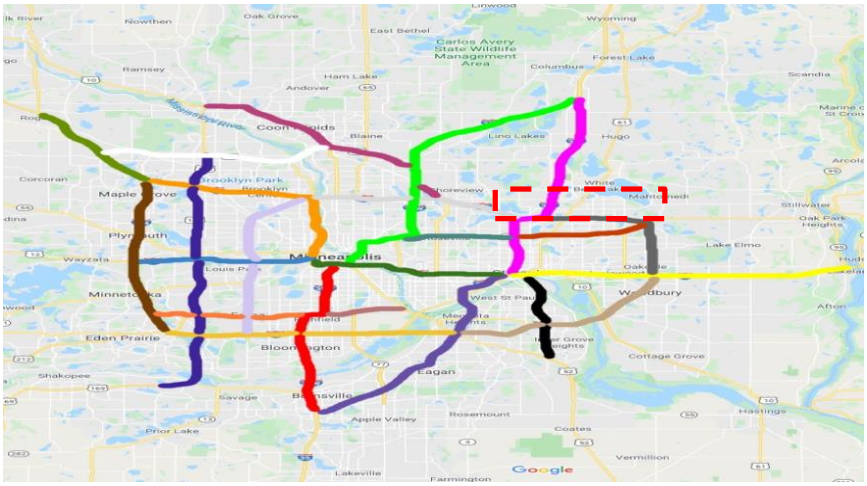
A.6.2.6 Variations of Traffic-Flow Measures



A.6.2.7 Trends Summary

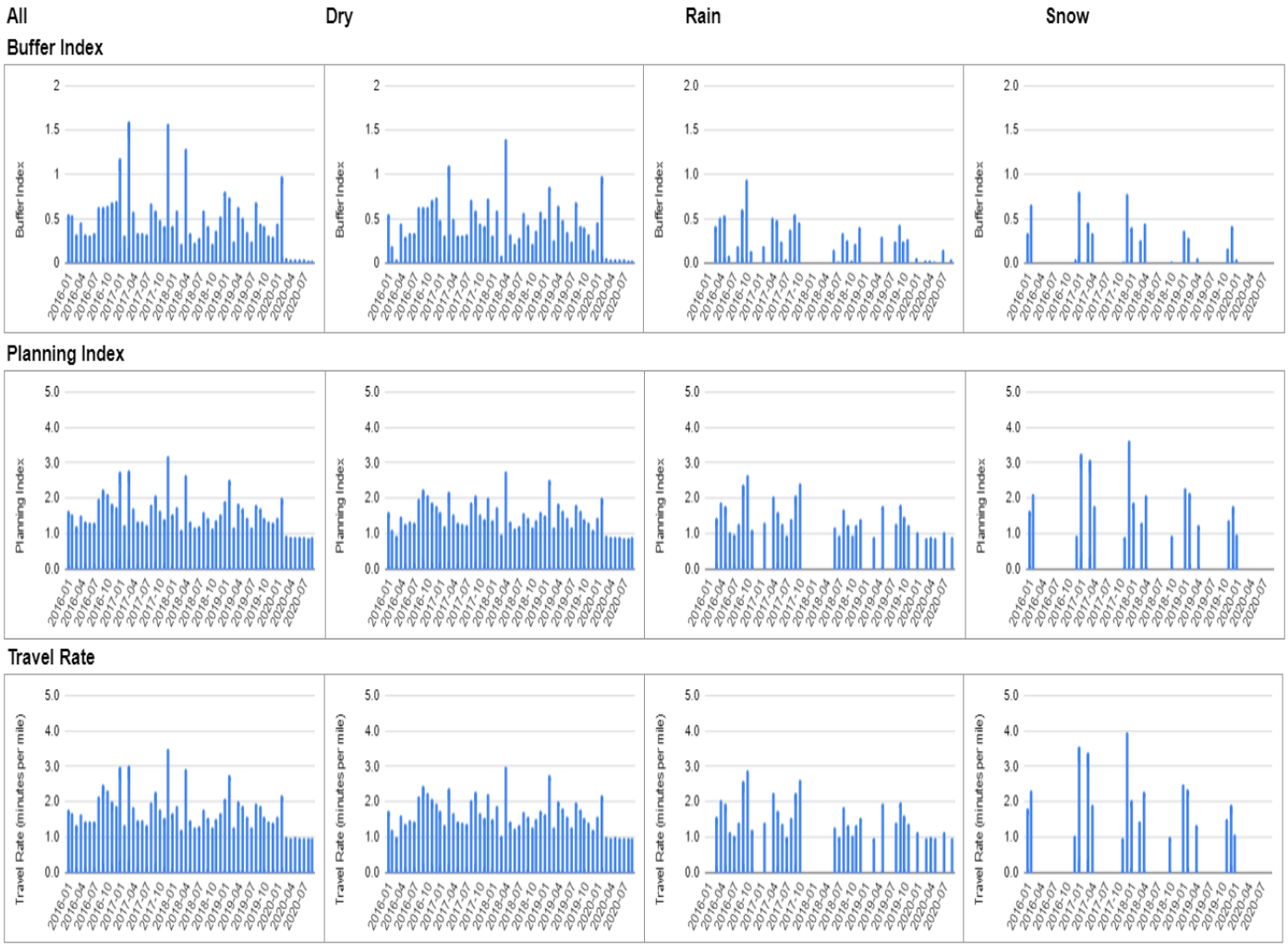
- Similar to the TH 52 NORTHBOUND route, the 95th %-ile travel time has remained stable, even though the traffic flow has continuously increased since 2016.
- Snow and incidents have been the main contributing factors to the increase in the variability of travel times.

A.7 TH-36 CORRIDOR 1 (I-694 – I-35E, EASTBOUND/WESTBOUND)

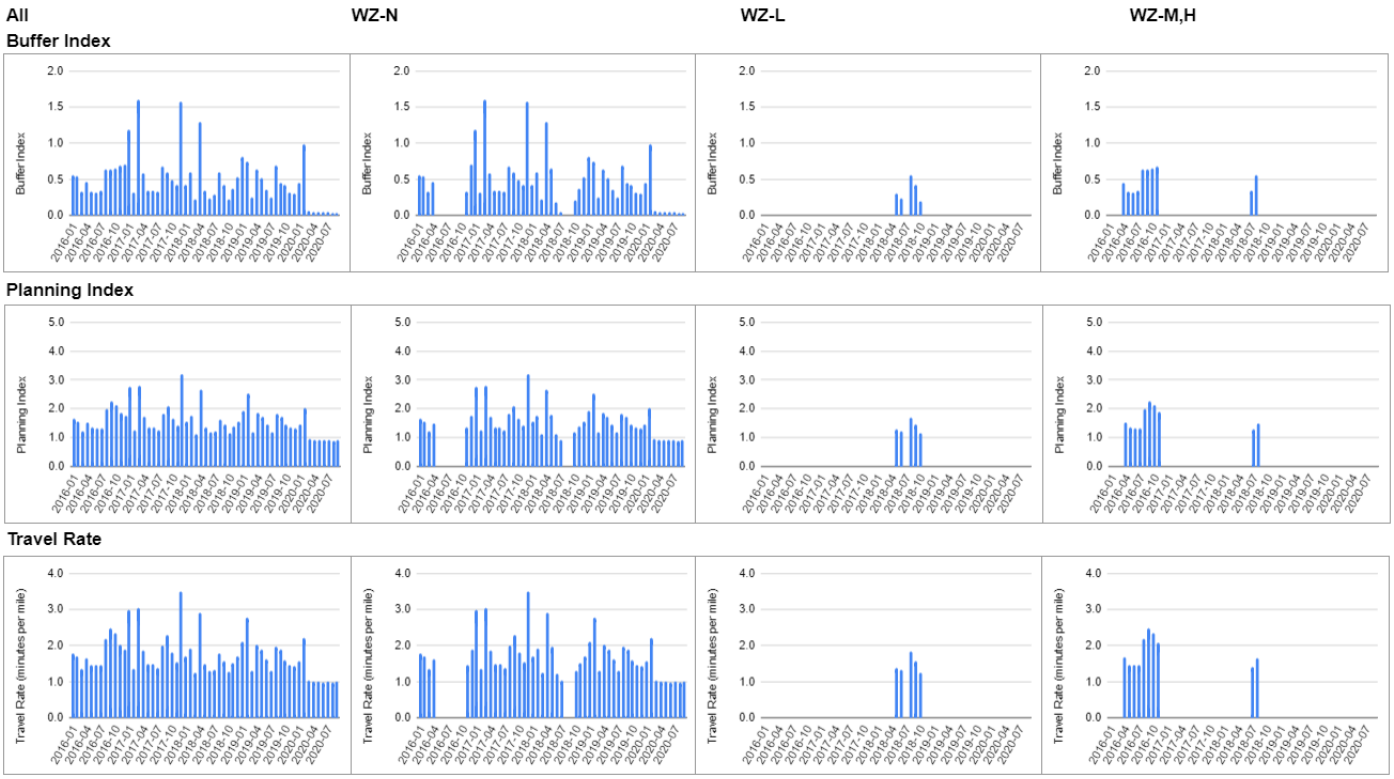


A.7.1 TH 36 WESTBOUND Route 1 (I-694 -> I-35E, Morning Peak)

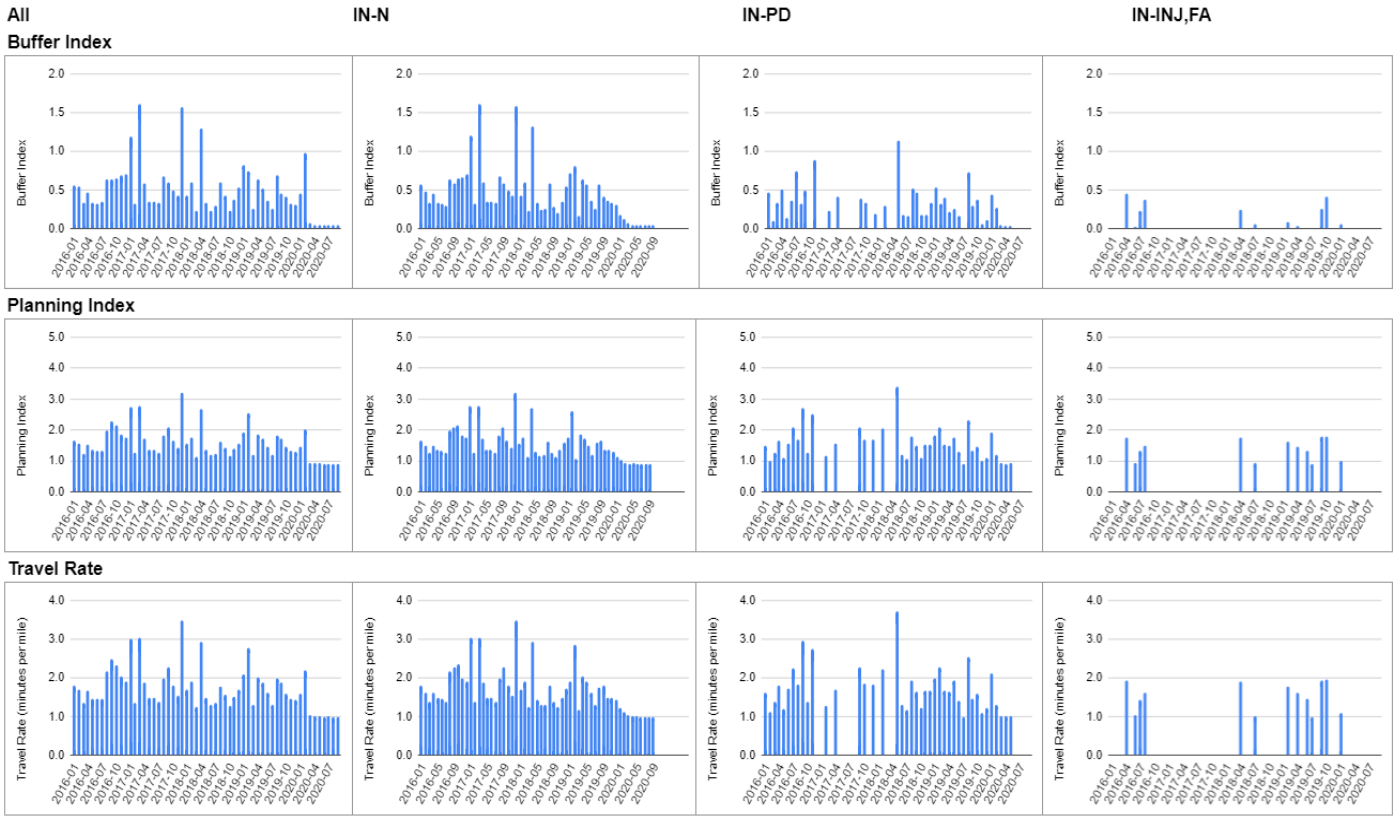
A.7.1.1 Effects of Weather



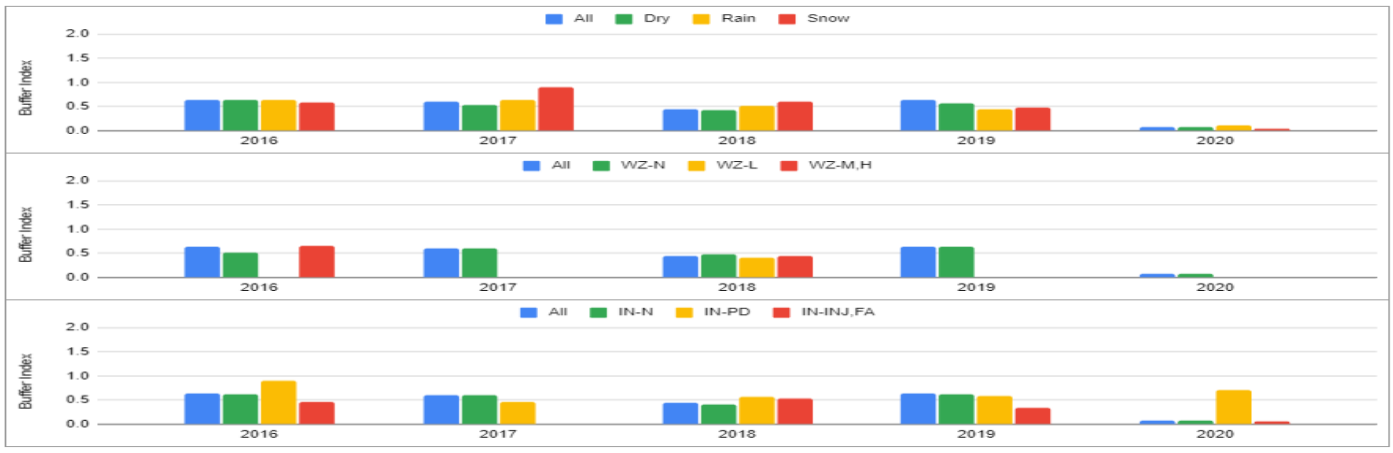
A.7.1.2 Effects of Work Zones

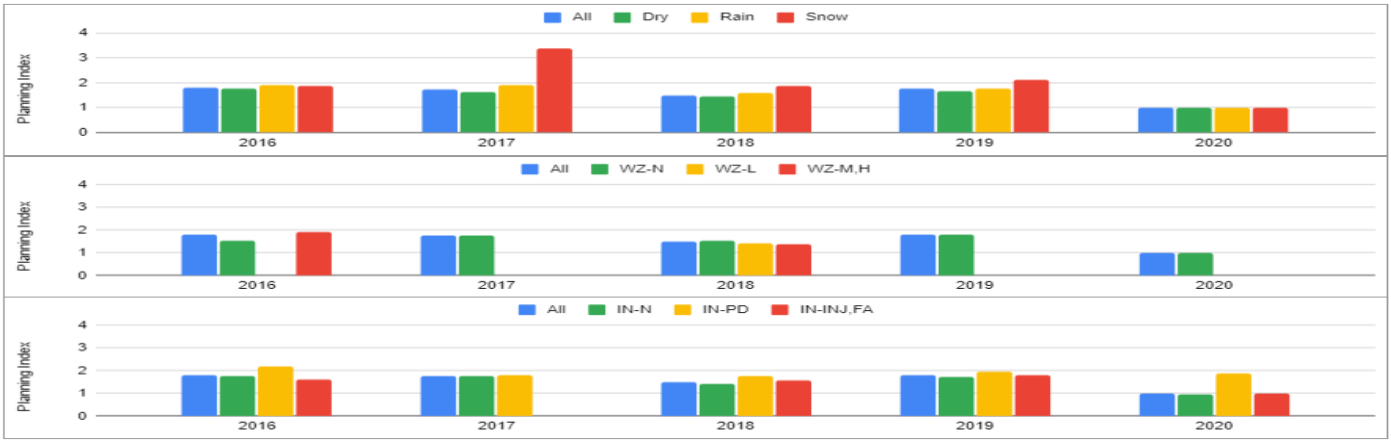


A.7.1.3 Effects of Incidents



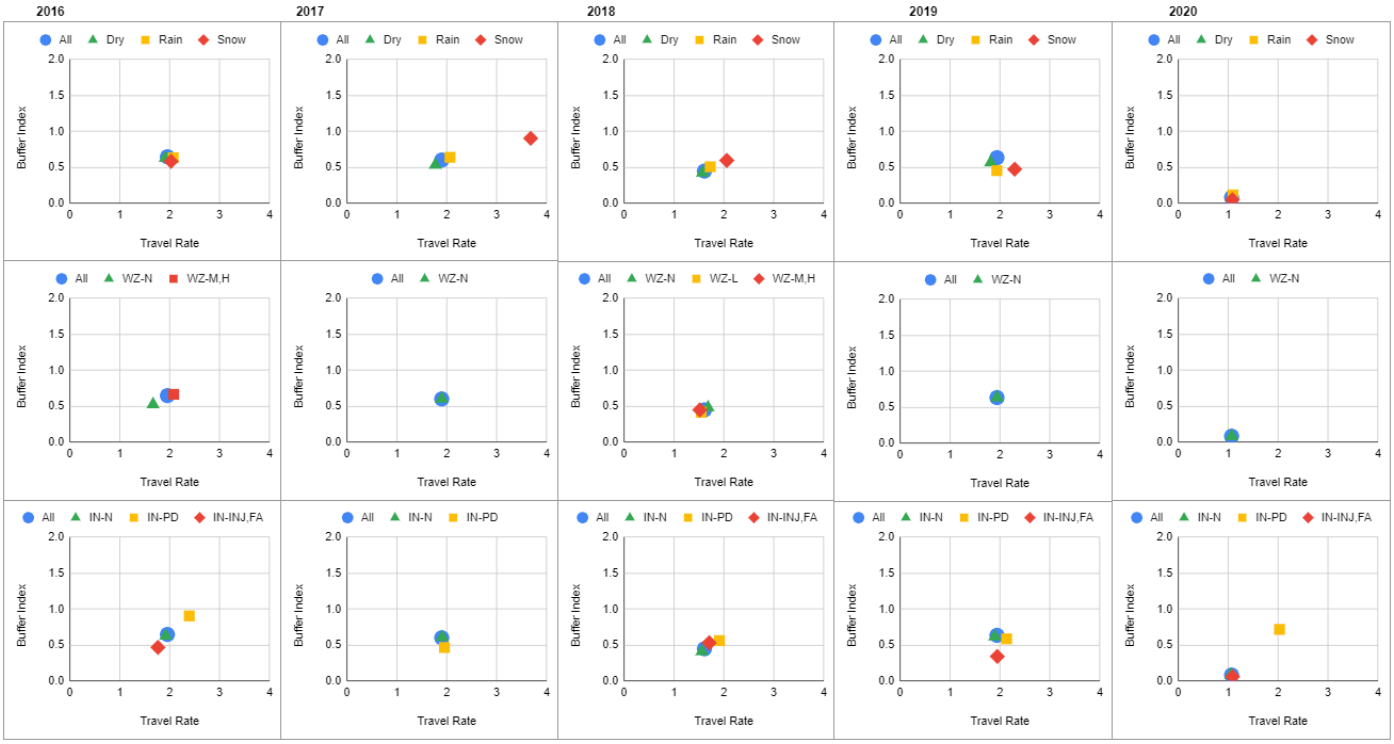
A.7.1.4 Yearly Variations




All
Dry
Rain
Snow
Planning Index
0
1
2
3
4
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
0
1
2
3
4
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
0
1
2
3
4
2016
2017
2018
2019
2020


All
Dry
Rain
Snow
Travel Rate
0
1
2
3
4
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
0
1
2
3
4
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
0
1
2
3
4
2016
2017
2018
2019
2020

A.7.1.5 Yearly Variations of Combined Index



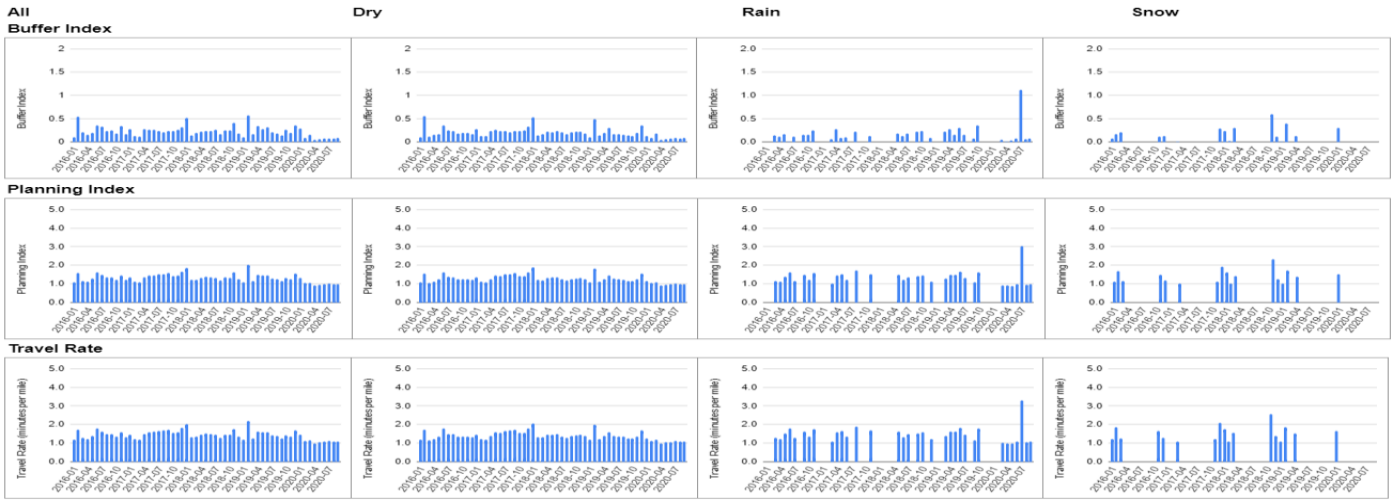
A.7.1.6 Variations of Traffic-Flow Measures

A.7.1.7 Trends Summary

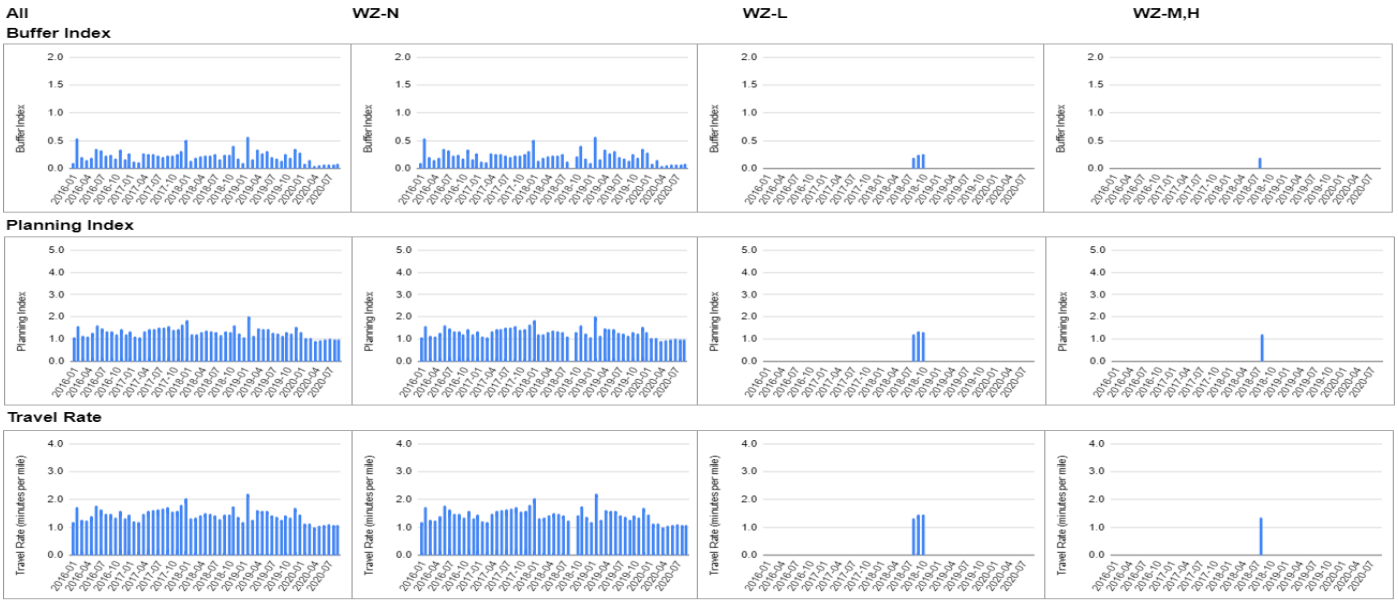
- Both VMT and delays have been increasing since 2017.
- The monthly variations of the reliability indices indicate both high level of congestion and large travel-time variations, whose main contributors include snow and incidents.

A.7.2 TH 36 EASTBOUND Route 1 (I-35E -> I-694, Afternoon Peak)

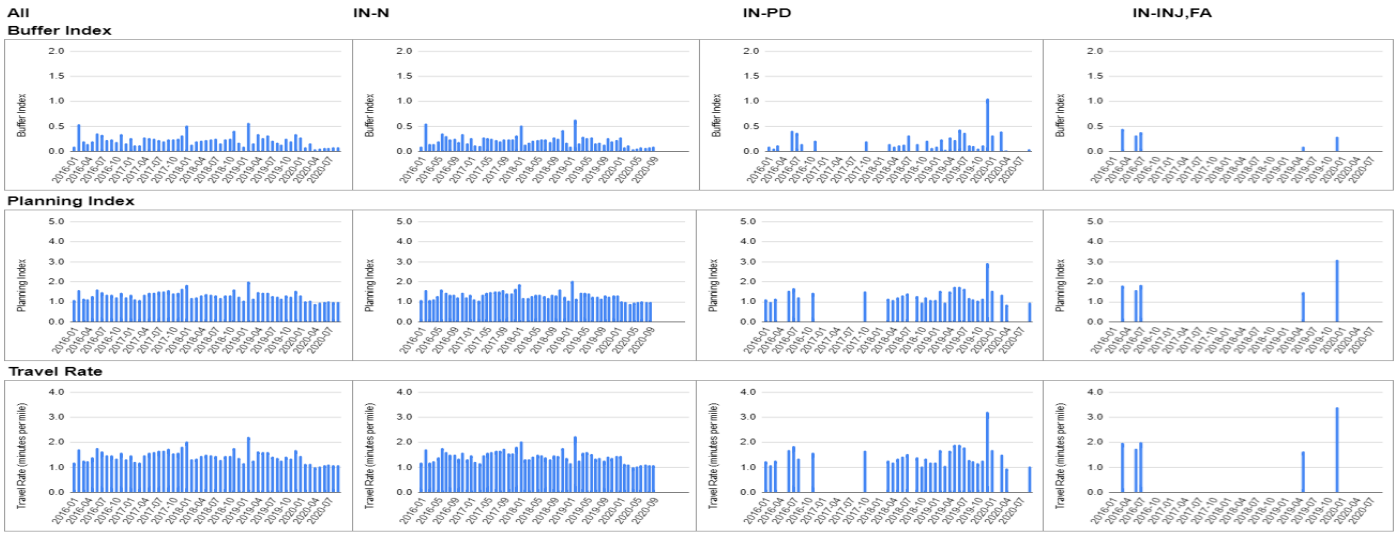
A.7.2.1 Effects of Weather



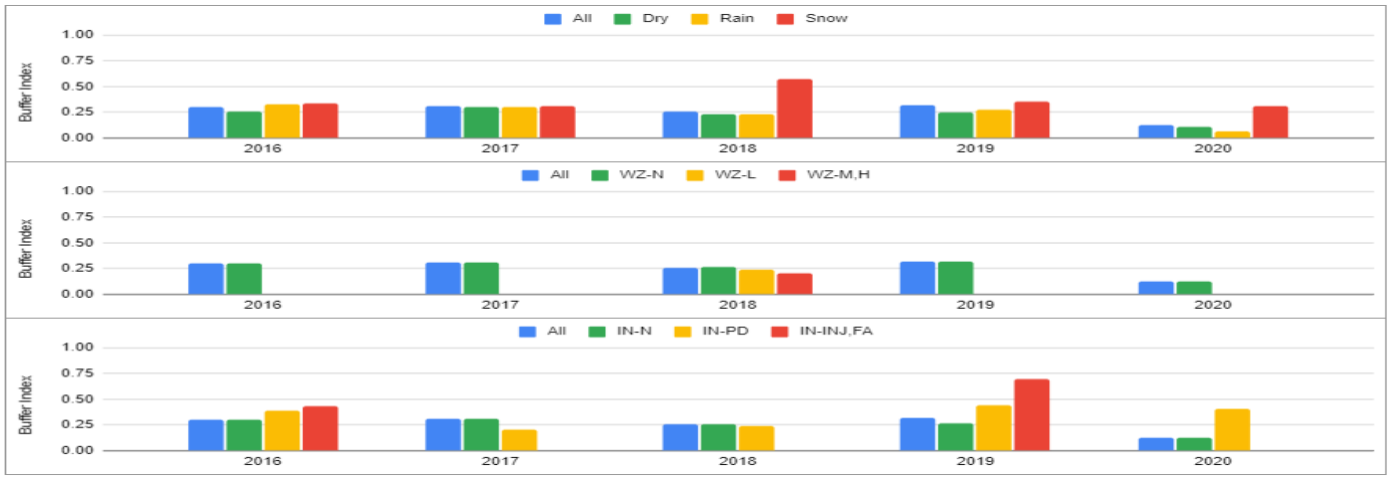
A.7.2.2 Effects of Work Zones



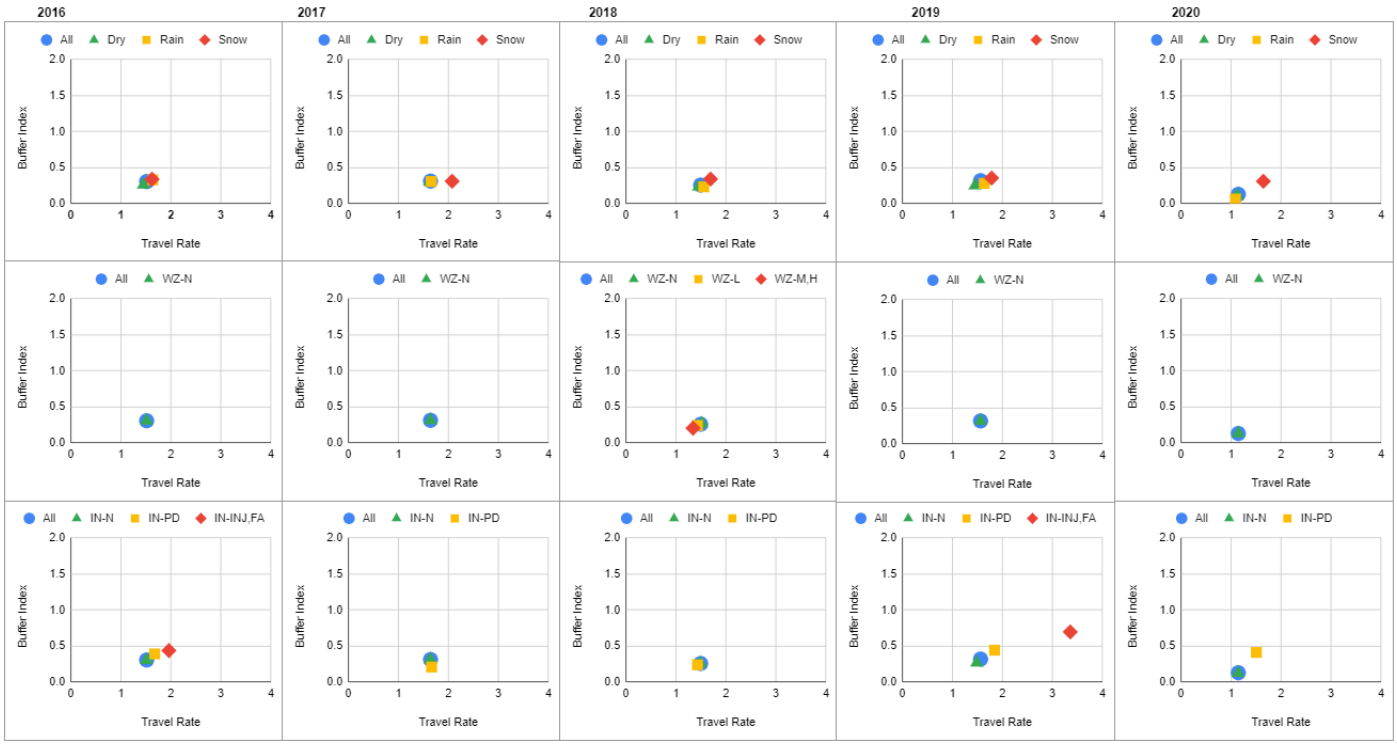
A.7.2.3 Effects of Incidents



A.7.2.4 Yearly Variations



A.7.2.5 Yearly Variations of Combined Index



A.7.2.6 Variations of Traffic-Flow Measures

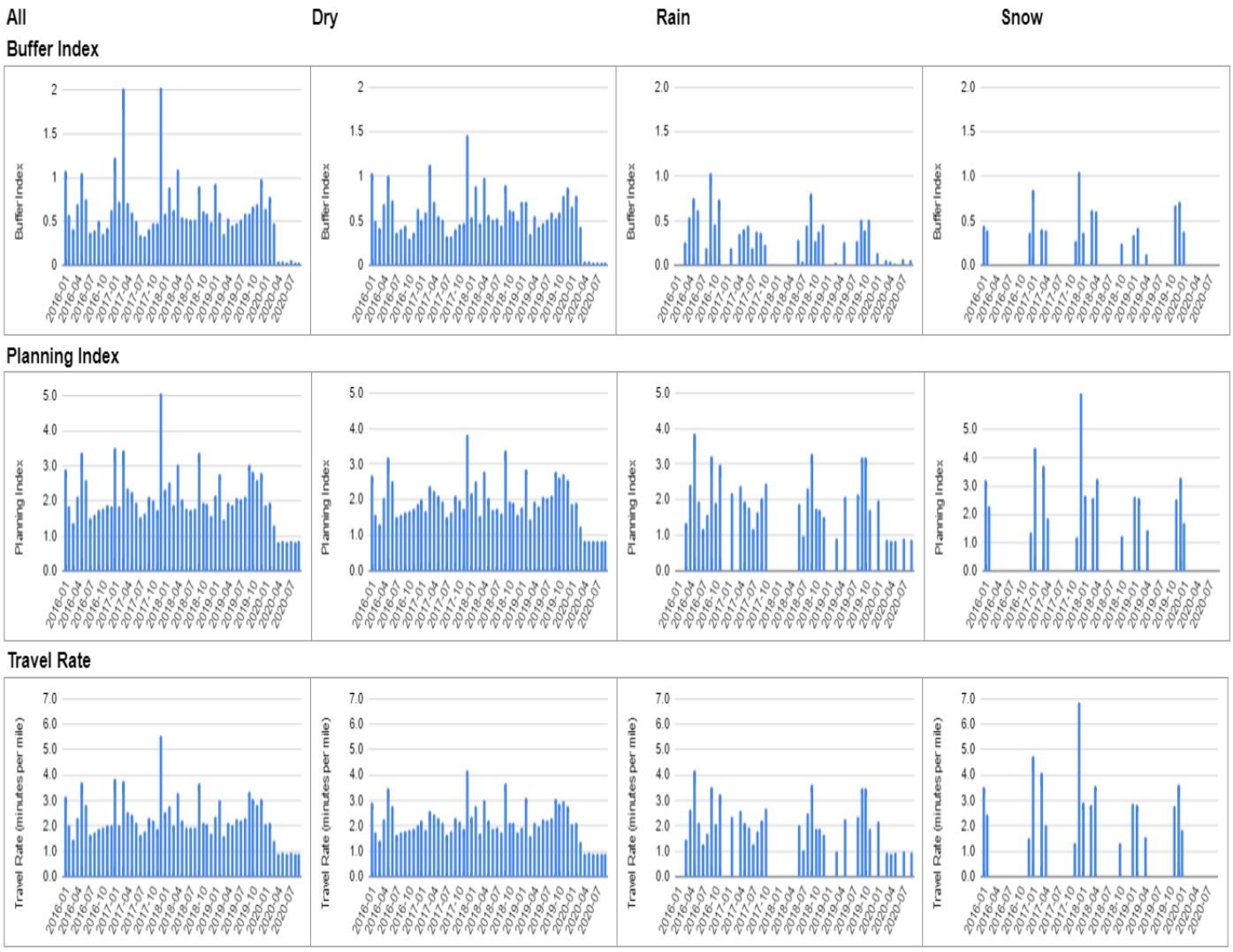
A.7.2.7 Trends Summary

- Both VMT and delays have been on a slightly downward trend.
- The monthly variations of both buffer and planning indices indicate relatively stable reliability patterns, while snow and incidents are the main contributing factors to the changes in reliability.

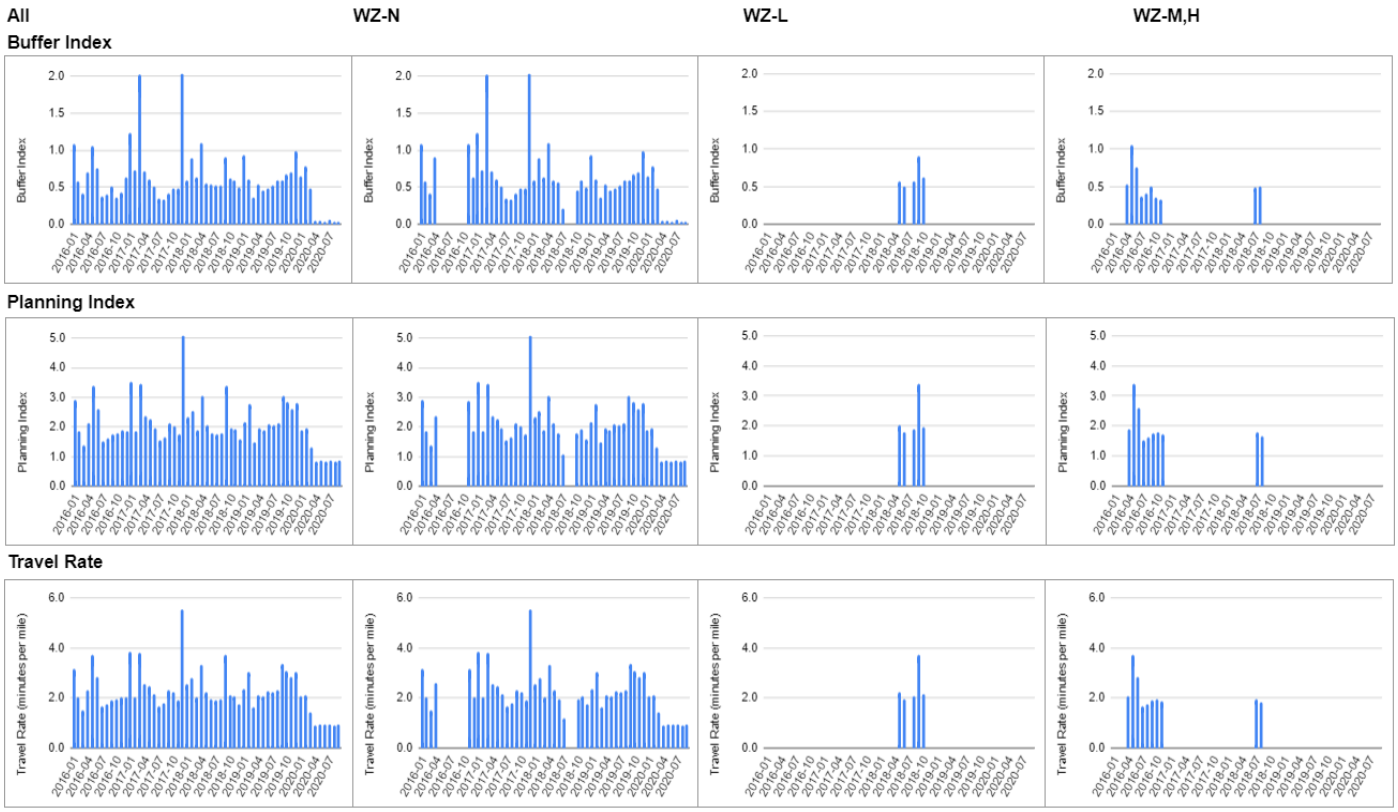
A.8 TH-36 CORRIDOR 2 (I-35E – I-35W, EASTBOUND/WESTBOUND)

A.8.1 TH 36 WESTBOUND Route 2 (I-35E -> I-35W, Morning Peak)

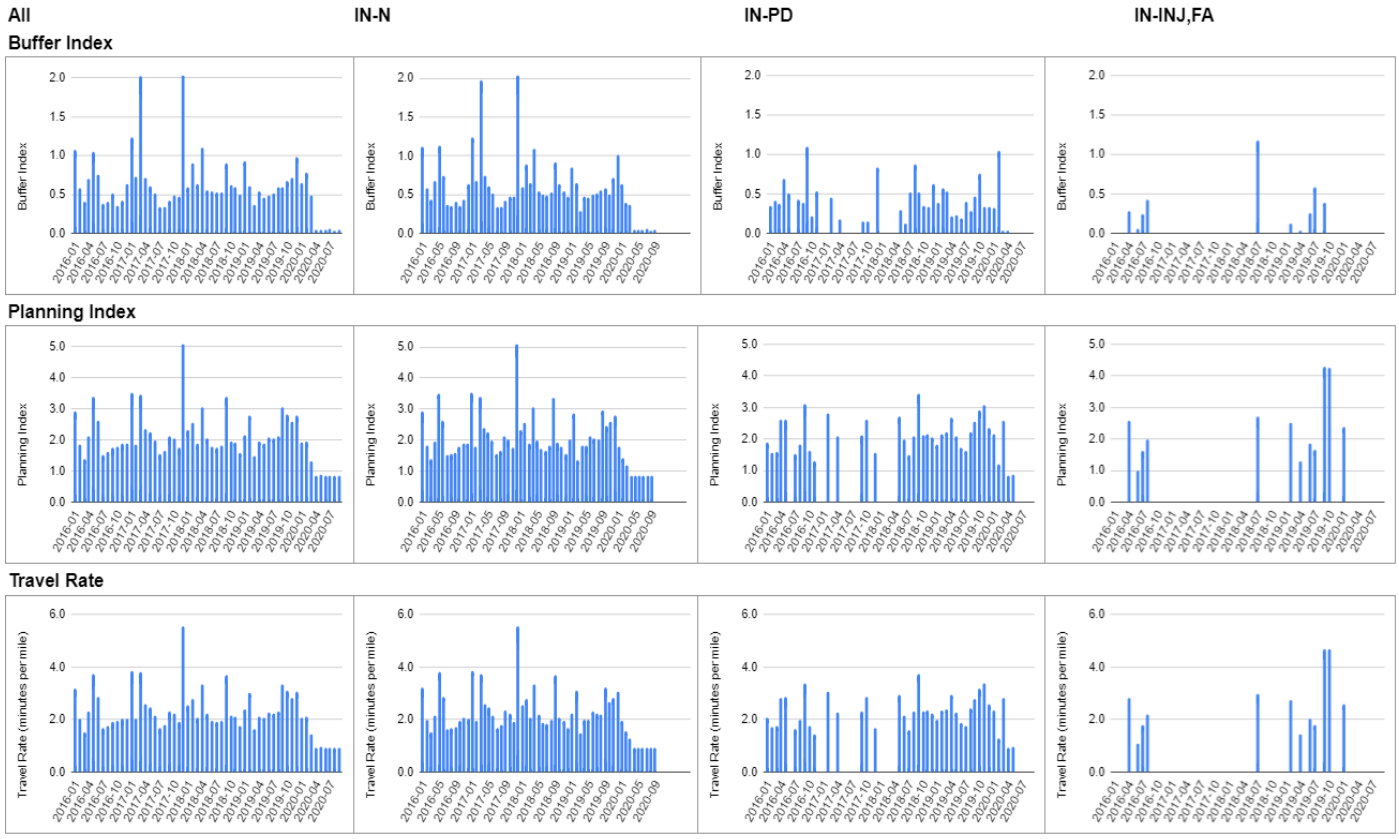
A.8.1.1 Effects of Weather



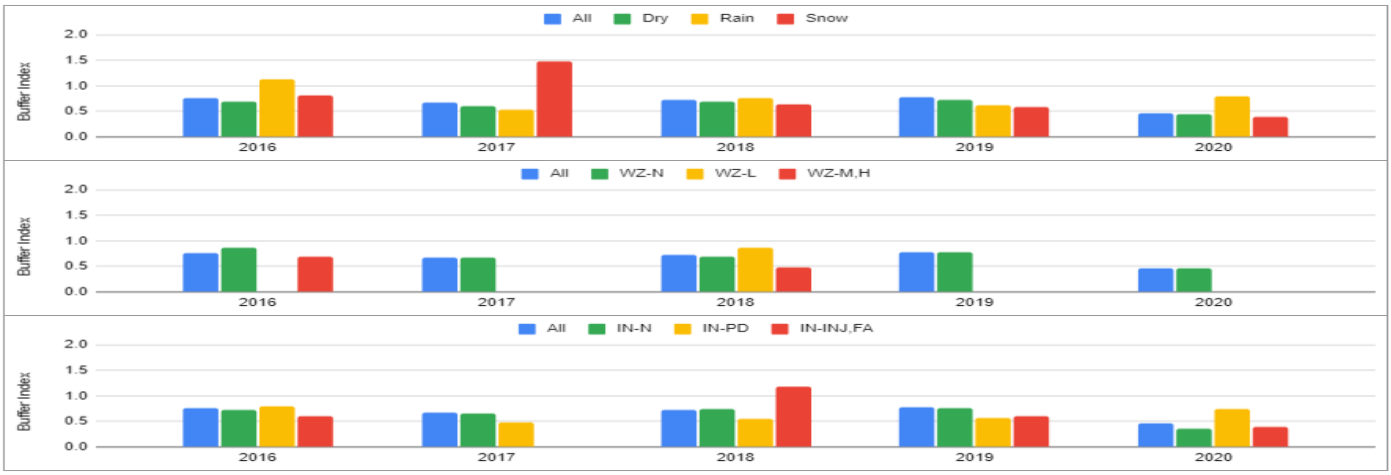
A.8.1.2 Effects of Work Zones

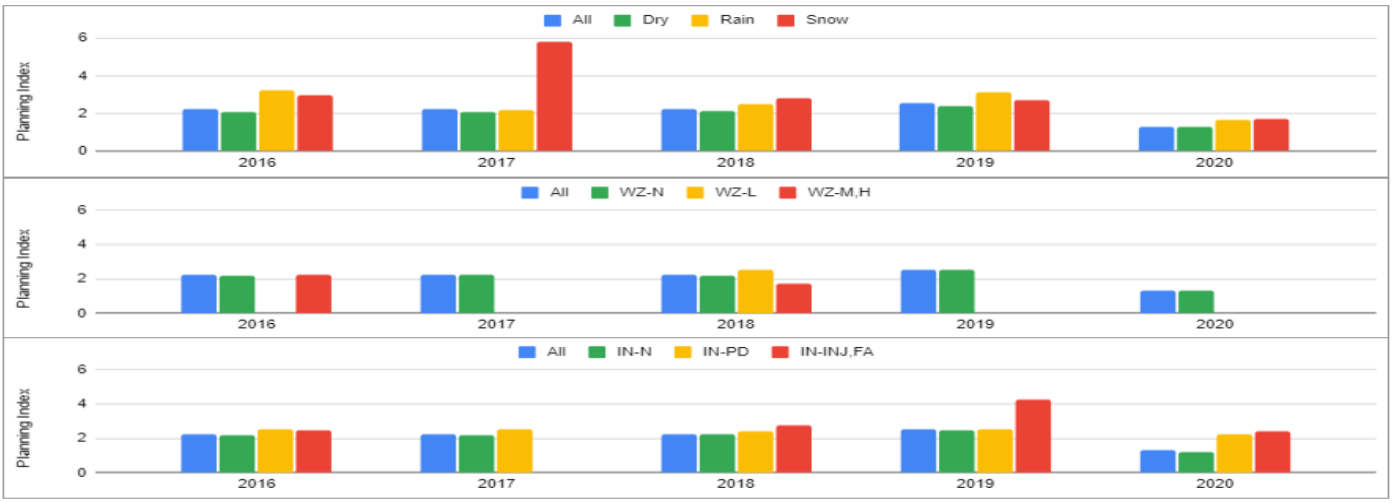


A.8.1.3 Effects of Incidents



A.8.1.4 Yearly Variations




All
Dry
Rain
Snow
Planning Index
6
4
2
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2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
6
4
2
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
6
4
2
0
2016
2017
2018
2019
2020


All
Dry
Rain
Snow
Travel Rate
6
4
2
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
6
4
2
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
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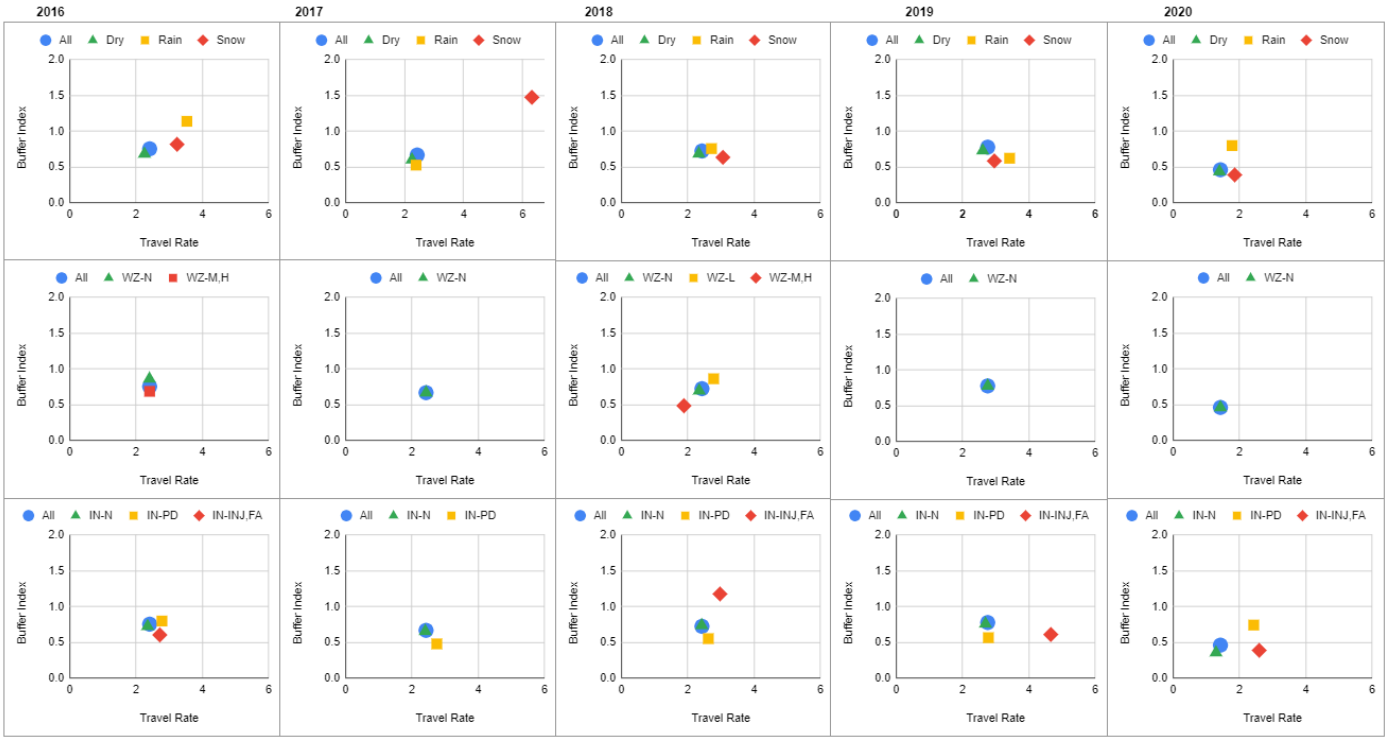
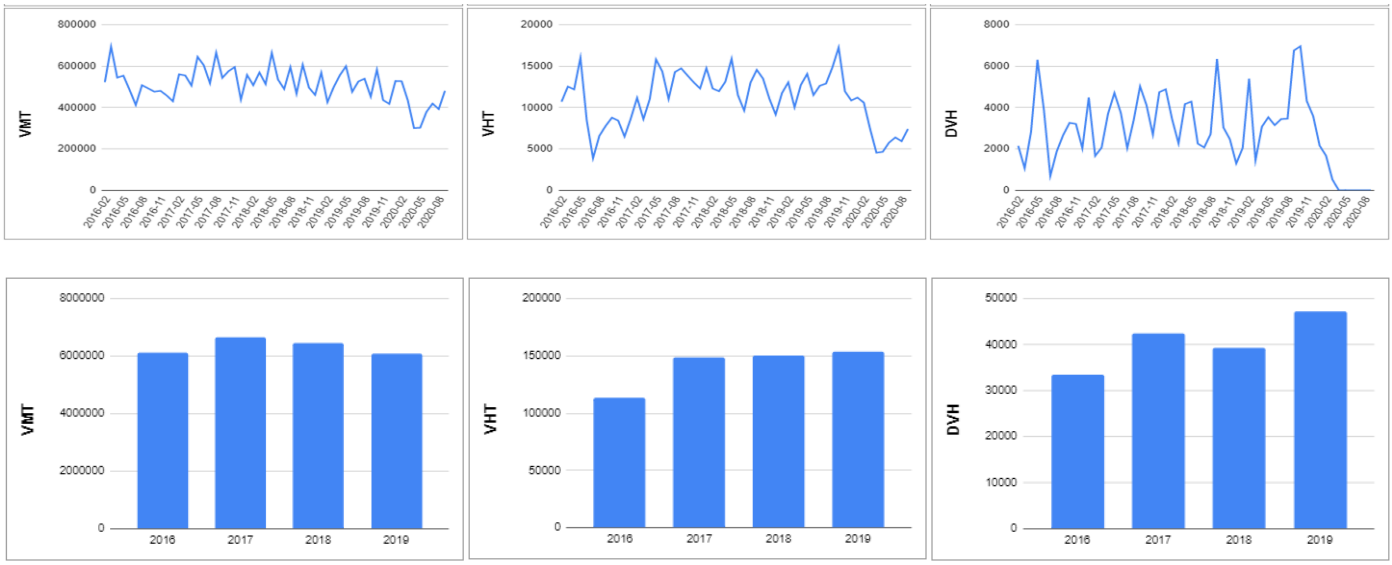
2016
2017
2018
2019
2020

A.8.1.5 Yearly Variations of Combined Index



A.8.1.6 Variations of Traffic-Flow Measures

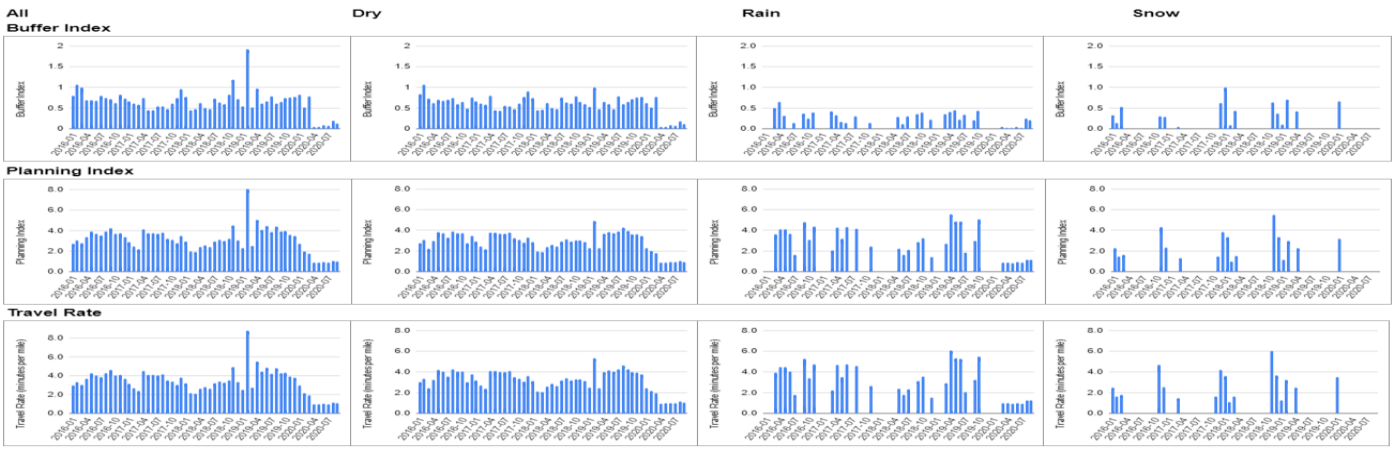


A.8.1.7 Trends Summary

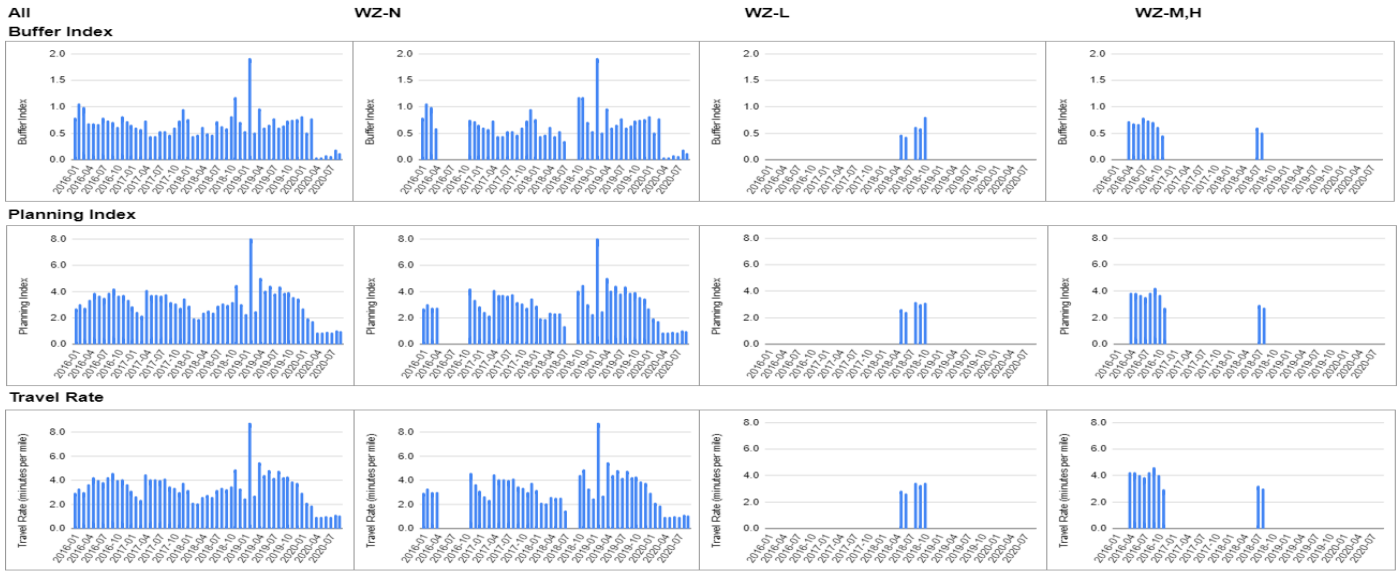
- VMT has been decreasing since 2017, while the delayed-vehicle hours show a fluctuating pattern.
- The monthly variations of both buffer and planning indices indicate large variations of travel times with relatively high level of congestion through time.
- Incidents have been the main factor affecting the variability of travel times, while snow has mostly contributed to the increase in the 95th %ile travel times.

A.8.2 TH 36 EASTBOUND Route 2 (I-35W -> I-35E, Afternoon Peak)

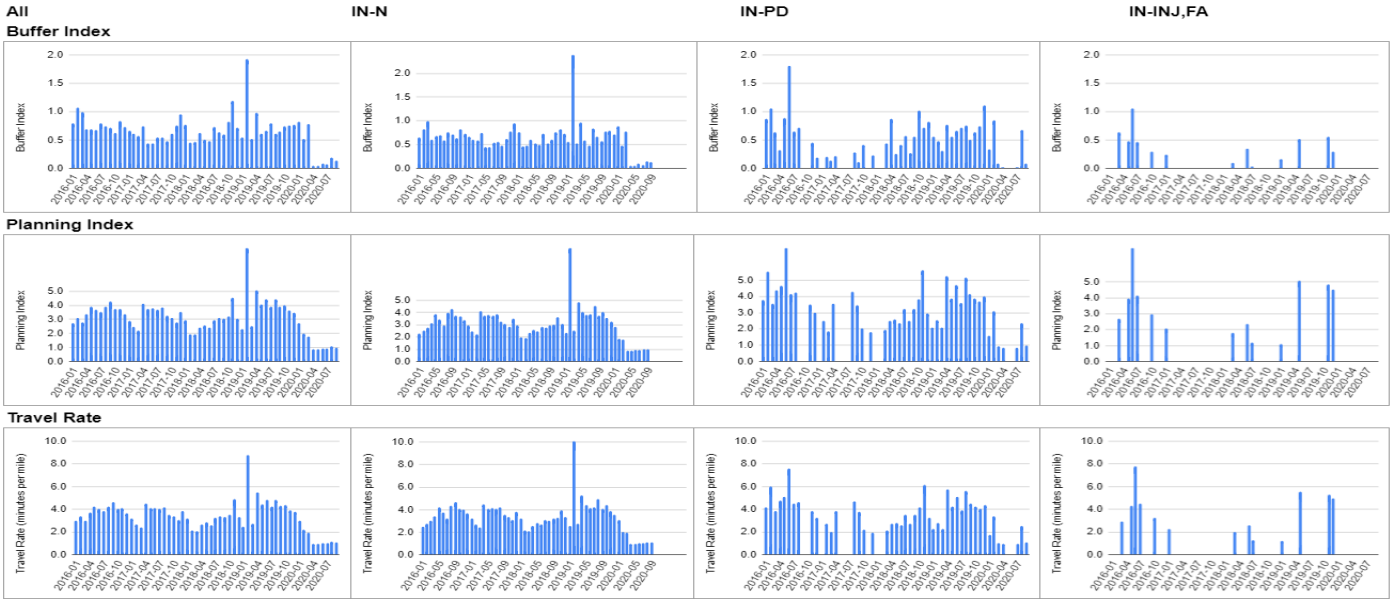
A.8.2.1 Effects of Weather



A.8.2.2 Effects of Work Zones

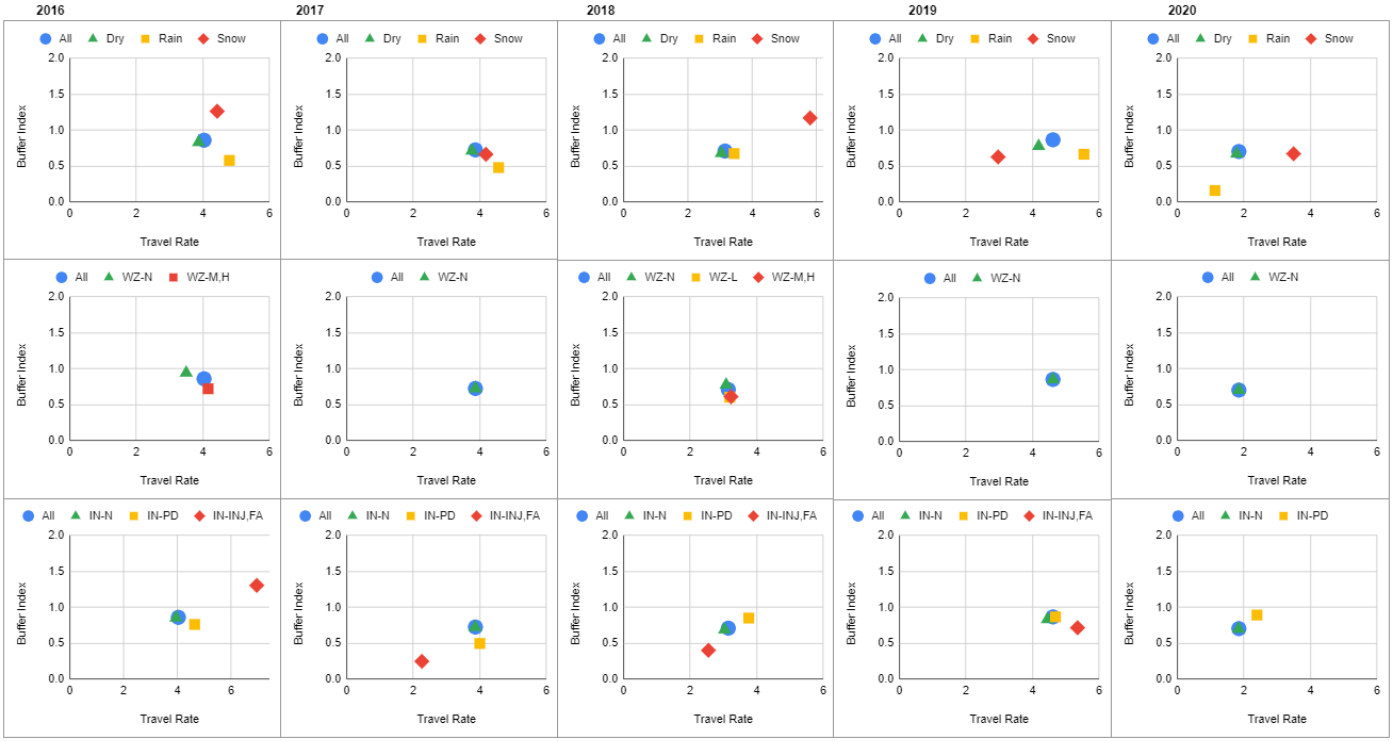


A.8.2.3 Effects of Incidents



A.8.2.4 Yearly Variations

A.8.2.5 Yearly Variations of Combined Index

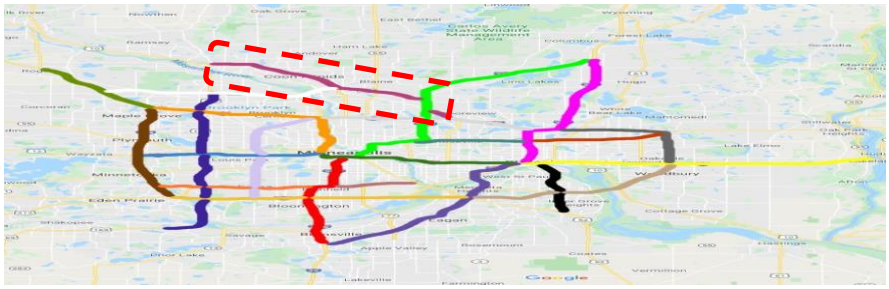


A.8.2.6 Variations of Traffic-Flow Measures

A.8.2.7 Trends Summary

- VMT has decreased in 2019, while the delayed vehicle hours have been continuously increasing.
- The monthly variations of the reliability measures indicate high level of congestion with significant variations in travel times through time.
- Weather has been the main contributing factor to the increase in the 95th %ile travel times, while the effects of snow on the travel time variability has not been consistent over time.

A.9 TH-10 CORRIDOR

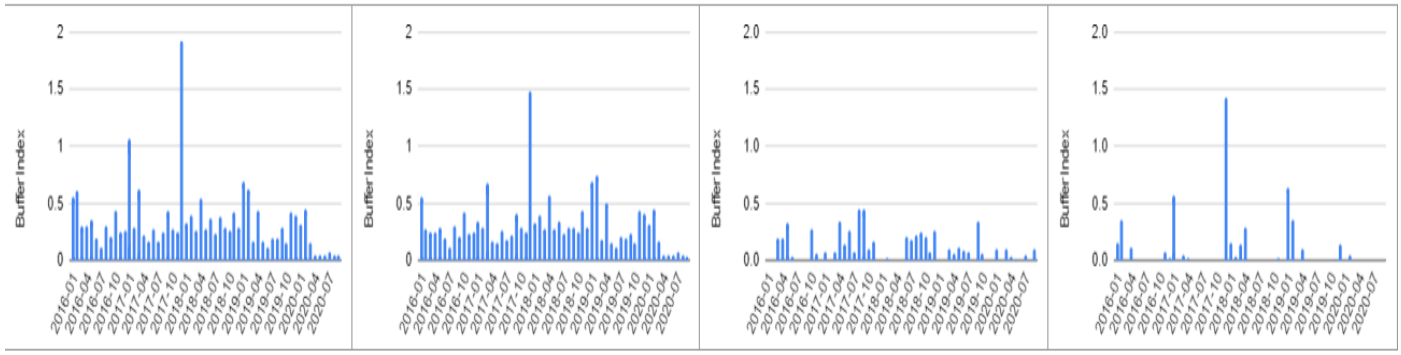


A.9.1 TH 10 EASTBOUND Route (Morning Peak)

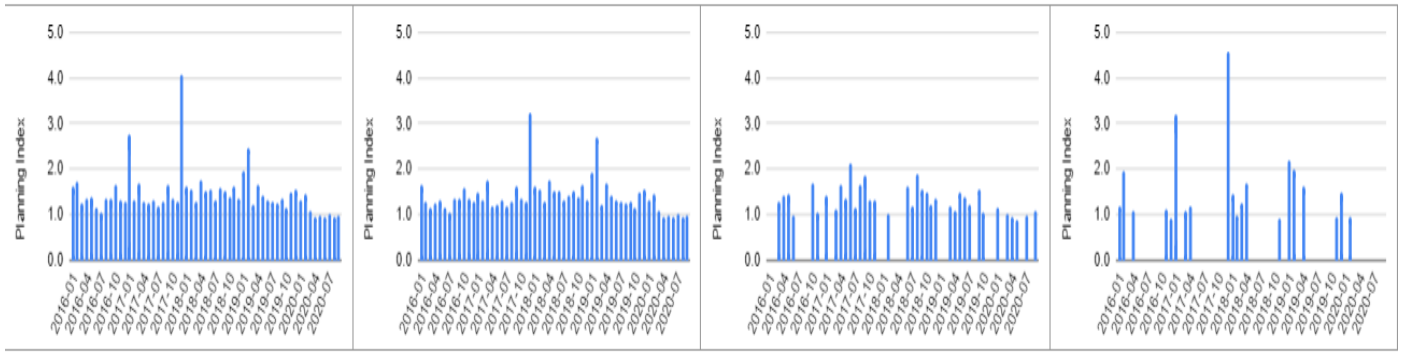
A.9.1.1 Effects of Weather

All Dry Rain Snow

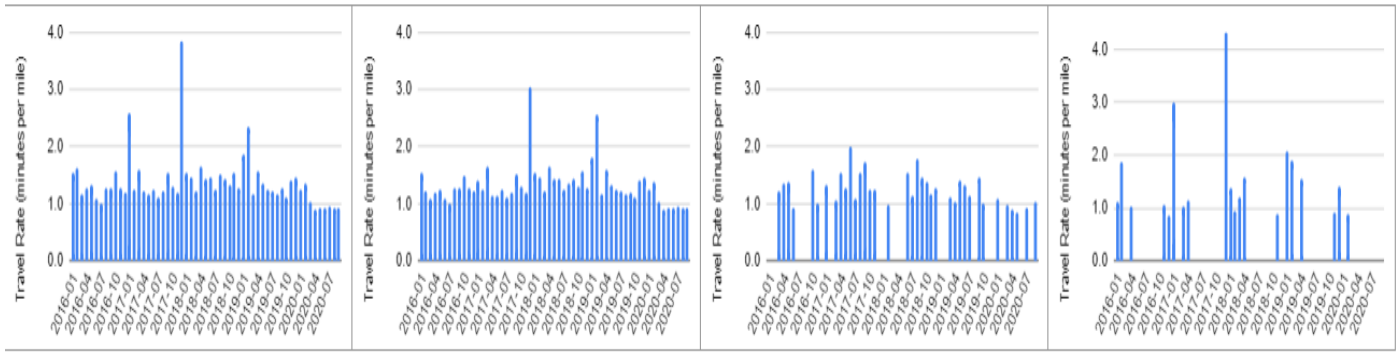
Buffer Index



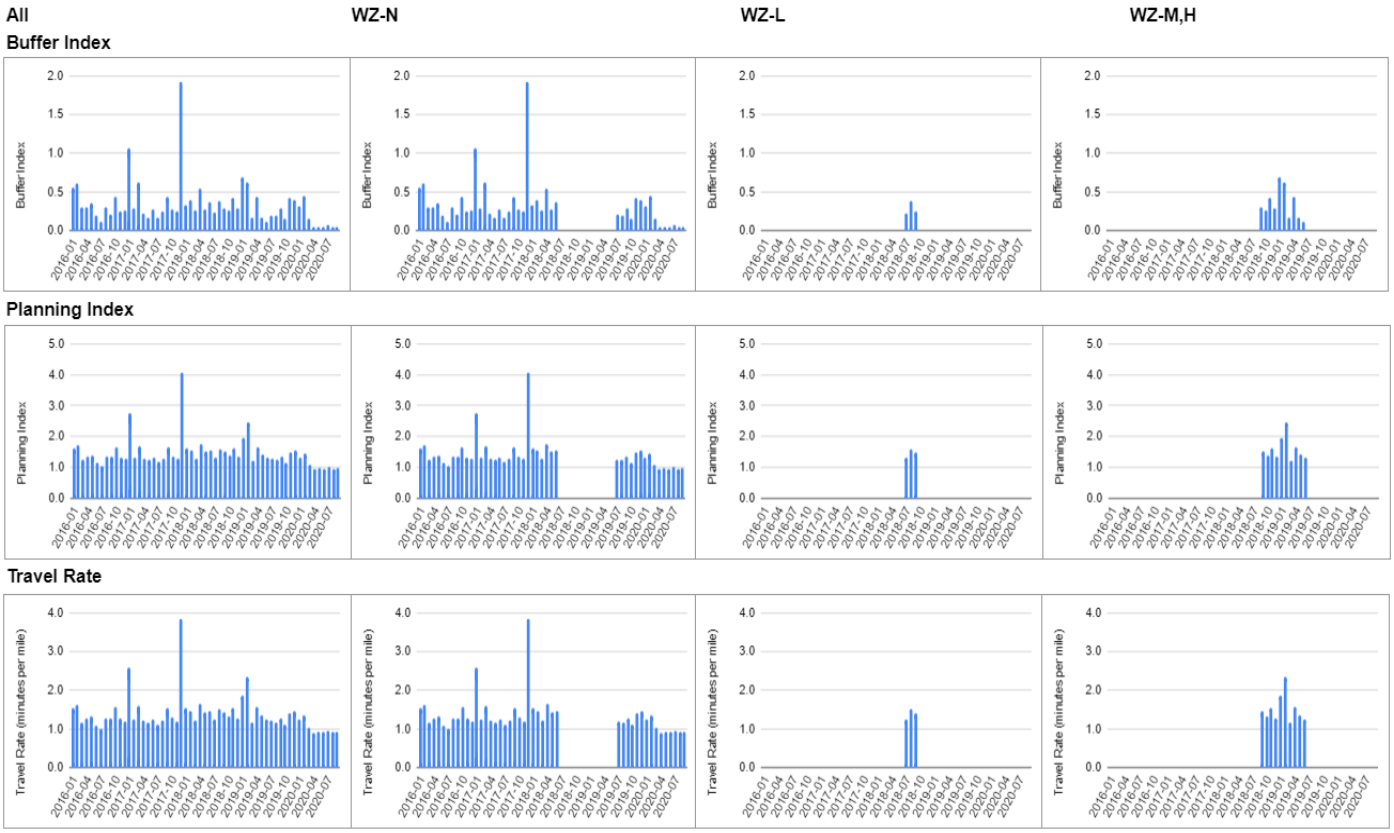
Planning Index



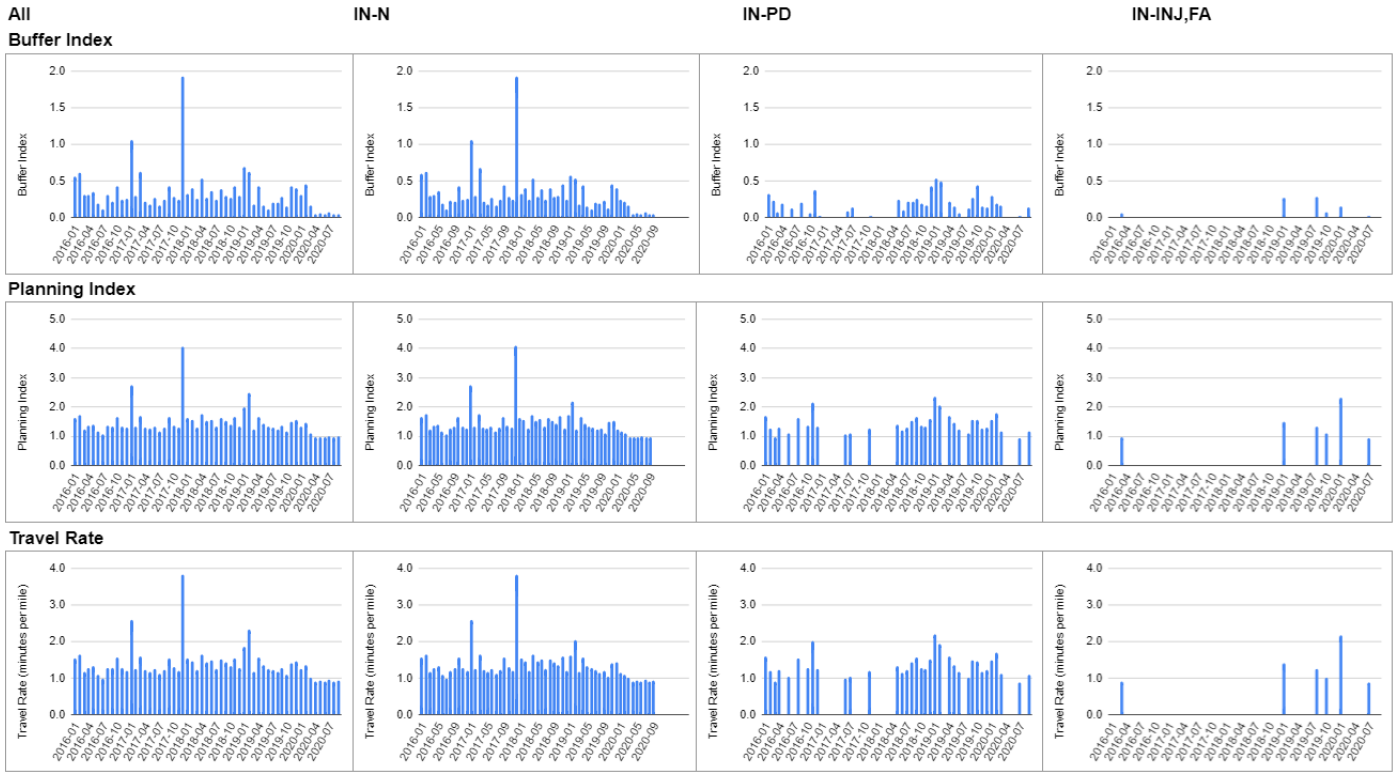
Travel Rate



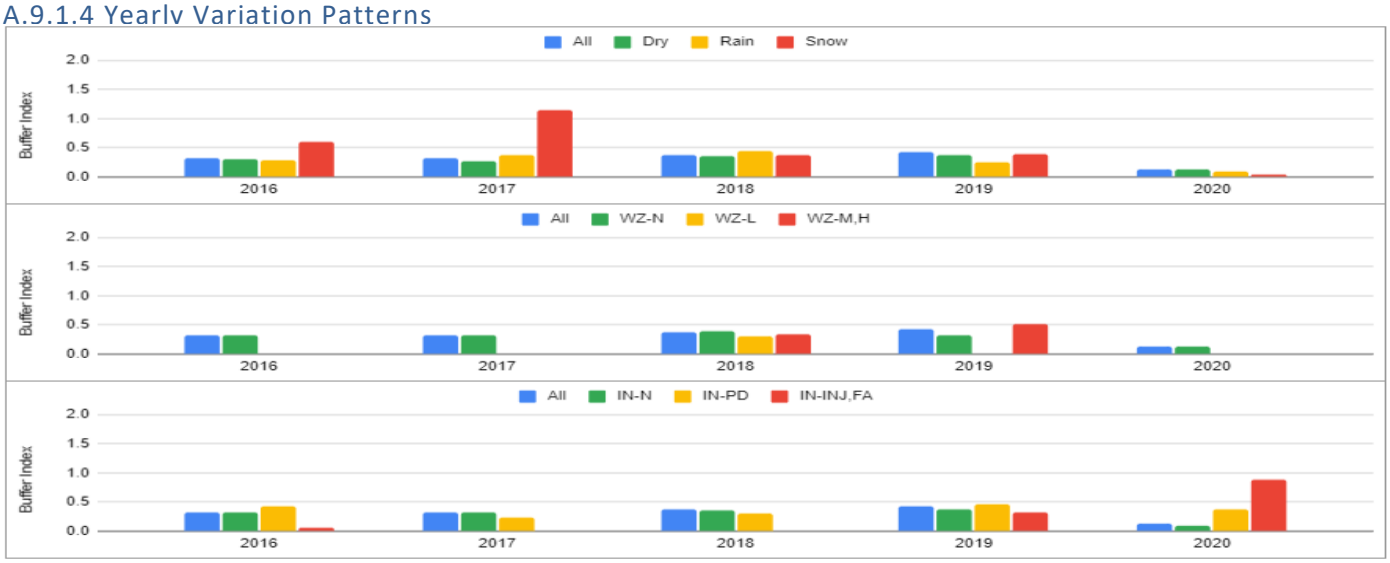
A.9.1.2 Effects of Work Zones



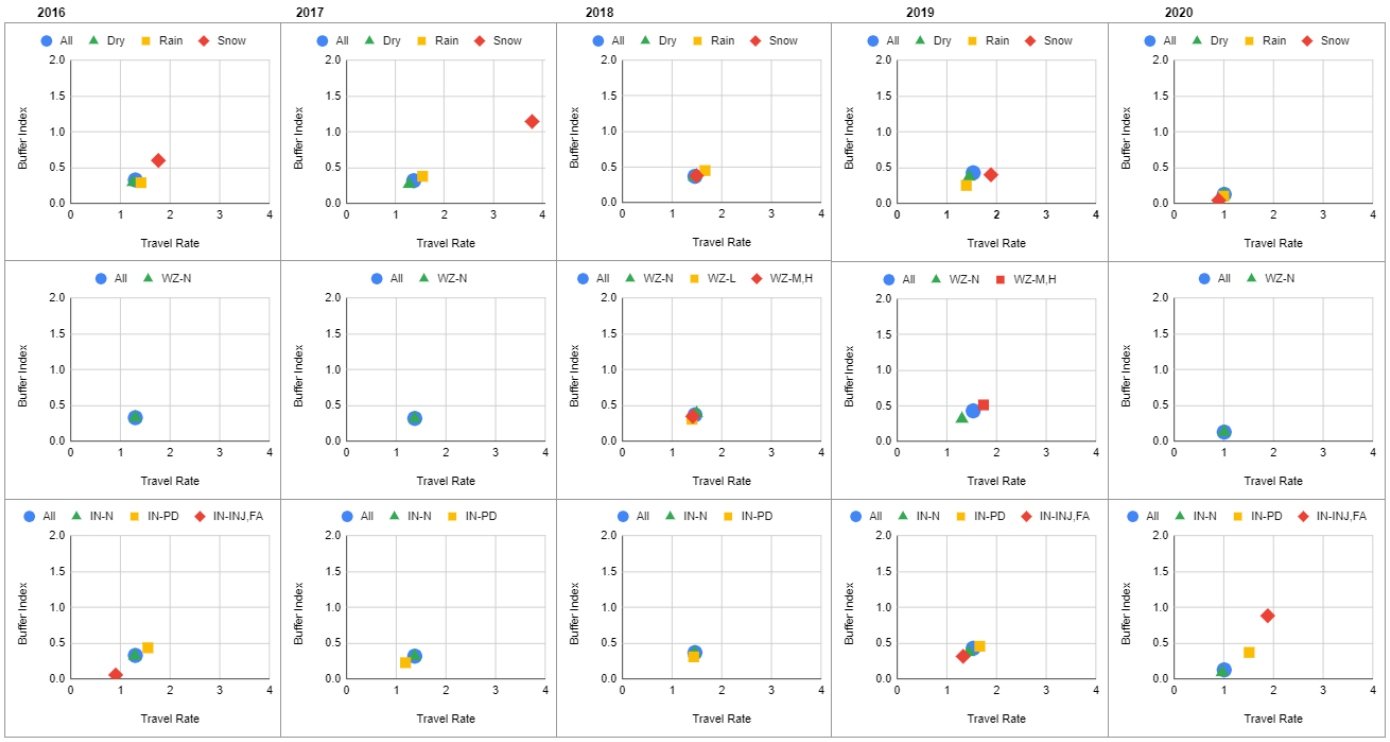
A.9.1.3 Effects of Incidents



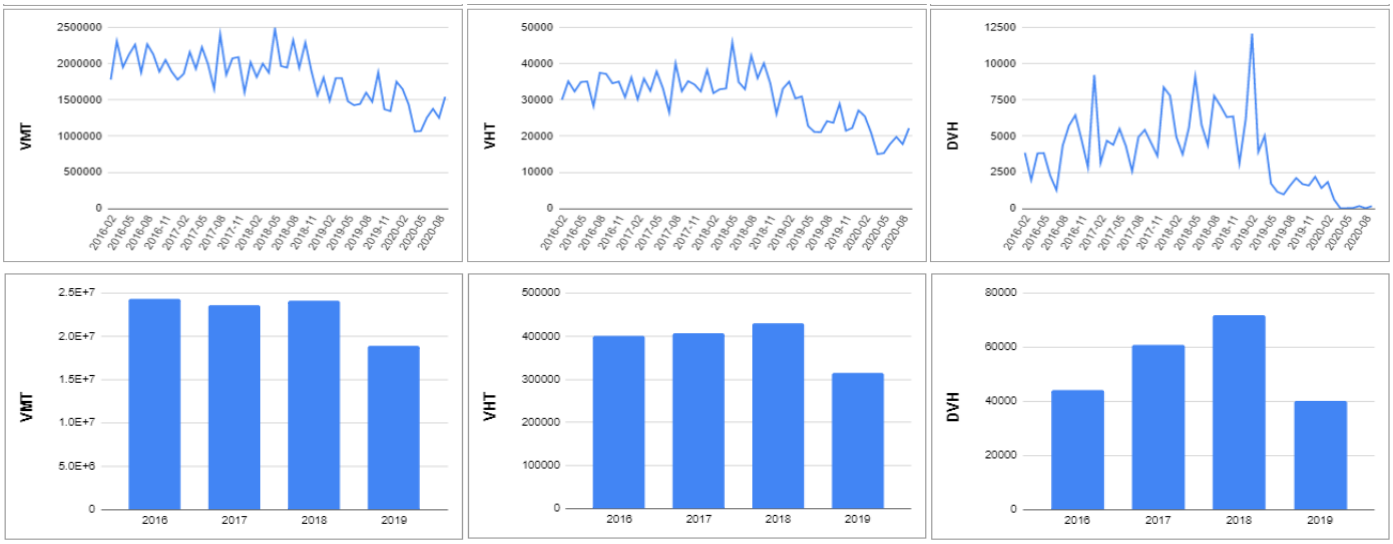
A.9.1.4 Yearly Variation Patterns



A.9.1.5 Yearly Variations – Combined Index



A.9.1.6 Variations of Traffic-Flow Measures

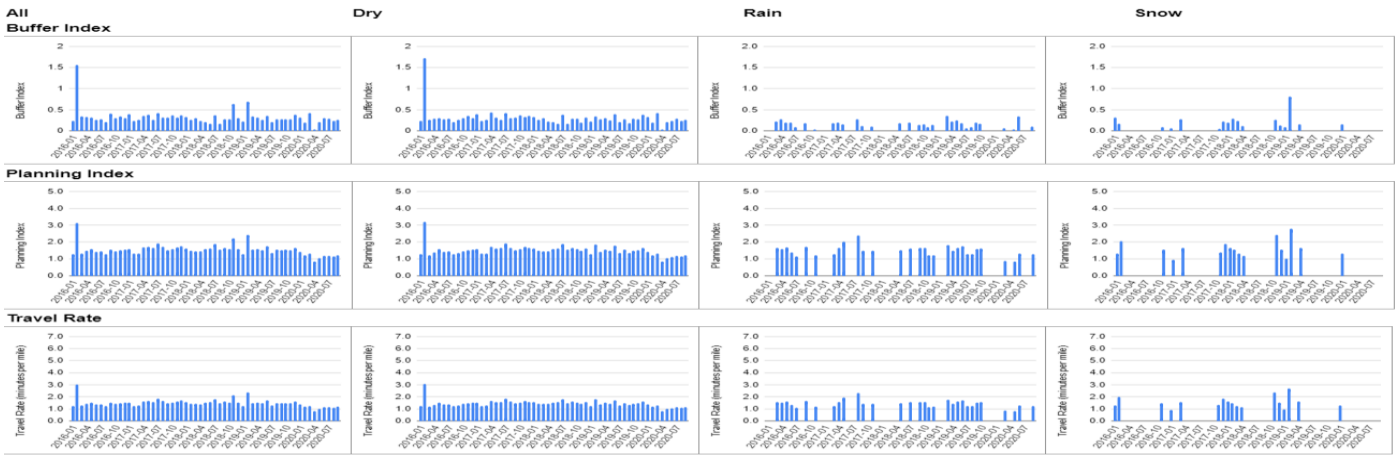


A.9.1.7 Trends Summary (TH 10 EASTBOUND Morning)

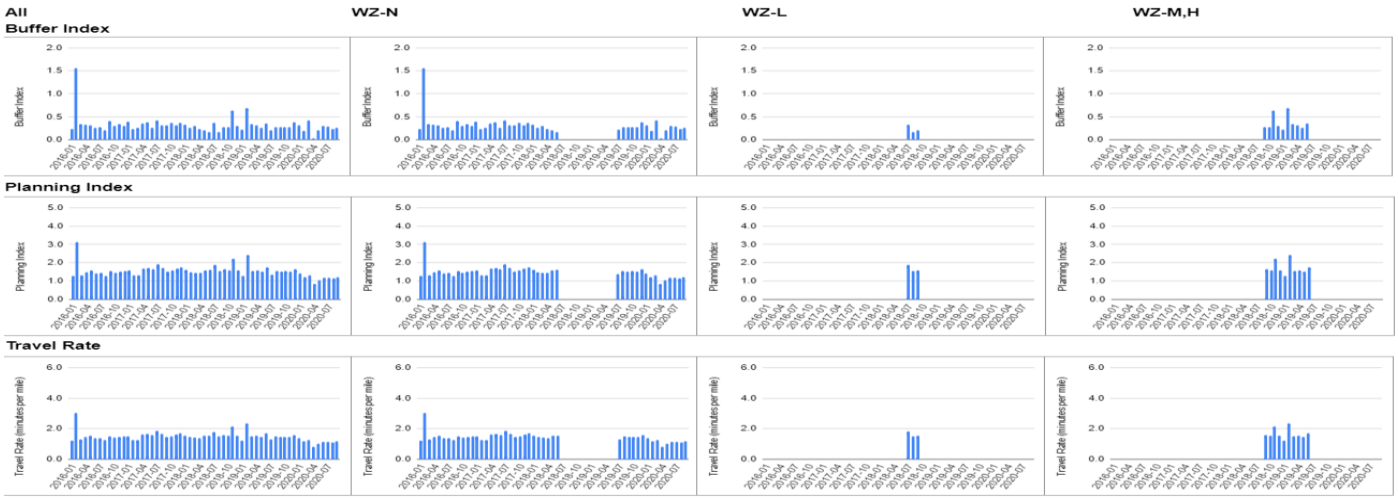
- The VMT shows a downward pattern from 2016 to 2018, however, the delay has continuously increased during the same period, which is also reflected in the slightly upward trends of the 95th %-ile travel time during the same period.
- The Buffer-Index significantly increases during the winter seasons indicating snow has the more effects than incidents or work zones on this route.

A.9.2 TH 10 WESTBOUND Route (Afternoon Peak)

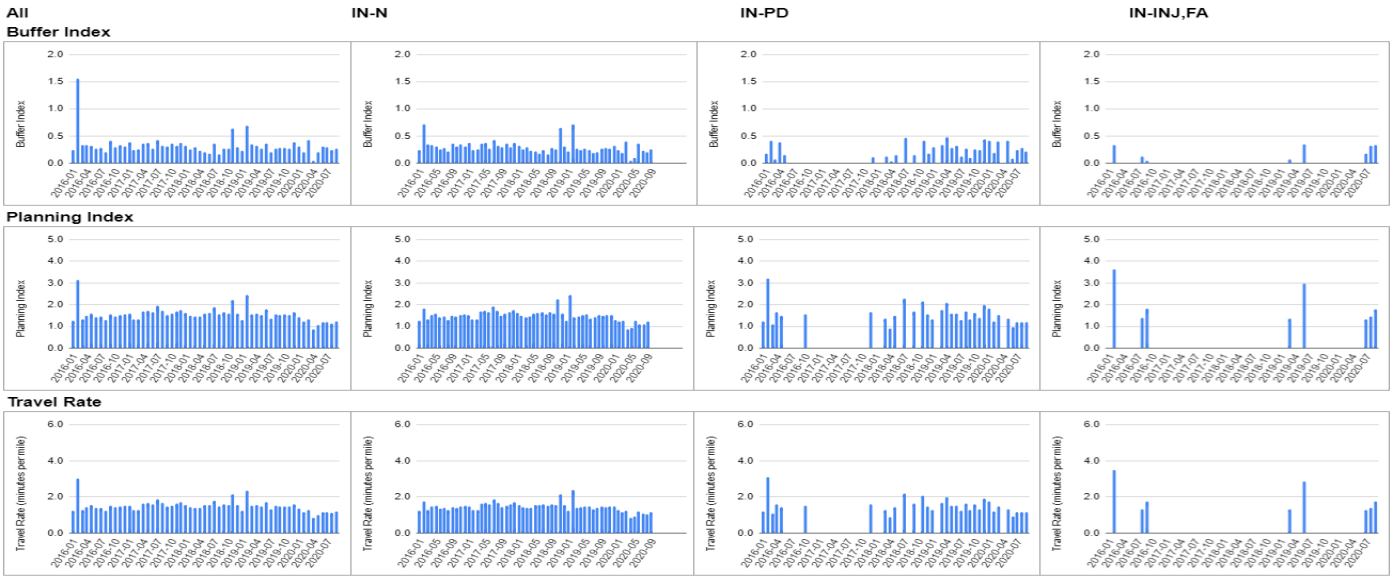
A.9.2.1 Effects of Weather



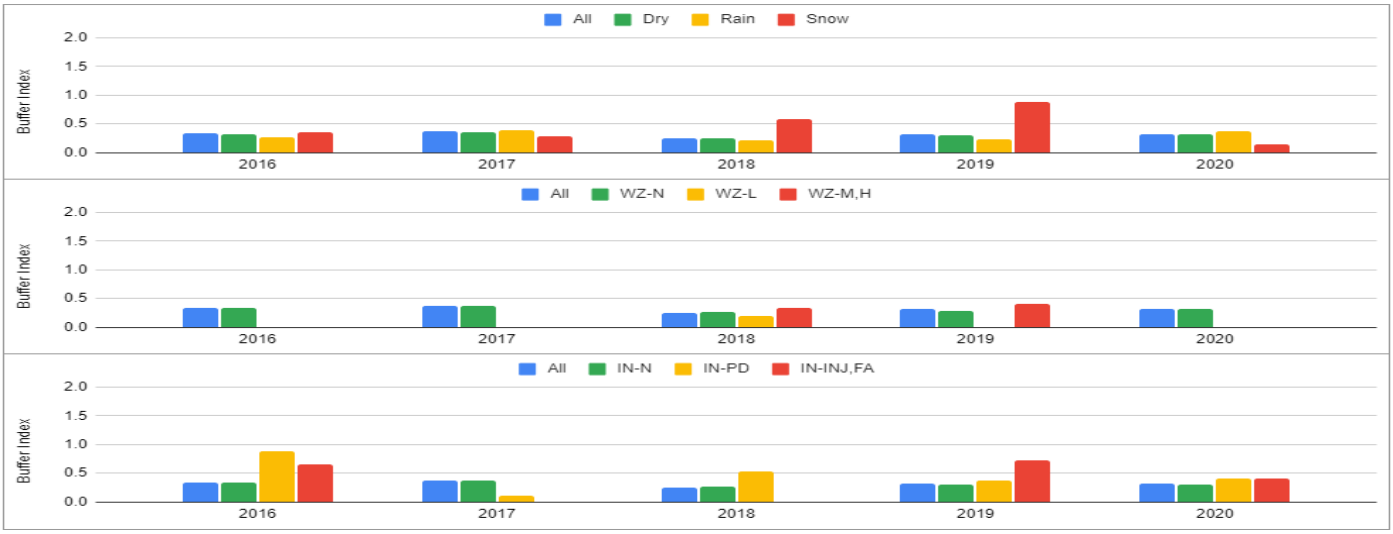
A.9.2.2 Effects of Work Zones



A.9.2.3 Effects of Incidents



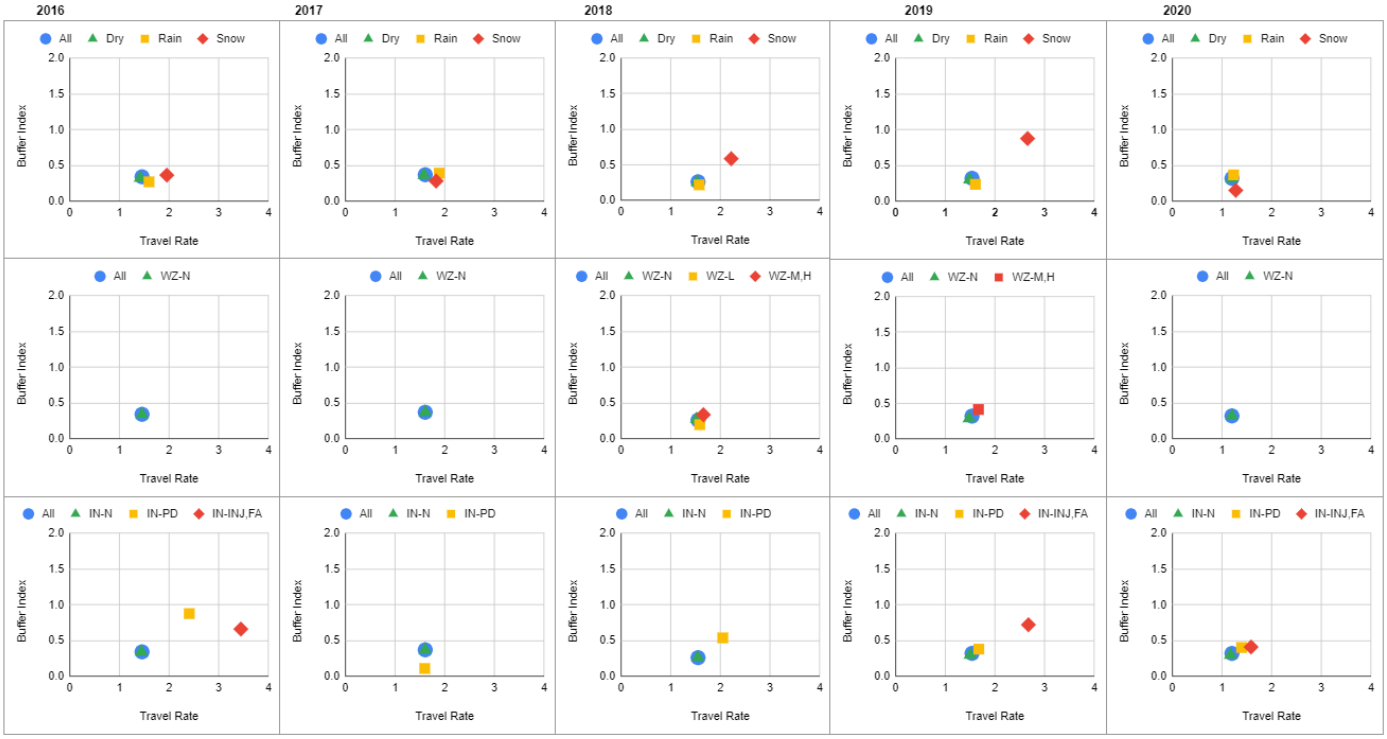
A.9.2.4 Yearly Variations




All
Dry
Rain
Snow
Planning Index
6
4
2
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
6
4
2
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
6
4
2
0
2016
2017
2018
2019
2020


All
Dry
Rain
Snow
Travel Rate
6
4
2
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
6
4
2
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
6
4
2
0
2016
2017
2018
2019
2020

A.9.2.5 Yearly Variations of Combined Index

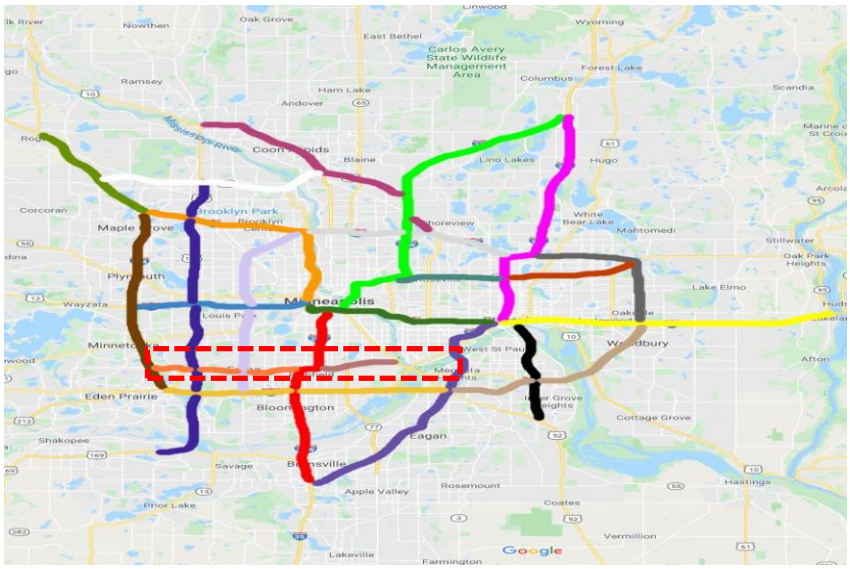


A.9.2.6 Variations of Traffic-Flow Measures

A.9.2.7 Trends Summary

- The VMT pattern shows slight downward trends during 2016 – 2018 period, while the delay has continuously increased during the same period. However, the 95th %-ile travel time has remained relatively stable.
- The snow has been the major factor affecting travel-time reliability on this route, and its effects have been continuously growing from 2016 through 2019.
- The effects of incidents on reliability also have been continuously increasing since 2016.

A.10 I-494 CORRIDOR 1 (TH 212 – I-35E, EASTBOUND/WESTBOUND)

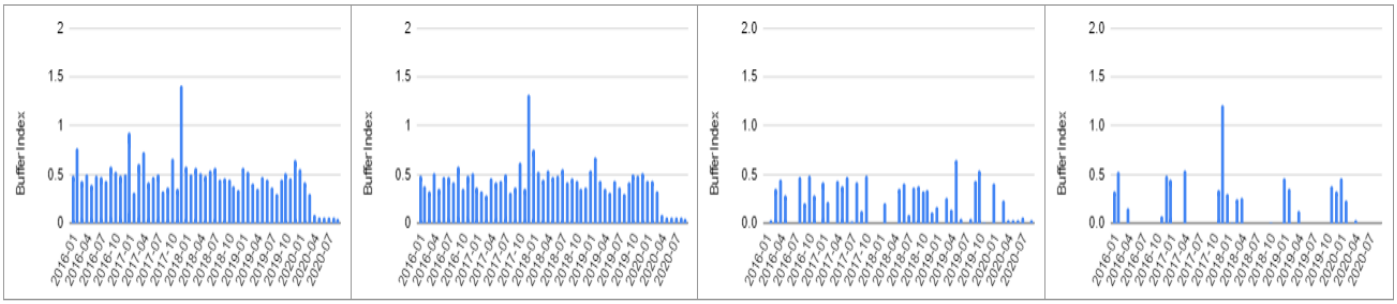


A.10.1 I-494 Corridor 1 WESTBOUND Route (I-35E -> TH 212: Morning Peak)

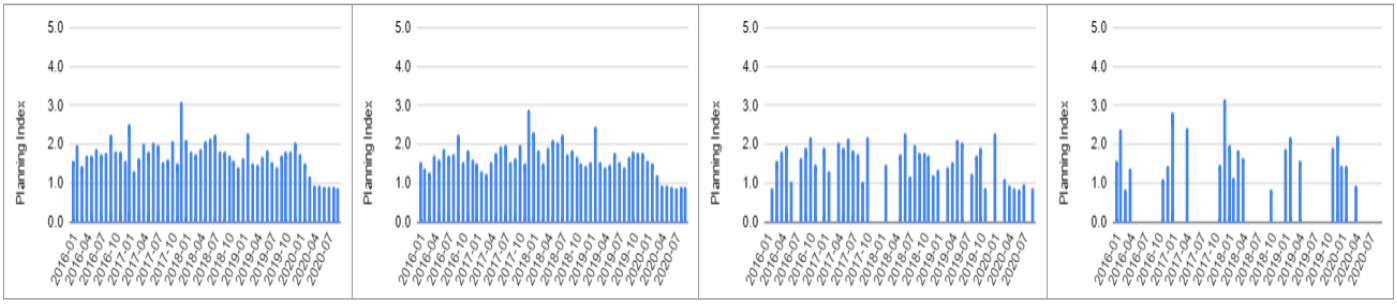
A.10.1.1 Effects of Weather

All | Dry | Rain | Snow

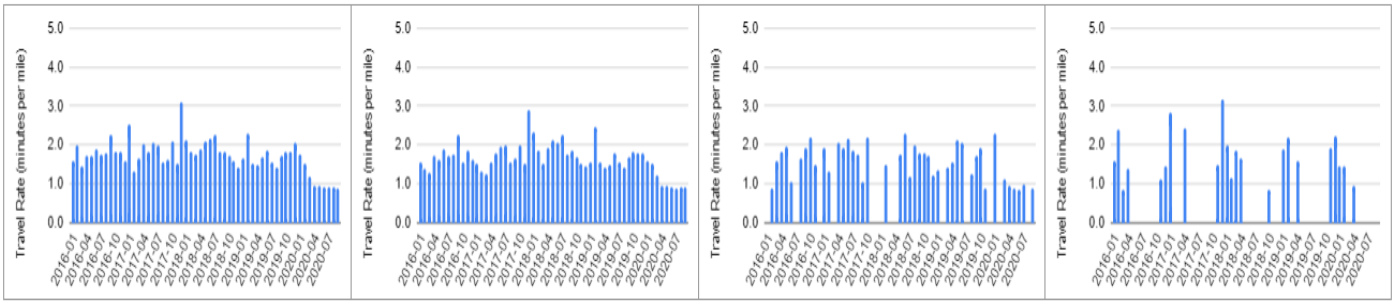
Buffer Index



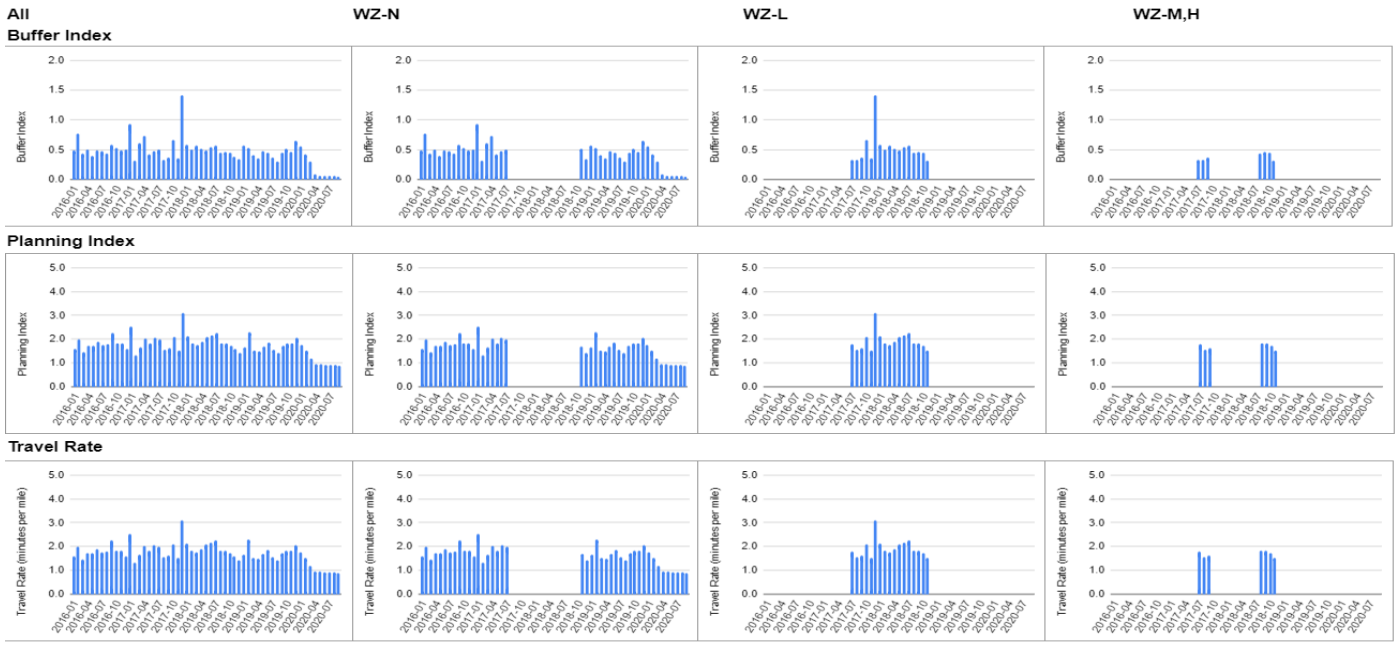
Planning Index



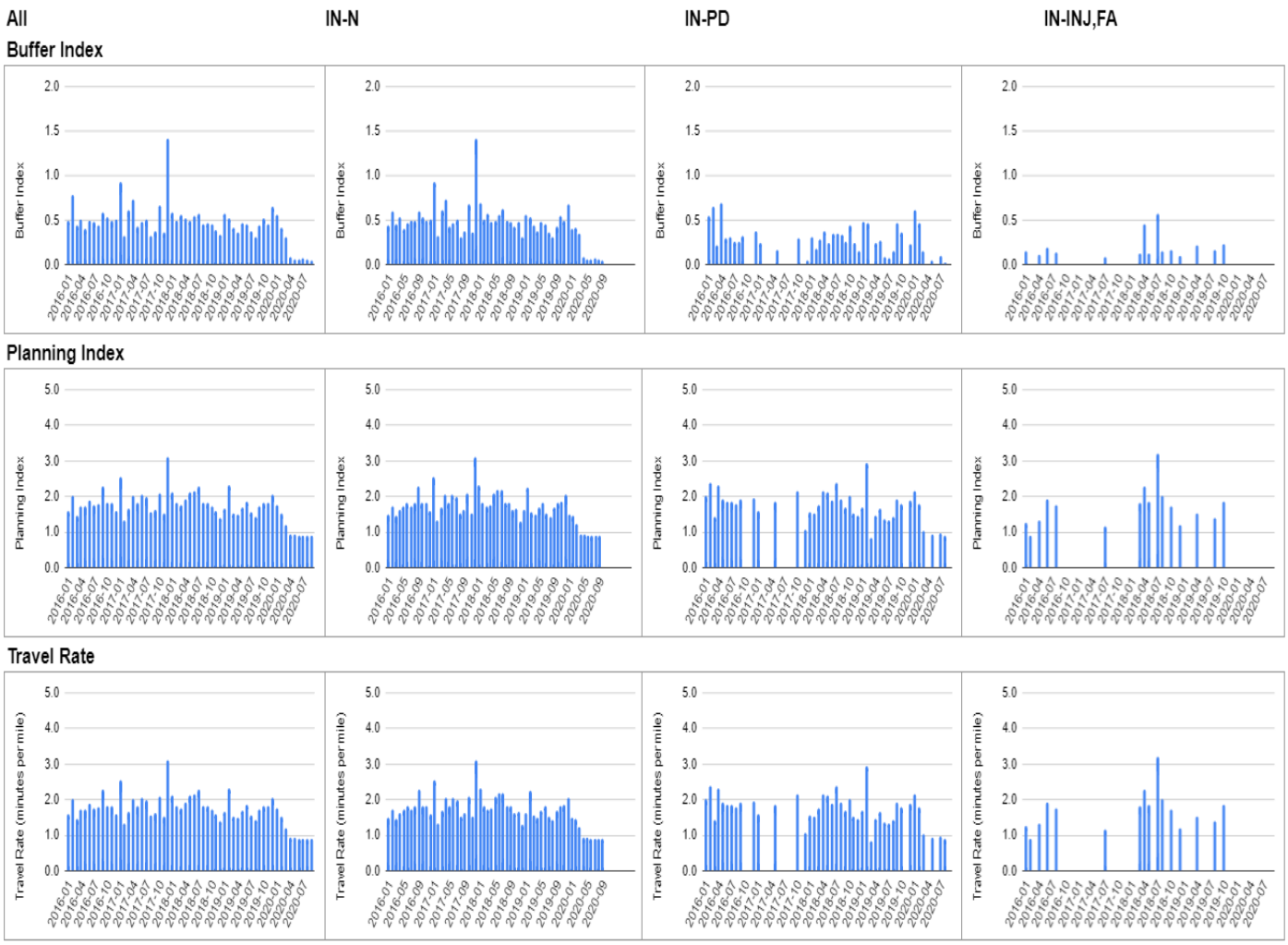
Travel Rate



A.10.1.2 Effects of Work Zones

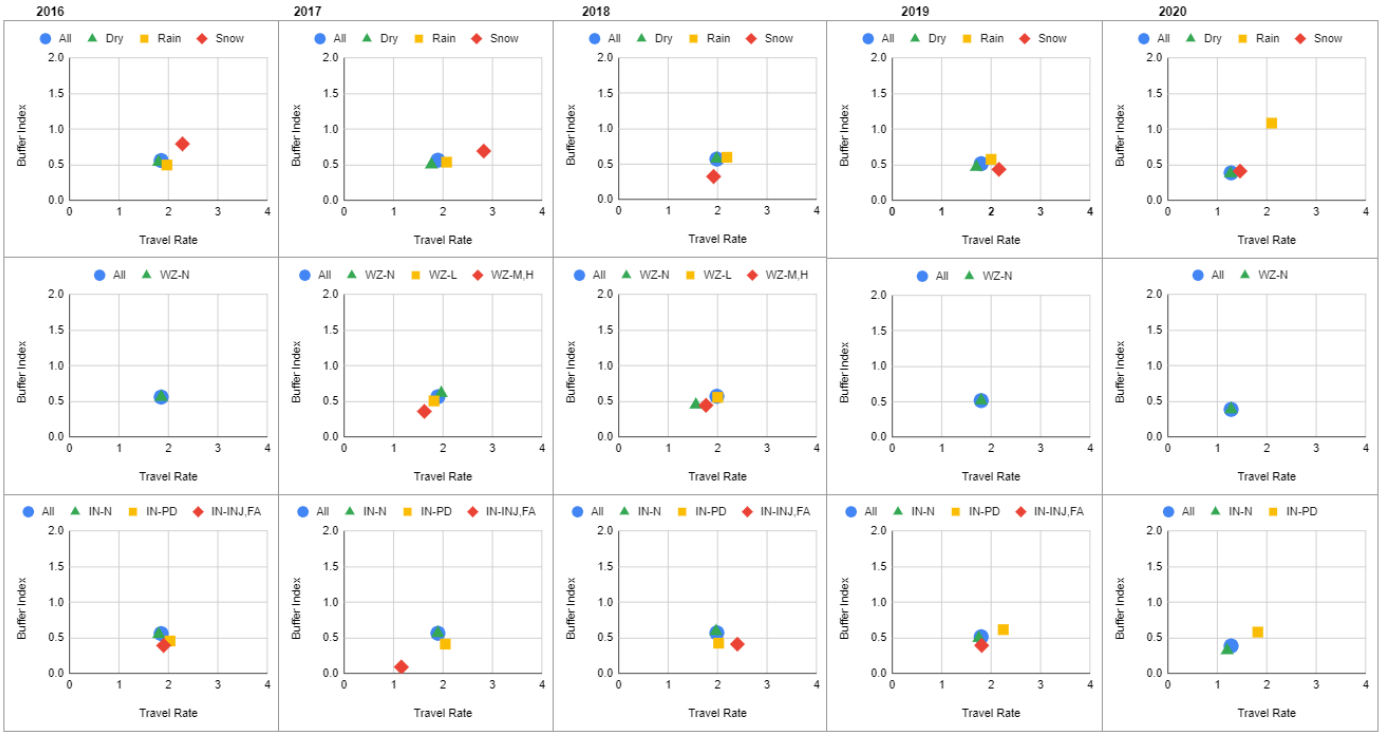


A.10.1.3 Effects of Incidents



A.10.1.4 Yearly Variations

A.10.1.5 Yearly Variations of Combined Index



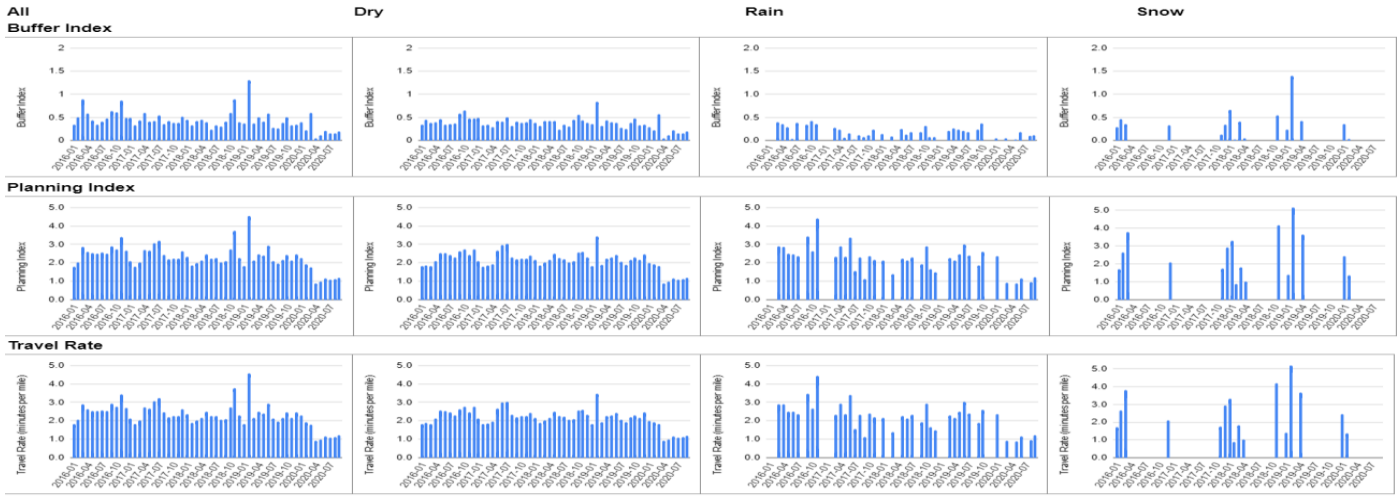
A.10.1.6 Variations of Traffic-Flow Measures

A.10.1.7 Trends Summary

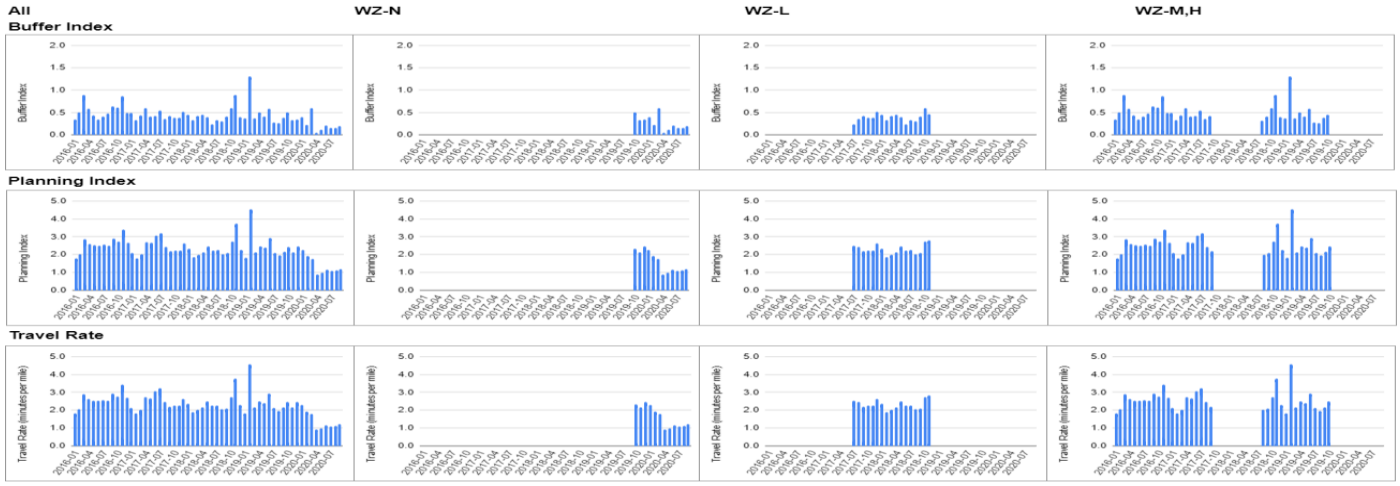
- Both VMT and Delayed-vehicle hours show a slight downward trend from 2016 to 2019, however, the monthly variations of the reliability measures during the same period indicate large variations in travel times with high level of congestion.
- Weather appears to be the main contributor affecting the reliability than other factors, such as incidents or work zones.

A.10.2 I-494 Corridor 1: EASTBOUND Rote (TH 212 -> I-35E, Afternoon Peak)

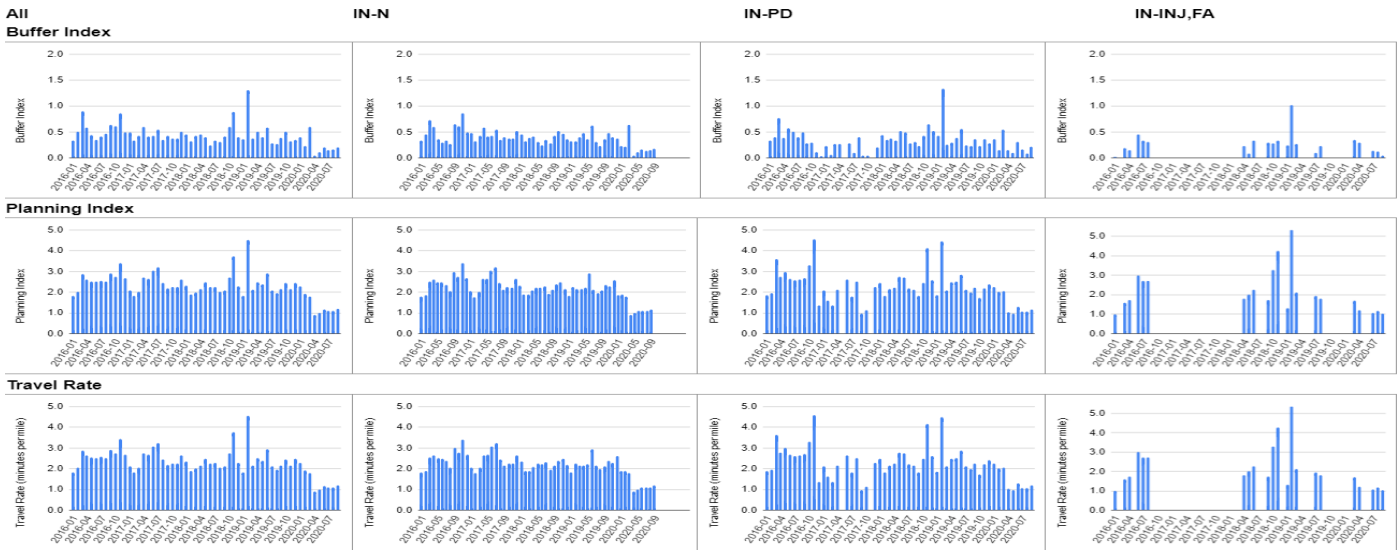
A.10.2.1 Effects of Weather



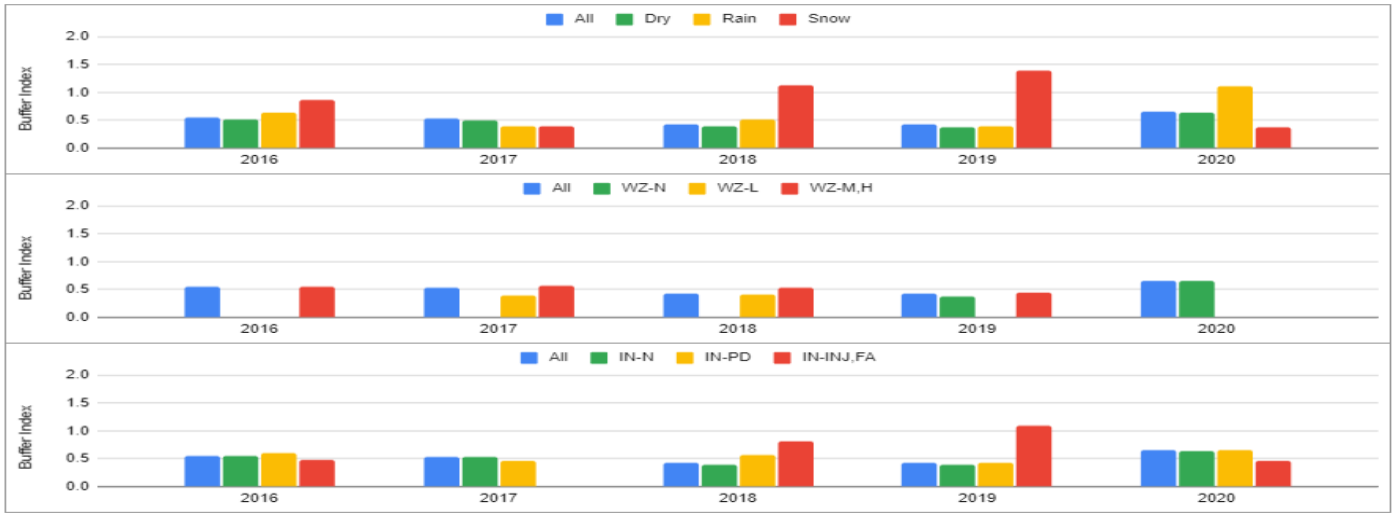
A.10.2.2 Effects of Work Zones



A.10.2.3 Effects of Incidents



A.10.2.4 Yearly Variations




All
Dry
Rain
Snow
Planning Index
0
1
2
3
4
5
2016
2017
2018
2019
2020

All
WZ-N
WZ-L
WZ-M,H
Planning Index
0
1
2
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5
2016
2017
2018
2019
2020

All
IN-N
IN-PD
IN-INJ,FA
Planning Index
0
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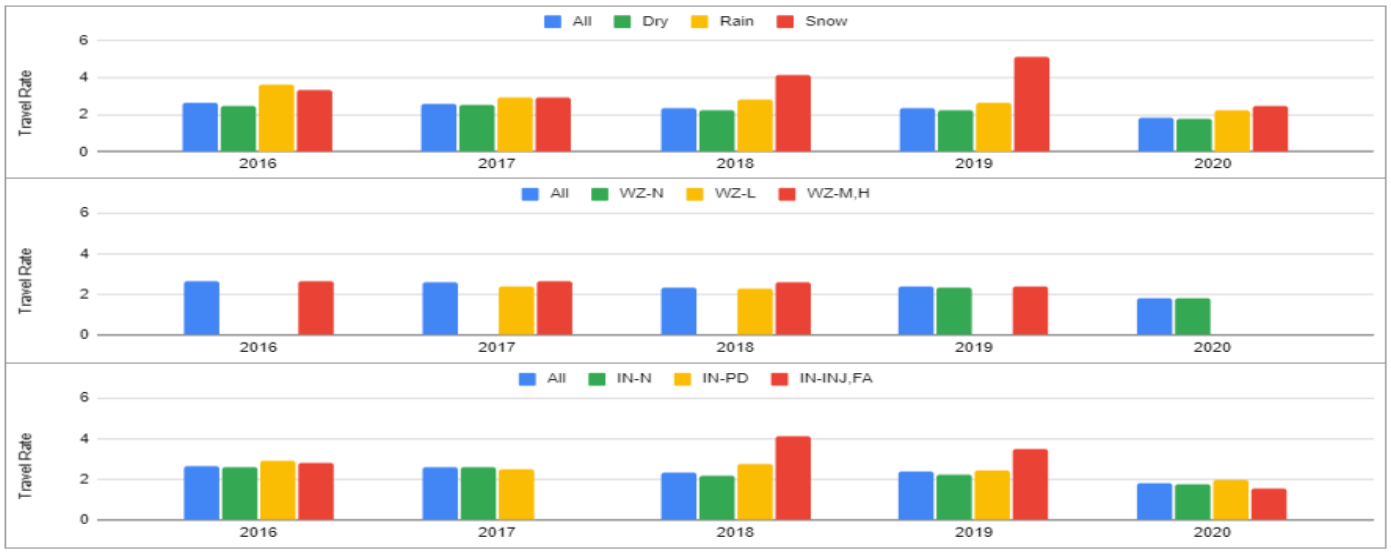
2016
2017
2018
2019
2020


All
Dry
Rain
Snow
Travel Rate
0
2
4
6
2016
2017
2018
2019
2020

All
WZ-N
WZ-L
WZ-M,H
Travel Rate
0
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2016
2017
2018
2019
2020

All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
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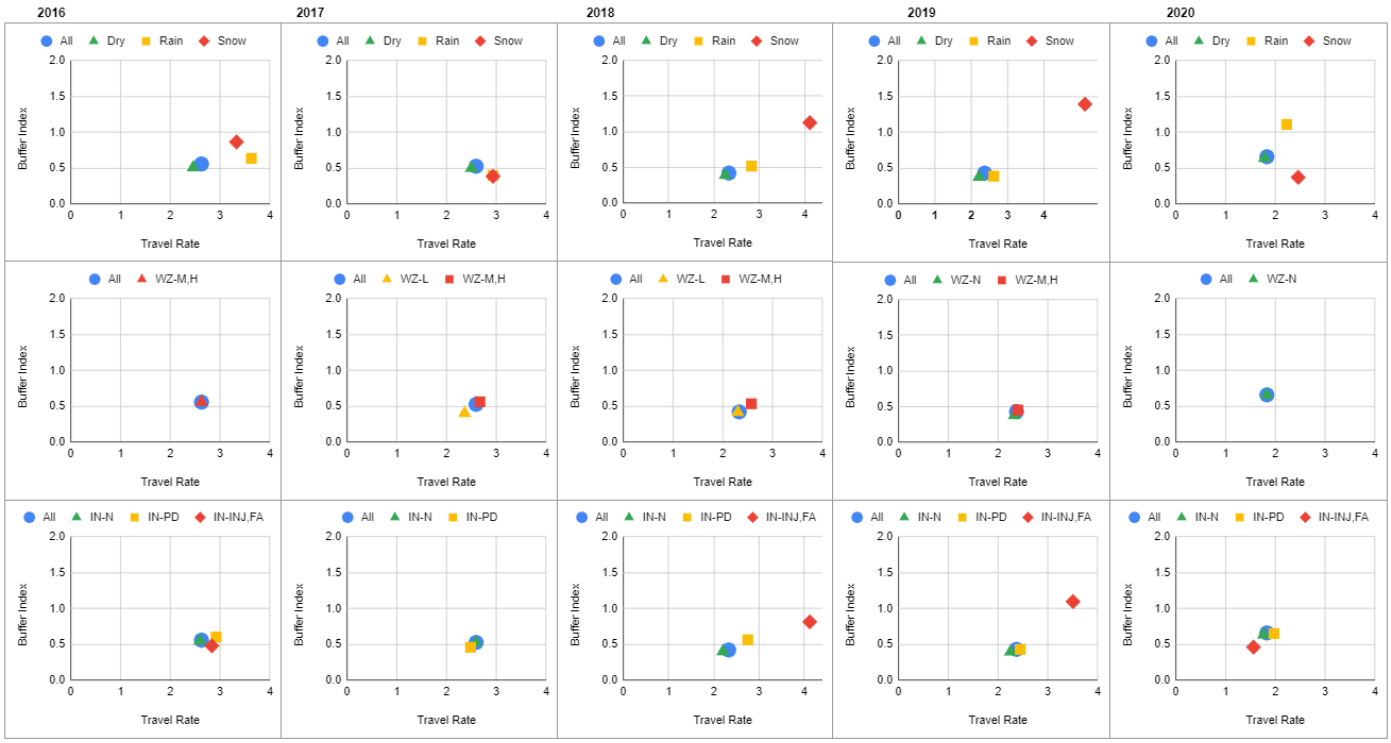
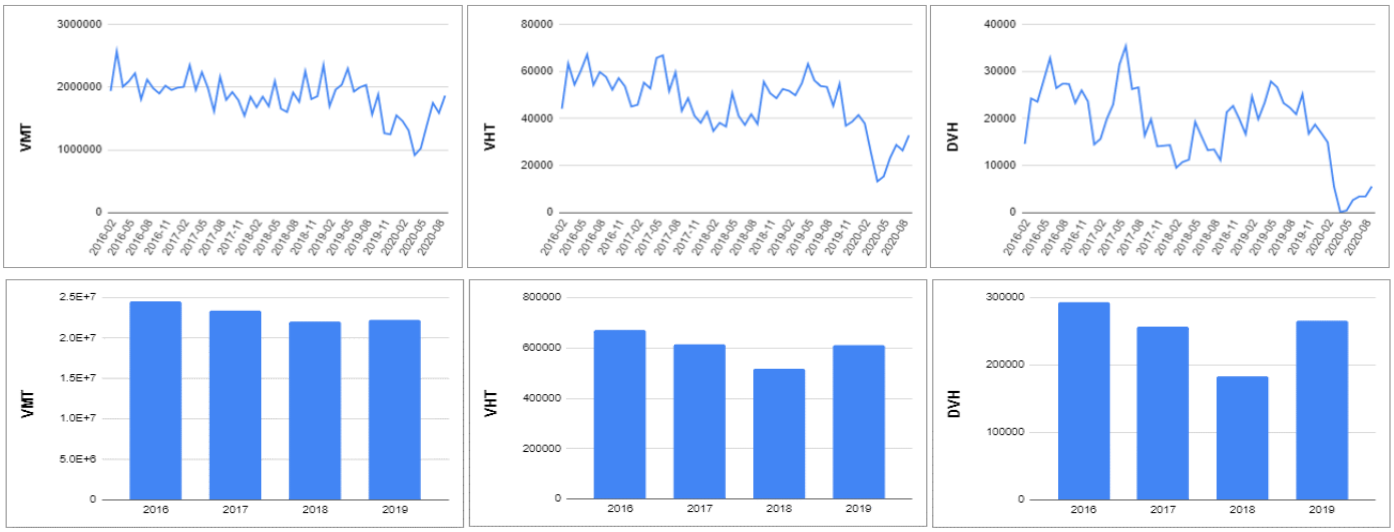
2018
2019
2020

A.10.2.5 Yearly Variations of Combined Index



A.10.2.6 Variations of Traffic-Flow Measures



A.10.2.7 Trends Summary

- The monthly variations of both buffer and planning indices show decreasing trends, i.e., improved reliability, since 2016, while the high values of the planning index indicate significant level of congestion has been continued on this route.
- The monthly/yearly variations of VMT and delayed-vehicle hours also indicate a downward trend from 2016, while 2019 shows an increase in delay, while VMT remains at the same level as in 2018.
- Both snow and incidents have been the major factors affecting the reliability on this route.

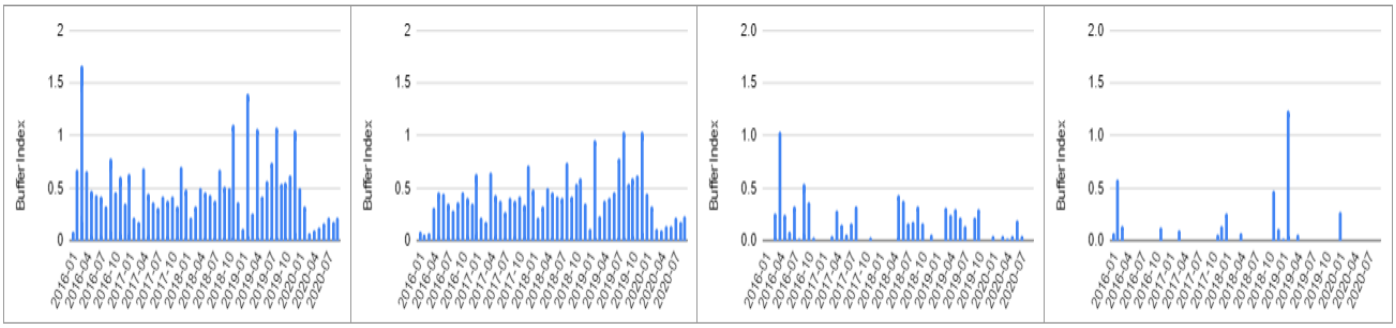
A.11 I-494 CORRIDOR 2 (I-35E – I-94, EASTBOUND/WESTBOUND)

A.11.1 I-494 EASTBOUND Route 2 (I-35E -> I-94, Afternoon Peak)

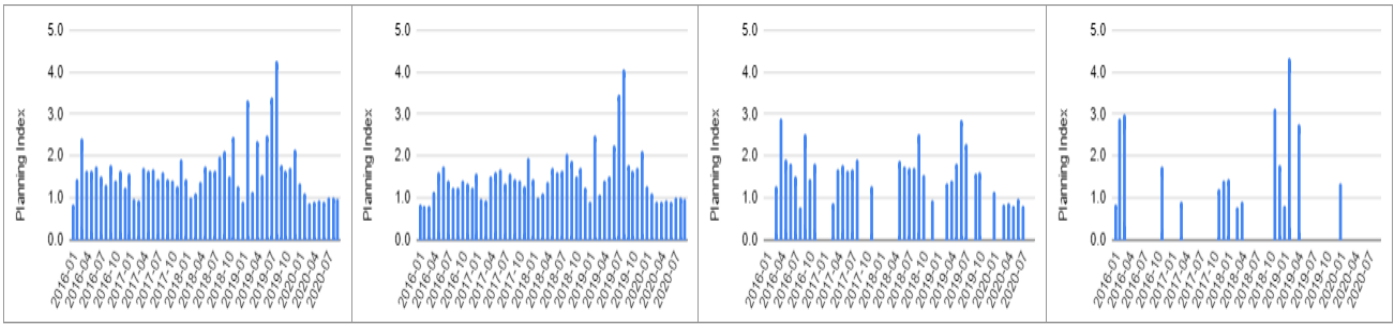
A.11.1.1 Effects of Weather

All | Dry | Rain | Snow

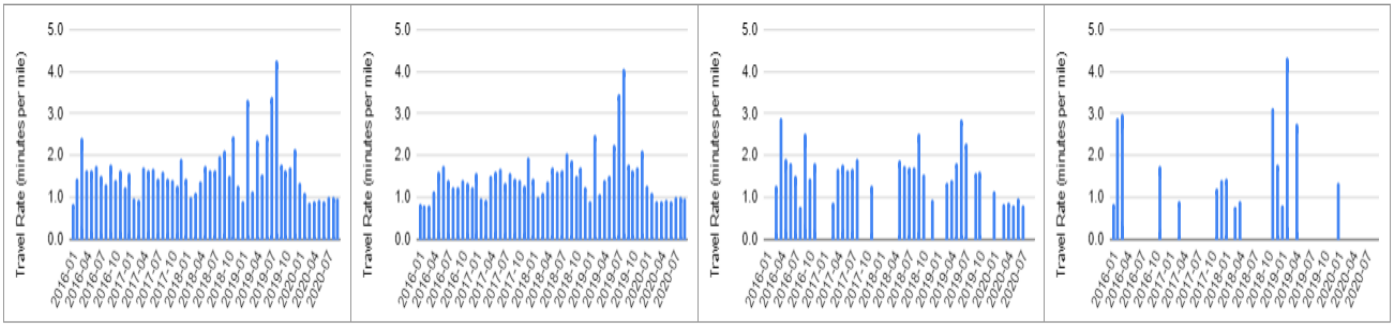
Buffer Index



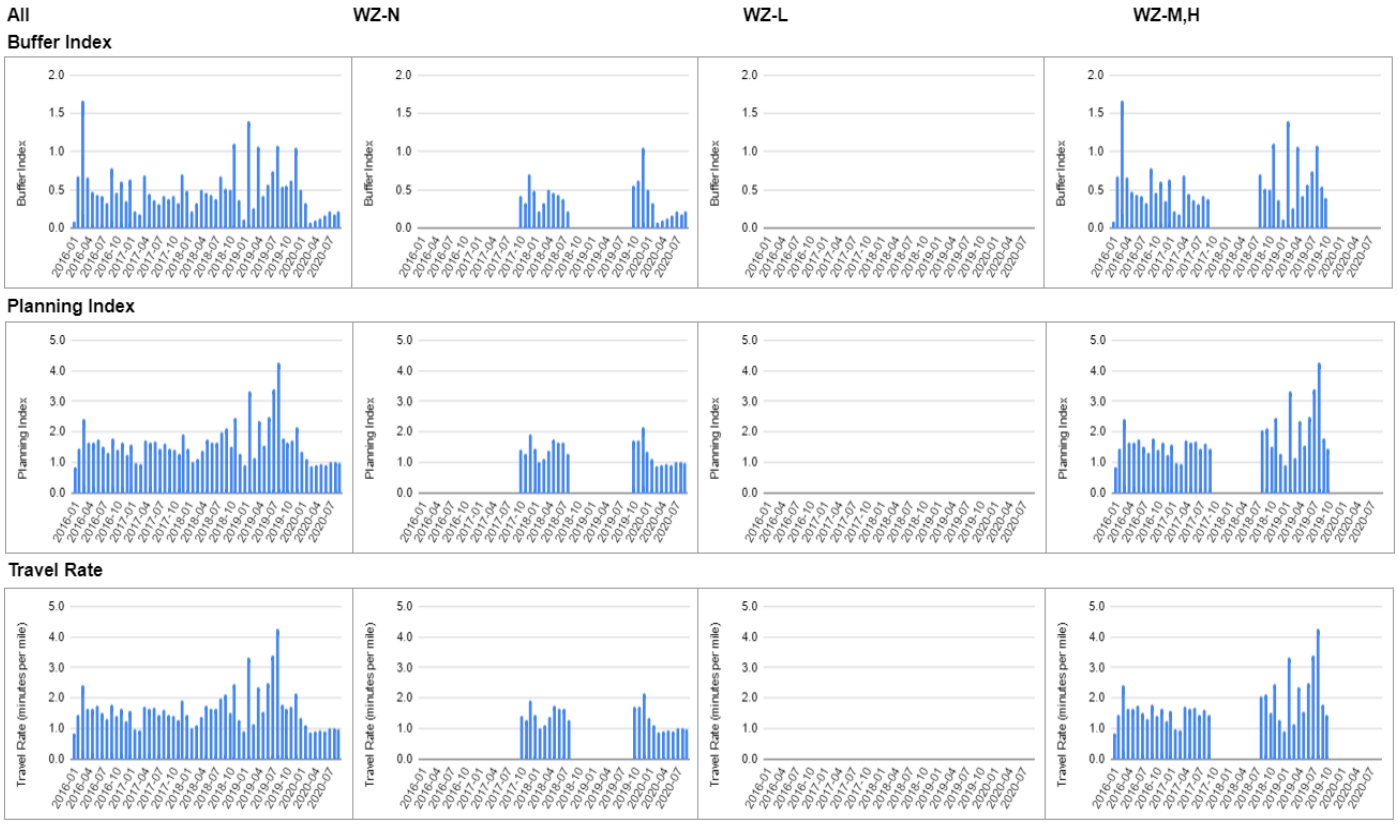
Planning Index



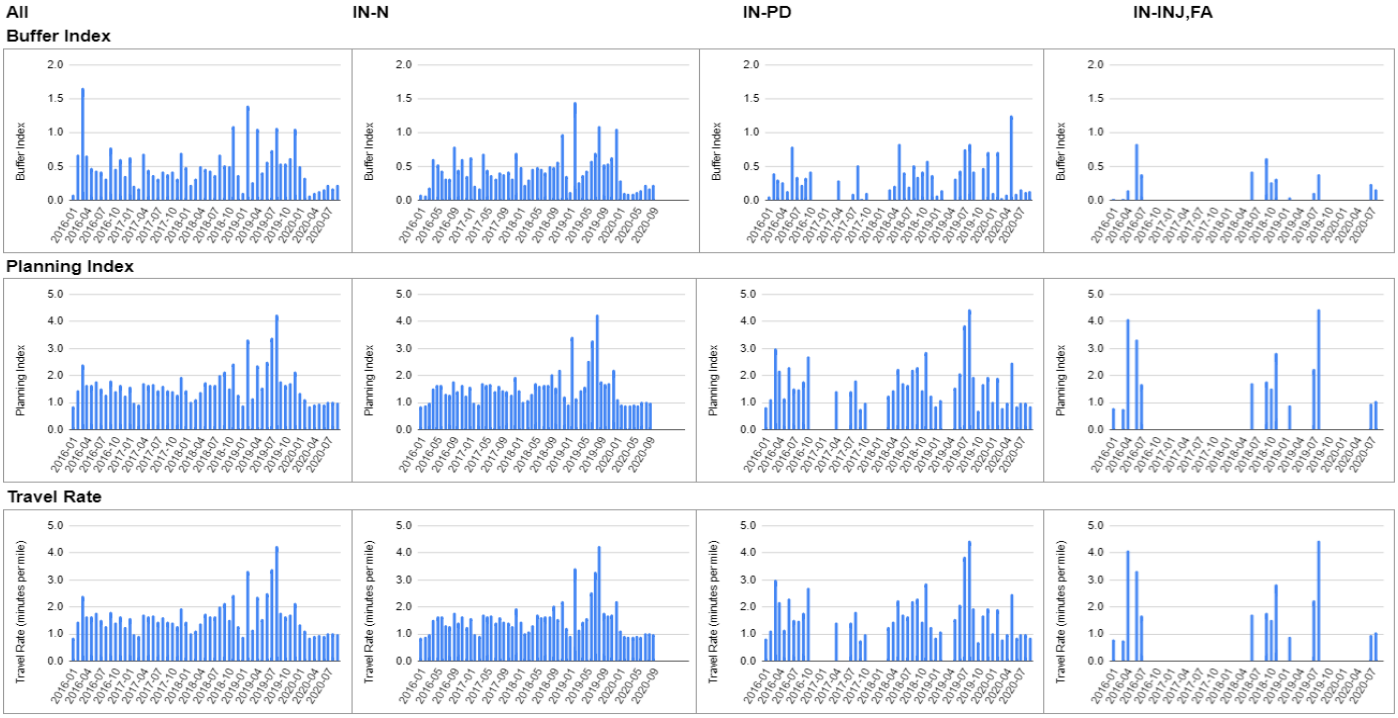
Travel Rate



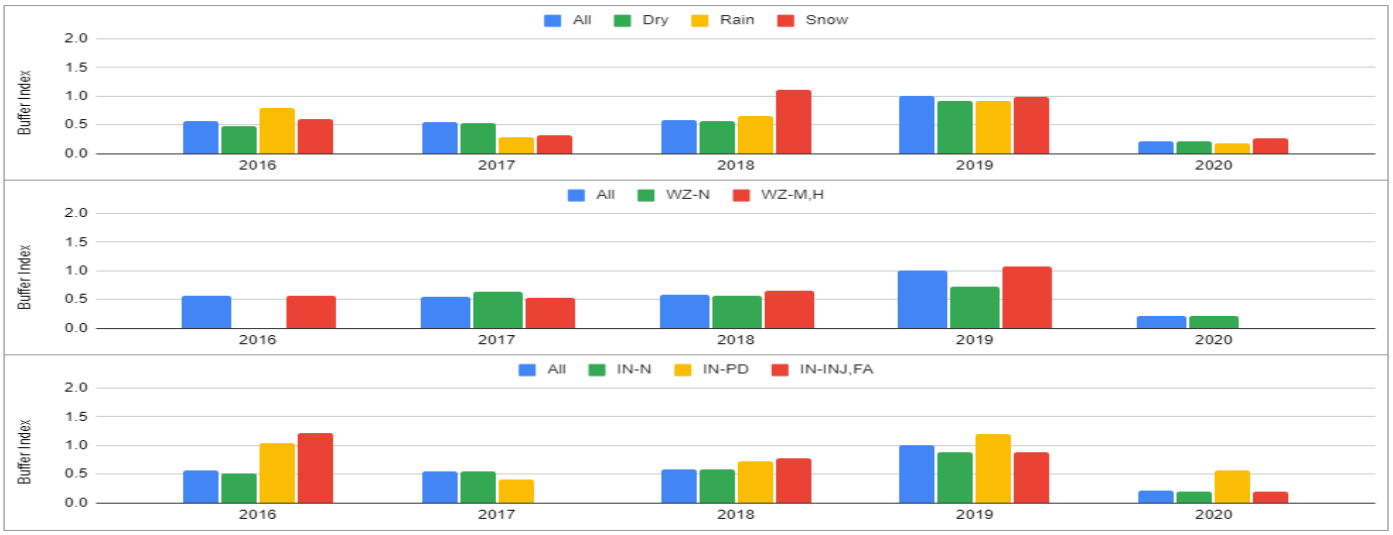
A.11.1.2 Effects of Work Zones

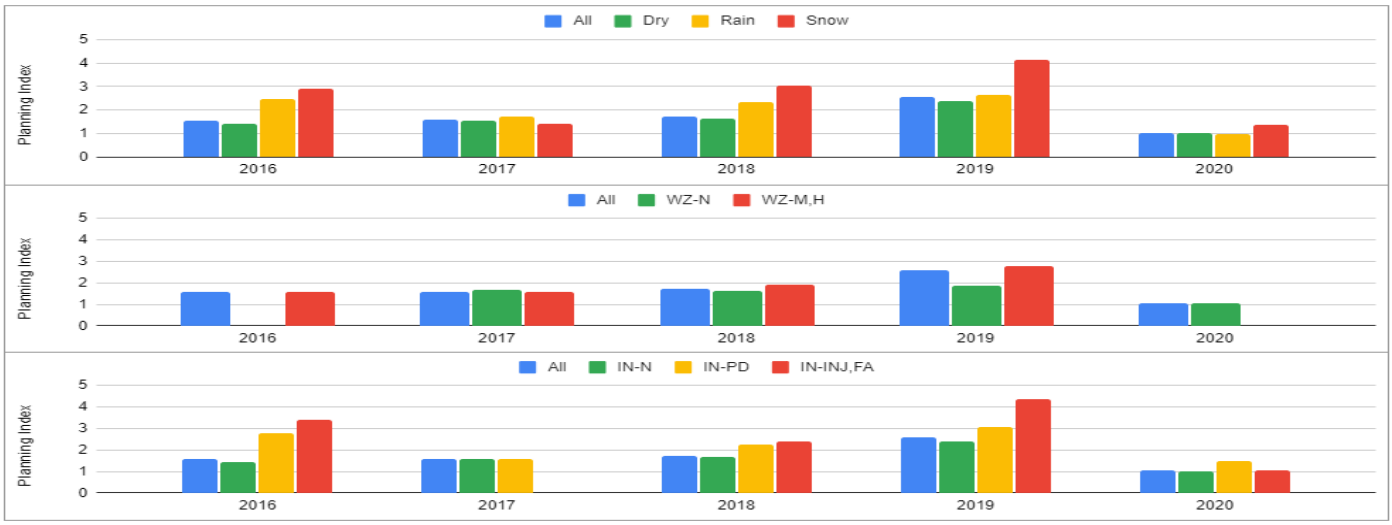


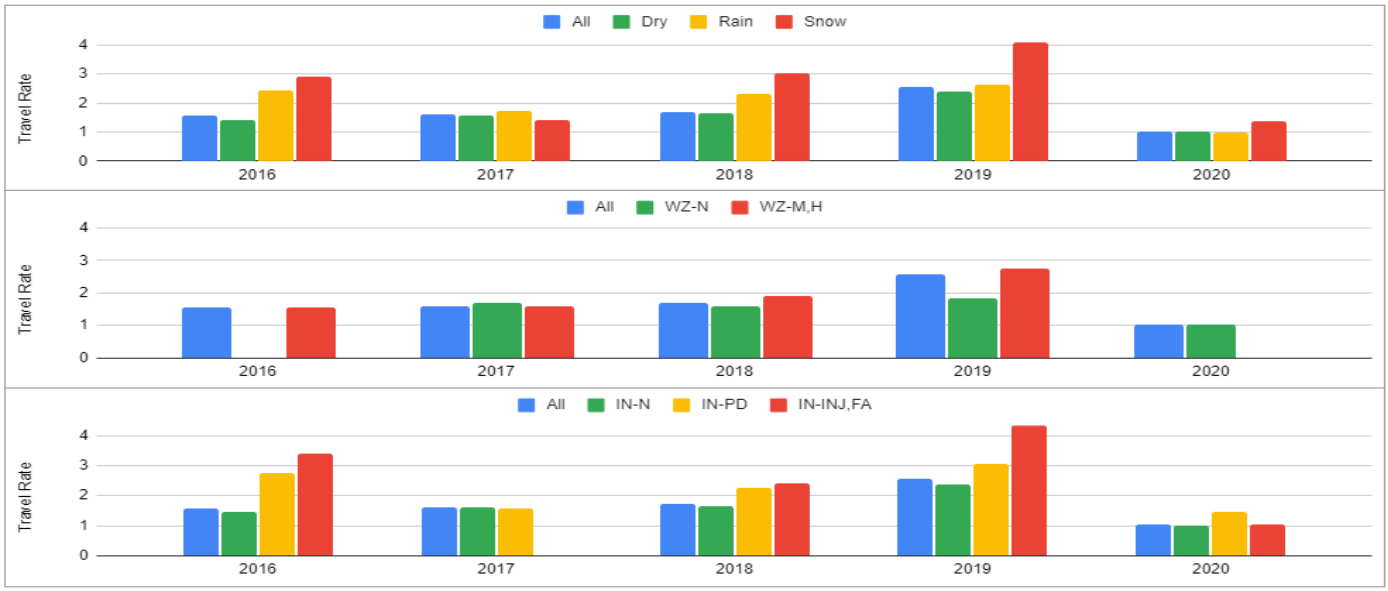
A.11.1.3 Effects of Incidents



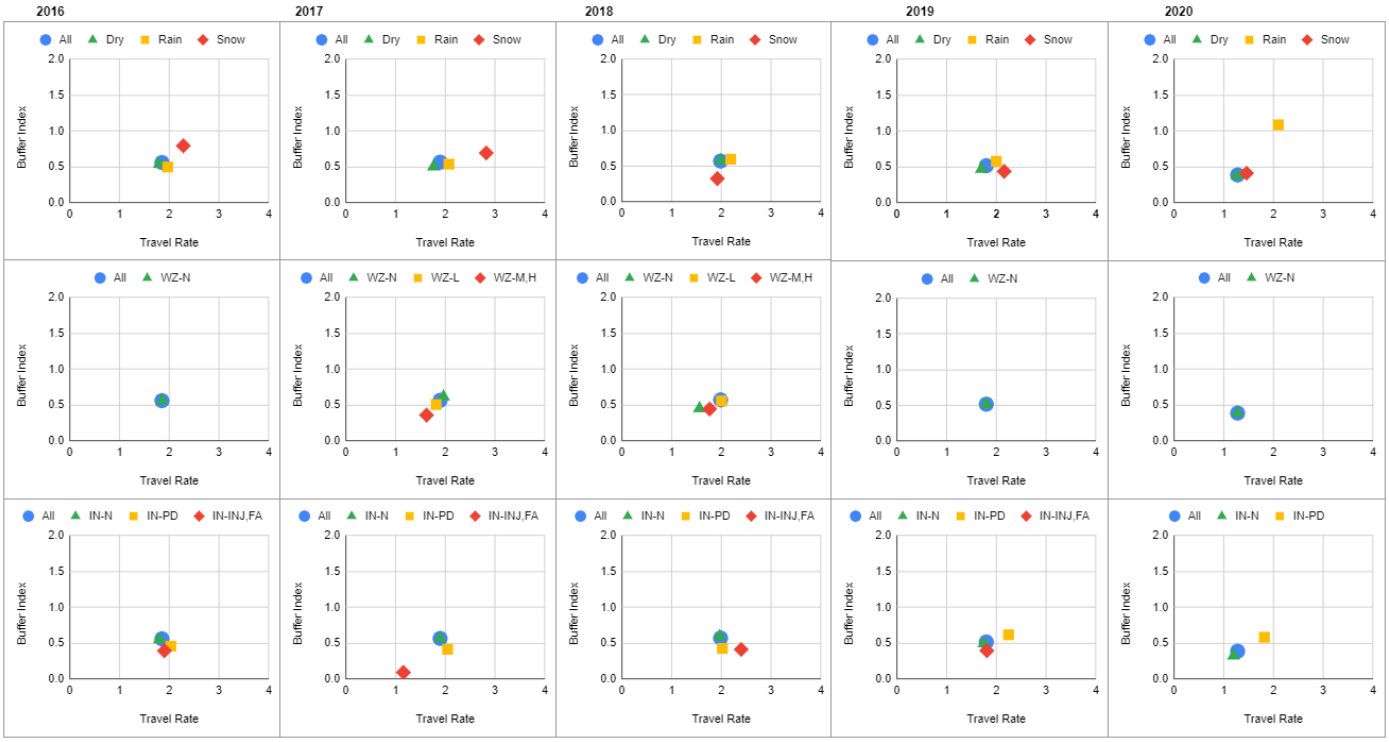
A.11.1.4 Yearly Variations



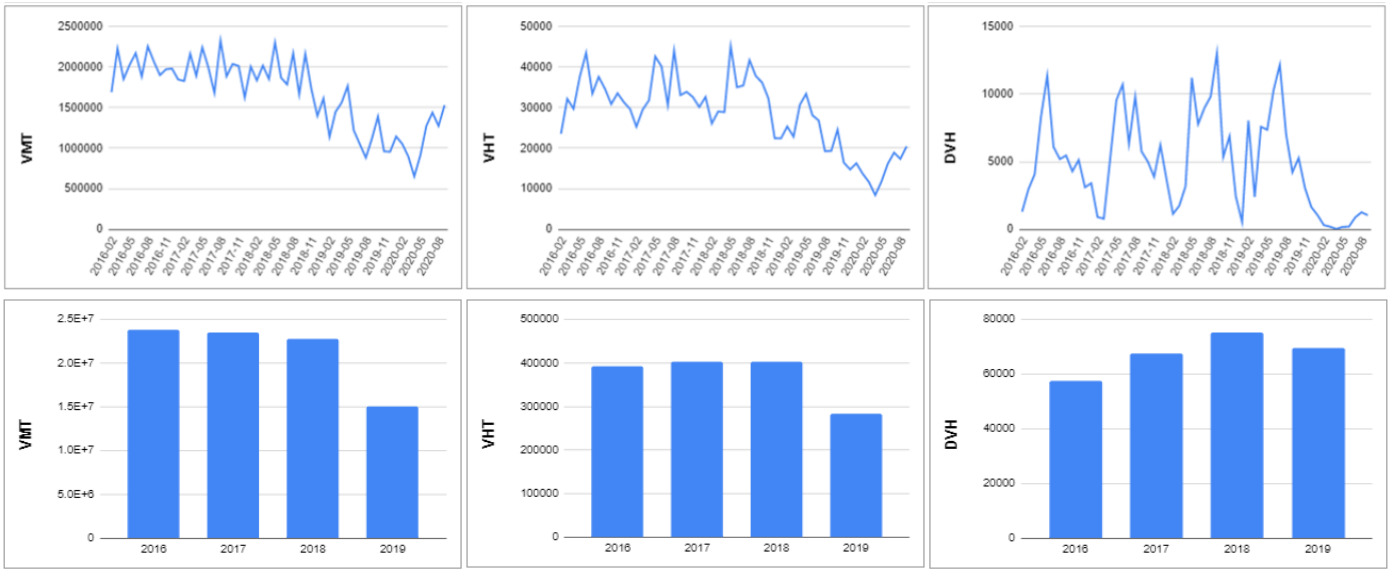




A.11.1.5 Yearly Variations of Combined Index



A.11.1.6 Variations of Traffic-Flow Measures

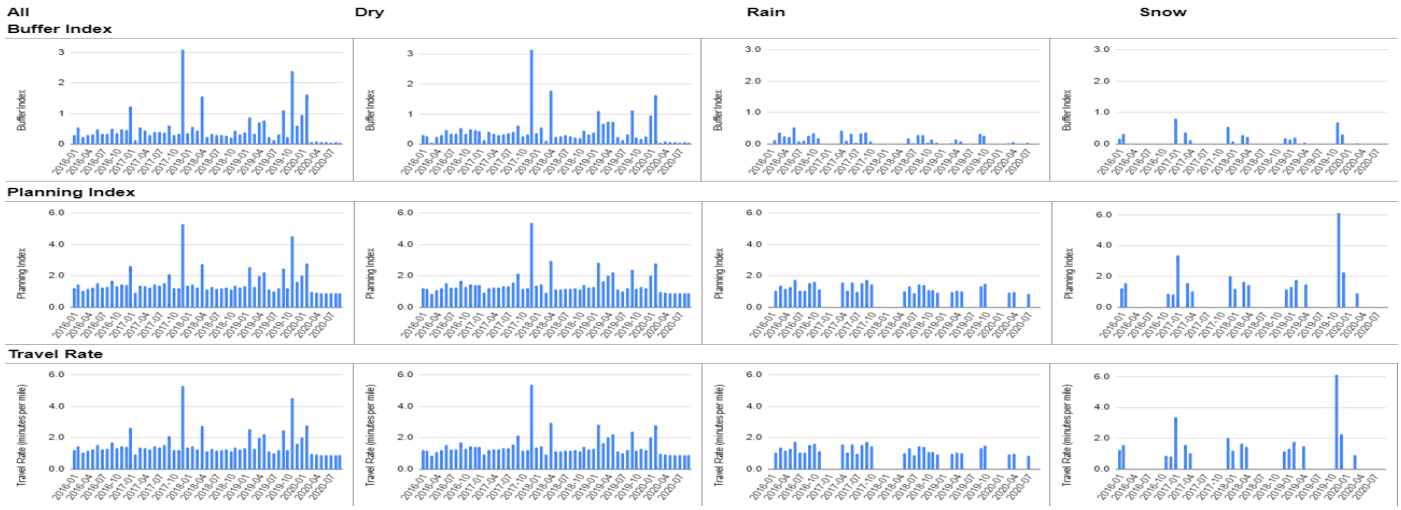


A.11.1.7 Trends Summary

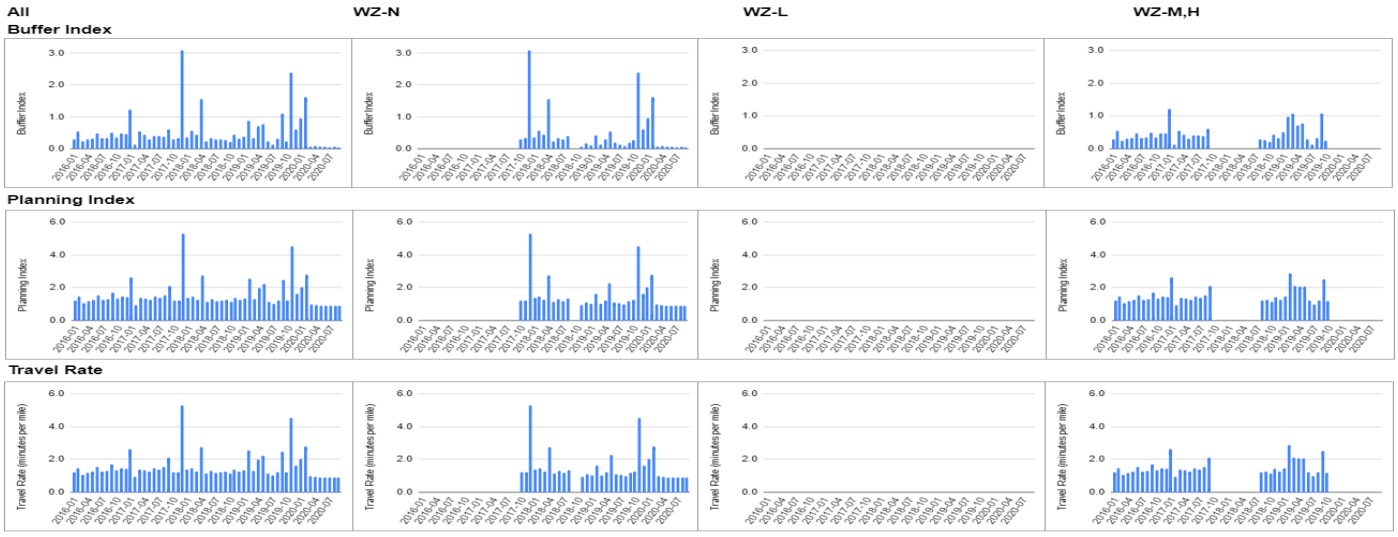
- The monthly/yearly variations of VMT show a clearly decreasing trend, while the delayed-vehicle hours have a fluctuating pattern, which could also be observed in the monthly variations of both buffer and planning indices.
- Incidents have been the main factor contributing to the congestion, while the effects of snow on the reliability have not been consistent.

A.11.2 I-494 WESTBOUND Route 2 (I-94 -> I-35E, Morning Peak)

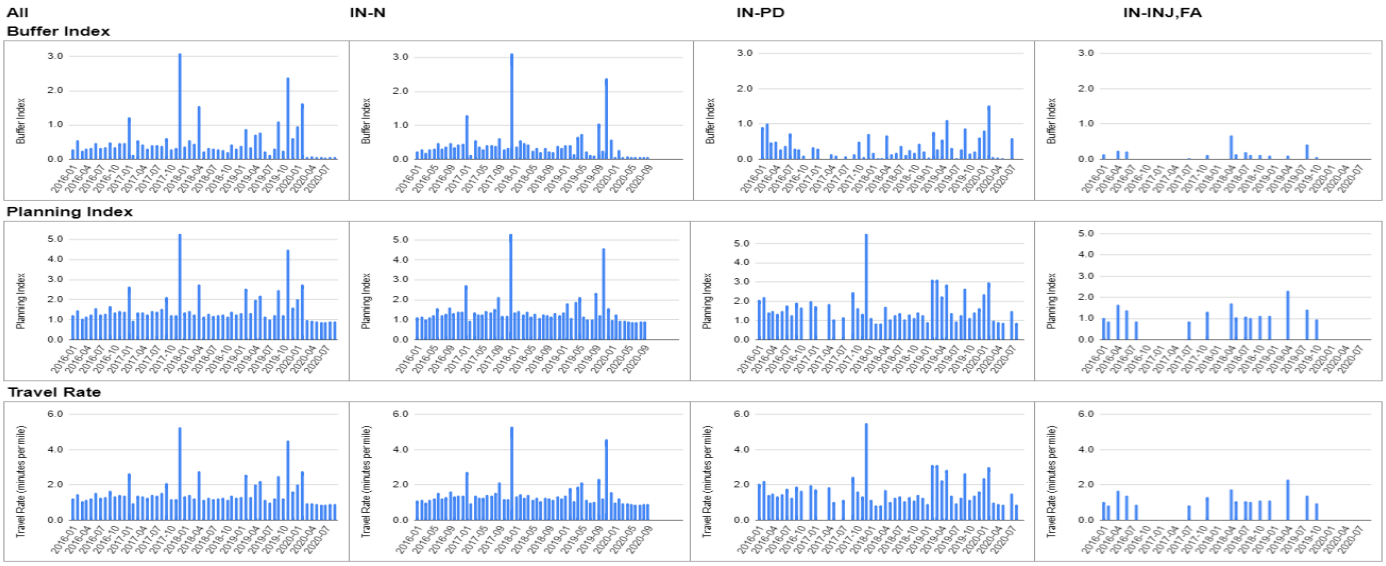
A.11.2.1 Effects of Weather



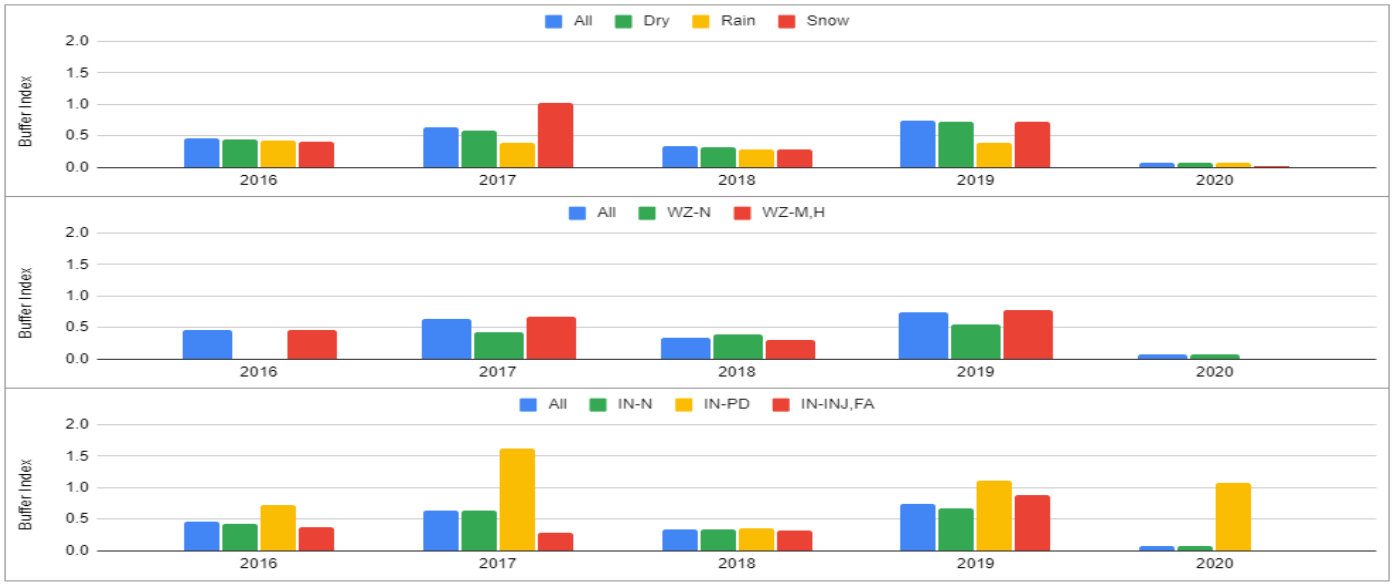
A.11.2.2 Effects of Work Zones

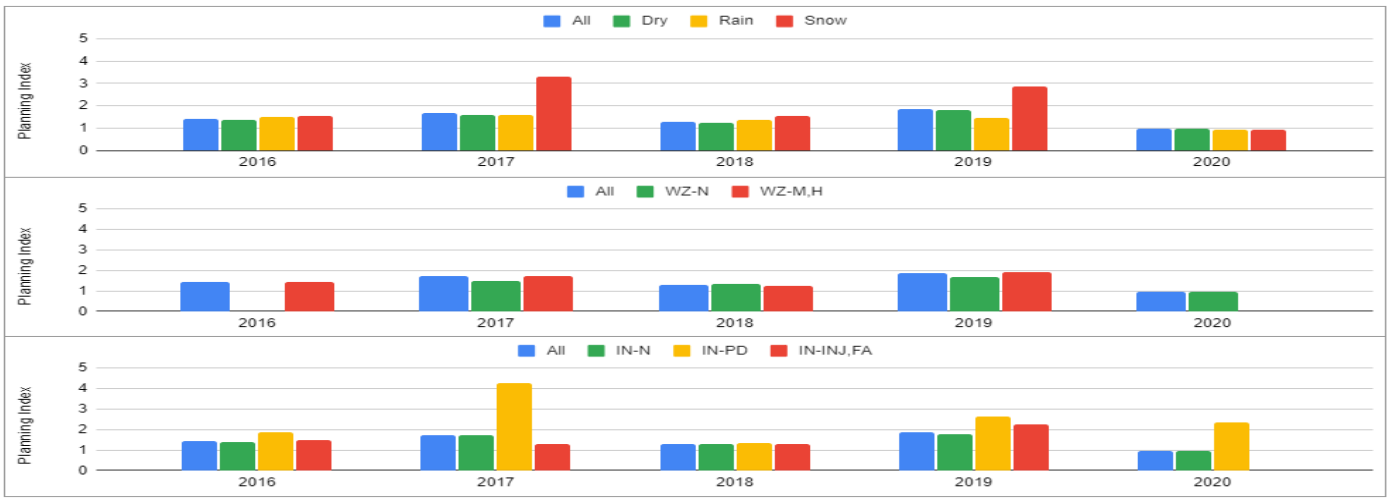


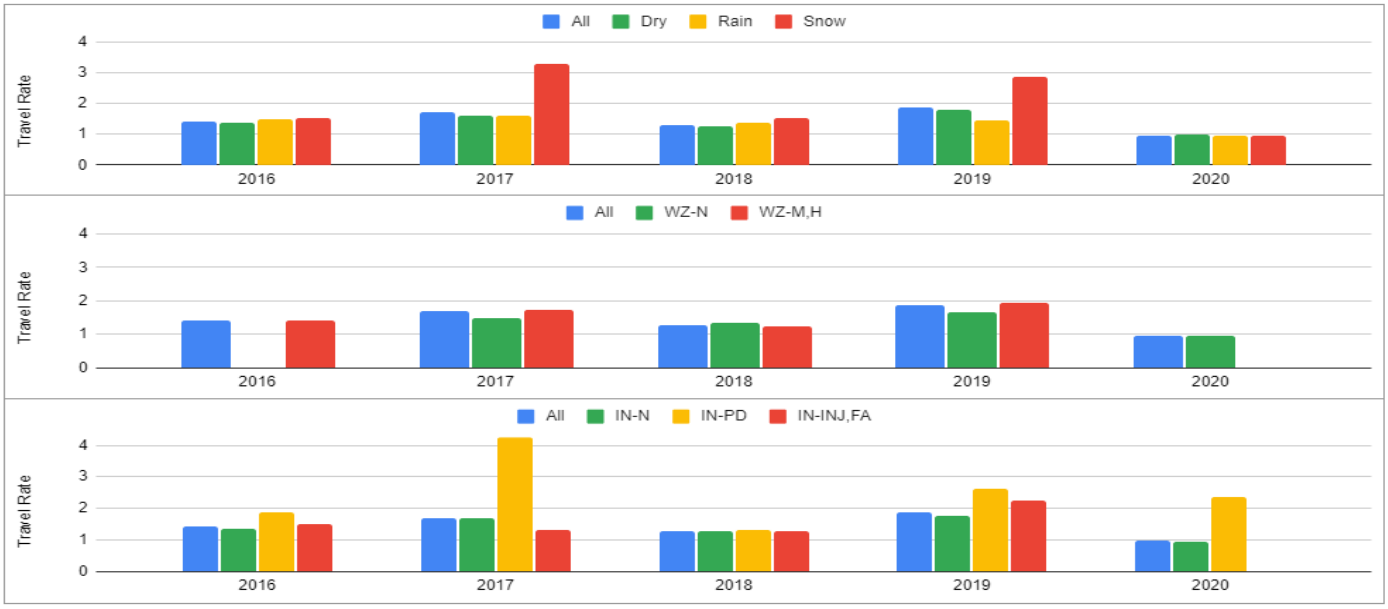
A.11.2.3 Effects of Incidents



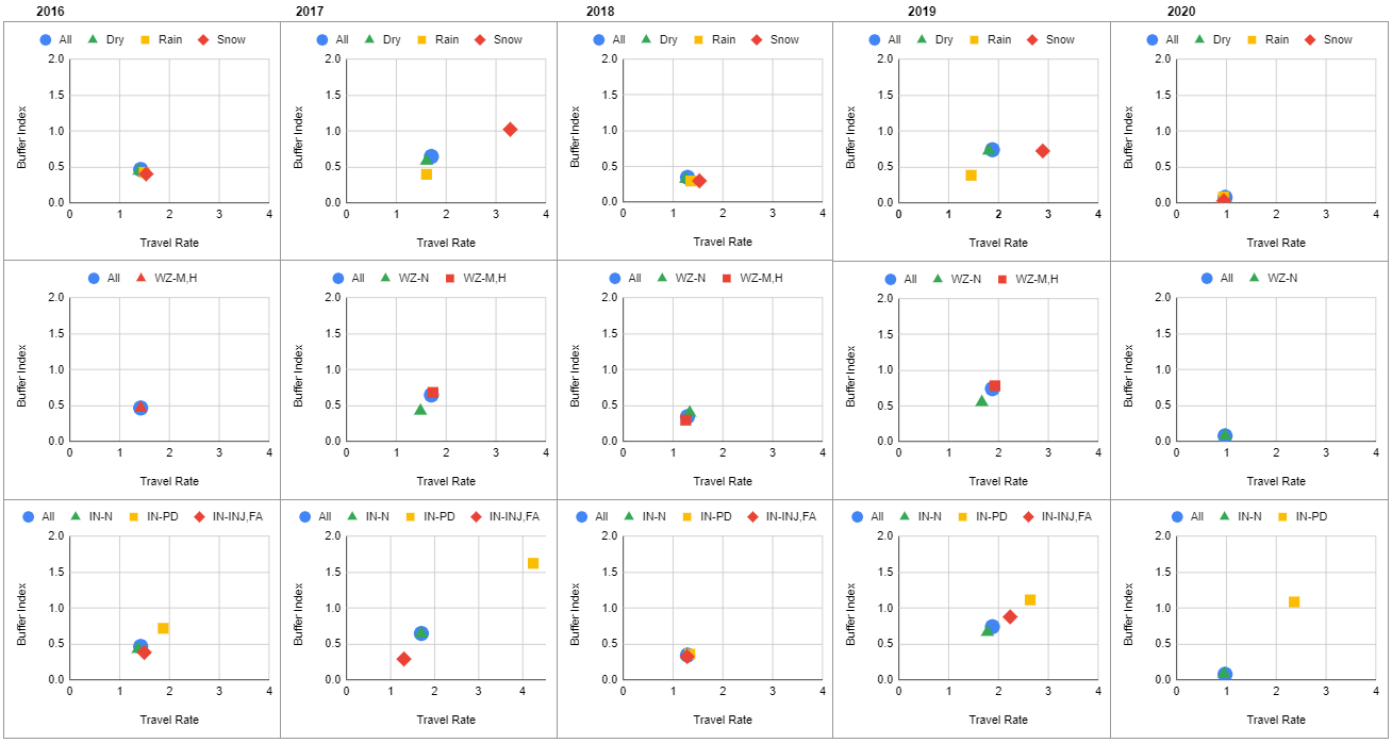
A.11.2.4 Yearly Variations



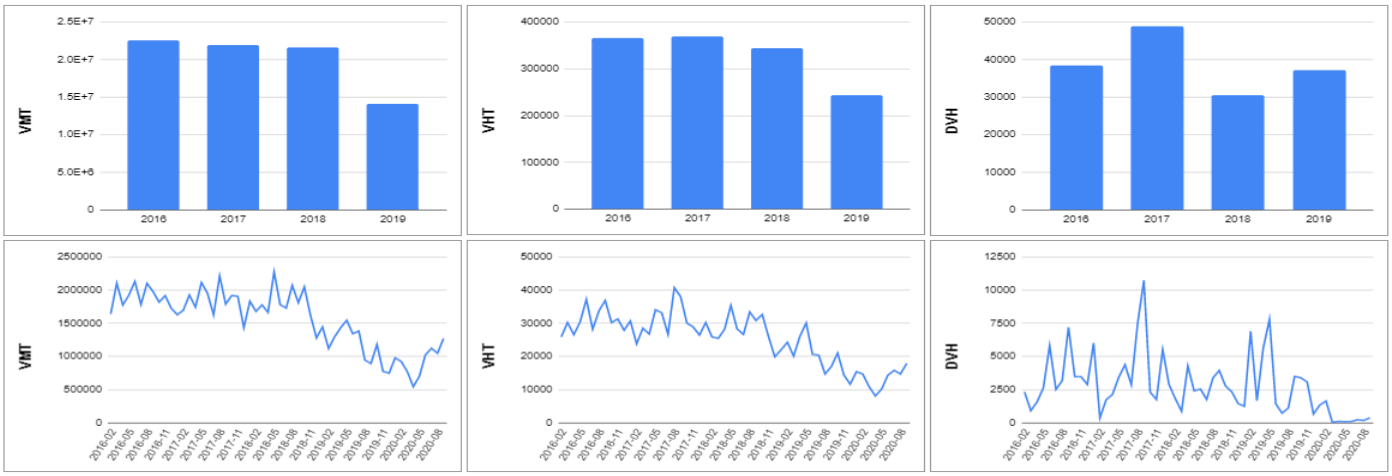

All
Dry
Rain
Snow
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020


All
Dry
Rain
Snow
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.11.2.5 Yearly Variations of Combined Index



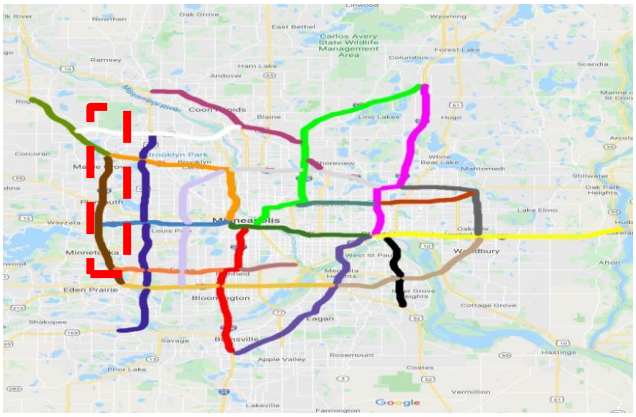
A.11.2.6 Variations of Traffic-Flow Measures



A.11.2.7 Trends Summary

- The variation patterns of the traffic-flow measures clearly indicate a downward trend on both traffic demand and delays.
- The reliability variation patterns show relatively stable trends in both travel-time variability and congestion levels, while those measures have been substantially affected by snow and incidents.

A.12 I-494 CORRIDOR 3 (TH 212 – I-694, NORTHBOUND/SOUTHBOUND)

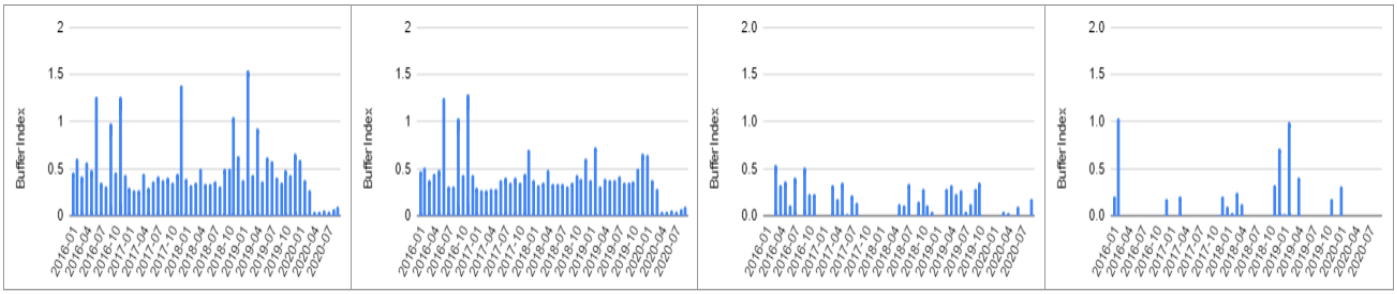


A.12.1 I-494 NORTHBOUND Route 3 (TH 212 -> I-694, Afternoon Peak)

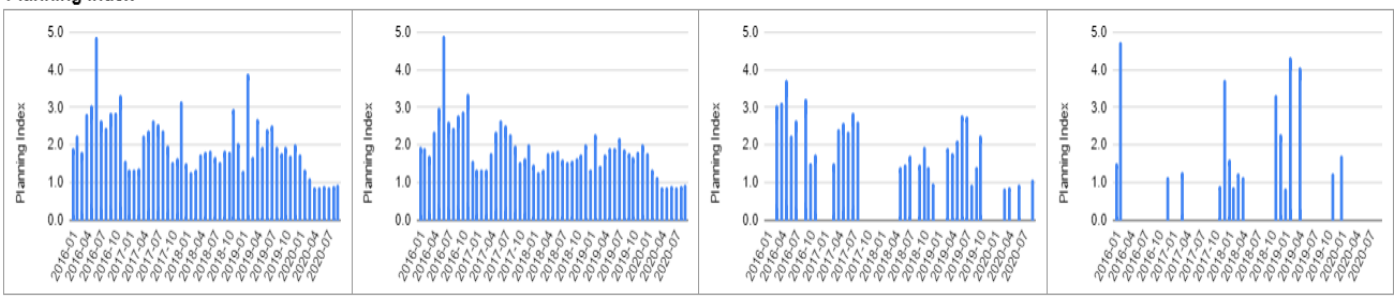
A.12.1.1 Effects of Weather

All | Dry | Rain | Snow

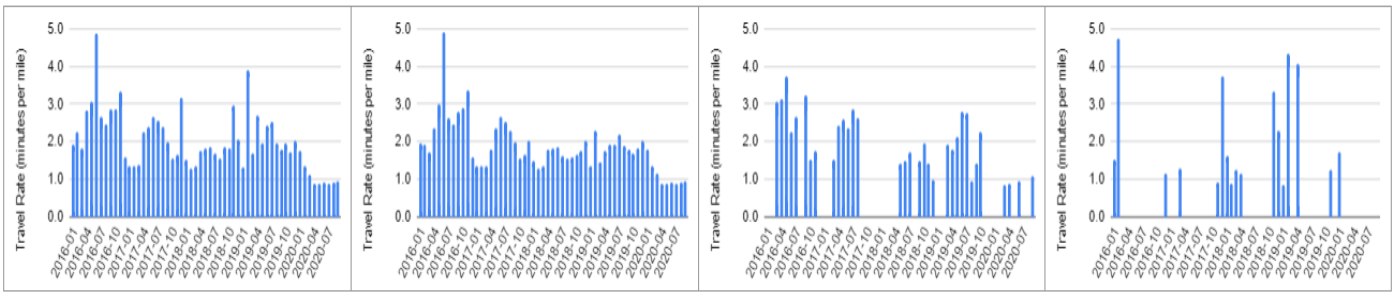
Buffer Index



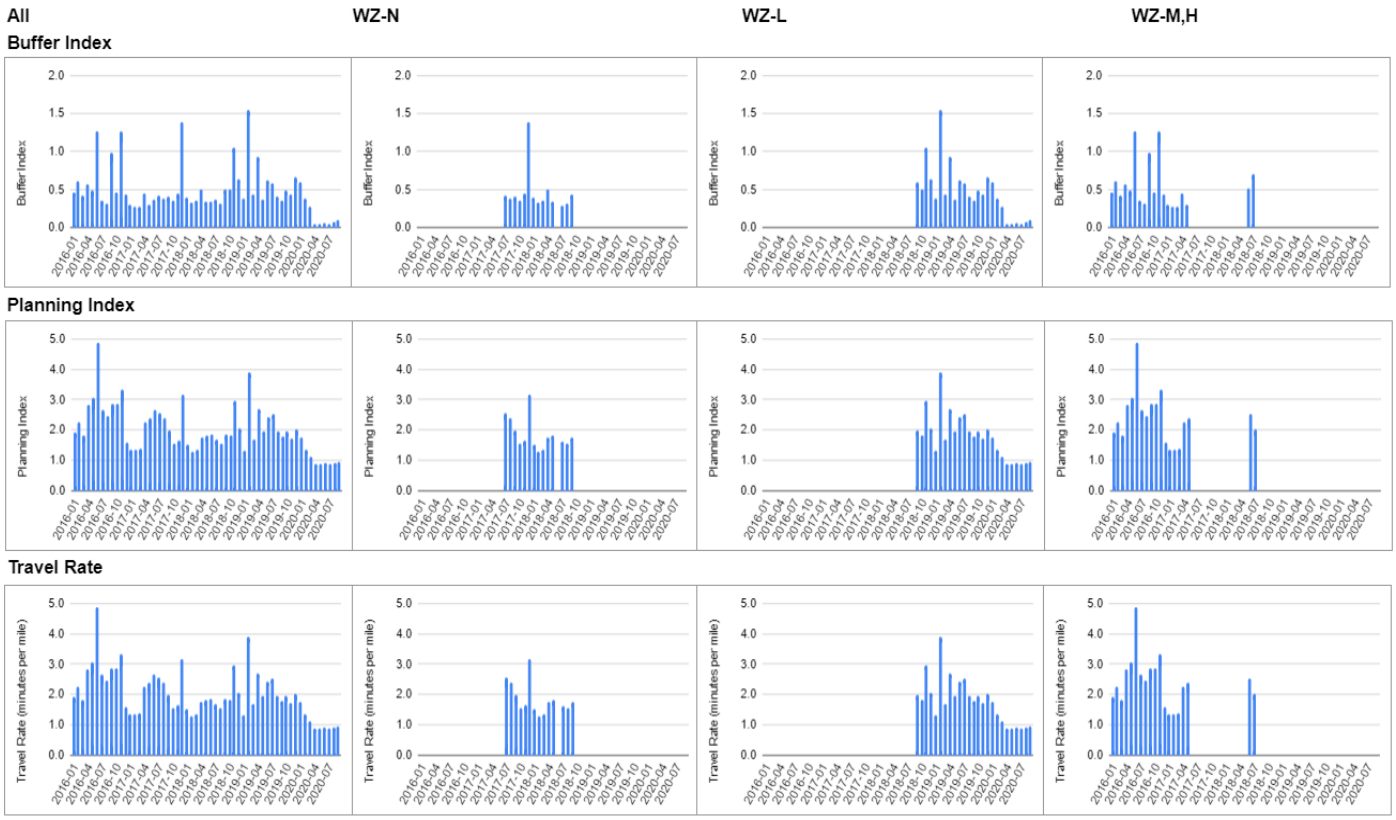
Planning Index



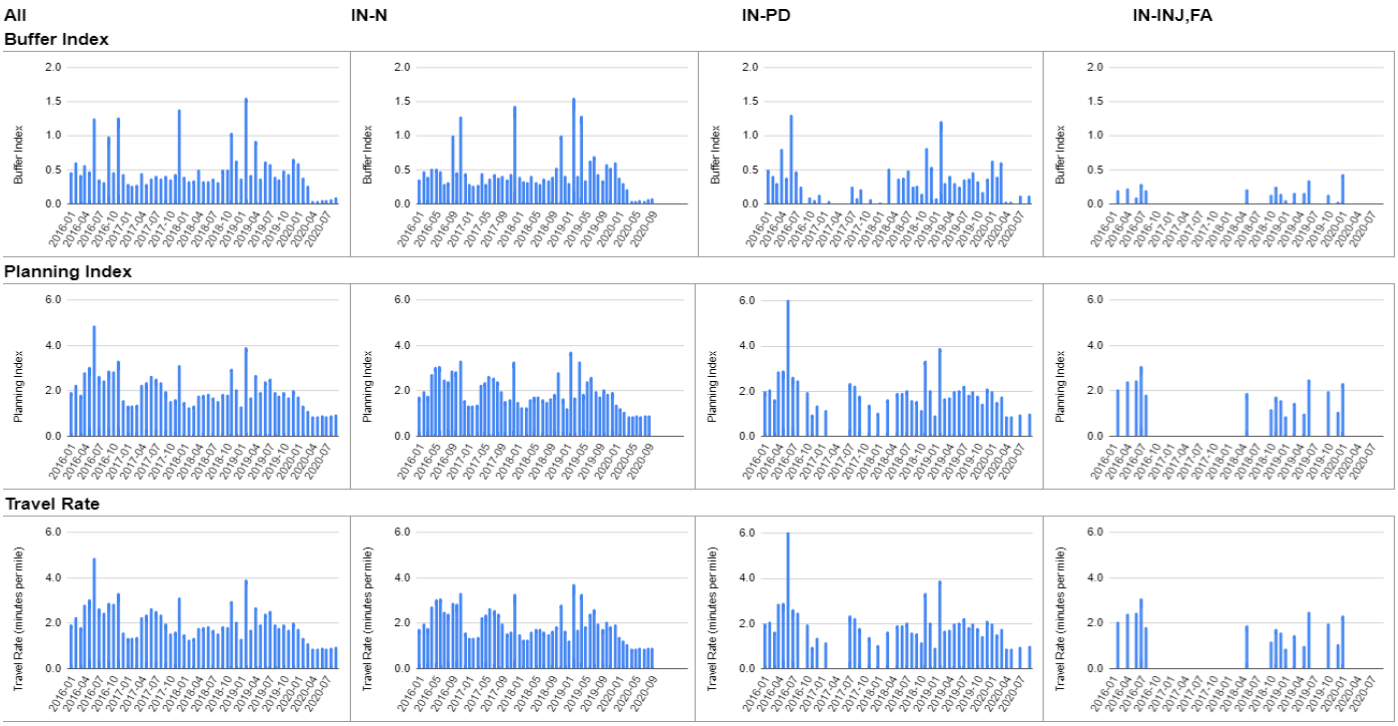
Travel Rate



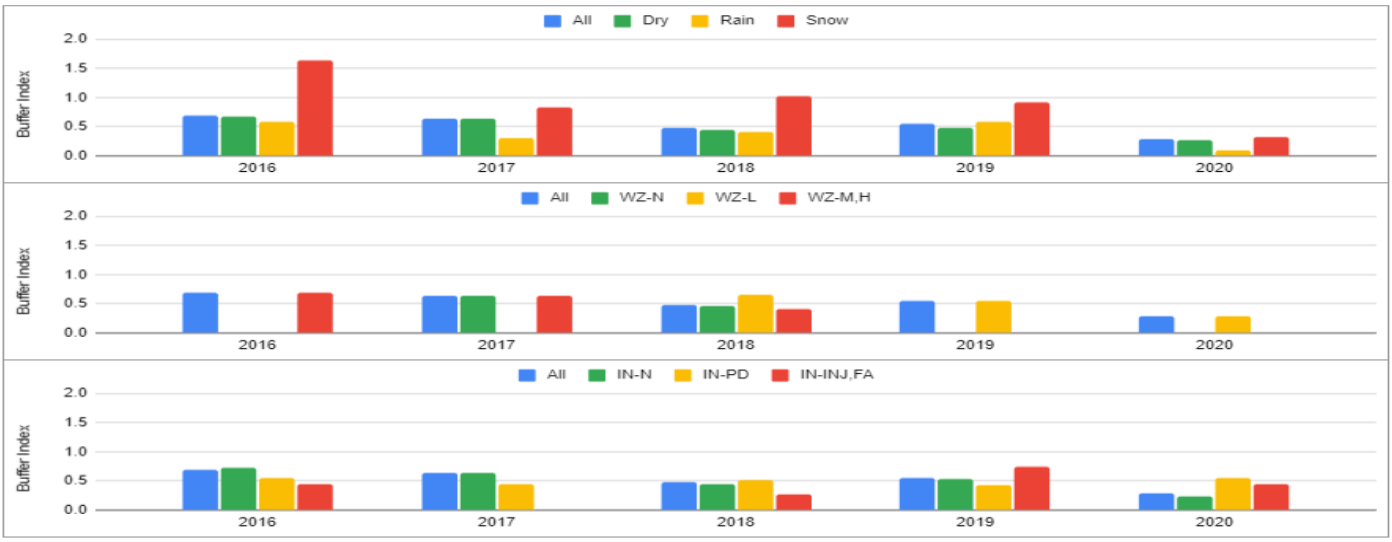
A.12.1.2 Effects of Work Zones



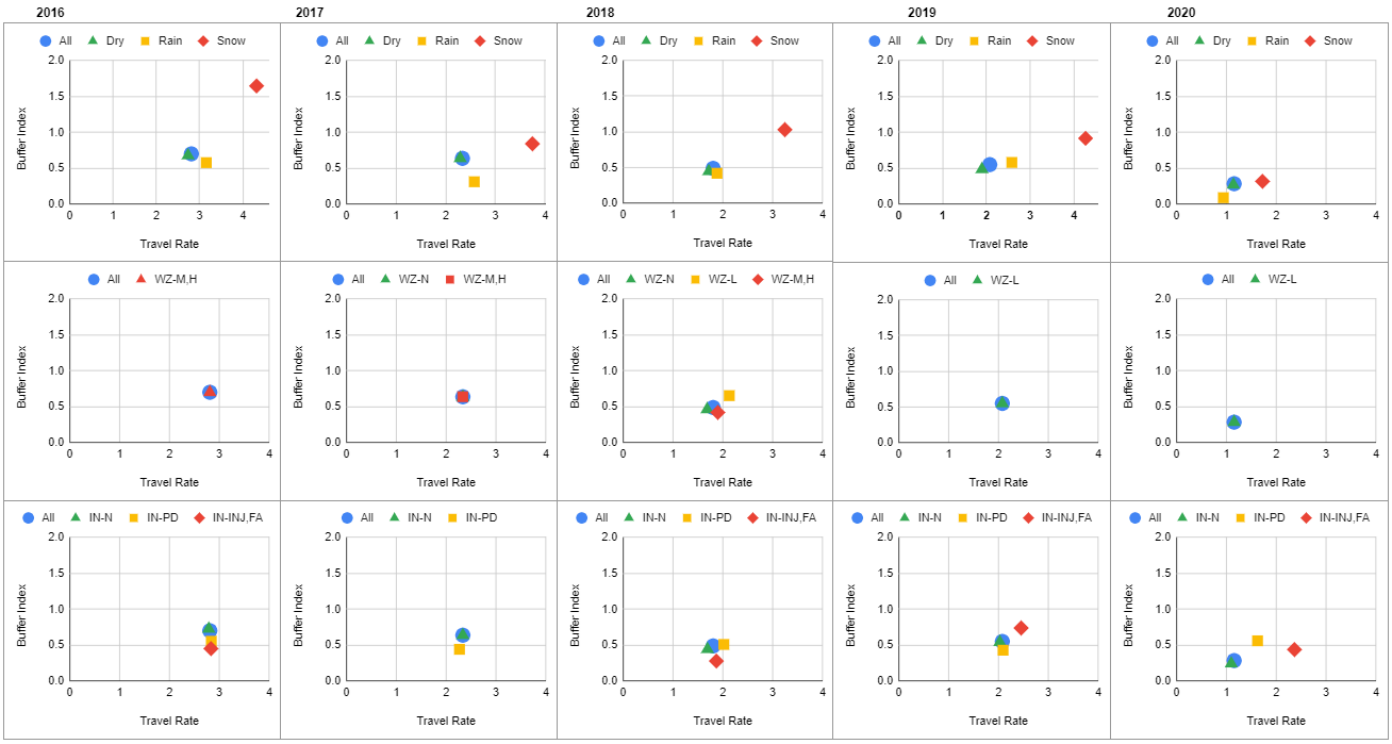
A.12.1.3 Effects of Incidents



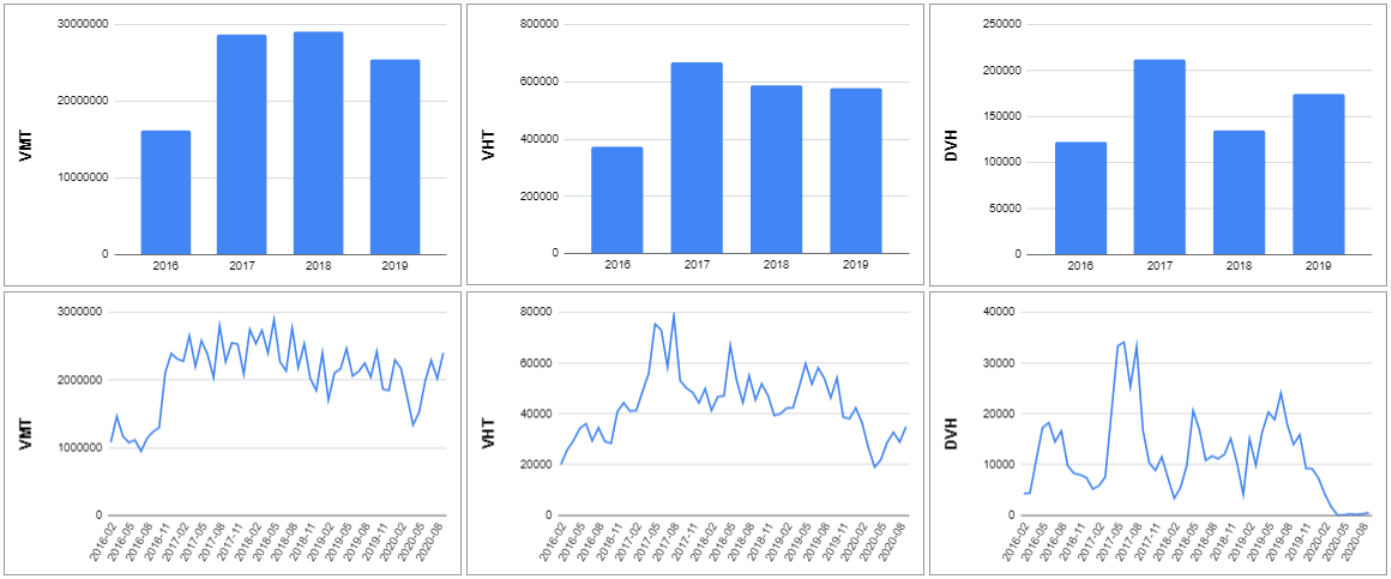
A.12.1.4 Yearly Variations



A.12.1.5 Yearly Variations of Combined Index



A.12.1.6 Variations of Traffic-Flow Measures

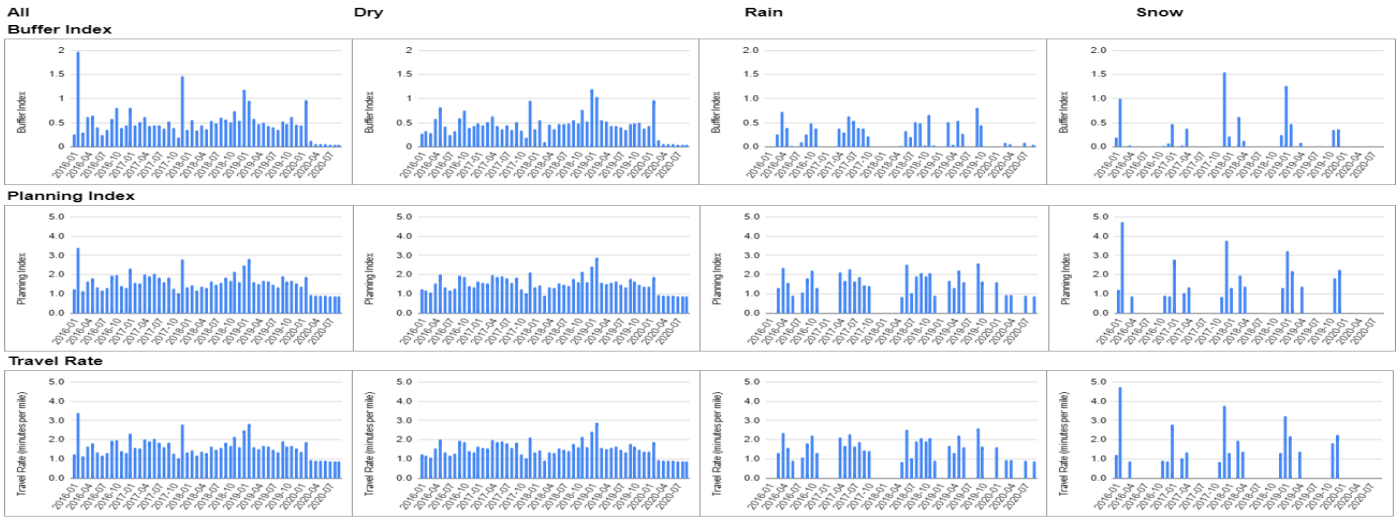


A.12.1.7 Trends Summary

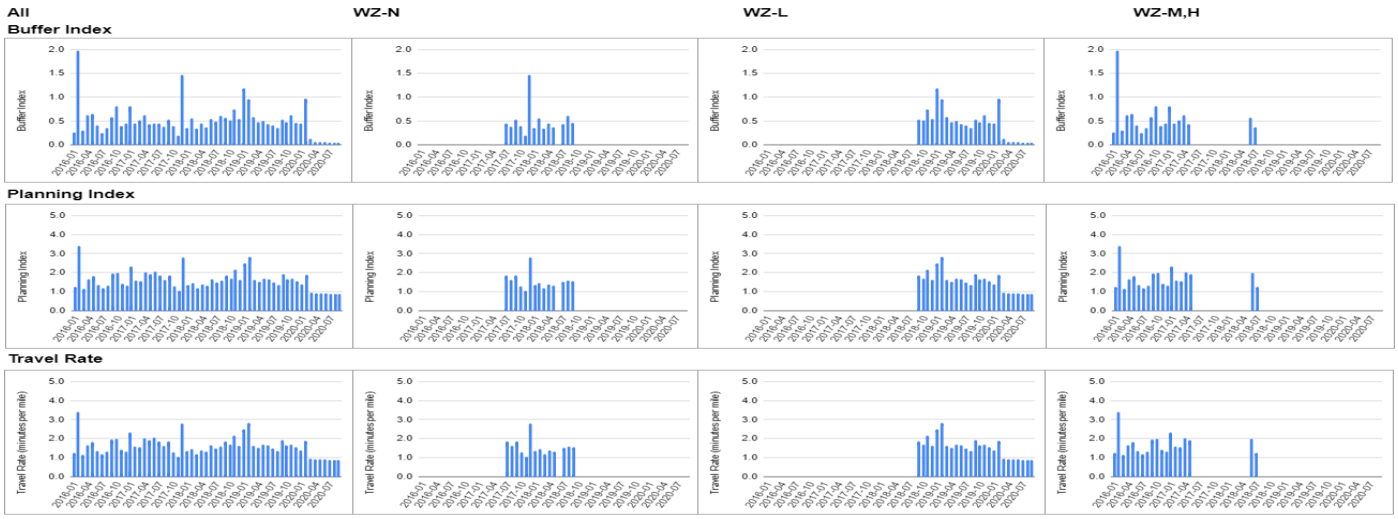
- The VMT and the overall variation trends of delays show downward trends since 2017, while the monthly measures of delayed-vehicle hours fluctuate significantly, indicating substantial variations in travel times.
- The monthly variations of both buffer and planning indices clearly show an upward trend from 2017, i.e., high levels of travel-time variability and congestion.
- Snow appears to be the major factor affecting the variability of travel times.

A.12.2 I-494 SOUTHBOUND Route 3 (I-694 -> TH 212, Morning Peak)

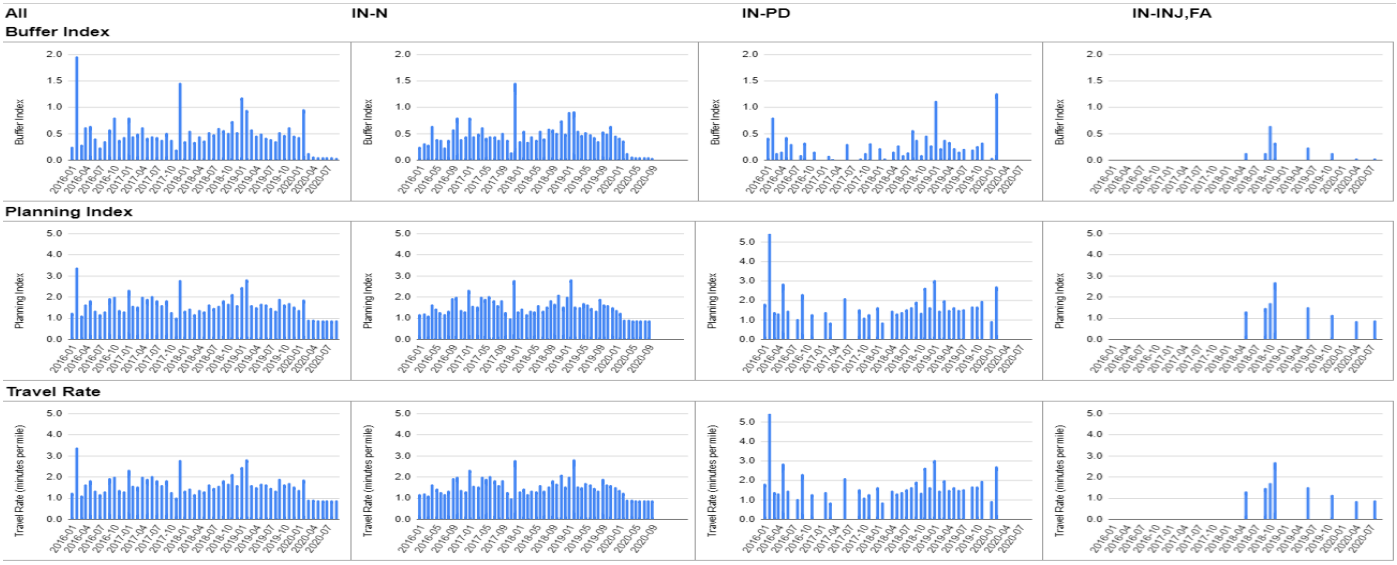
A.12.2.1 Effects of Weather



A.12.2.2 Effects of Work Zones

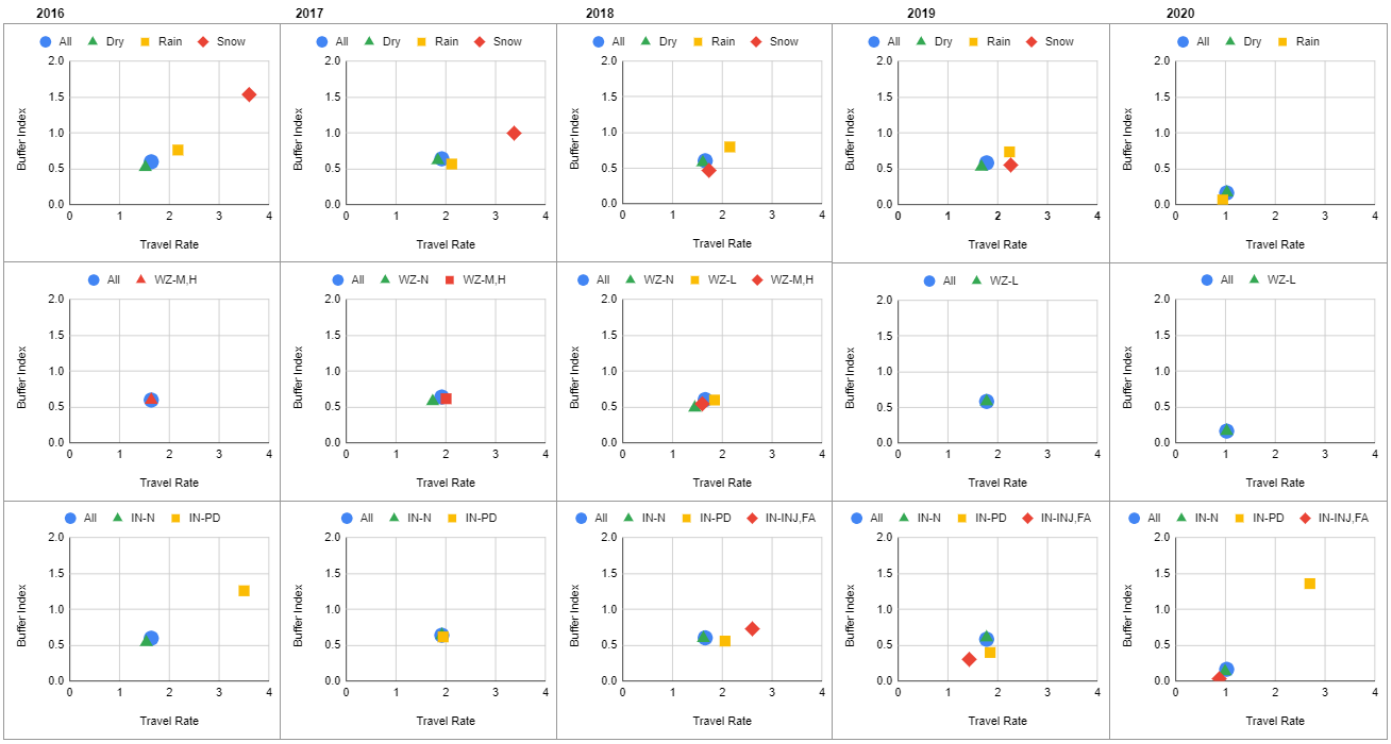


A.12.2.3 Effects of Incidents

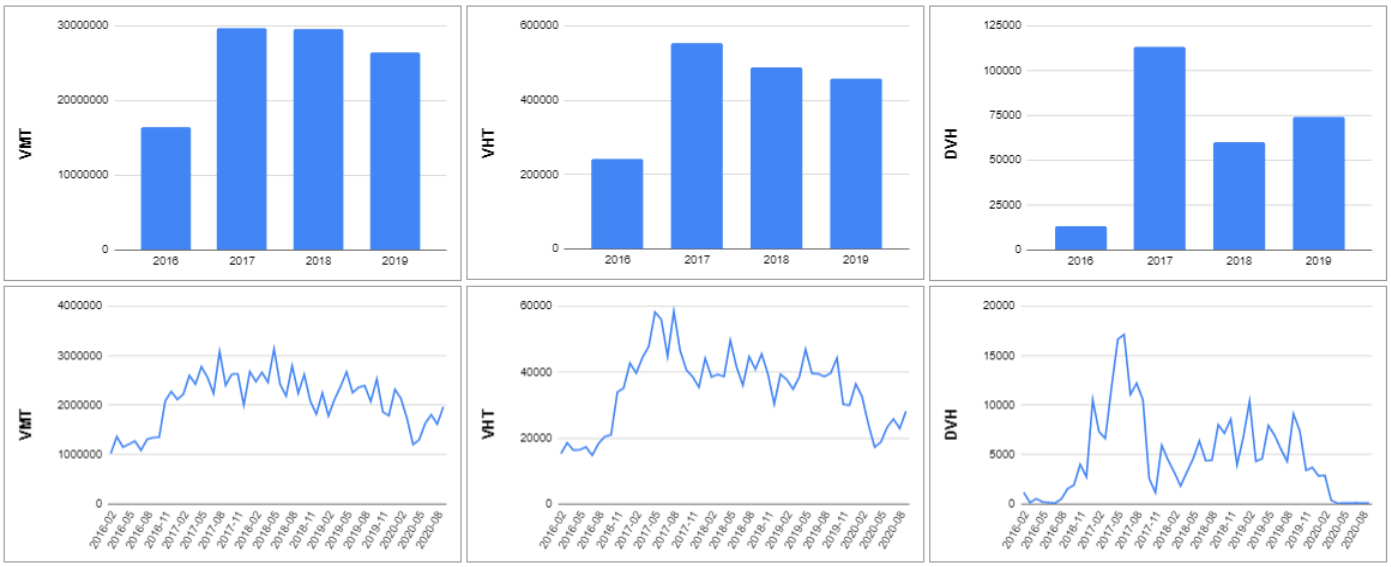


A.12.2.4 Yearly Variations

A.12.2.5 Yearly Variations of Combined Index



A.12.2.6 Variations of Traffic-Flow Measures



A.12.2.7 Trends Summary

- The monthly variations of the reliability measures show relatively stable patterns, which can be also observed on the variation patterns of the traffic-flow measures.
- The effects of snow appear to be affecting more on the congestion level than the travel-time variability.

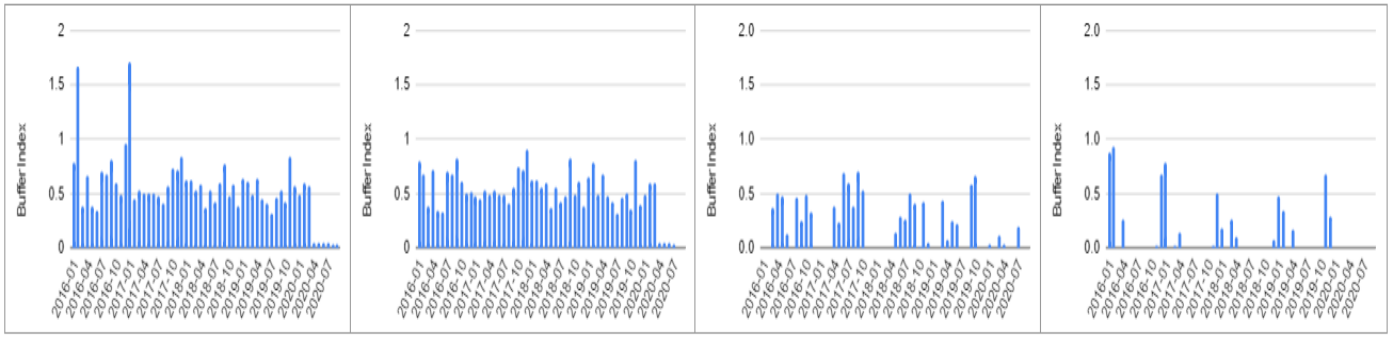
A.13 I-394 CORRIDOR (EASTBOUND/WESTBOUND)

A.13.1 I-394 EASTBOUND Route (Morning Peak)

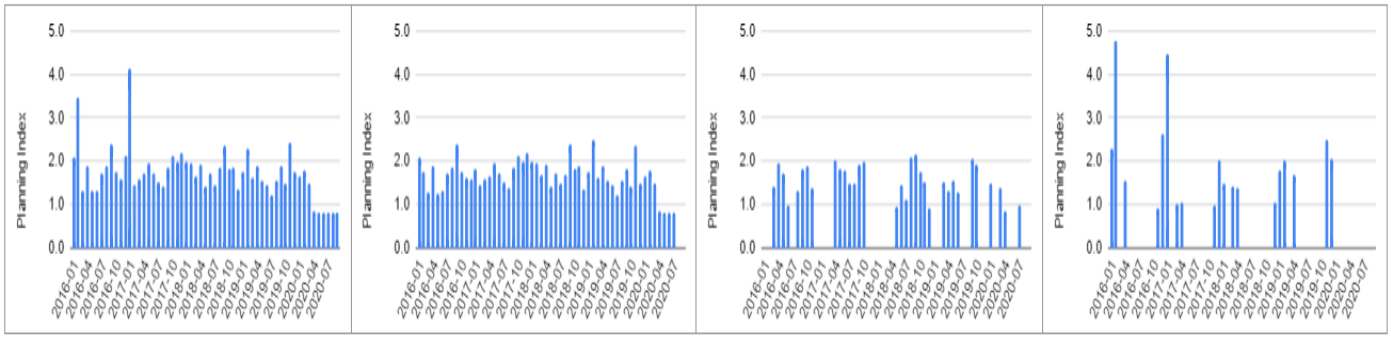
A.13.1.1 Effects of Weather

All | Dry | Rain | Snow

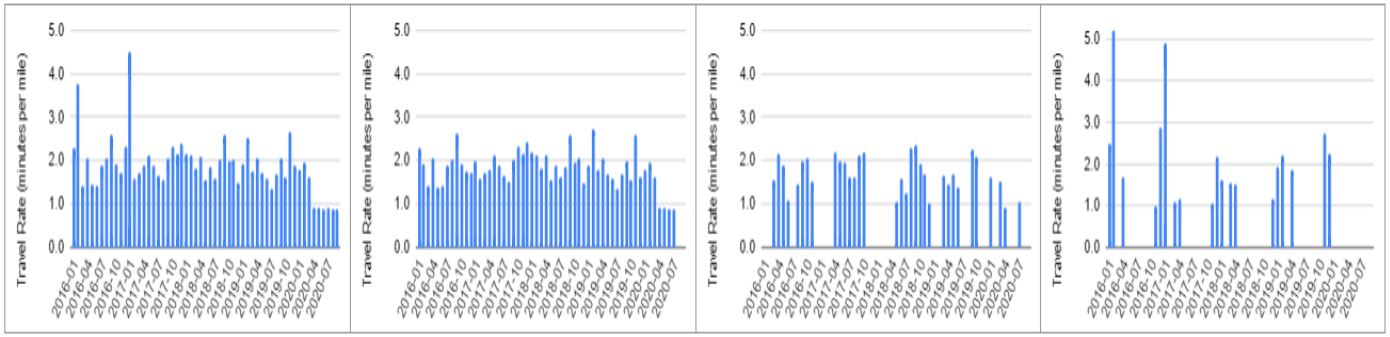
Buffer Index



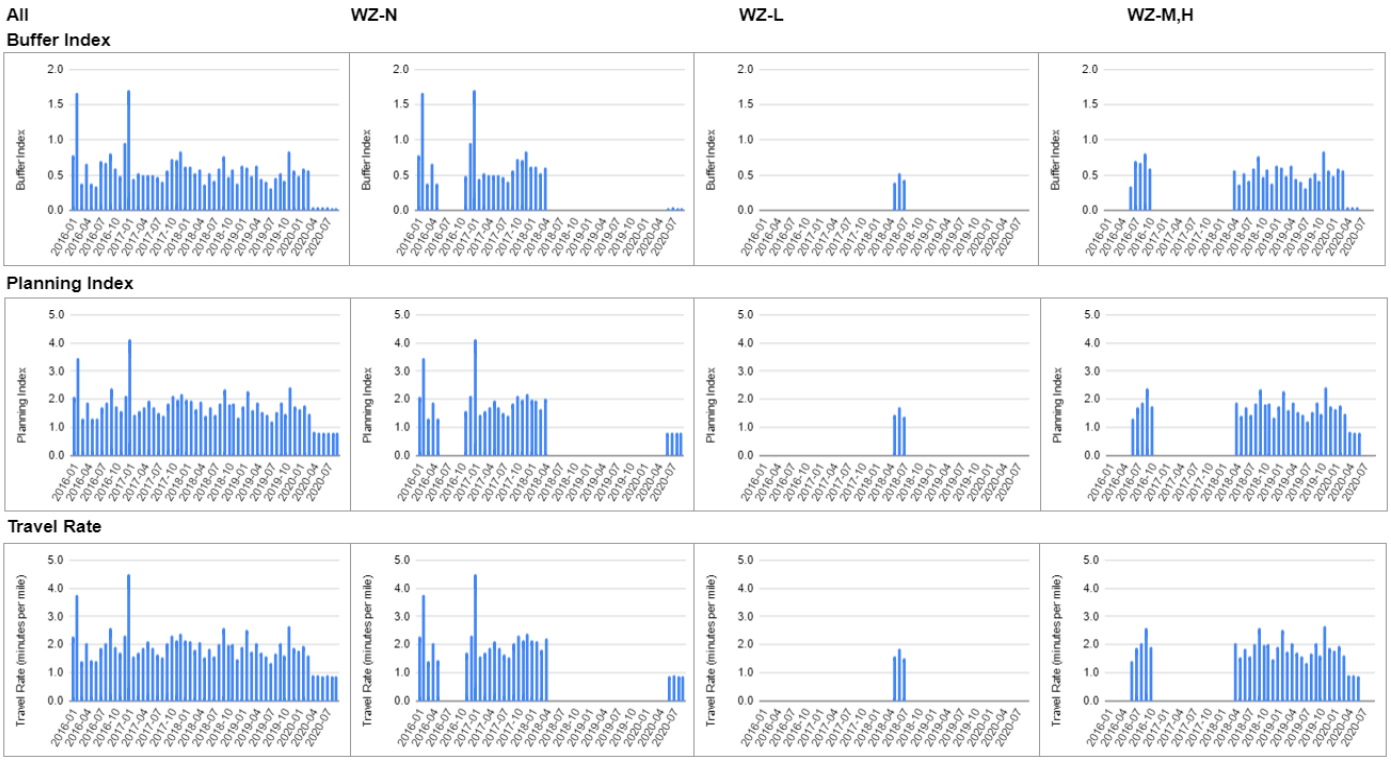
Planning Index



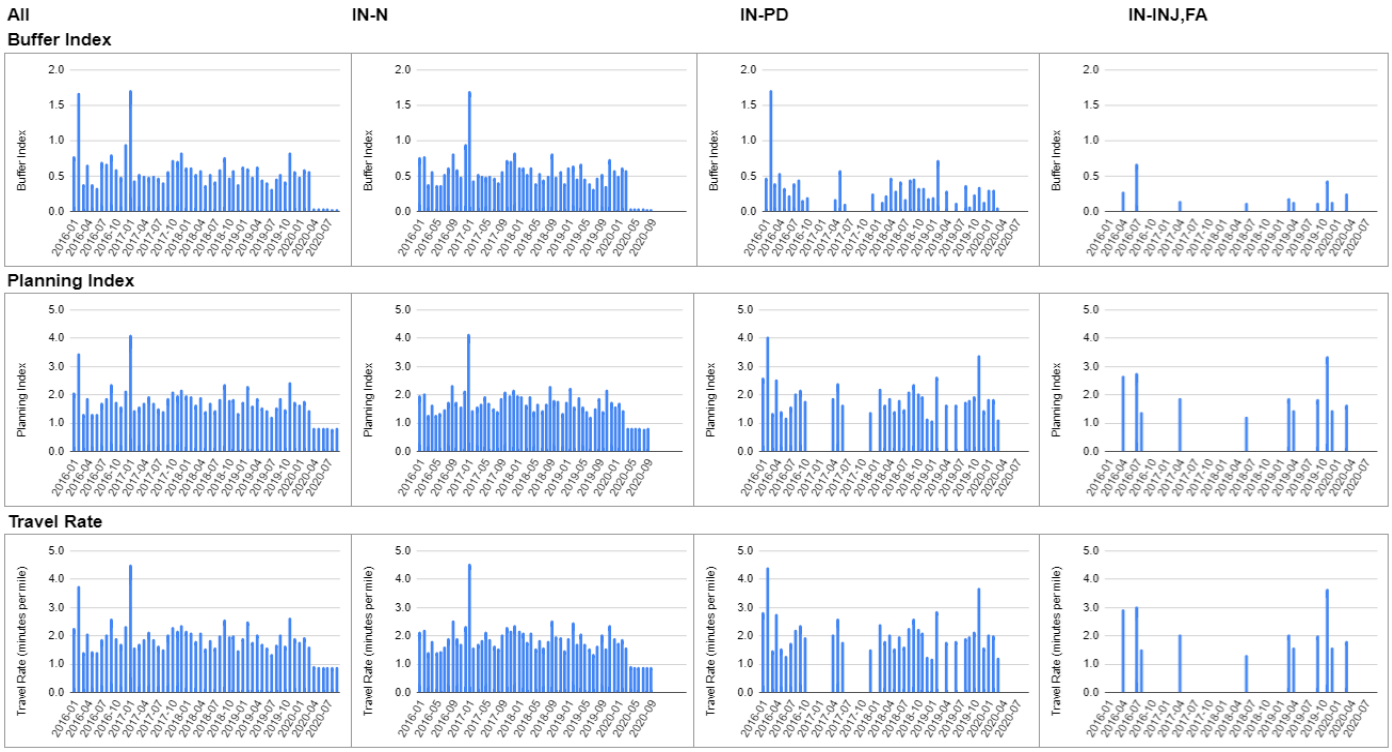
Travel Rate



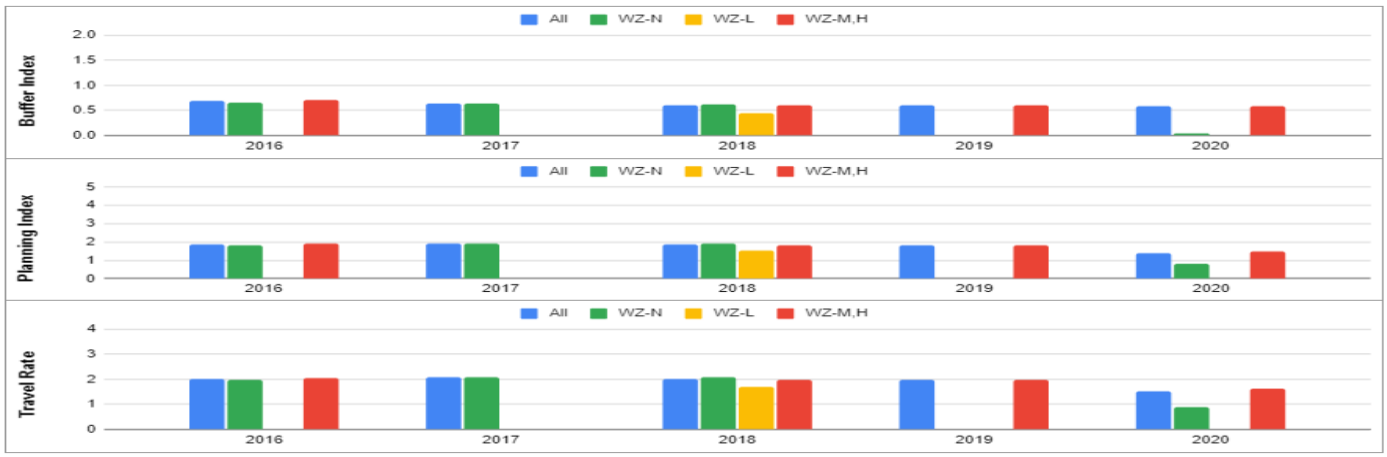
A.13.1.2 Effects of Work Zones



A.13.1.3 Effects of Incidents

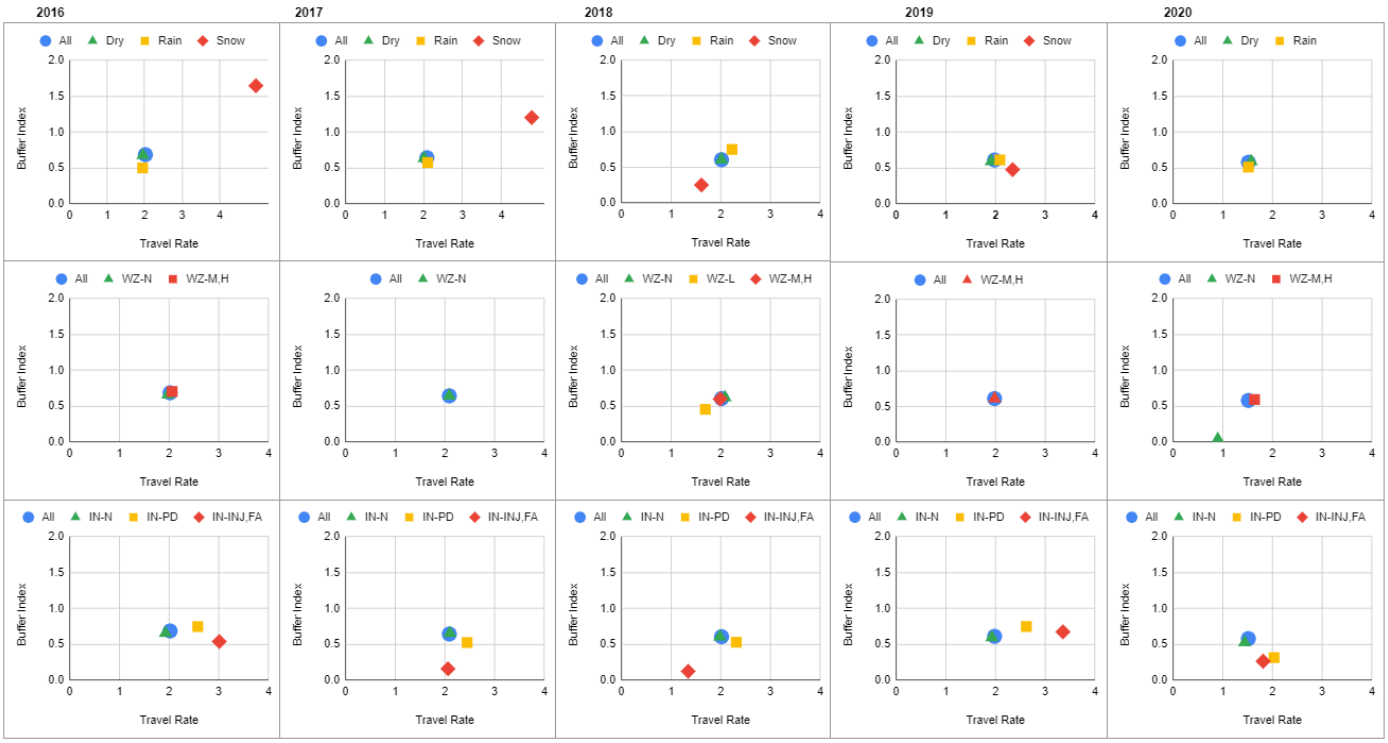


A.13.1.4 Yearly Variations

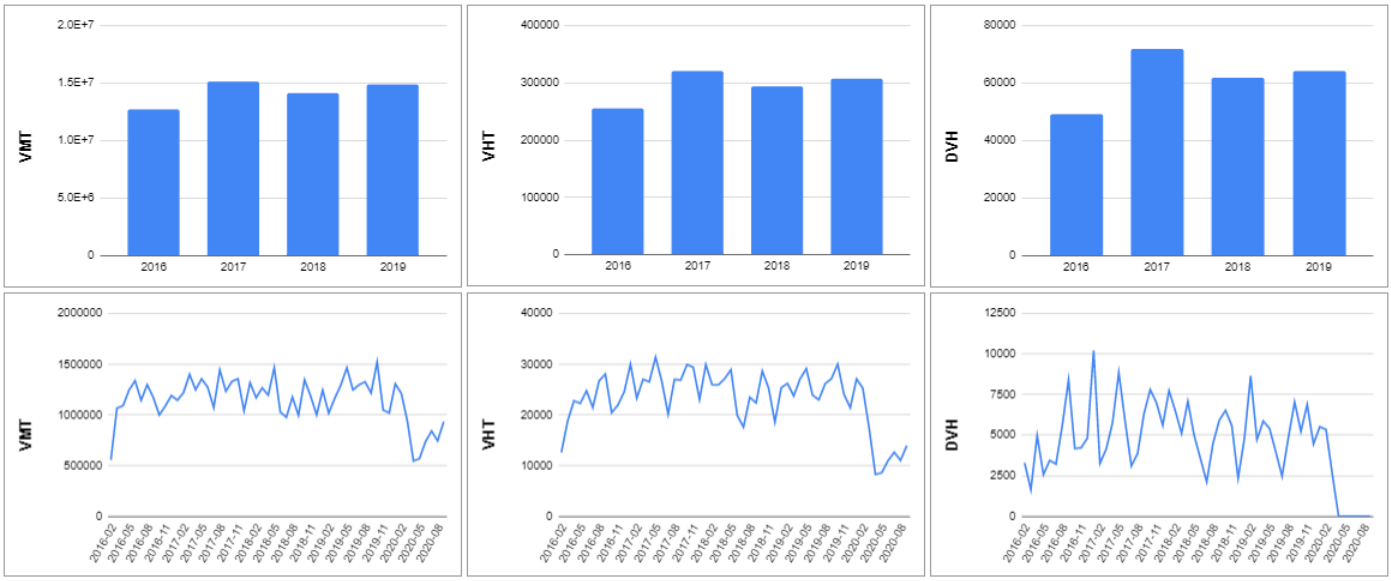

All
WZ-N
WZ-L
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.13.1.5 Yearly Variations of Combined Index



A.13.1.6 Variations of Traffic-Flow Measures

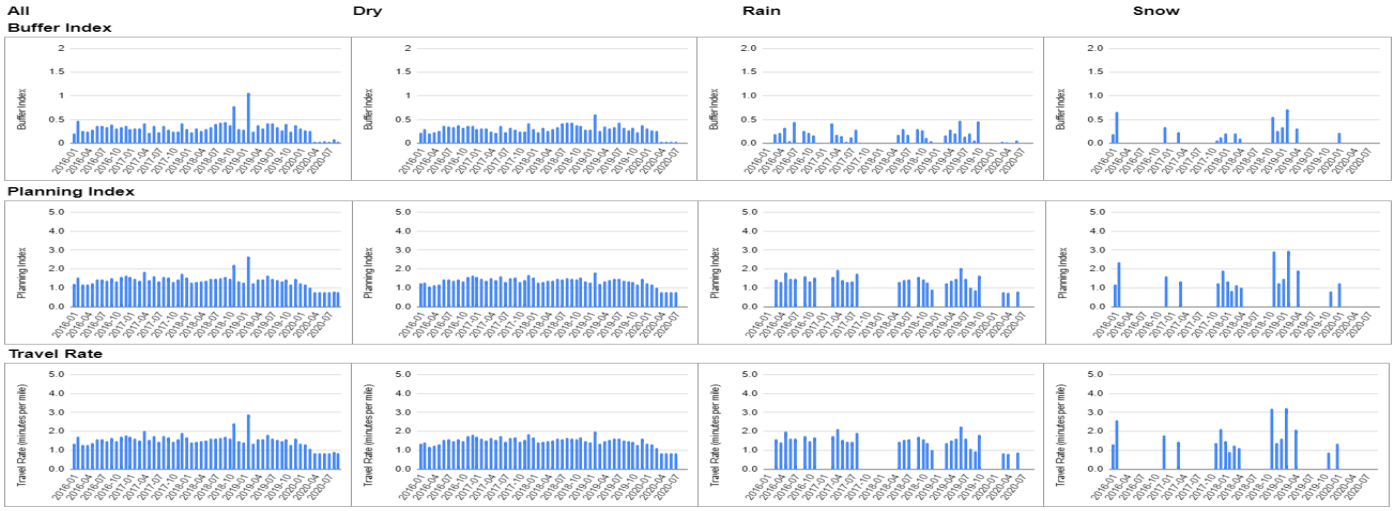


A.13.1.7 Trends Summary

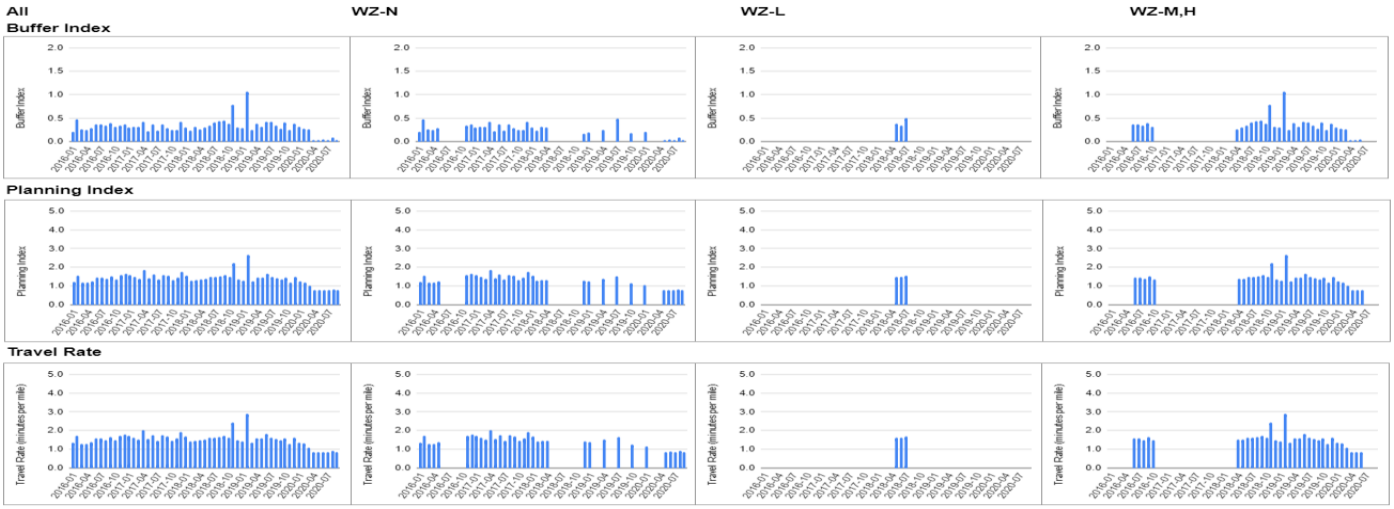
- Both VMT and delays have been increasing on this route with the fluctuating pattern of the monthly delayed-vehicle hours.
- The monthly values of the reliability measures also exhibit a fluctuating pattern with high levels of travel-time variability and congestion.
- Incidents have consistently affected the reliability, while the effects of weather do not appear to be significant.

A.13.2 I-394 WESTBOUND Route (Afternoon Peak)

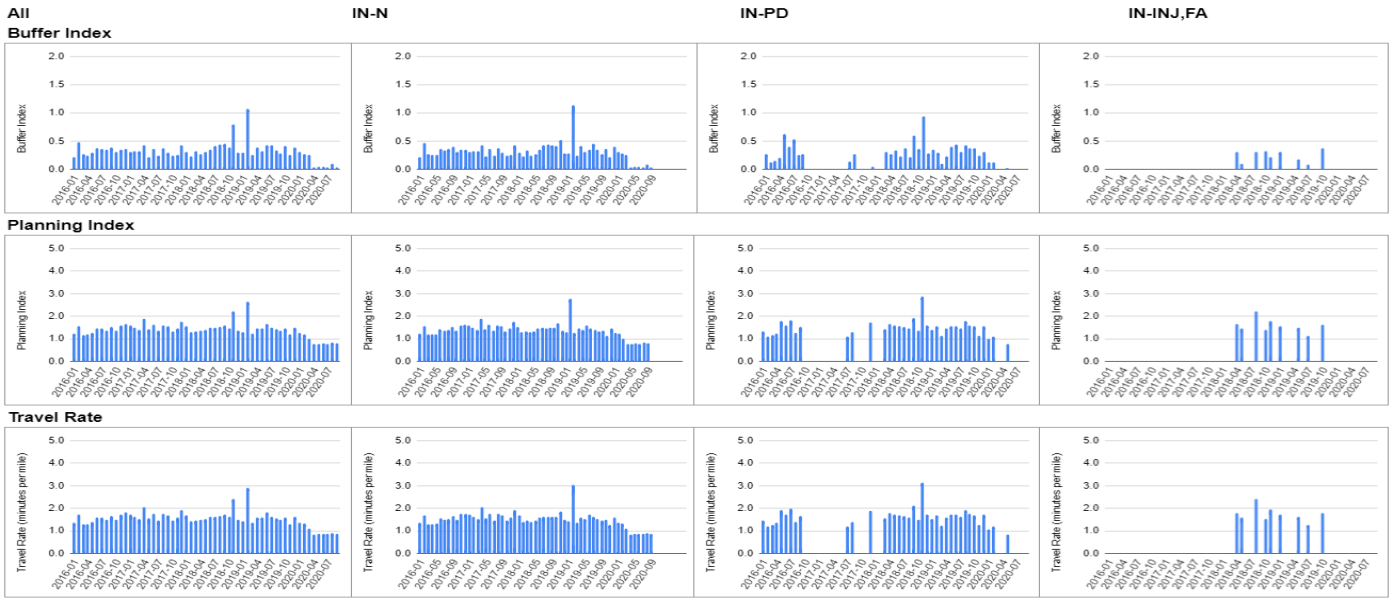
A.13.2.1 Effects of Weather



A.13.2.2 Effects of Work Zones

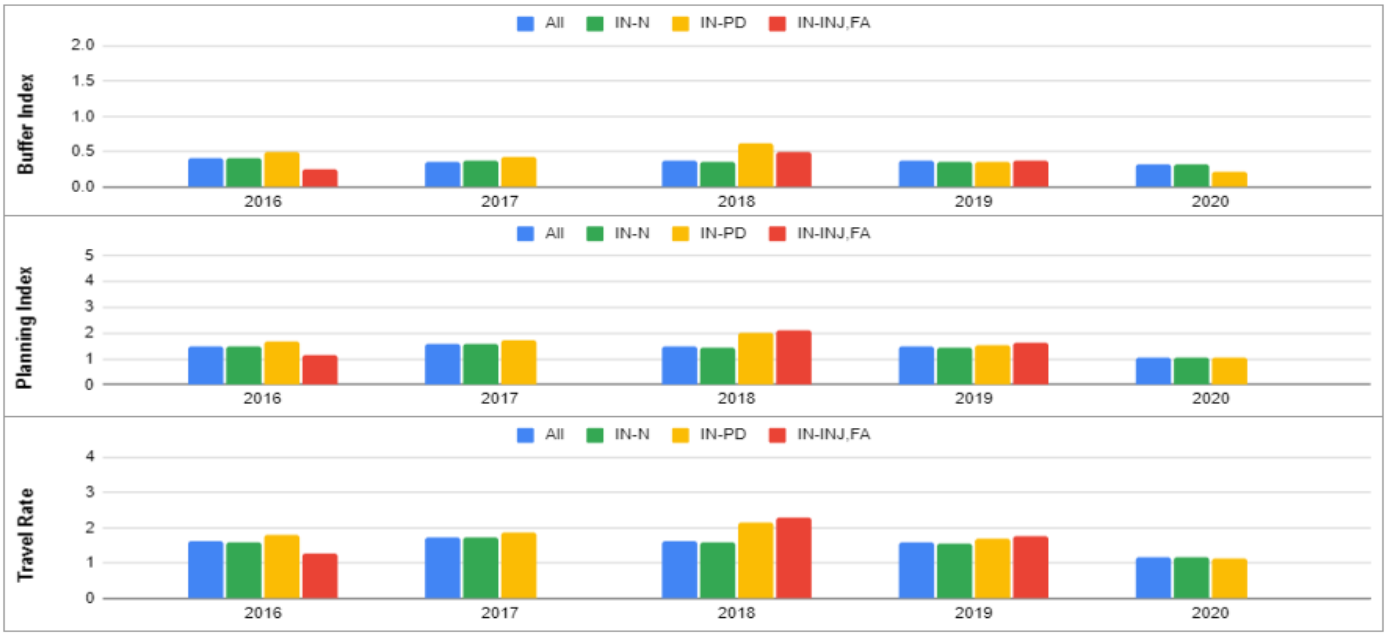


A.13.2.3 Effects of Incidents

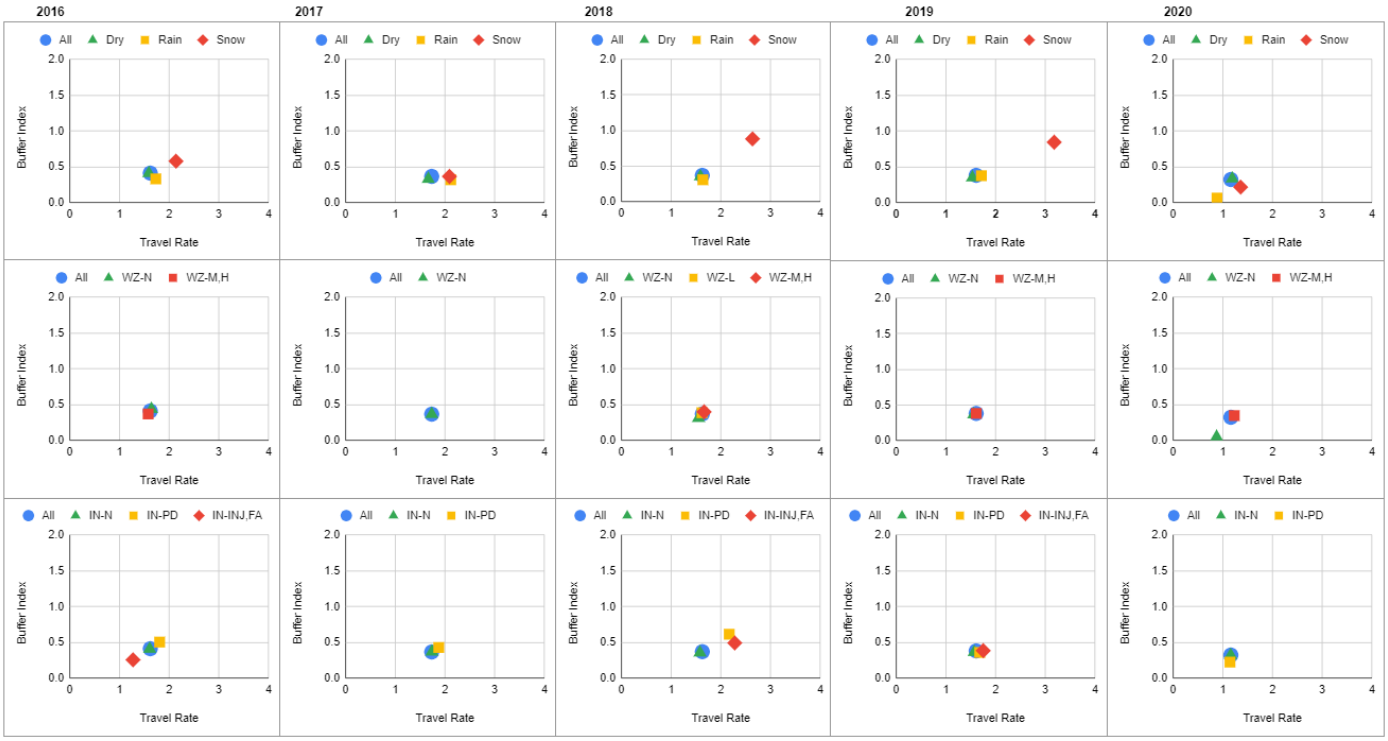


A.13.2.4 Yearly Variations

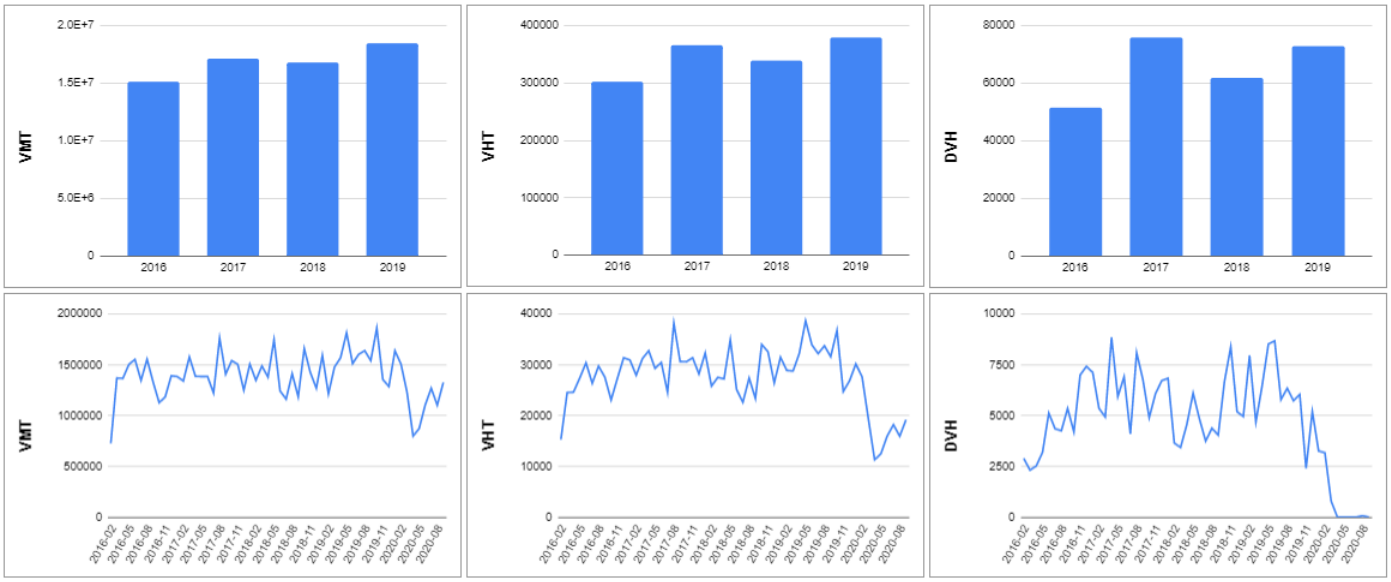

All
WZ-N
WZ-L
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.13.2.5 Yearly Variations of Combined Index



A.13.2.6 Variations of Traffic-Flow Measures



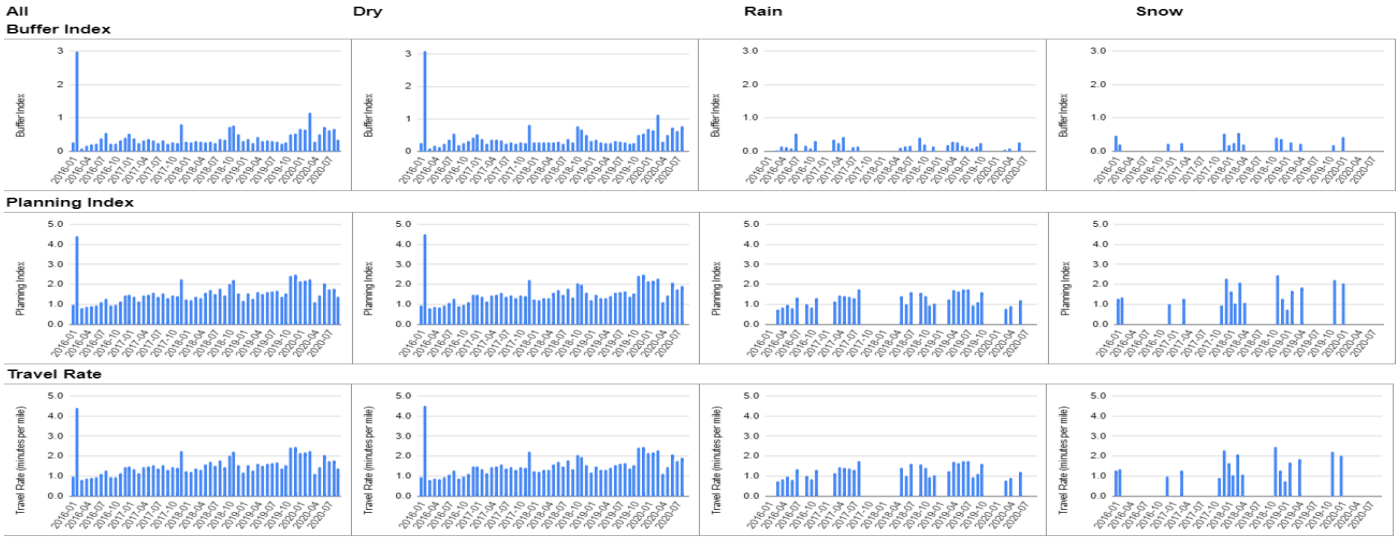
A.13.2.7 Trends Summary

- The monthly variations of the reliability measures show a stable pattern, while both VMT and delays have been growing.
- Snow has significantly affected both the travel-time variability and congestion. The effects of incidents on the reliability have also been increasing.

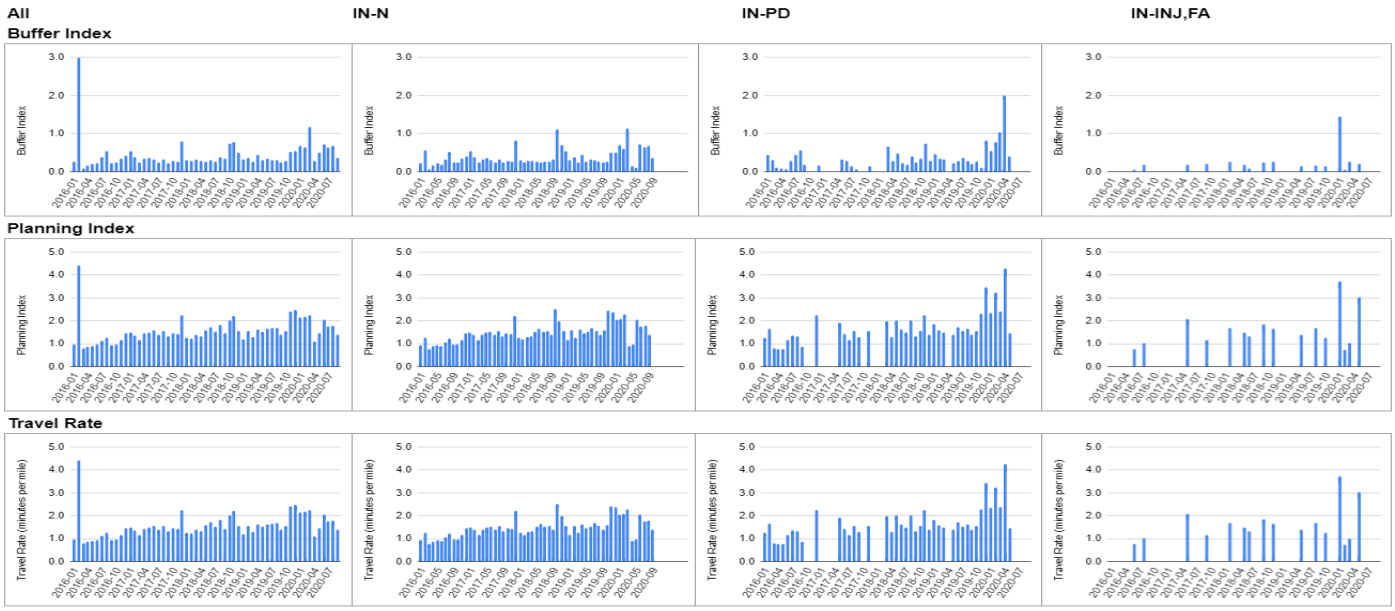
A.14 I-94 CORRIDOR 1 (I494 - TH101, EASTBOUND/WESTBOUND)

A.14.1 I-94 Corridor 1 EASTBOUND (TH 101 to I494, Morning Peak)

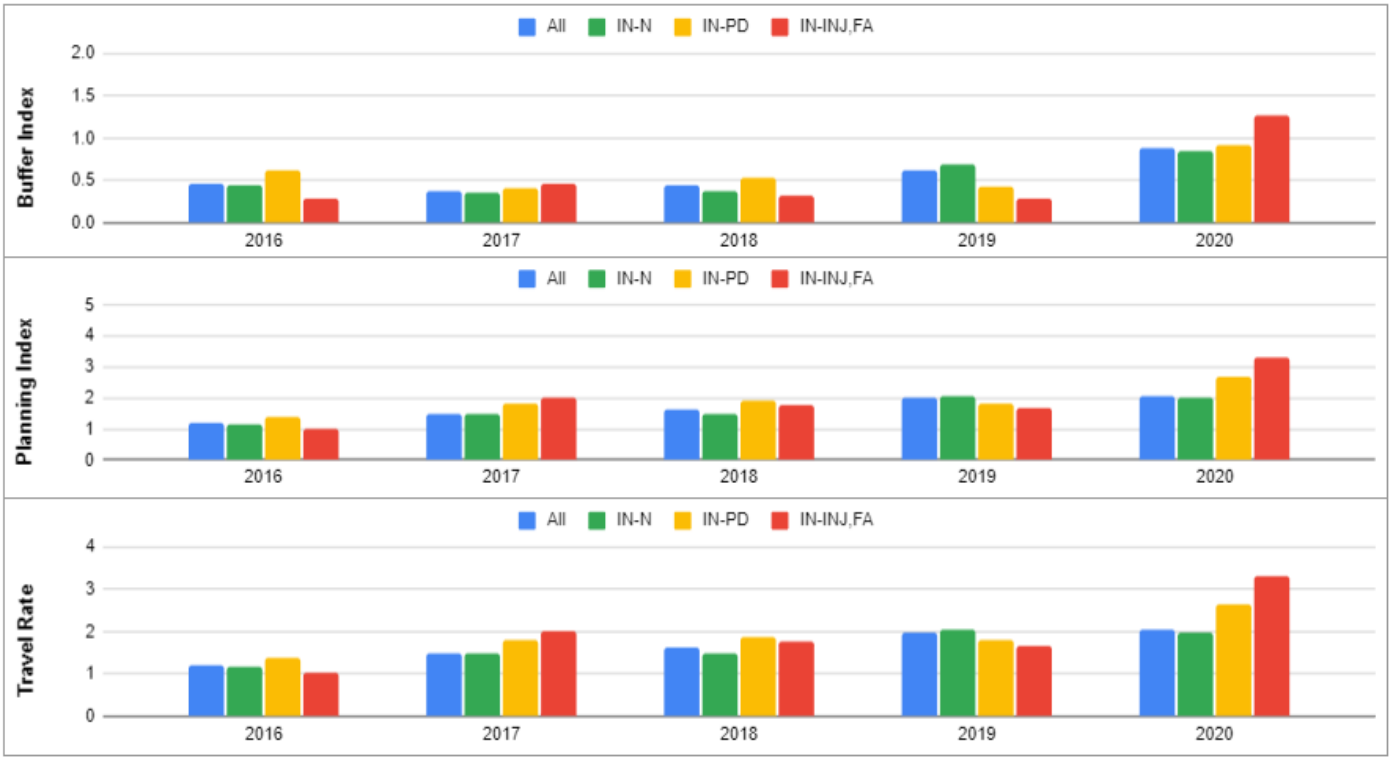
A.14.1.1 Effects of Weather



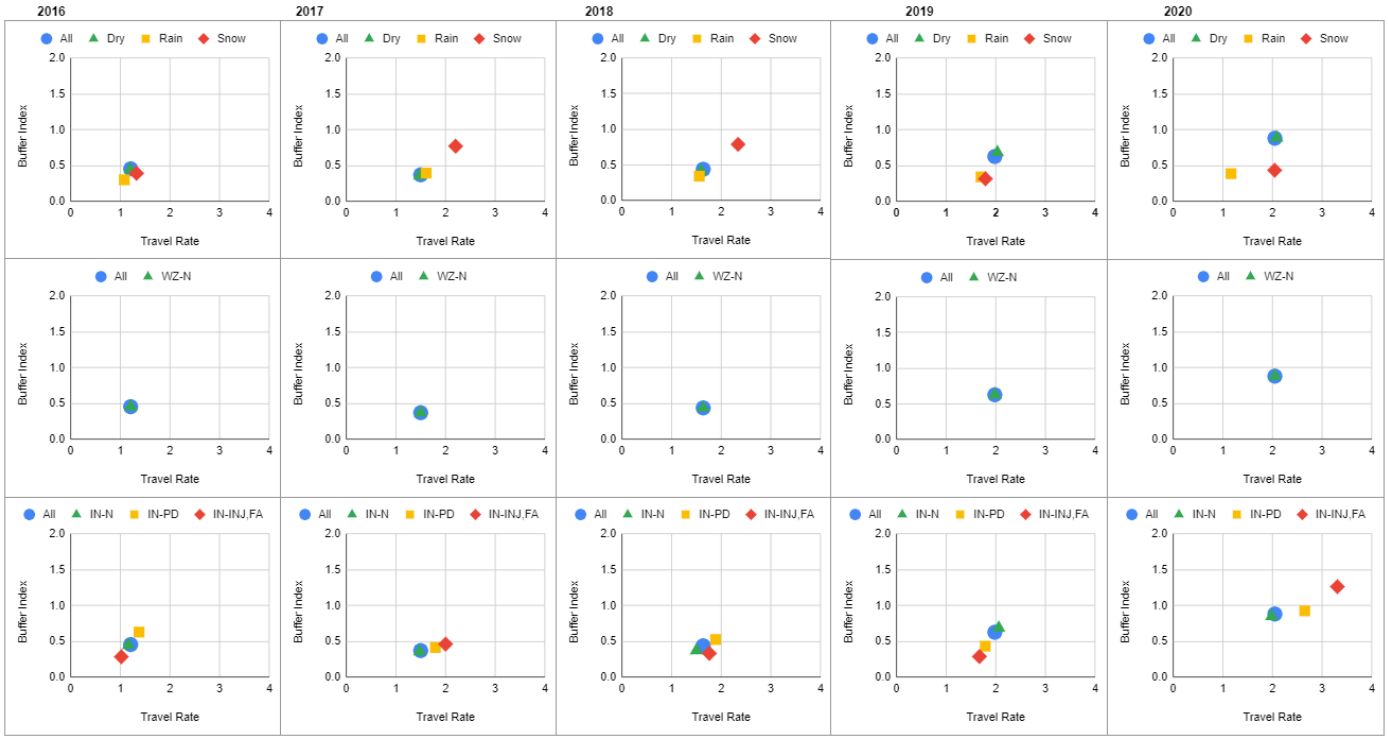
A.14.1.2 Effects of Incidents



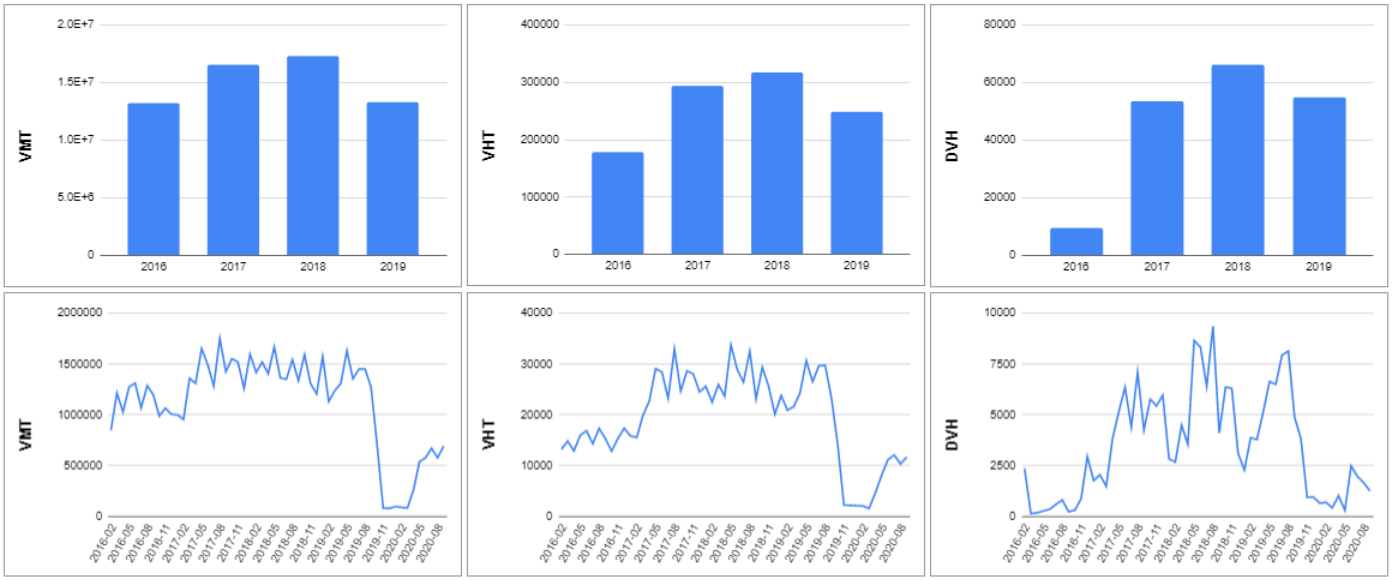
A.14.1.3 Yearly Variations



A.14.1.4 Yearly Variations of Combined Index



A.14.1.5 Variations of Traffic-Flow Measures

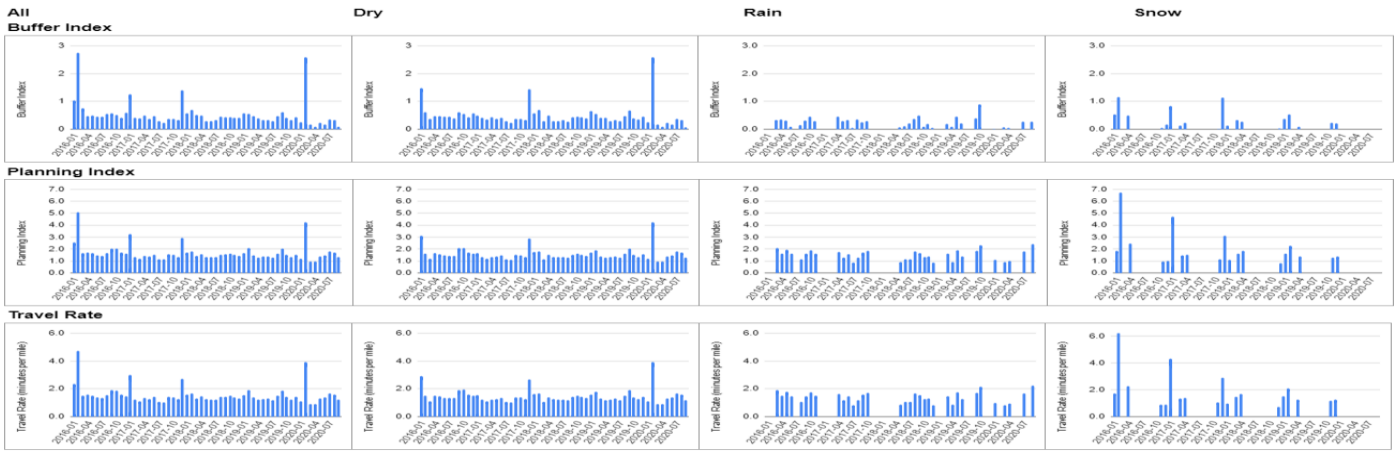


A.14.1.6 Trends Summary

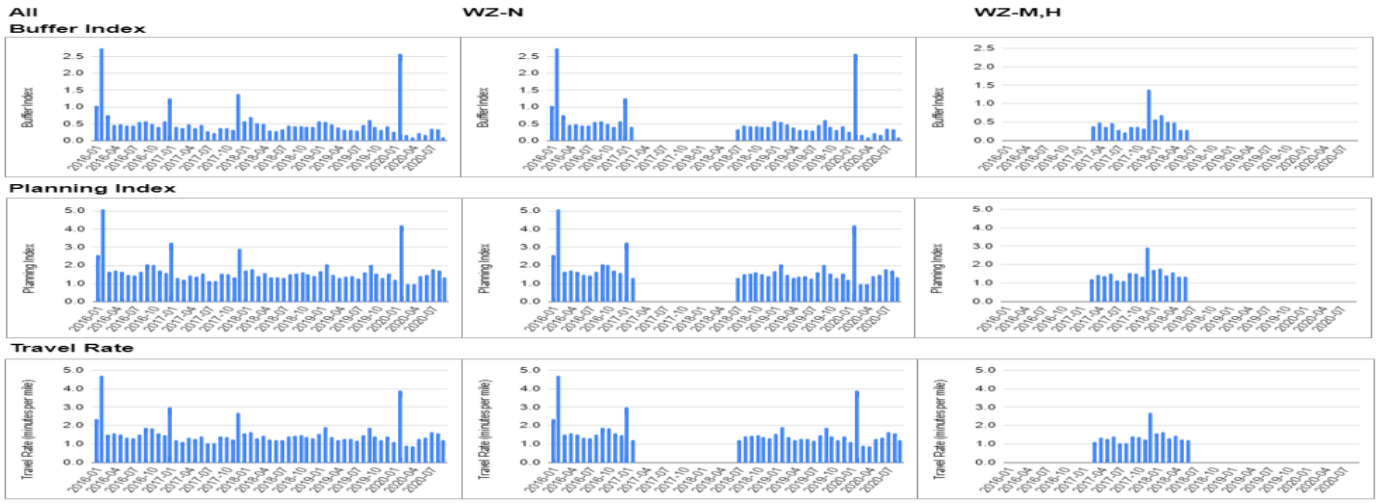
- The traffic flow has significantly been reduced in 2019, however, the 95th %-ile travel times have been continuously increasing as indicated by the monthly variations of both planning index and travel rate.
- Snow and incidents were the main factors affecting the reliability for 2017-18, while their effects in 2019 were not significant.

A.14.2 I-94 Corridor 1 WESTBOUND (TH101 to I-494, Afternoon Peak)

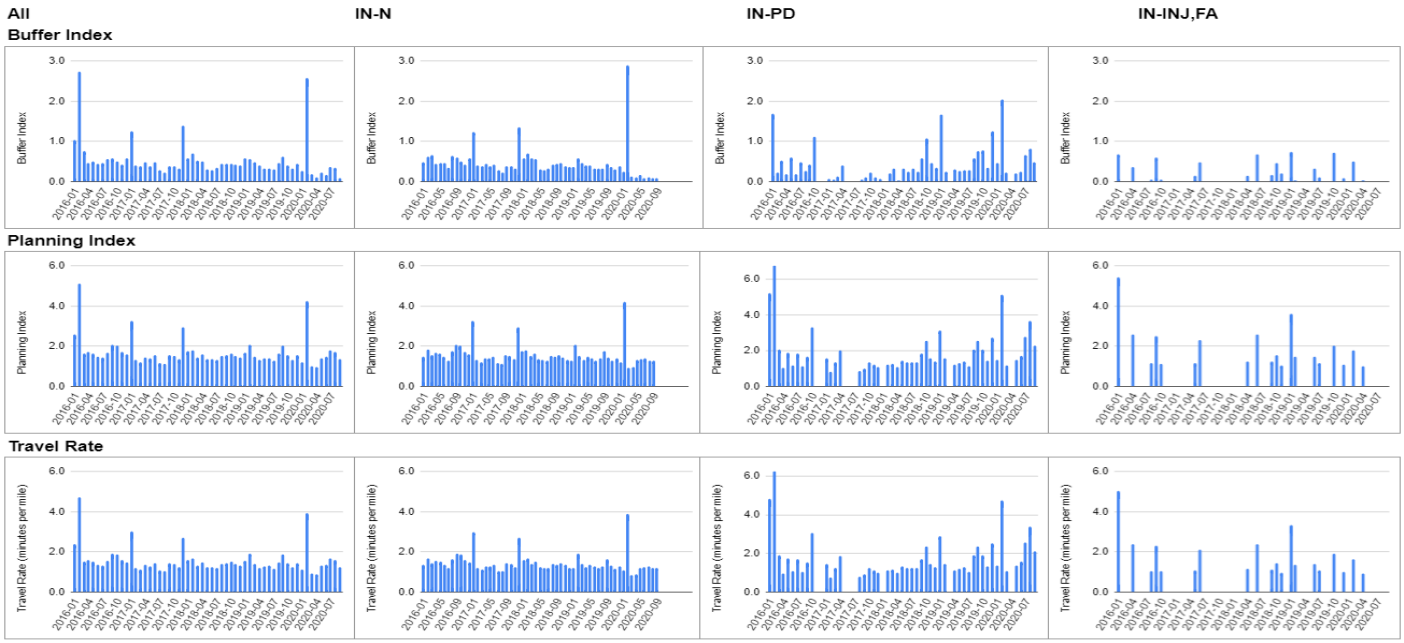
A.14.2.1 Effects of Weather



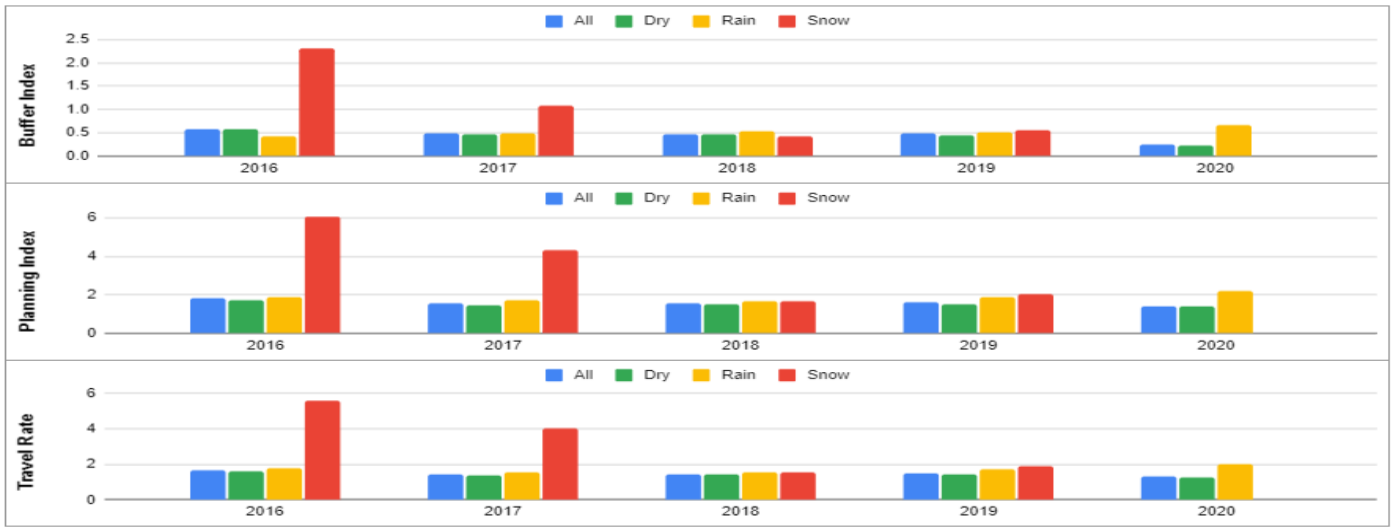
A.14.2.2 Effects of Work Zones

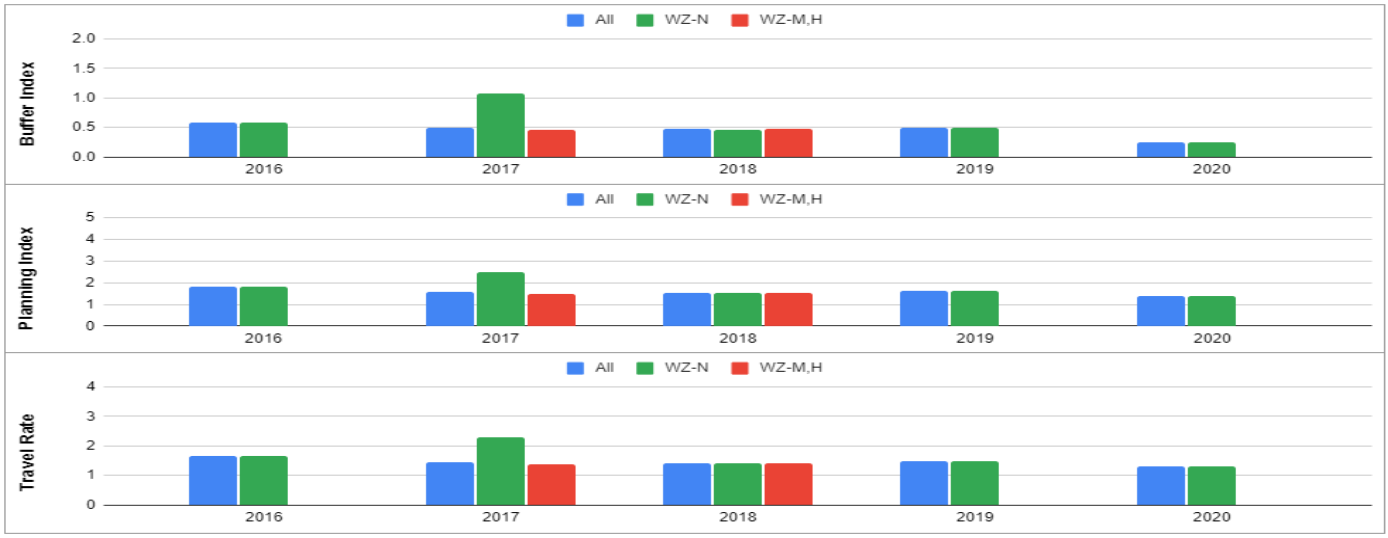


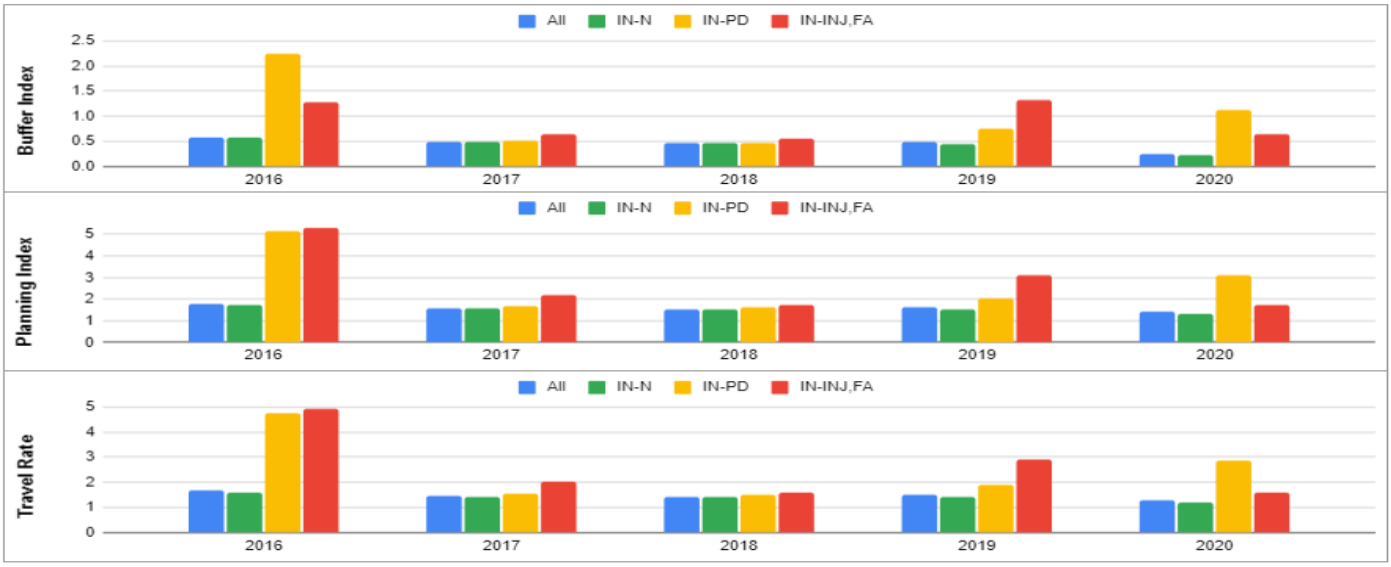
A.14.2.3 Effects of Incidents



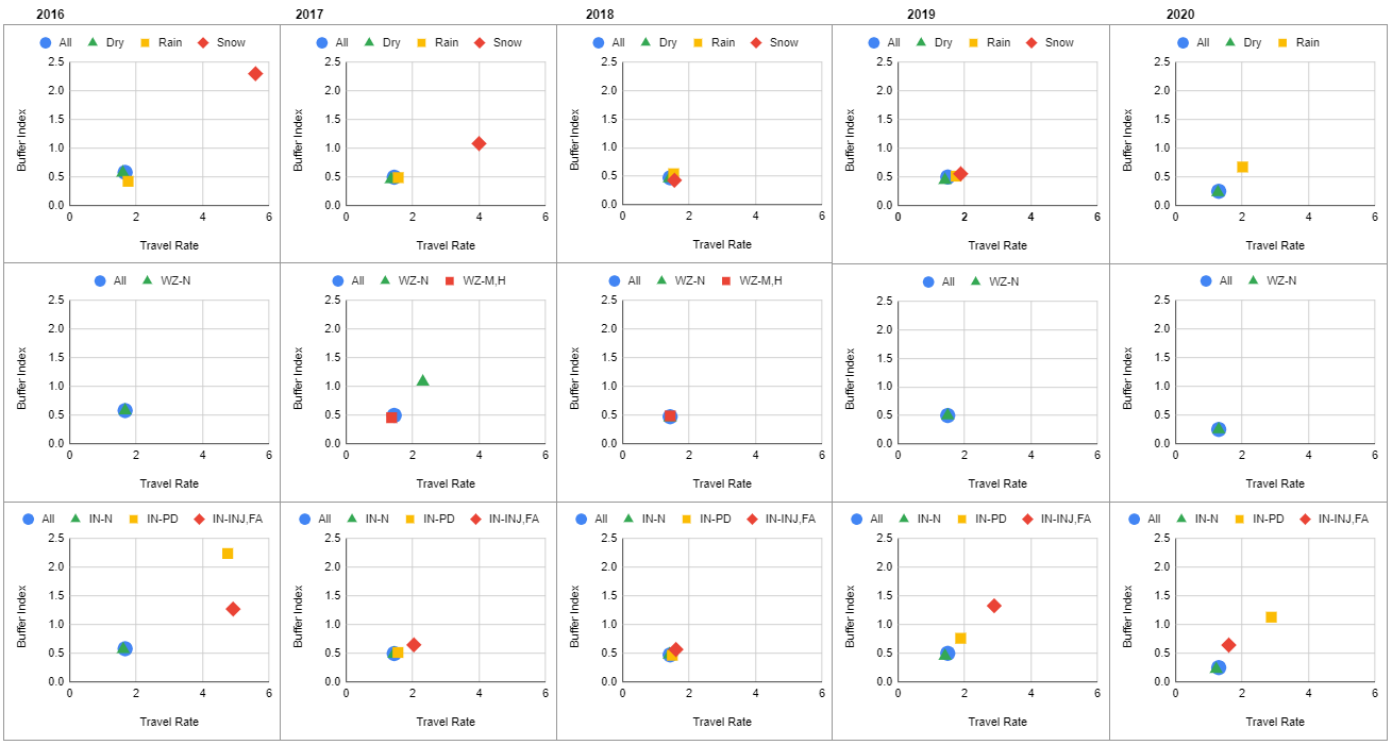
A.14.2.4 Yearly Variations



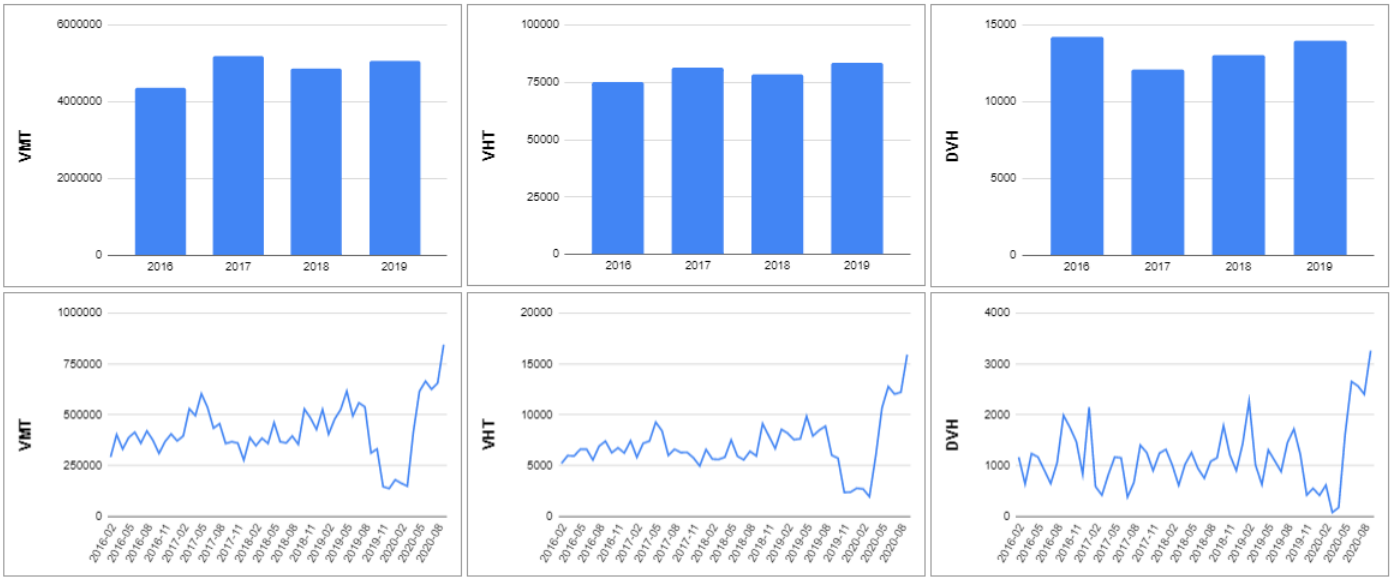




A.14.2.5 Yearly Variations of Combined Index



A.14.2.6 Variations of Traffic-Flow Measures



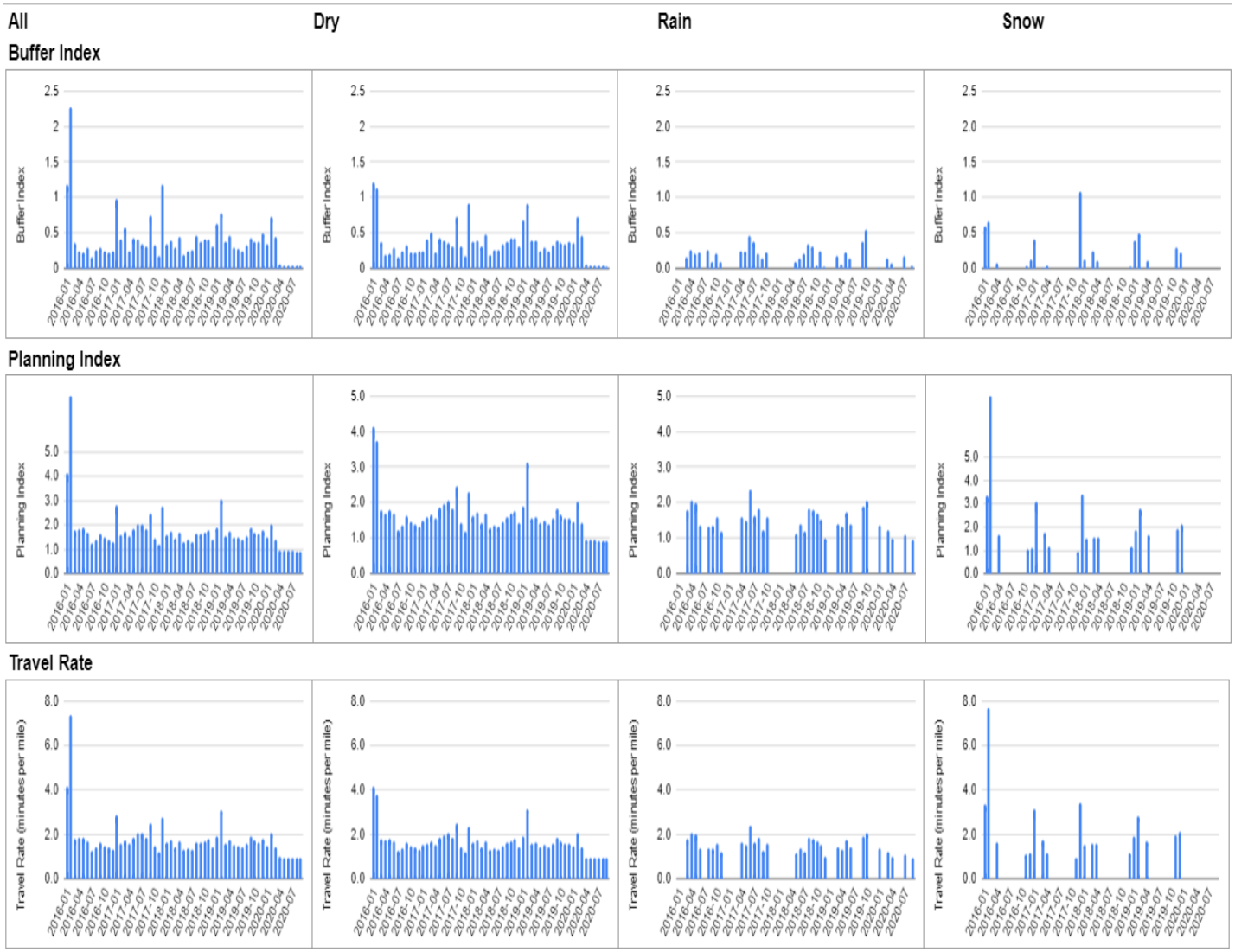
A.14.2.7 Trends Summary

- The VMT and delay have been continuously increasing on this route during 2016-19, while the variations of the delayed vehicle hours show relatively stable pattern than the EASTBOUND route.
- The monthly reliability measures exhibit stable patterns except those periods directly affected by snow or incidents.
- Both weather and incidents have been the main factors affecting the reliability on this route.

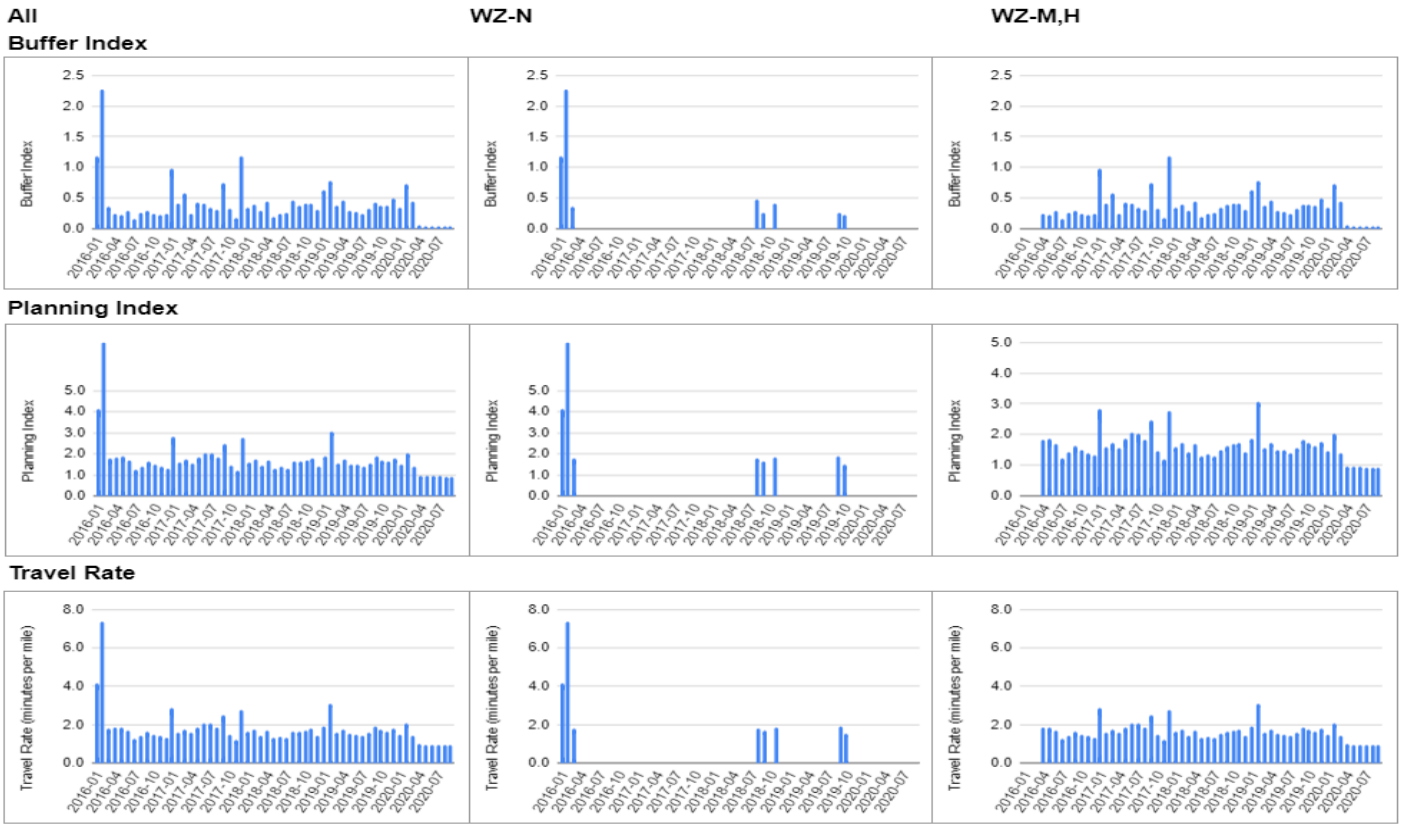
A.15 I-94 CORRIDOR 2 (I494 – MPLS, EASTBOUND/WESTBOUND)

A.15.1 I-94 EASTBOUND Route 2 (I-494 to Mpls, Morning Peak)

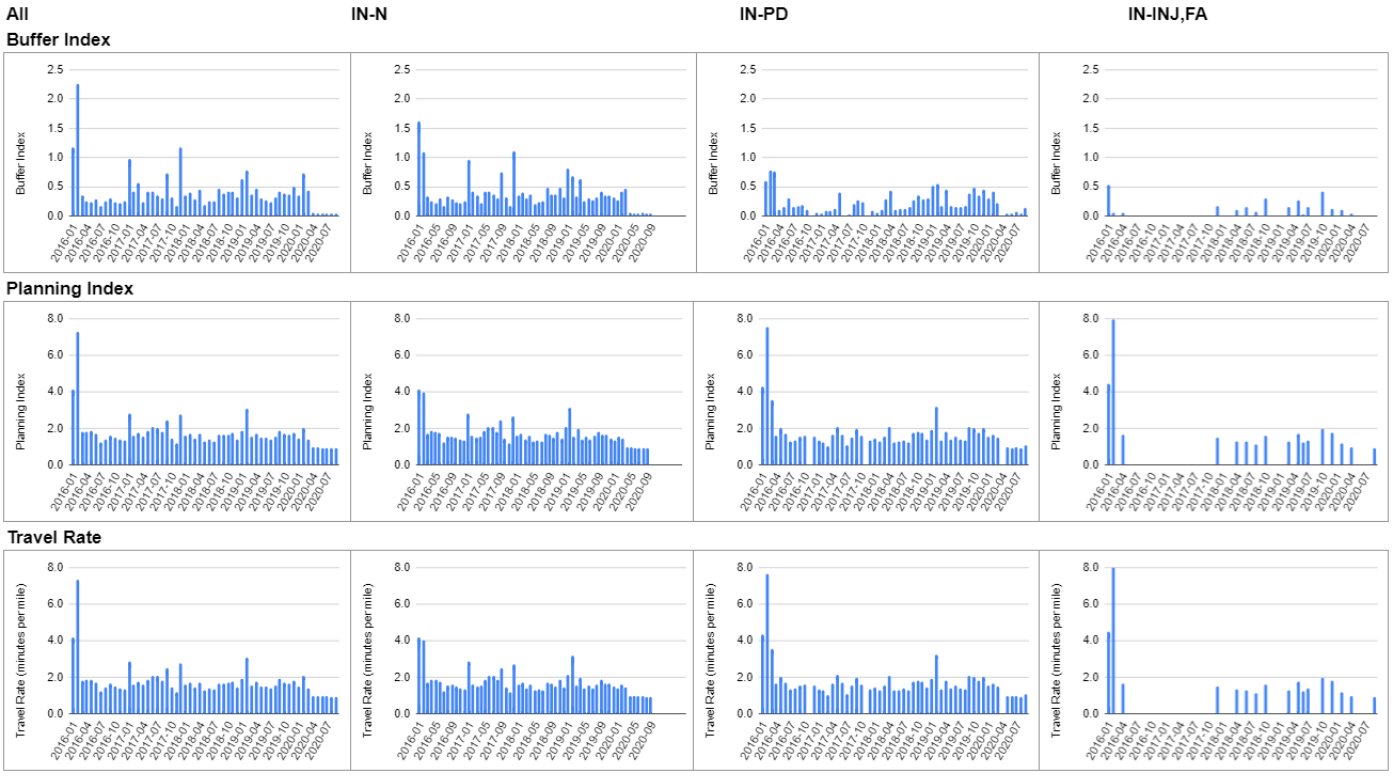
A.15.1.1 Effects of Weather



A.15.1.2 Effects of Work Zones



A.15.1.3 Effects of Incidents

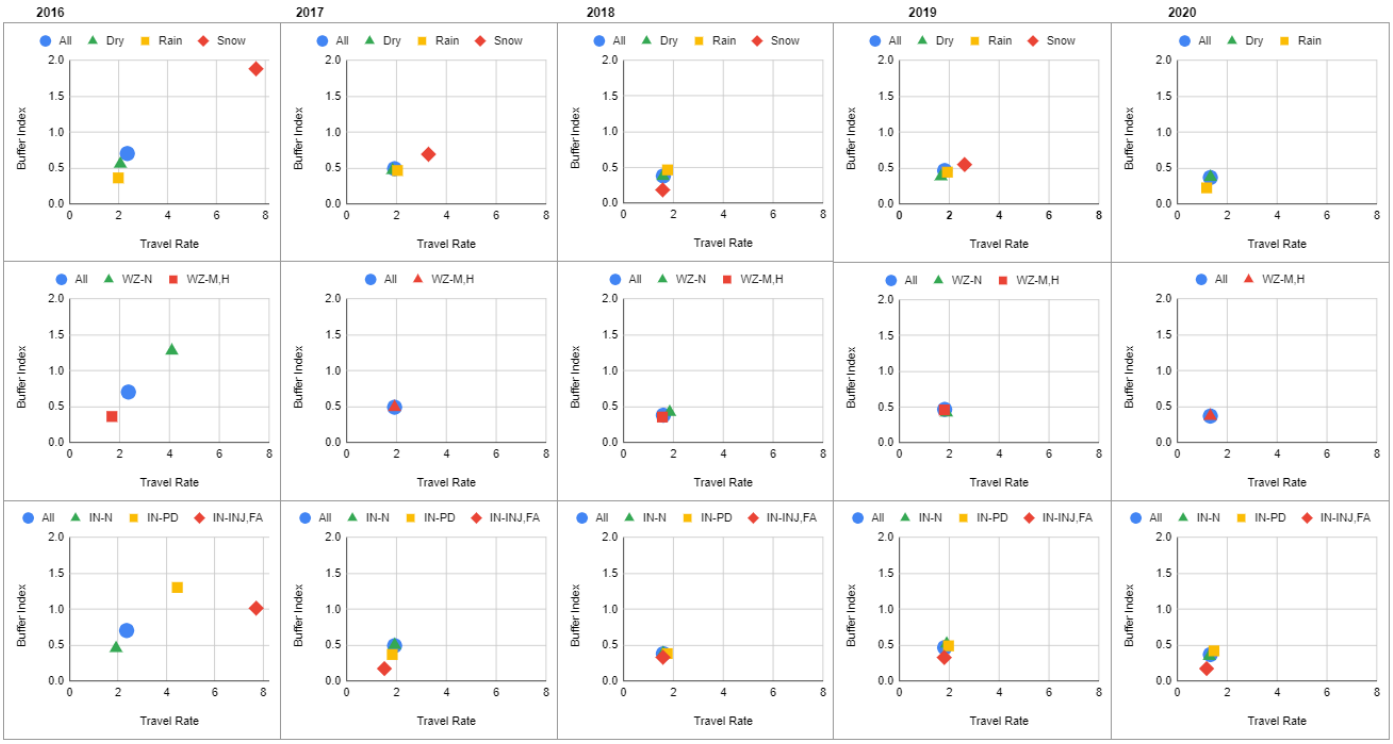


A.15.1.4 Yearly Variations

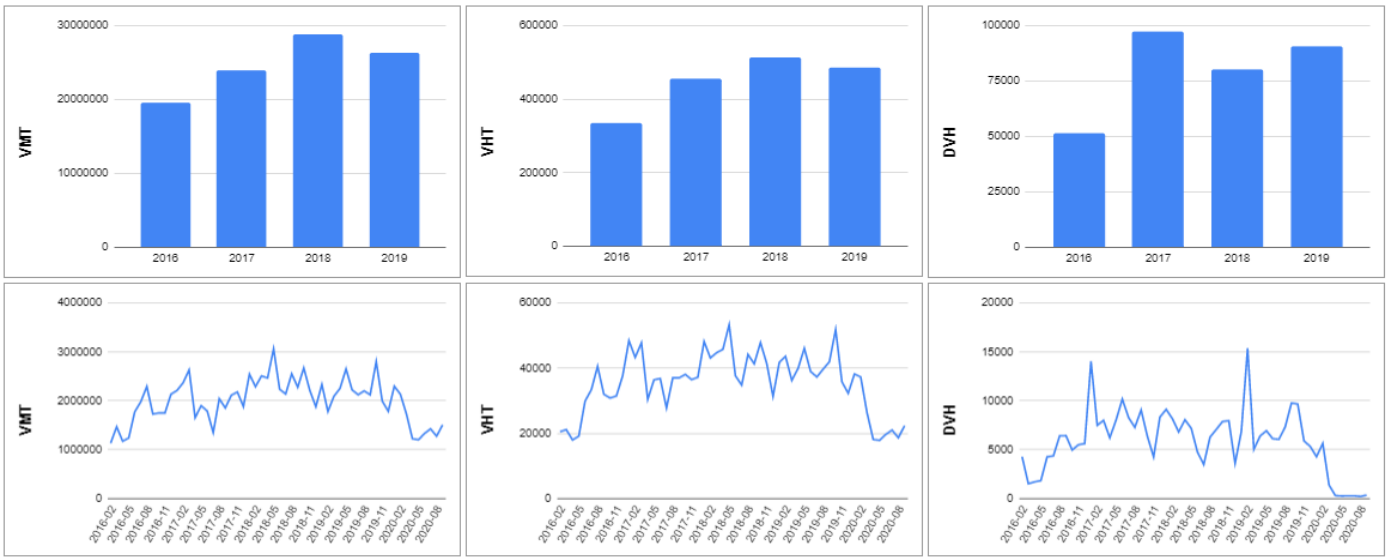

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
8
6
4
2
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
8
6
4
2
0
2016
2017
2018
2019
2020

A.15.1.5 Yearly Variations of Combined Index



A.15.1.6 Variations of Traffic-Flow Measures

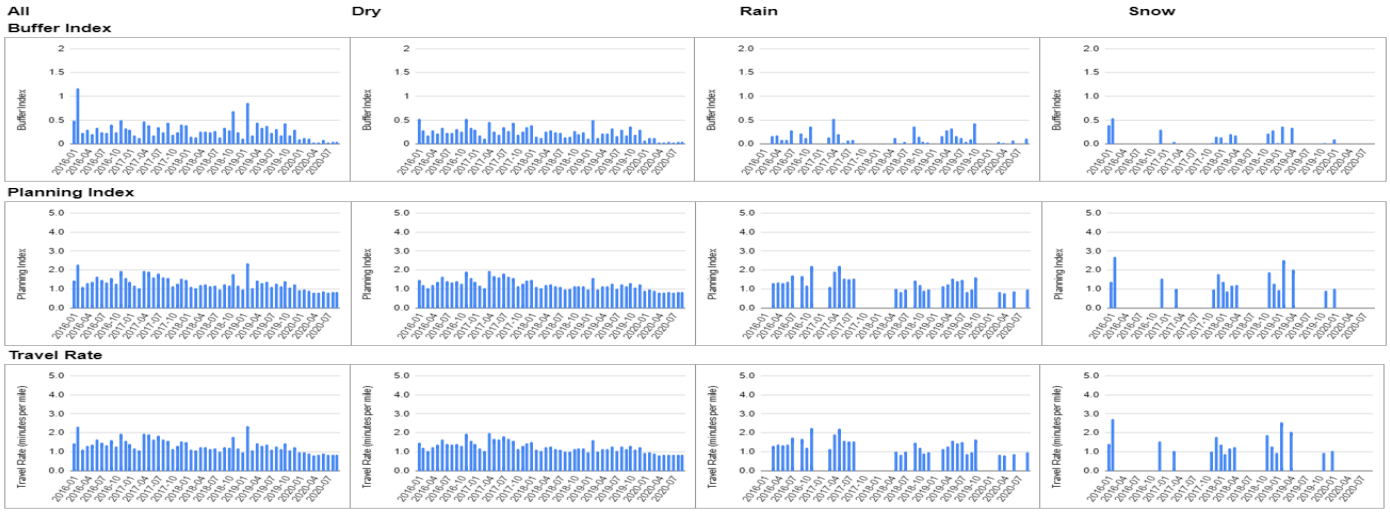


A.15.1.7 Trends Summary

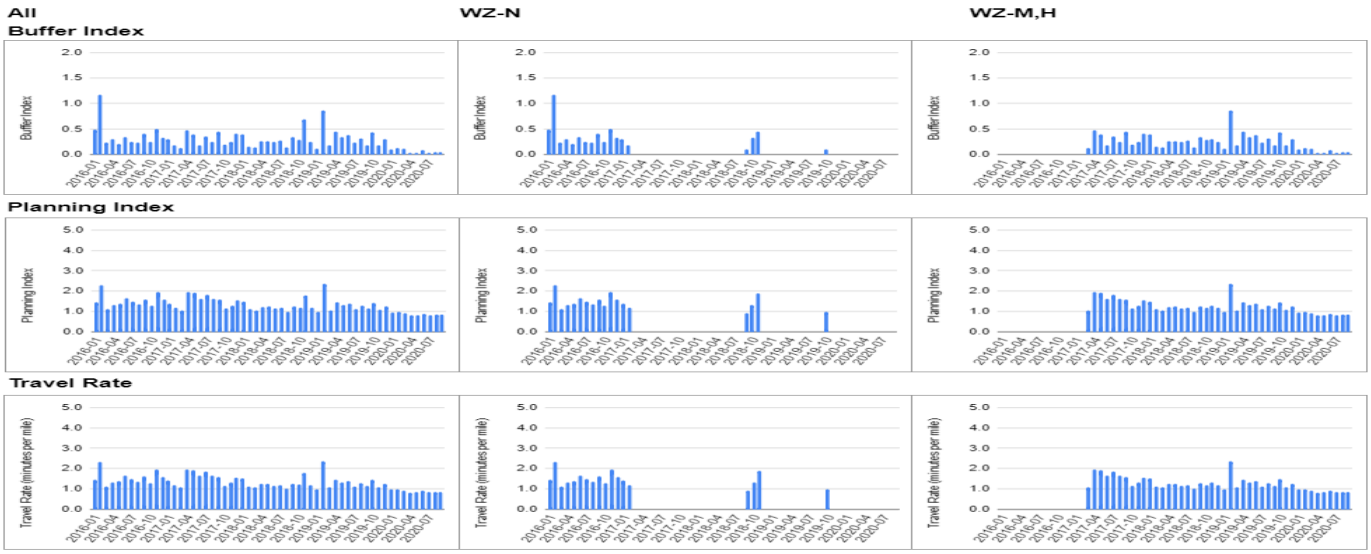
- The growth pattern of the traffic flow was stopped in 2019, when both VMT and delays were reduced.
- The reliability patterns in 2016 and those from 2017 are quite different, i.e., in 2016, both weather and incidents substantially affected the travel-time variability and congestion level. However, from 2017, the effects of incidents on reliability are not significant, while snow still has been a contributing factor.

A.15.2 I-94 WESTBOUND Route 2 (MPLS to I494, Afternoon Peak)

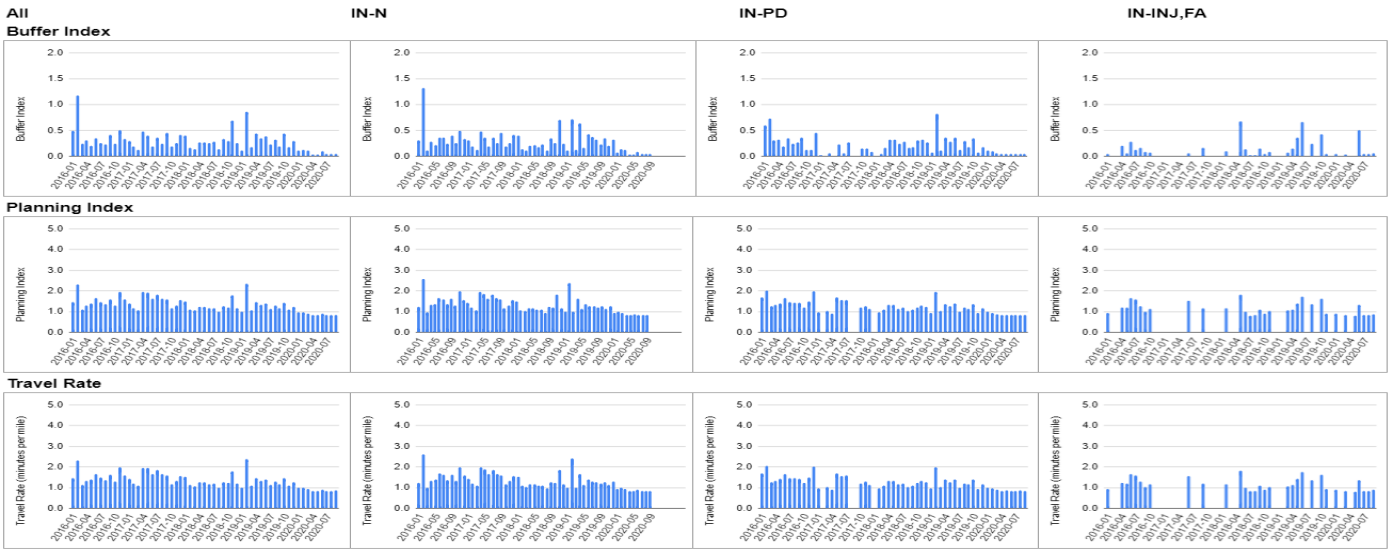
A.15.2.1 Effects of Weather



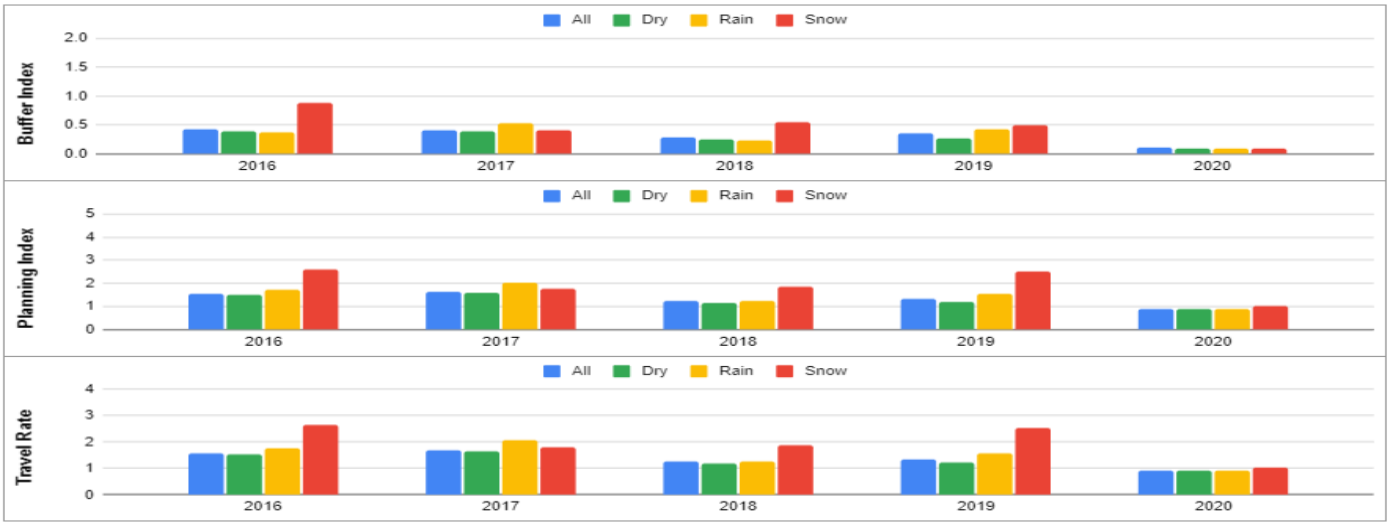
A.15.2.2 Effects of Work Zones



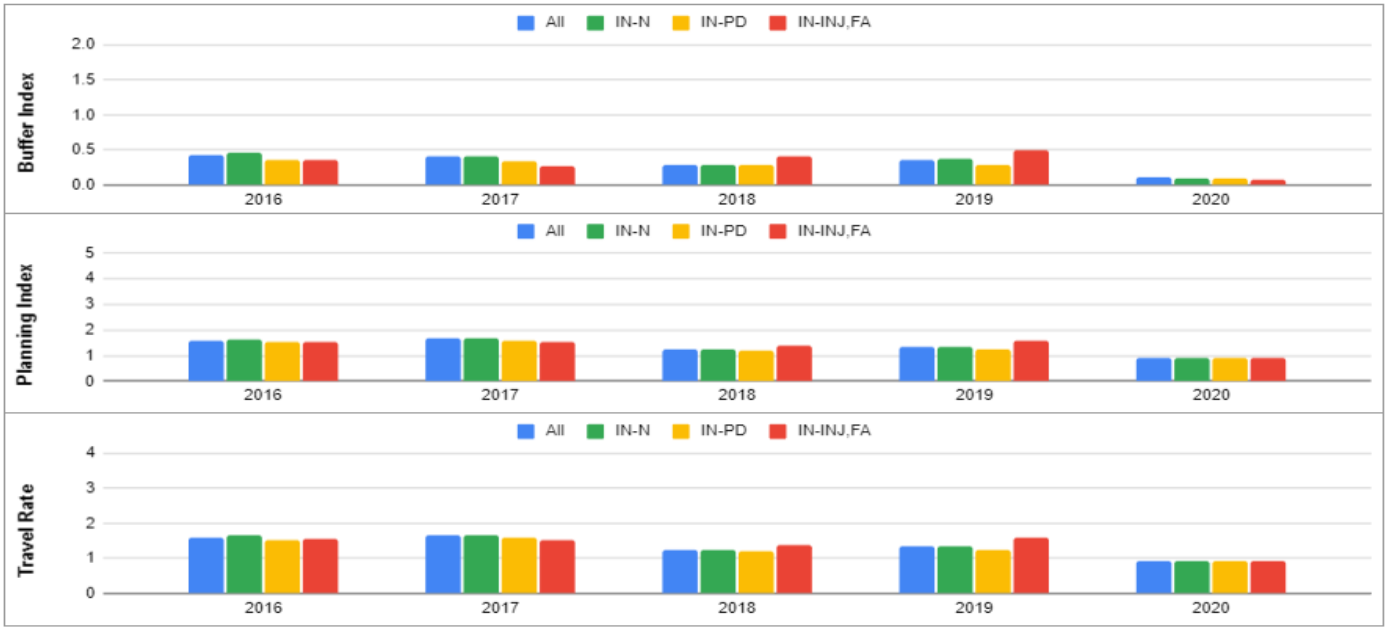
A.15.2.3 Effects of Incidents



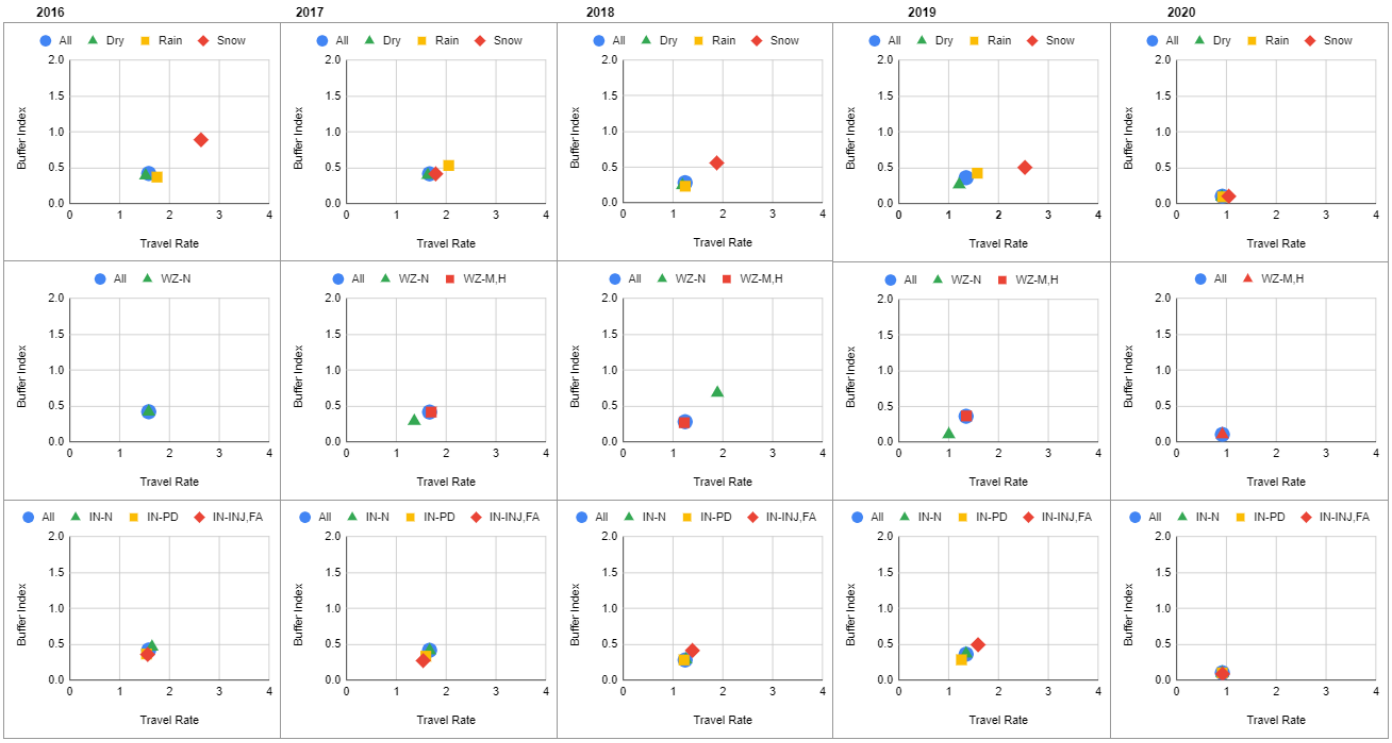
A.15.2.4 Yearly Variations



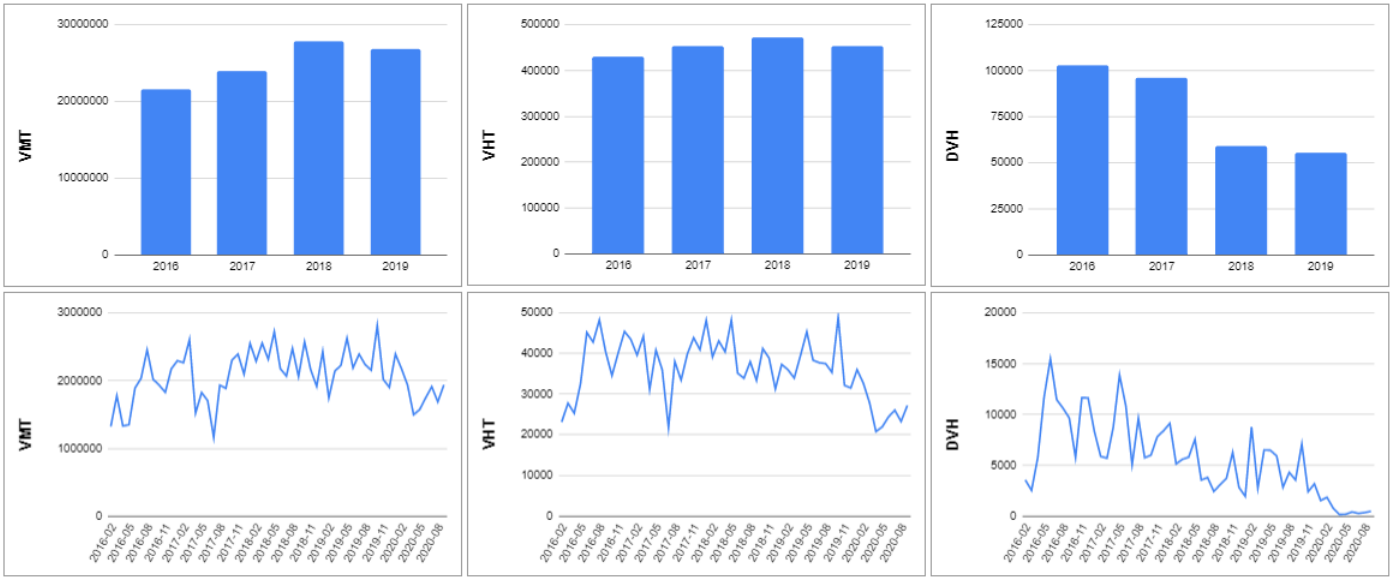

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.15.2.5 Variations of Combined Index



A.15.2.6 Variations of Traffic-Flow Measures



A.15.2.7 Trends Summary

- The traffic flow has increased for the period of 2016-2018, however, the monthly variations of the reliability measures show stable patterns in both travel-time variability and congestion levels.
- Weather, in particular, snow has been the main contributing factor to the reliability measures, while the effects of incidents have not been significant.

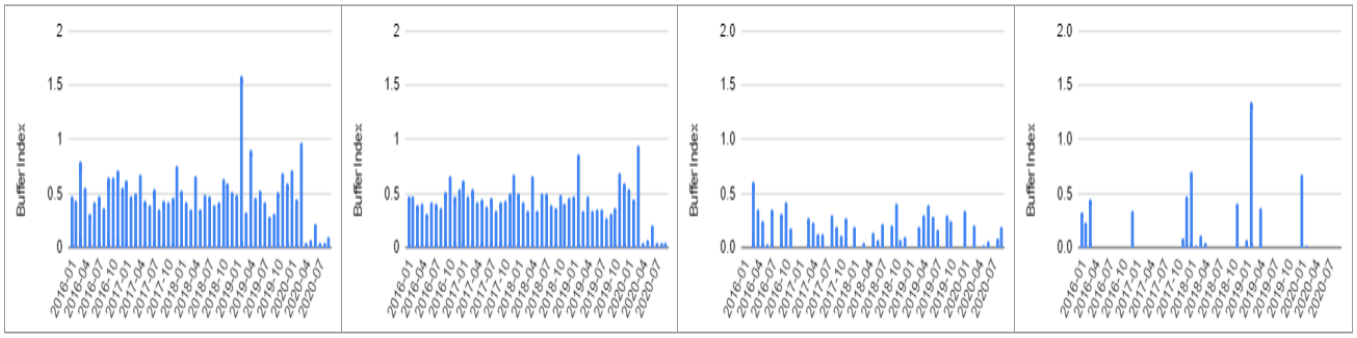
A.16 I-94 CORRIDOR 3 (MPLS – STPL, EASTBOUND/WESTBOUND)

A.16.1 I-94 EASTBOUND Route 3 (Mpls to STPL, Afternoon Peak)

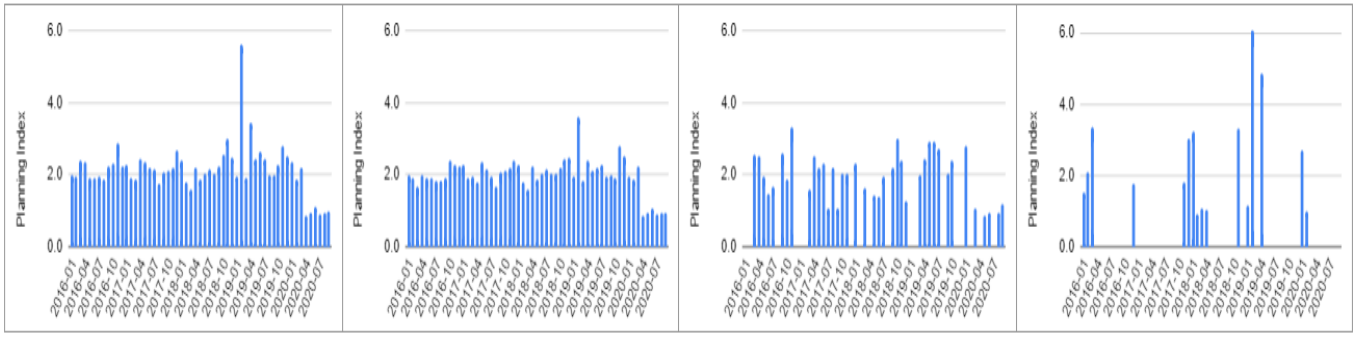
A.16.1.1 Effects of Weather

All Dry Rain Snow

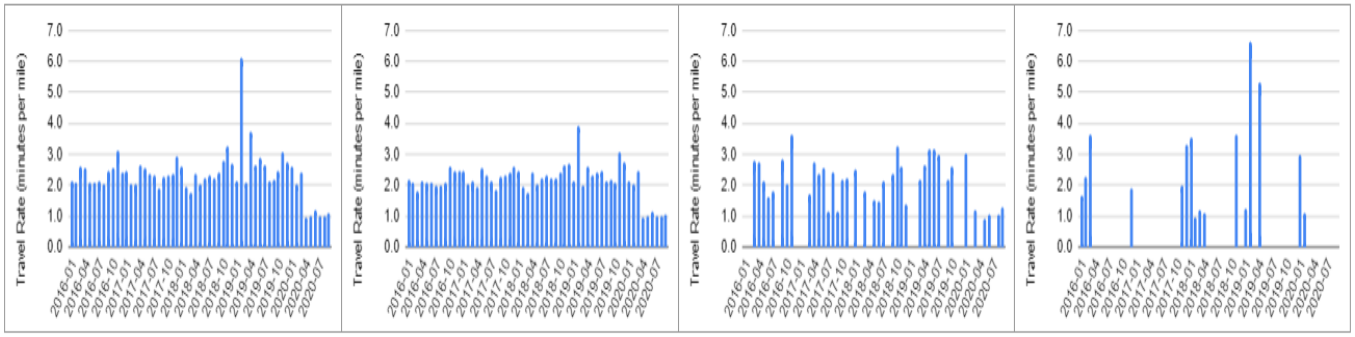
Buffer Index



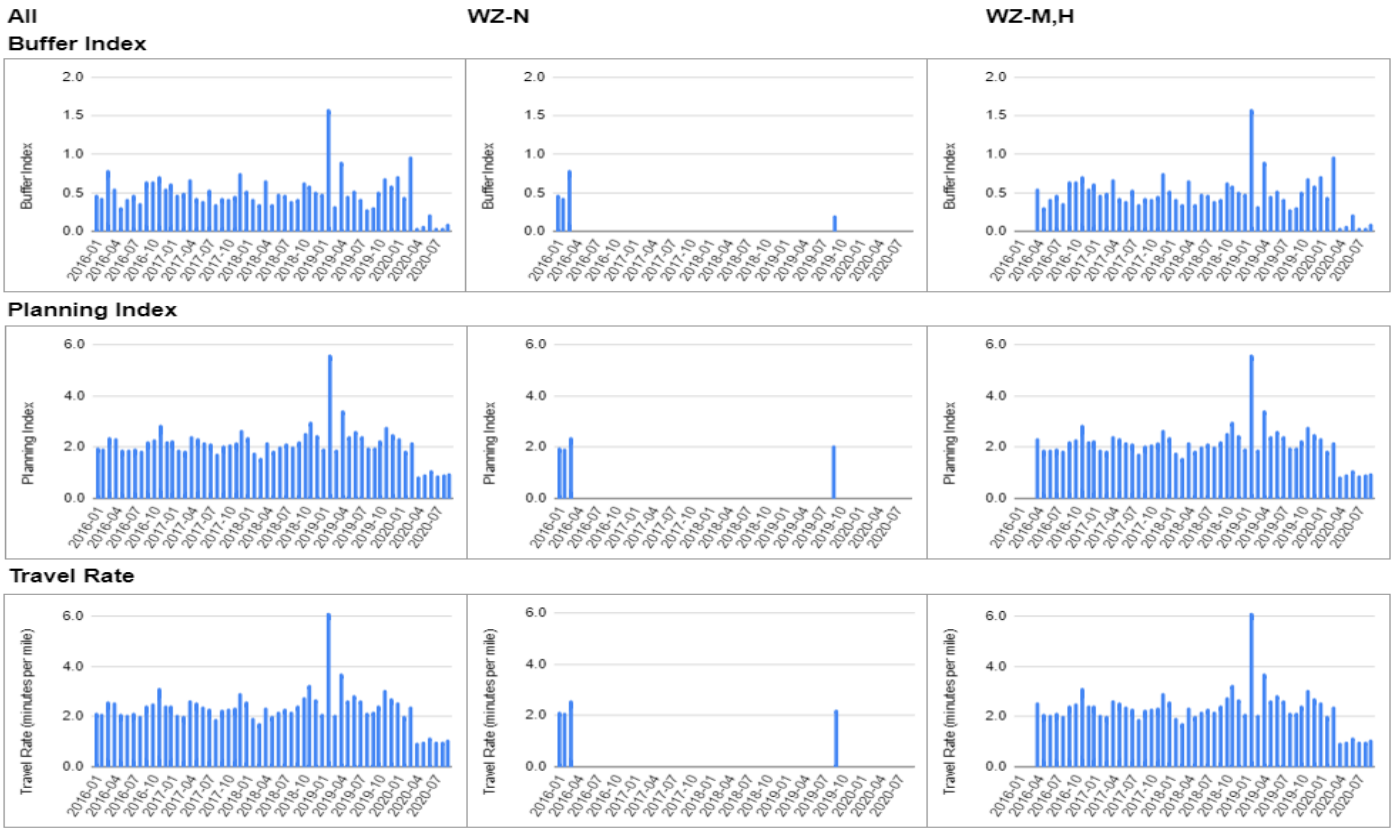
Planning Index



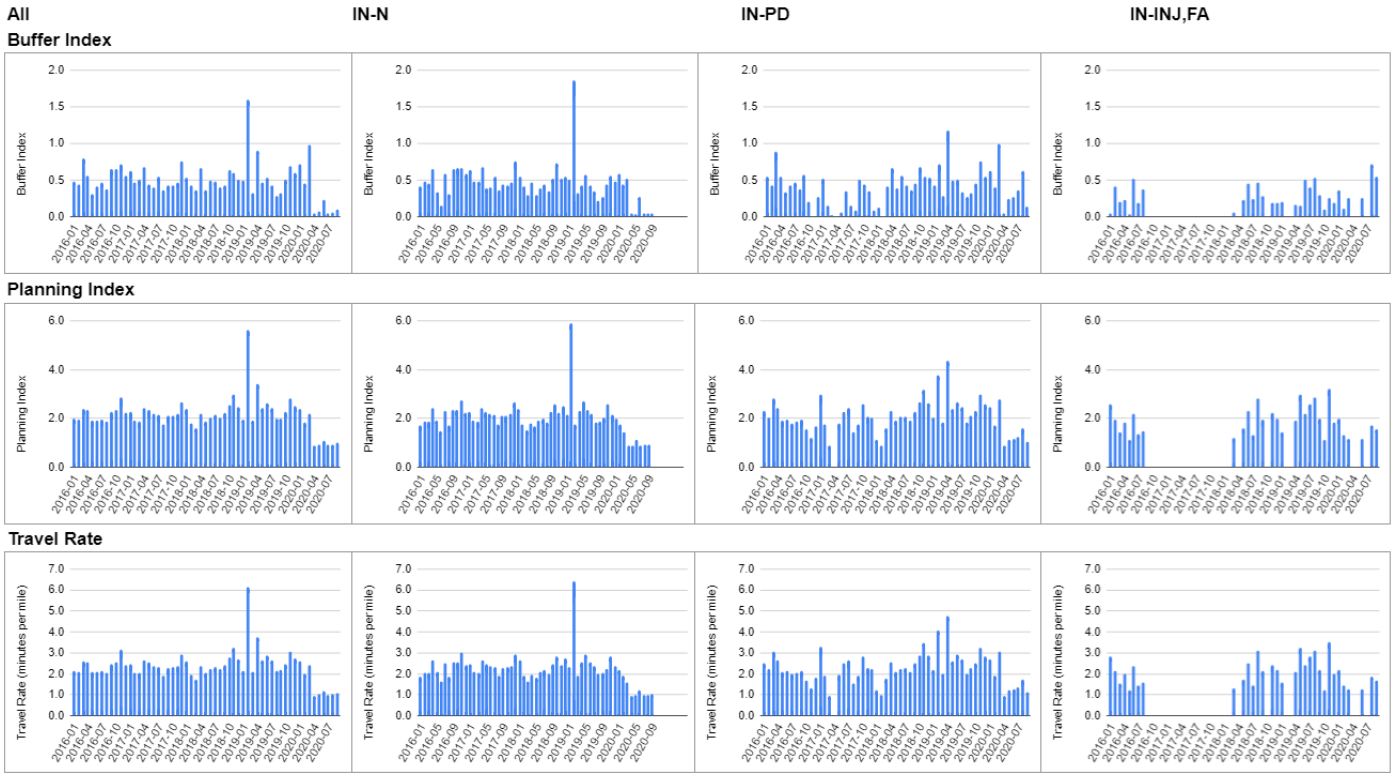
Travel Rate



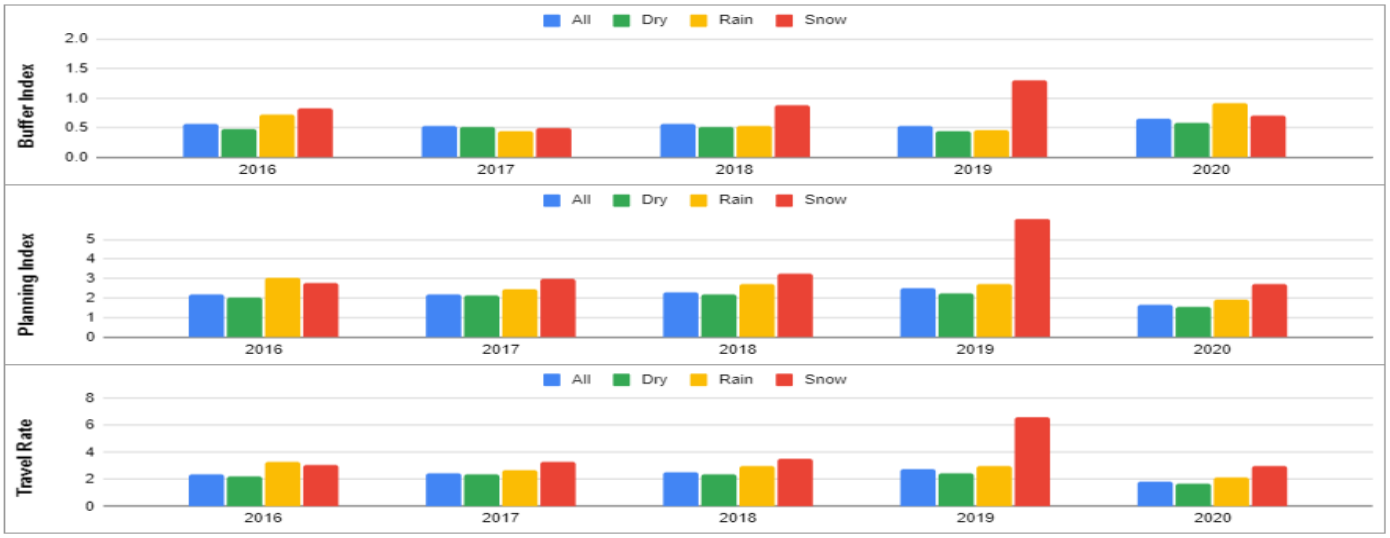
A.16.1.2 Effects of Work Zones

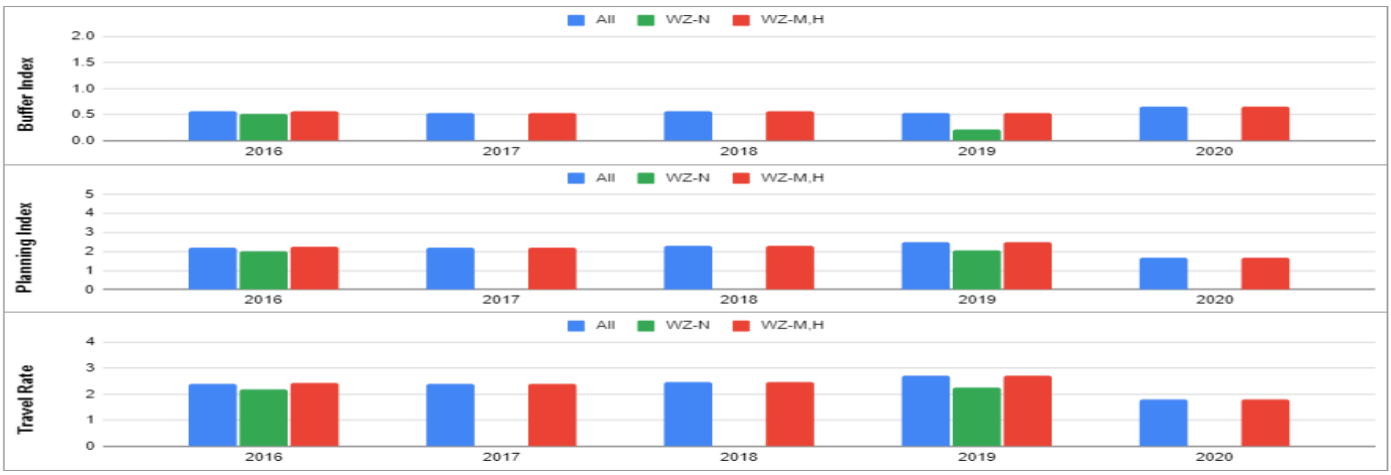


A.16.1.3 Effects of Incidents



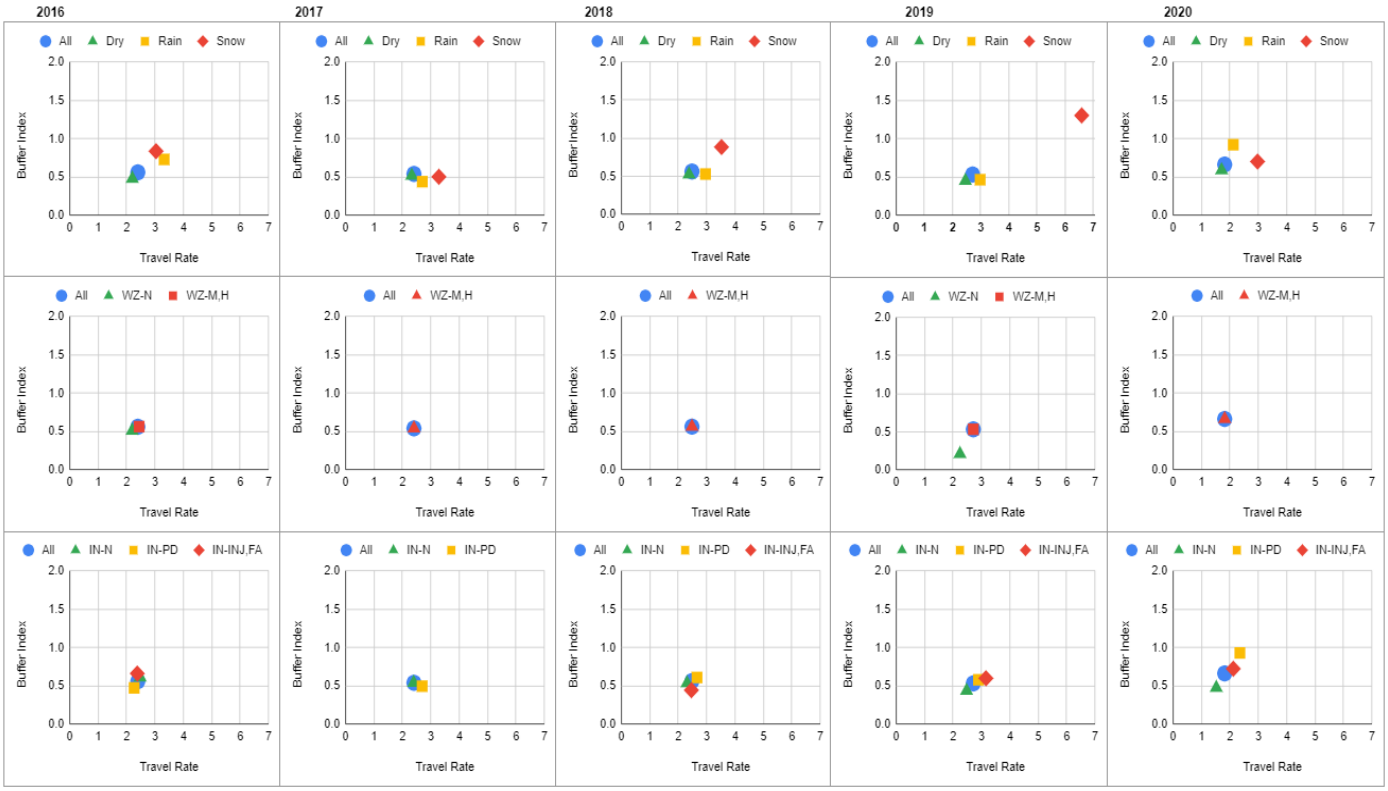
A.16.1.4 Yearly Variations



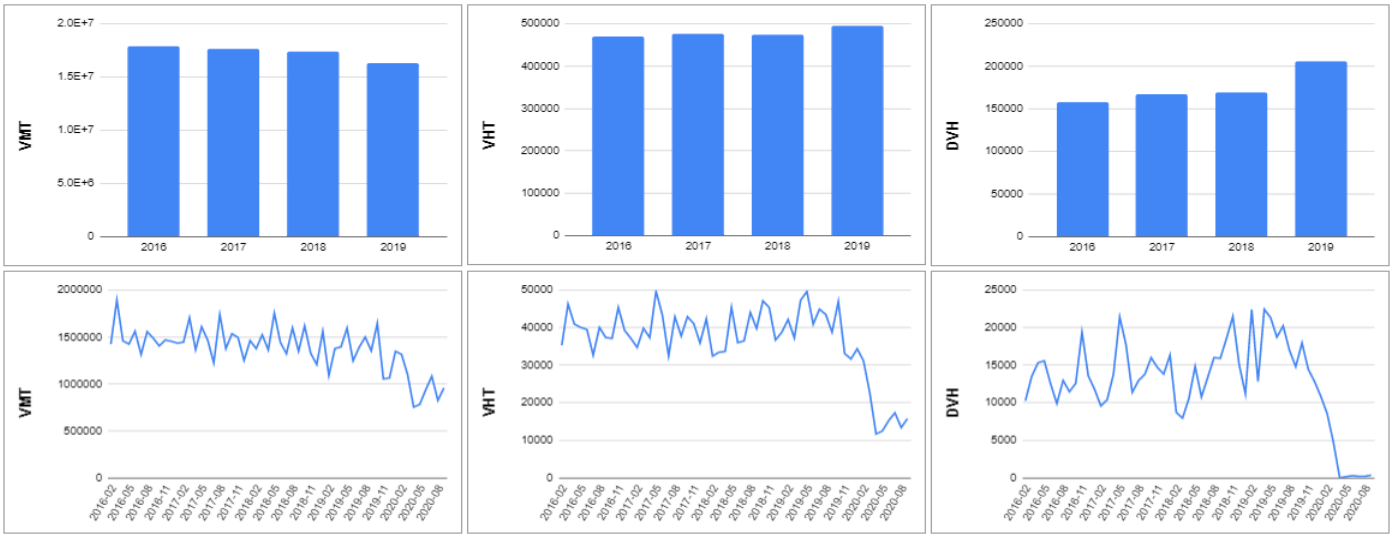

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.16.1.5 Variations of Combined Index



A.16.1.6 Variations of Traffic-Flow Measures

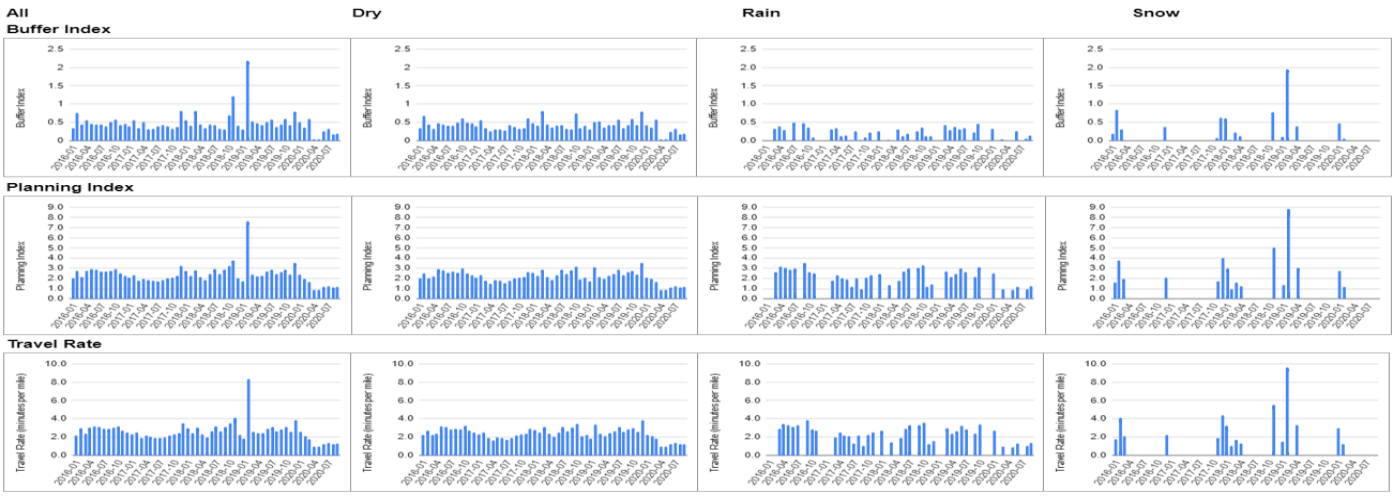


A.16.1.7 Trends Summary

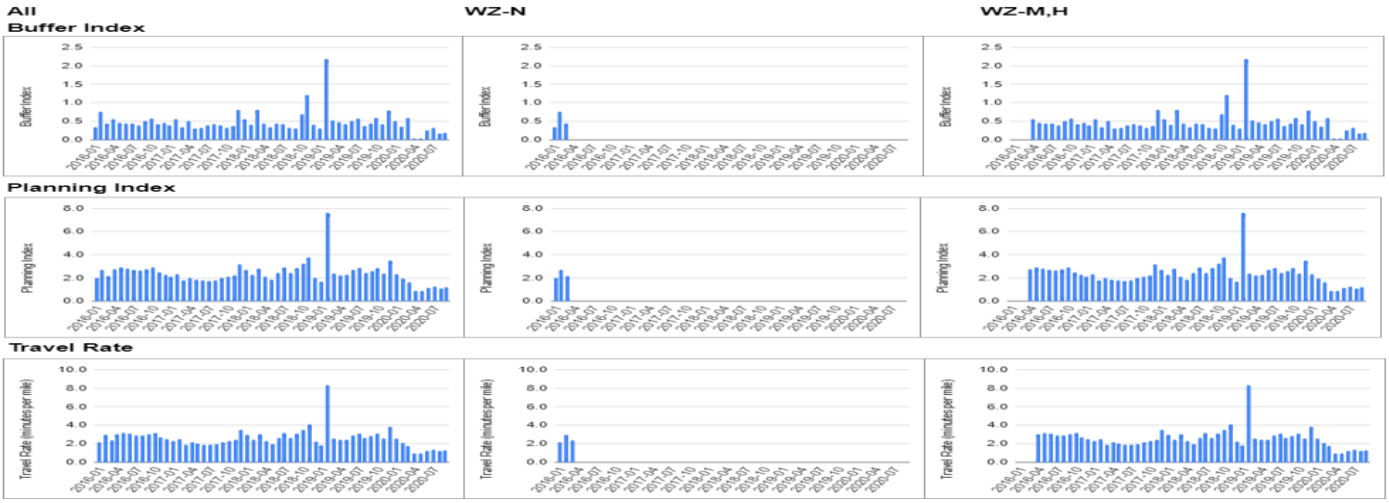
- The VMT has been a slightly downward trend for 2016-19, however, delays have not been reduced during the same period. This trend is also observed in the monthly variations of the planning index, i.e., high levels of congestion has continued during the same period.
- The changes in the reliability measures were mostly affected by snow, while incidents have also been a consistent factor.

A.16.2 I-94 WESTBOUND Route 3 (STPL to MPLS, Afternoon Peak)

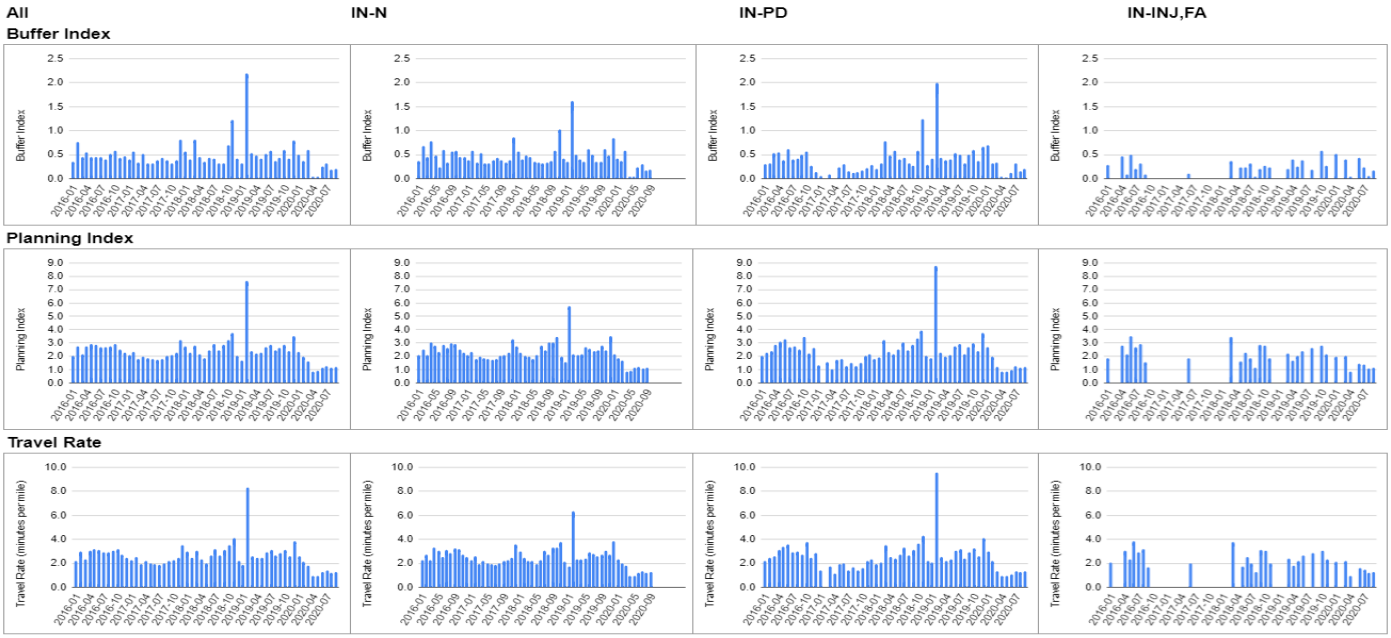
A.16.2.1 Effects of Weather



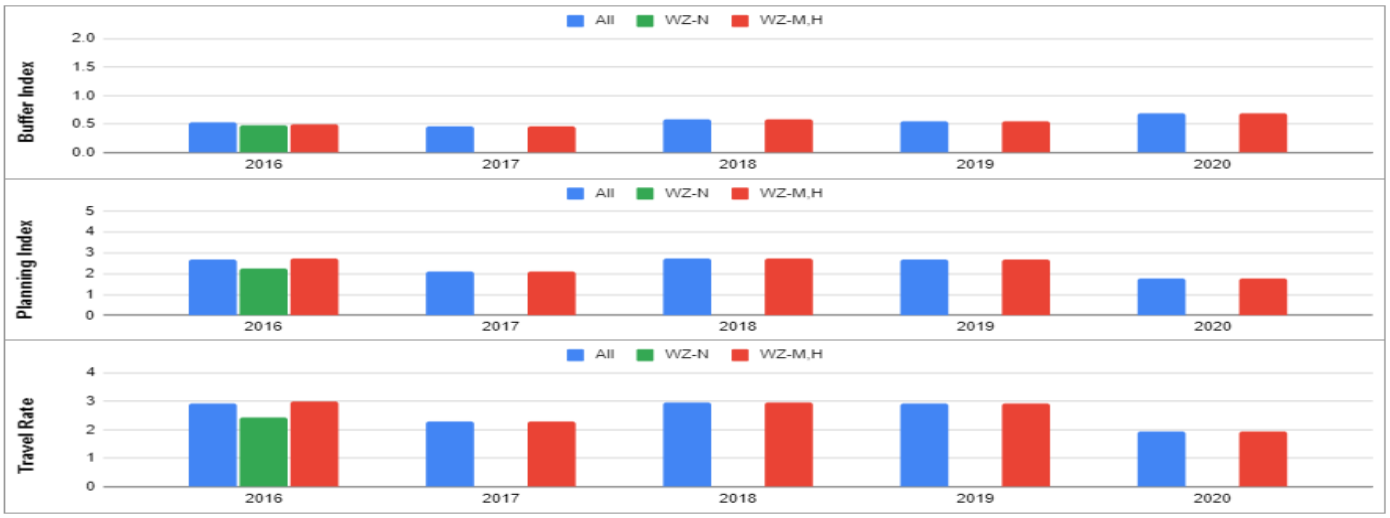
A.16.2.2 Effects of Work Zones

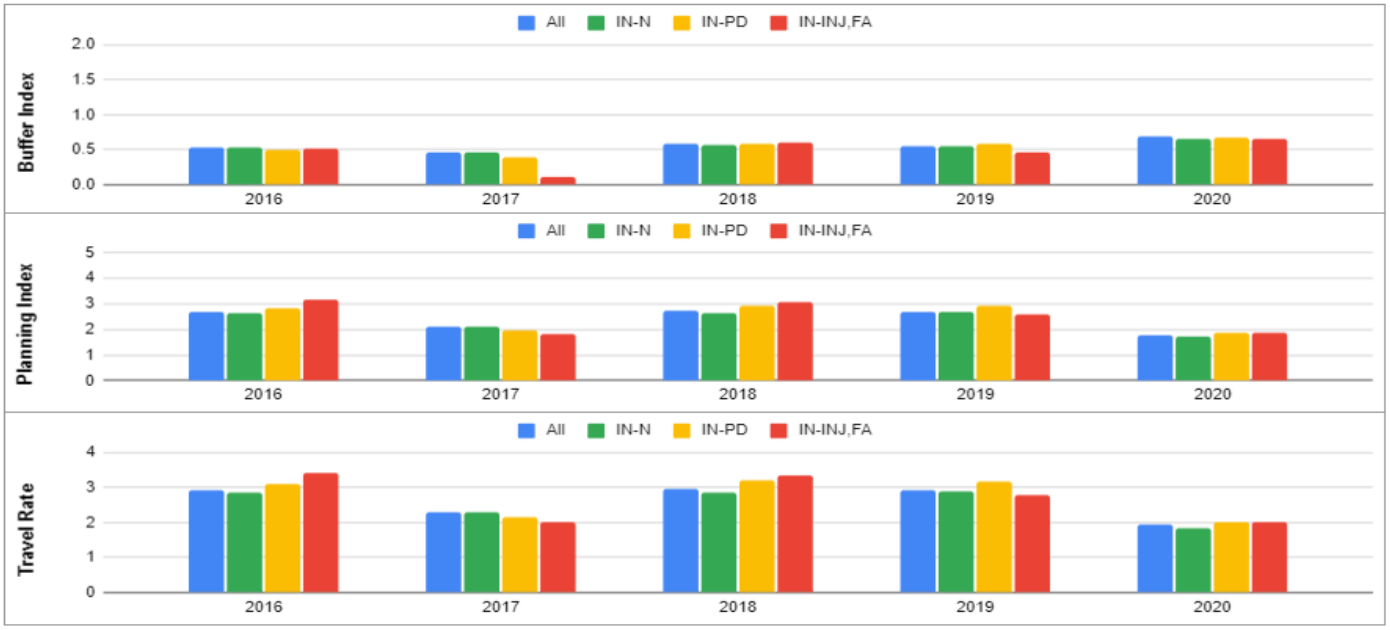


A.16.2.3 Effects of Incidents

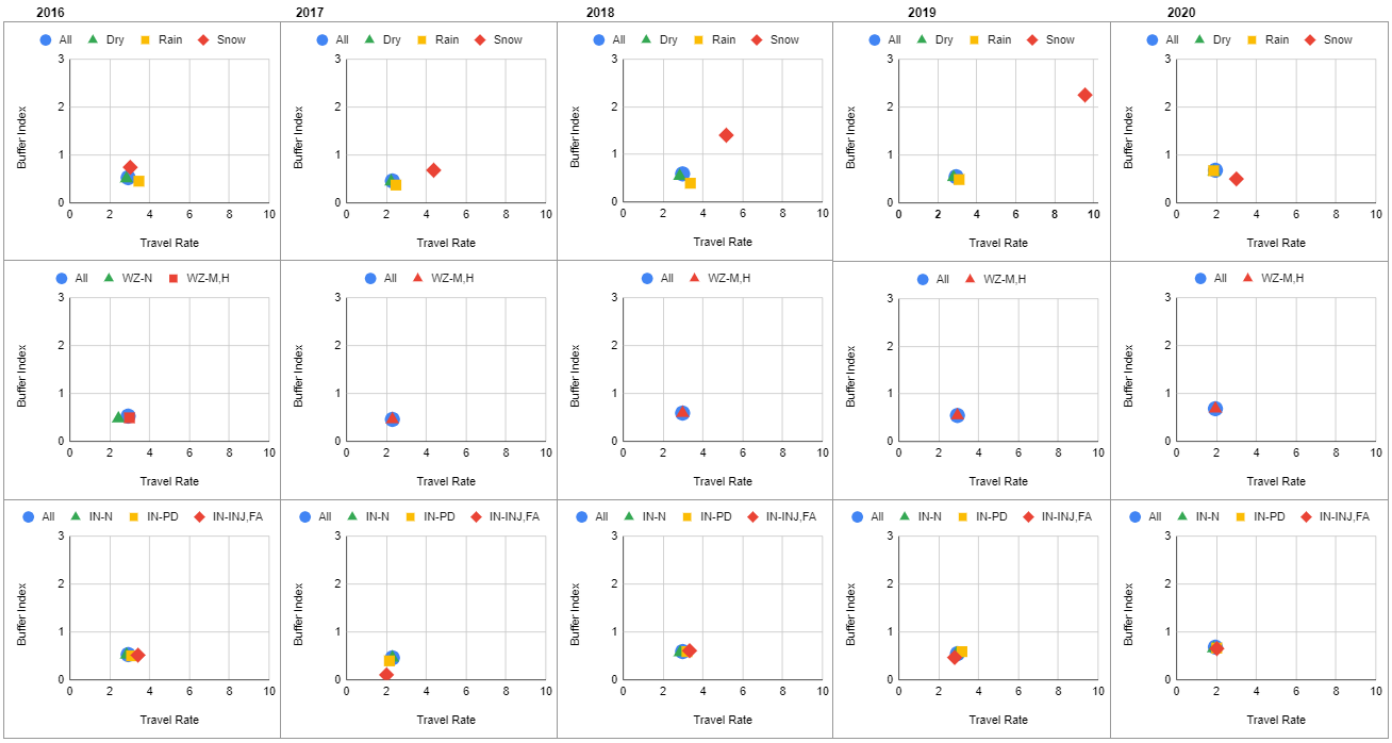


A.16.2.4 Yearly Variations

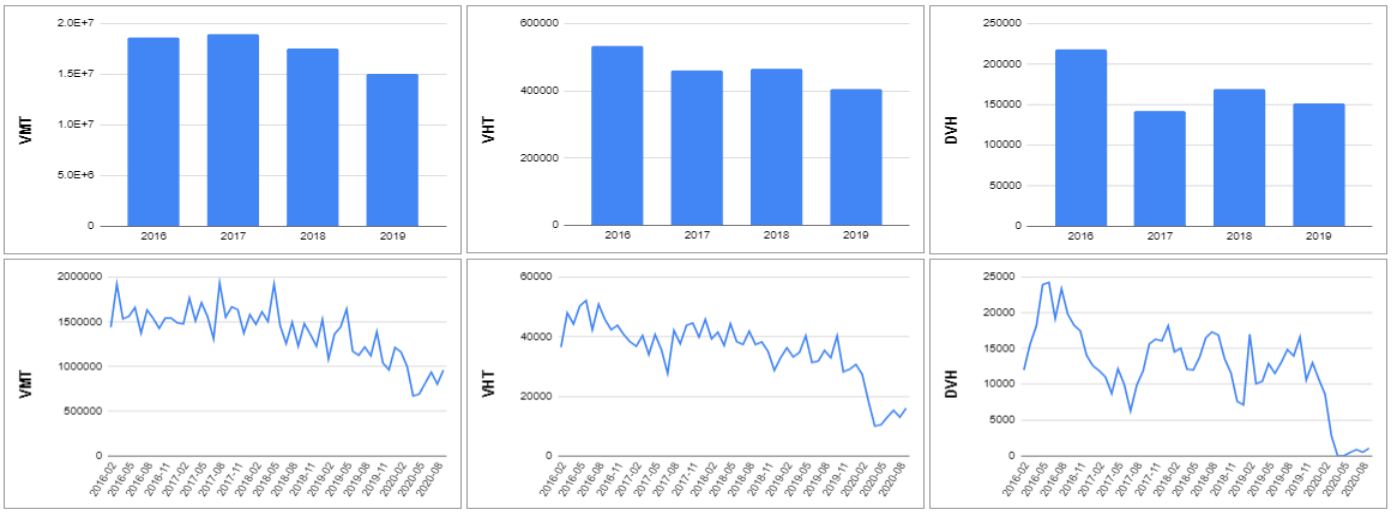

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.16.2.5 Yearly Variations



A.16.2.6 Variations of Traffic-Flow Measures

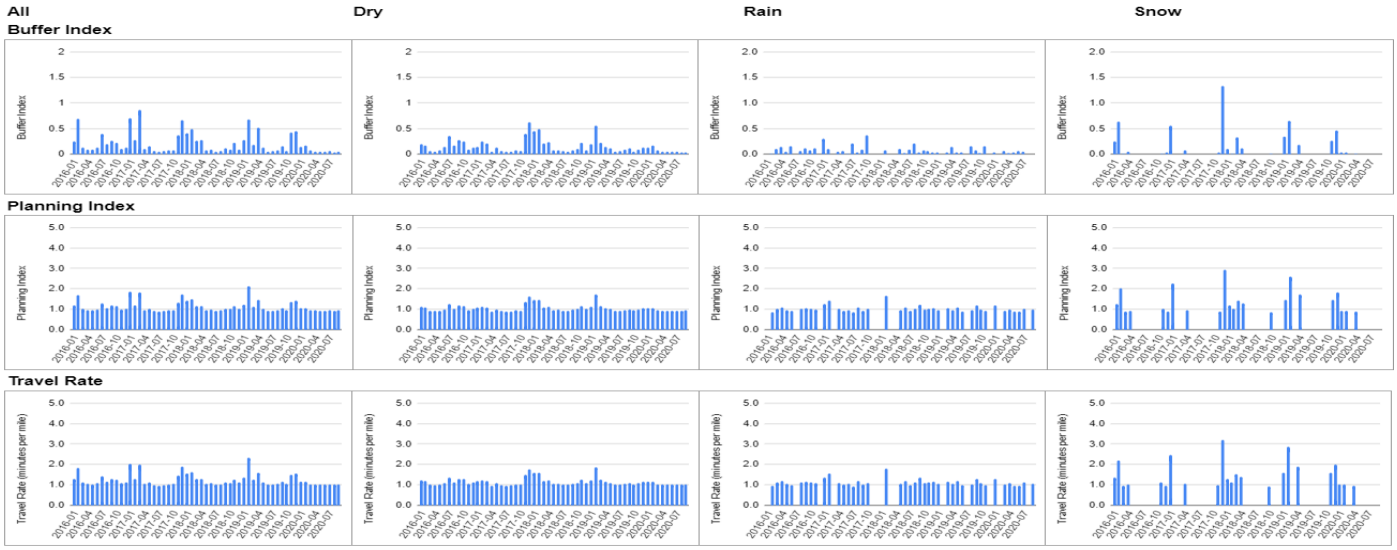


A.16.2.7 Trends Summary

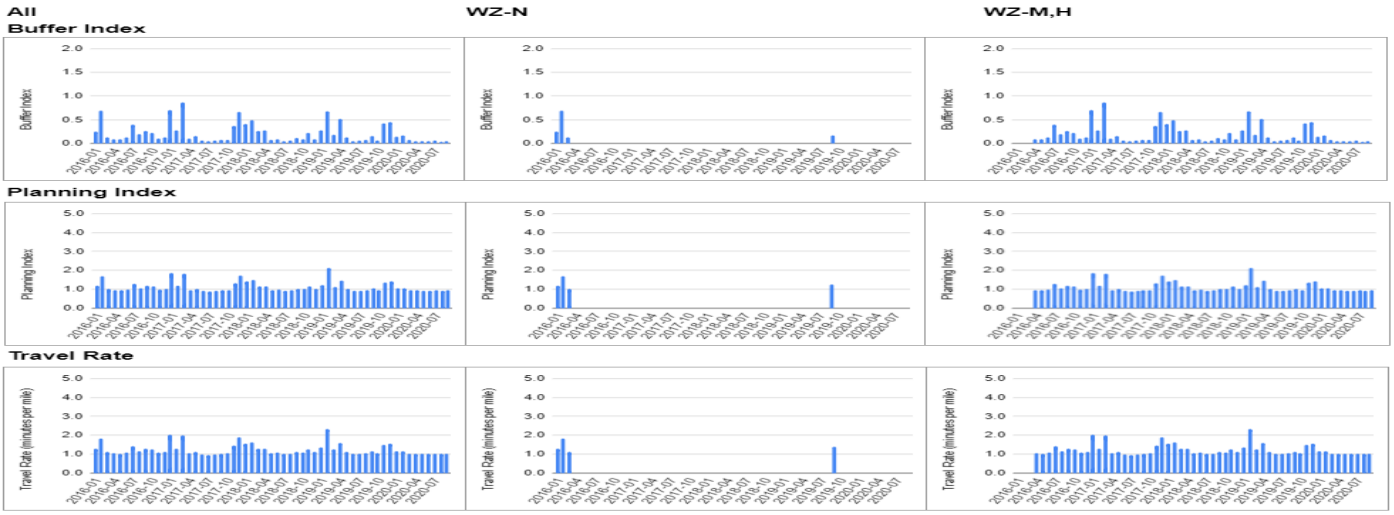
- Both VMT and vehicle hours have been decreasing on this route for the period of 2016-19, however, the 95th %-ile travel times have not been reduced during the same period.
- The effects of snow on both travel-time variability and congestion level have been continuously growing since 2016.

A.16.3 I-94 EASTBOUND Route 3 (Mpls to STPL, Morning Peak)

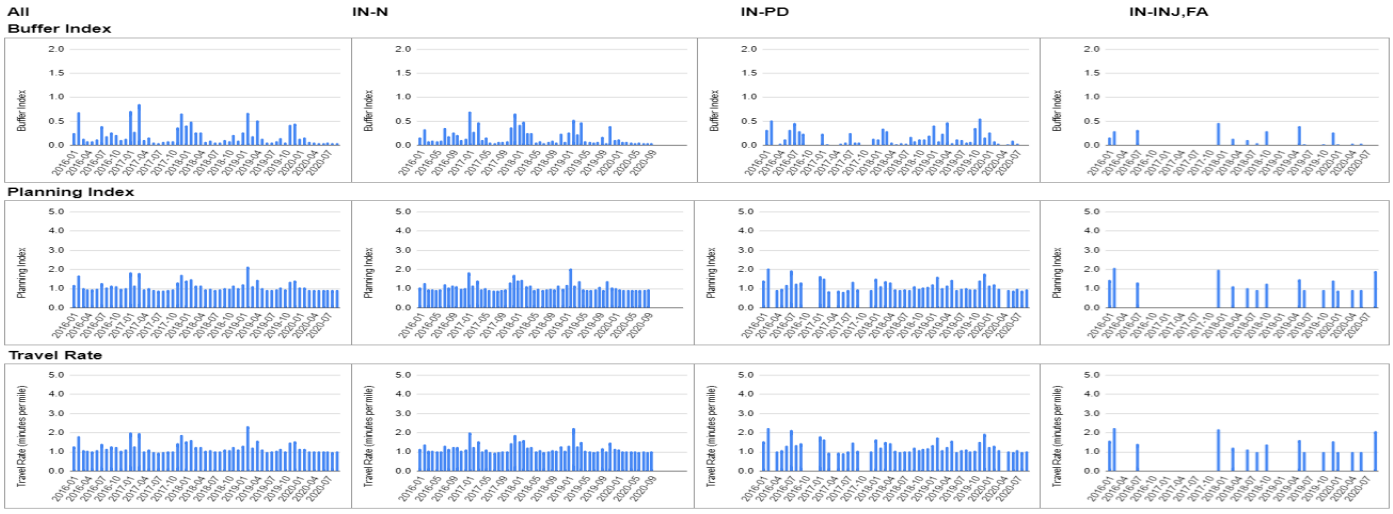
A.16.3.1 Effects of Weather



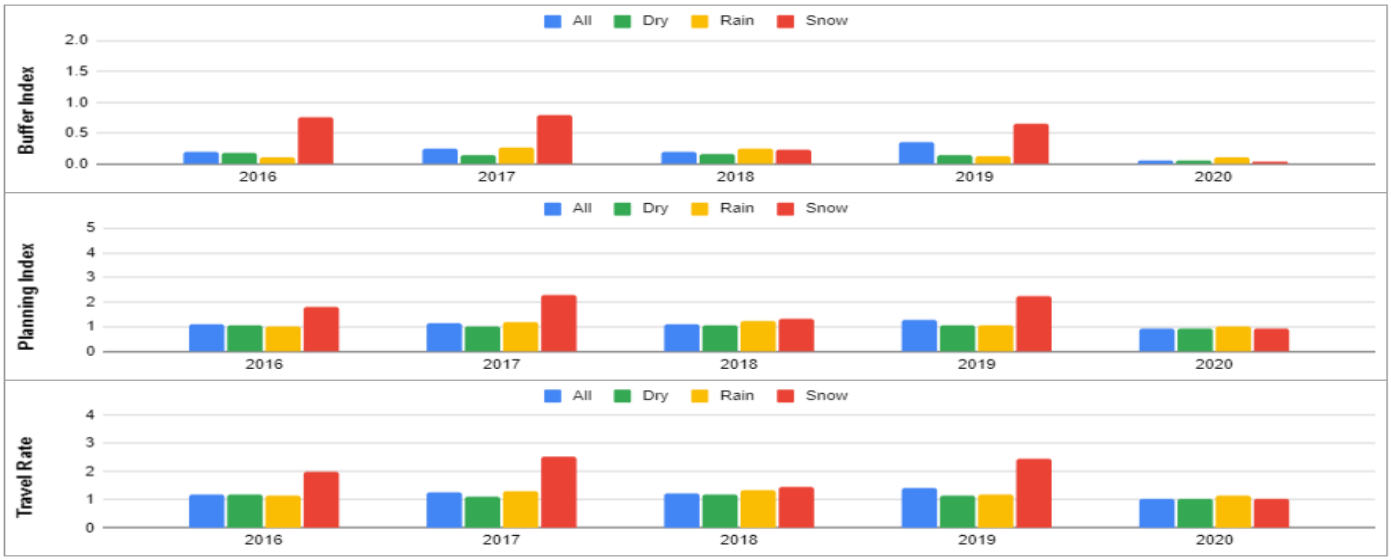
A.16.3.2 Effects of Work Zones

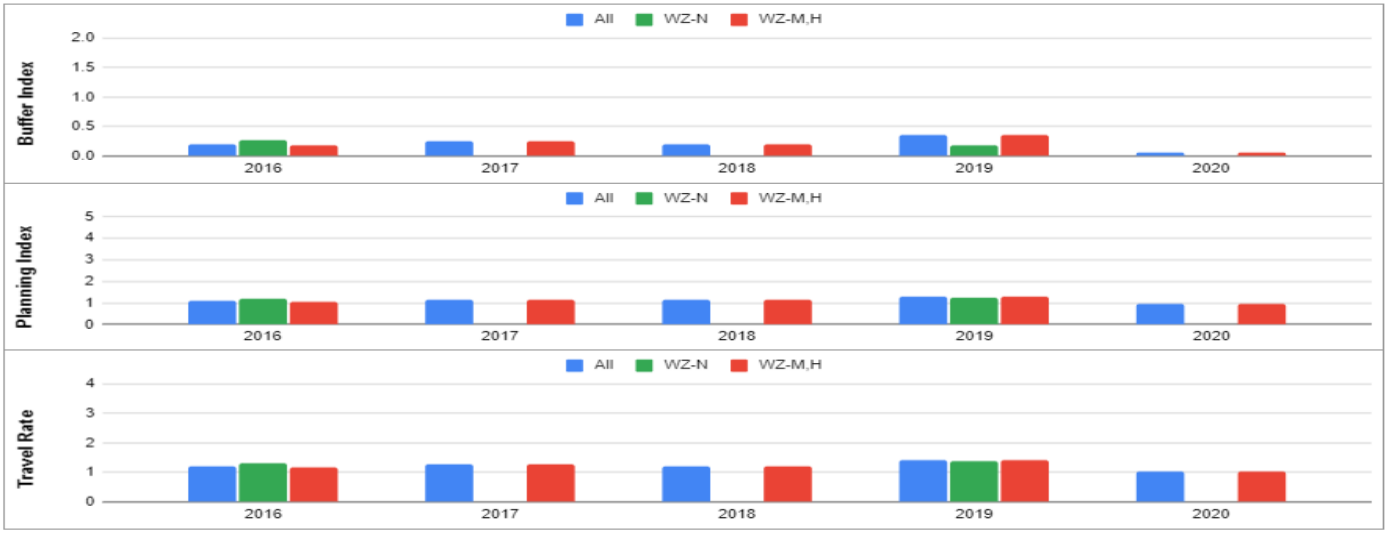


A.16.3.3 Effects of Incidents



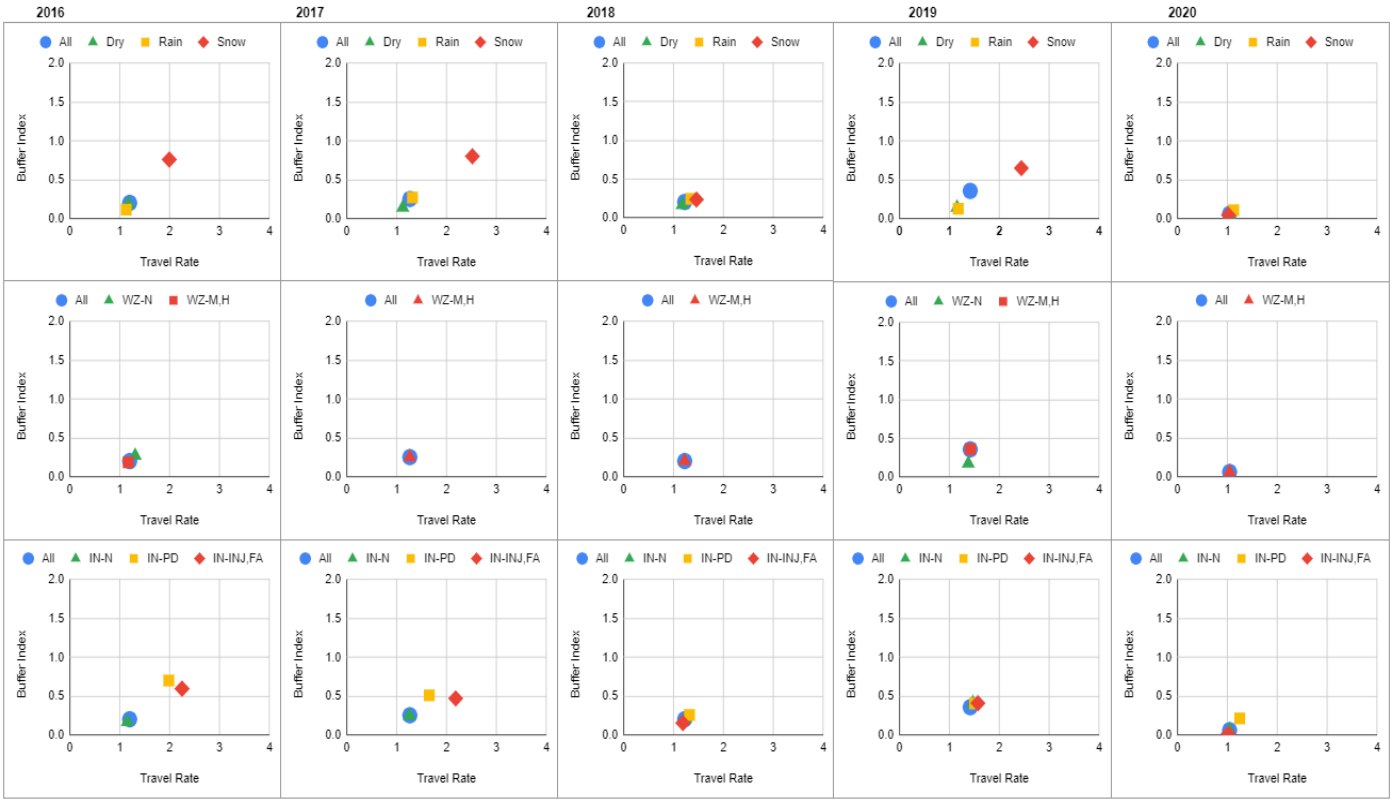
A.16.3.4 Yearly Variations



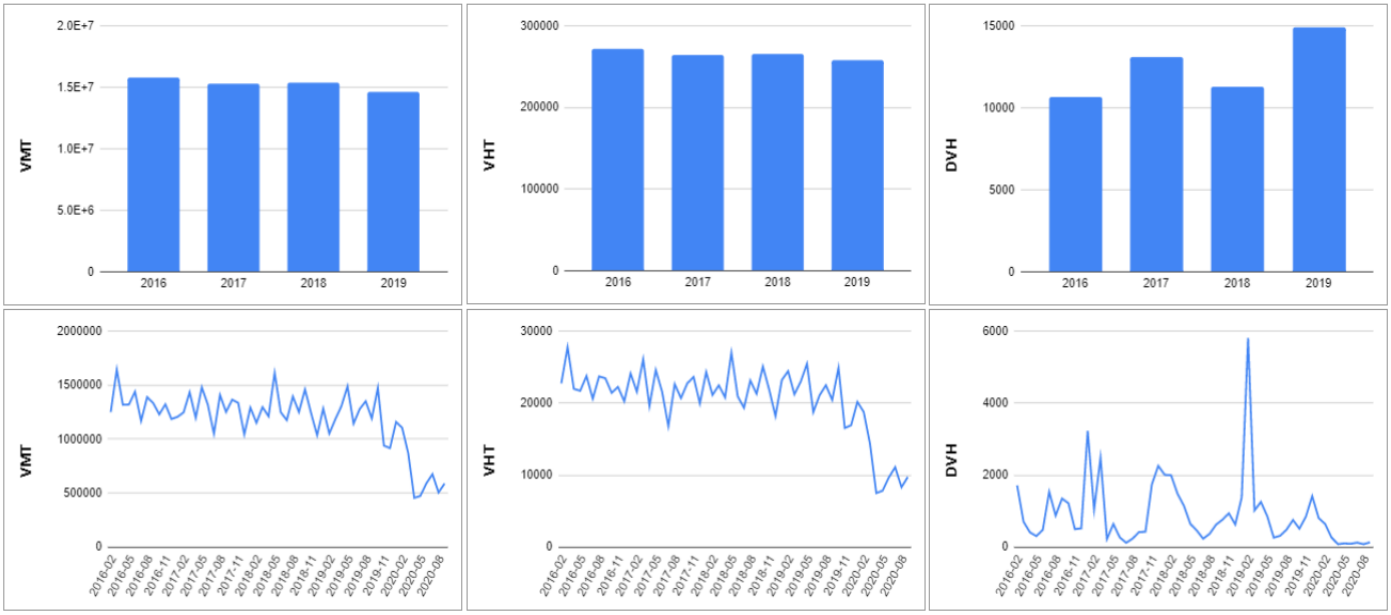

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.16.3.5 Variations of Combined Index

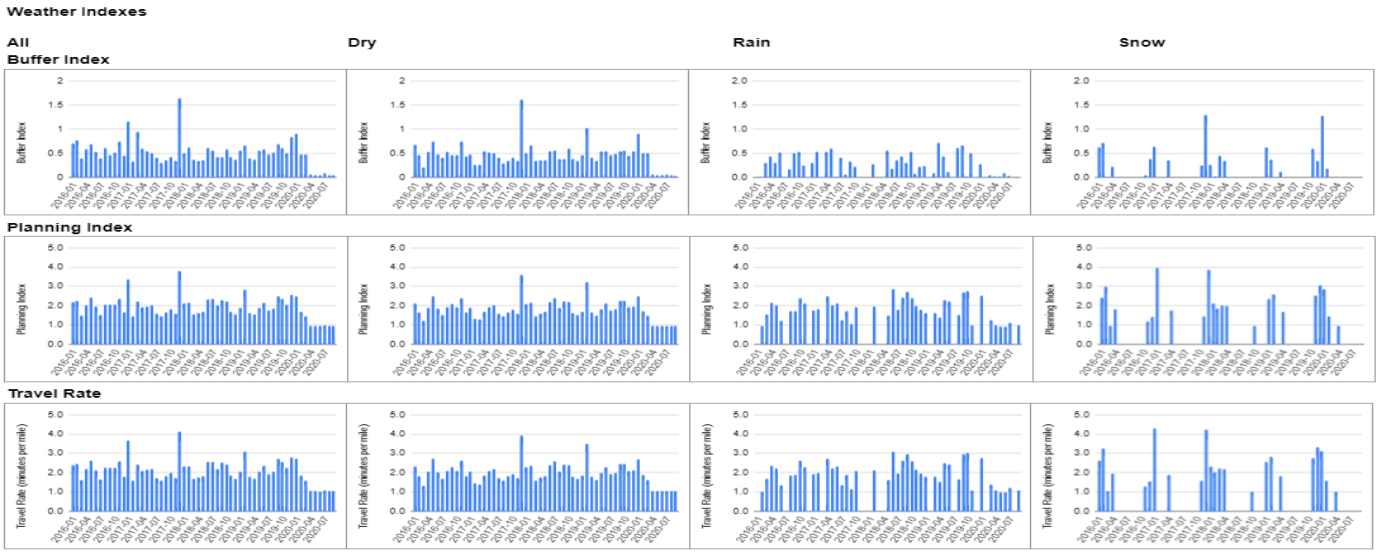


A.16.3.6 Variations of Traffic-Flow Measures

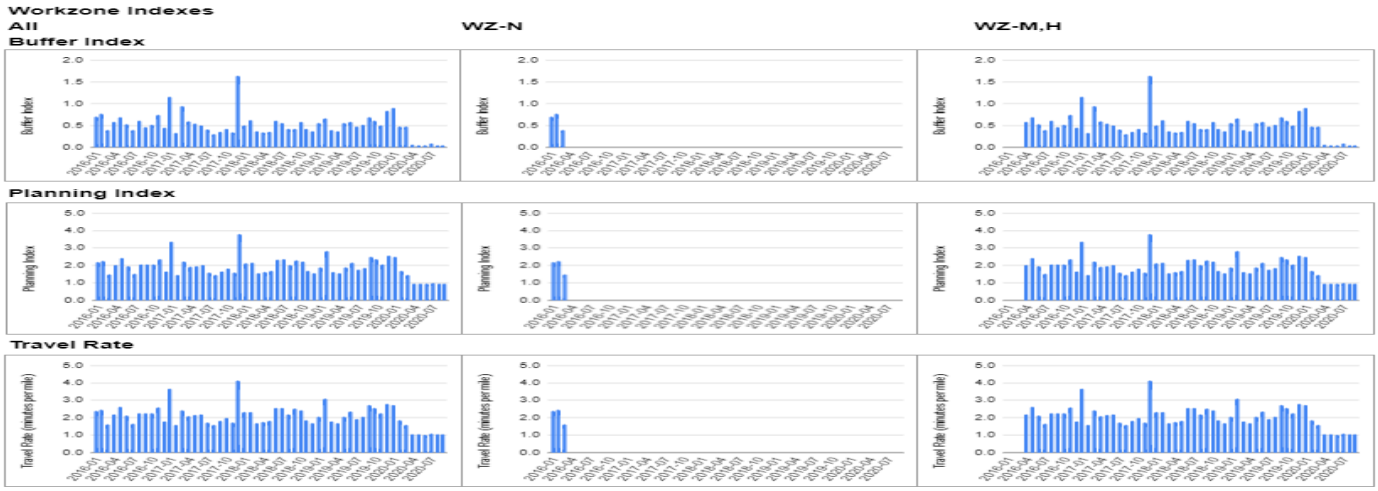


A.16.4 I-94 WESTBOUND Route 3 (STPL to MPLS, Morning Peak)

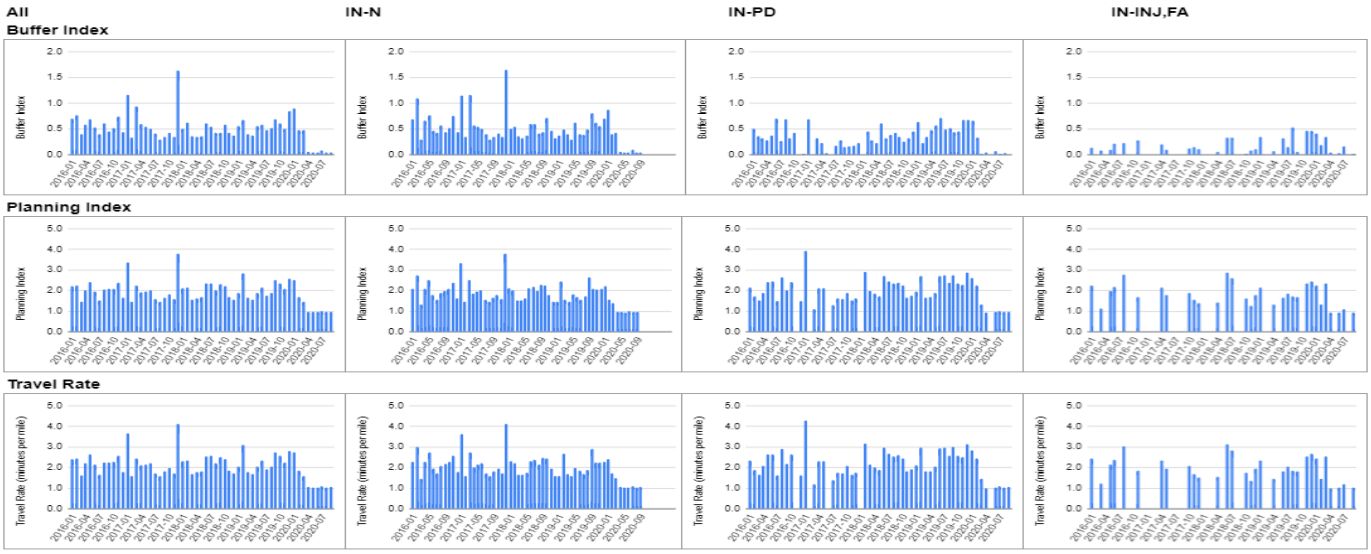
A.16.4.1 Effects of Weather



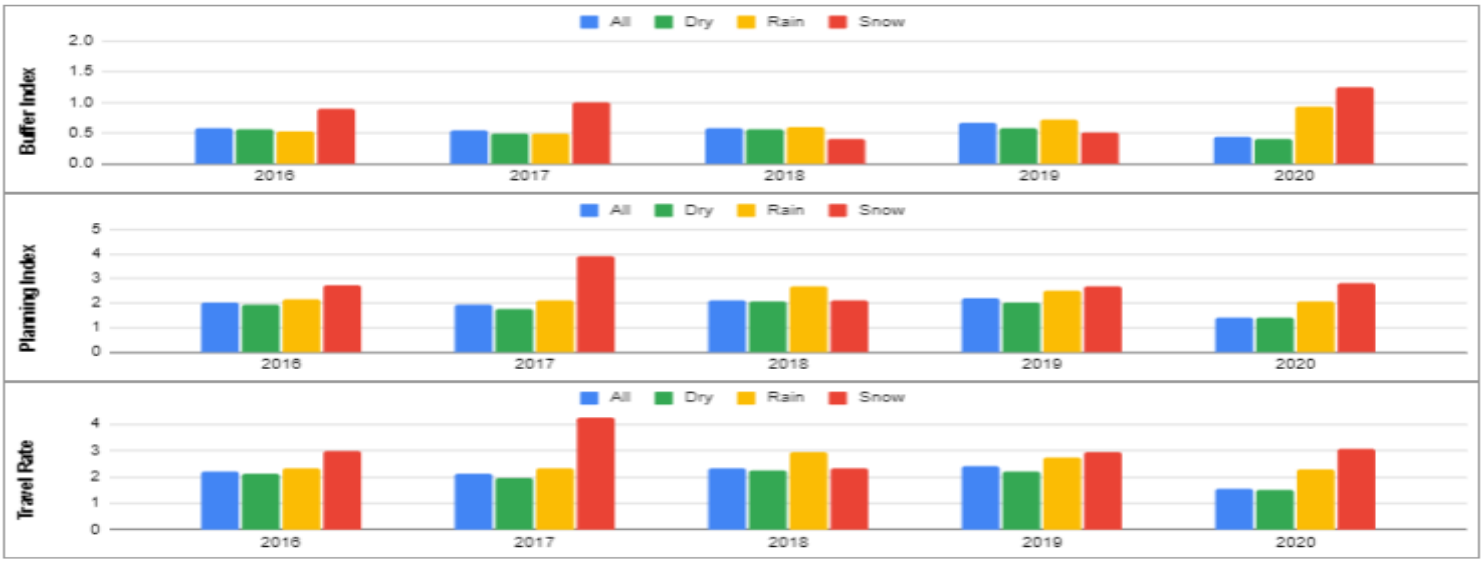
A.16.4.2 Effects of Work Zones

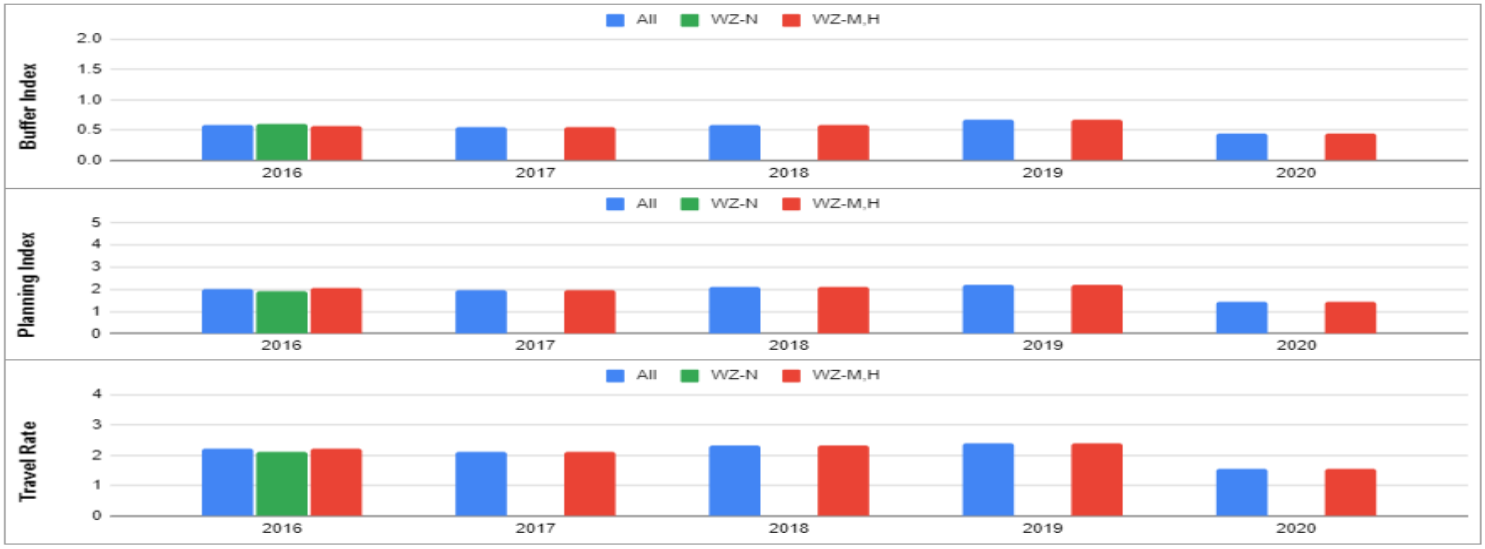


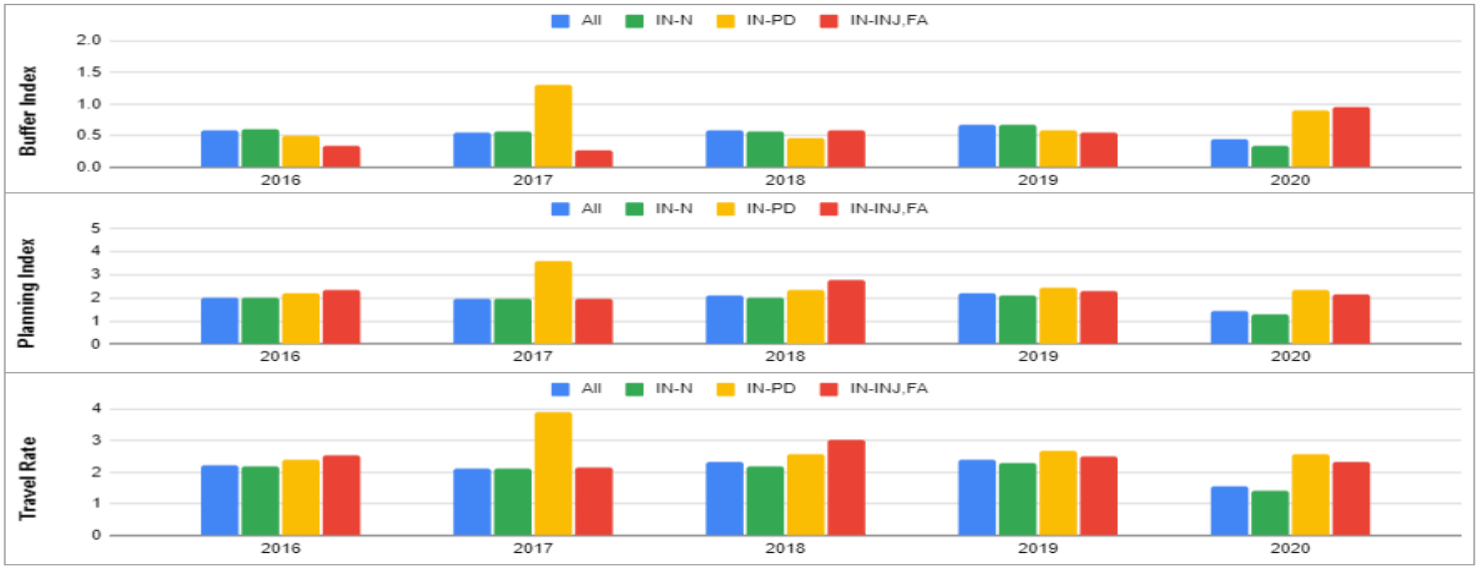
A.16.4.3 Effects of Incidents



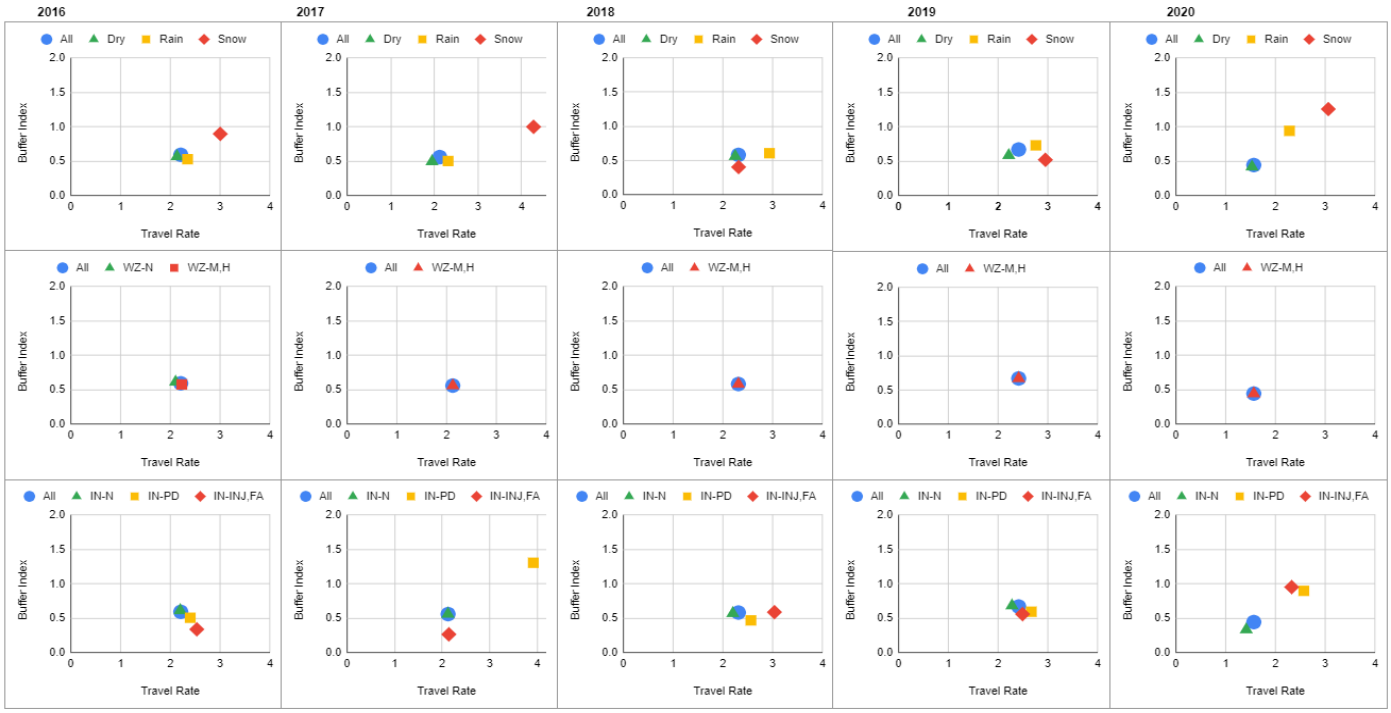
A.16.4.4 Yearly Variations



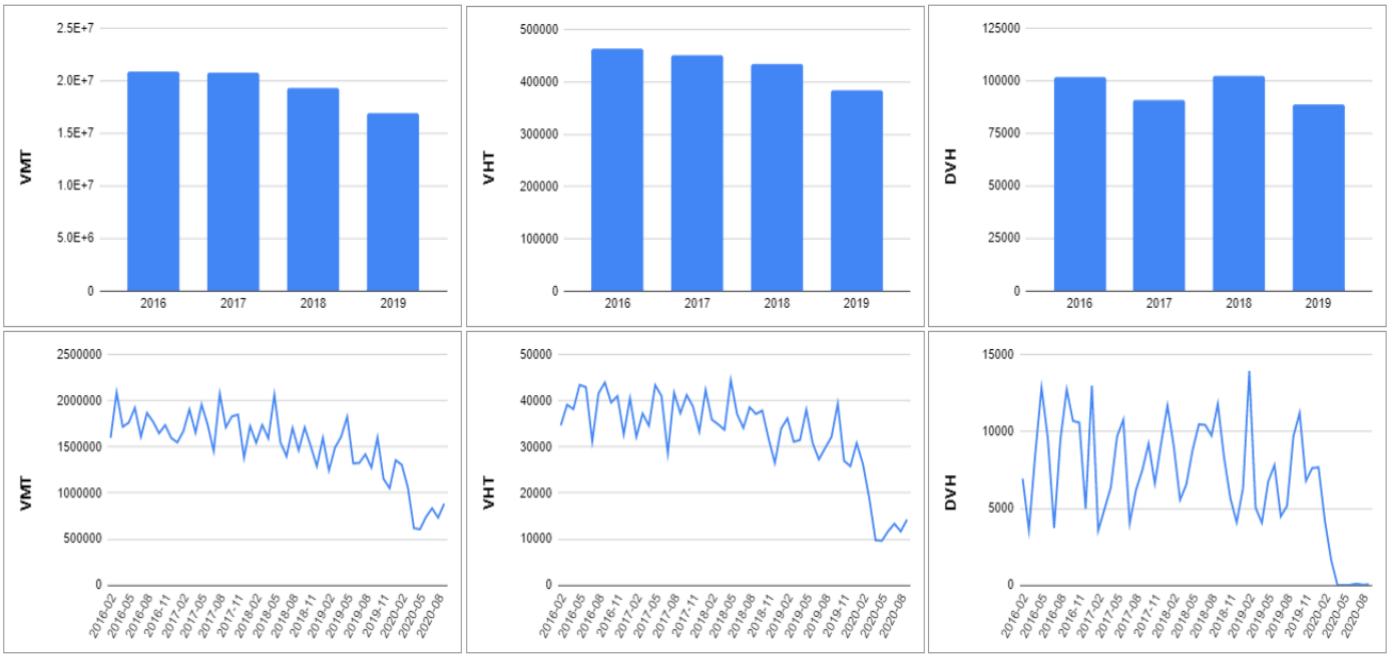

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.16.4.5 Yearly Variations of Combined Index



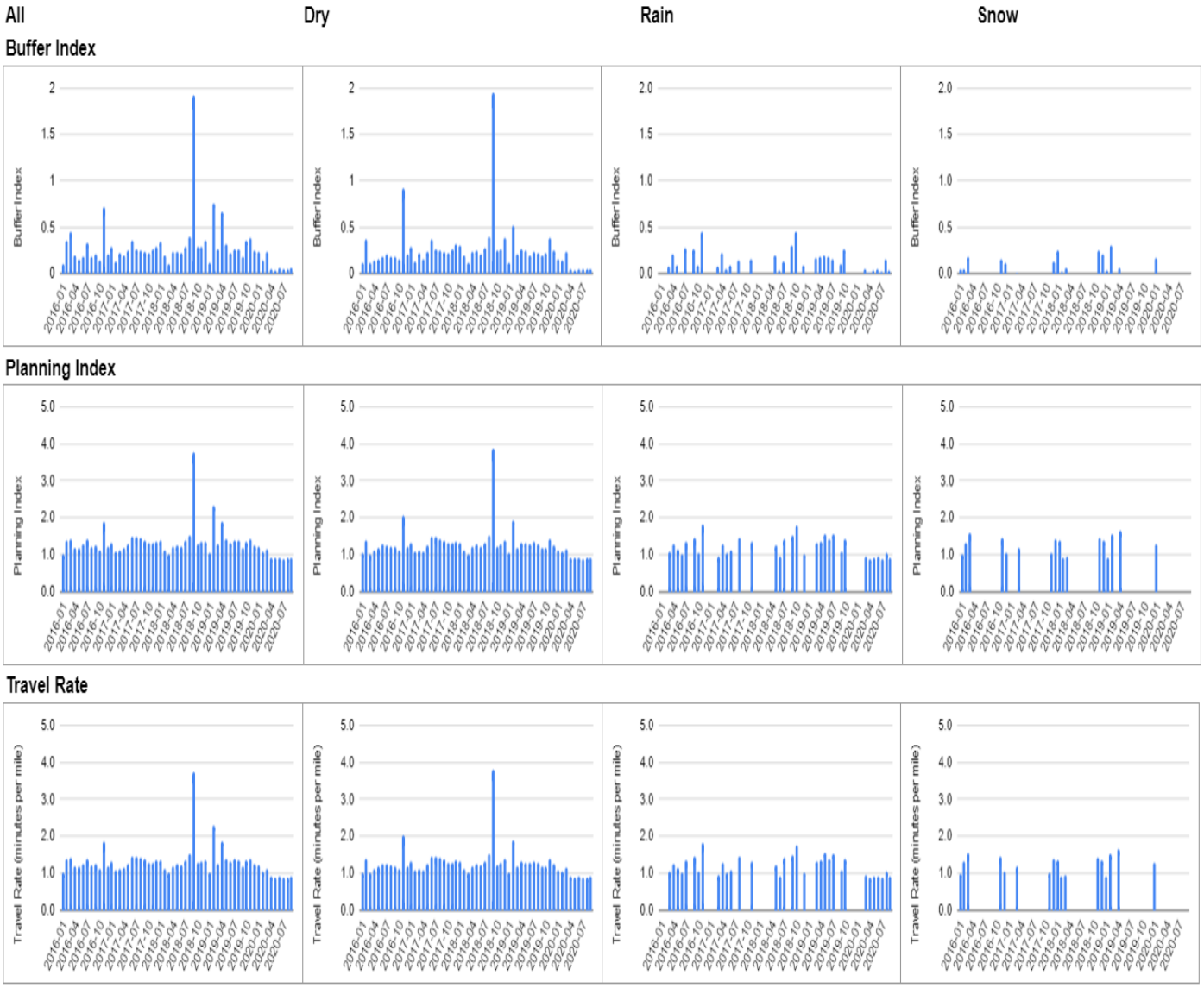
A.16.4.6 Variations of Traffic-Flow Measures



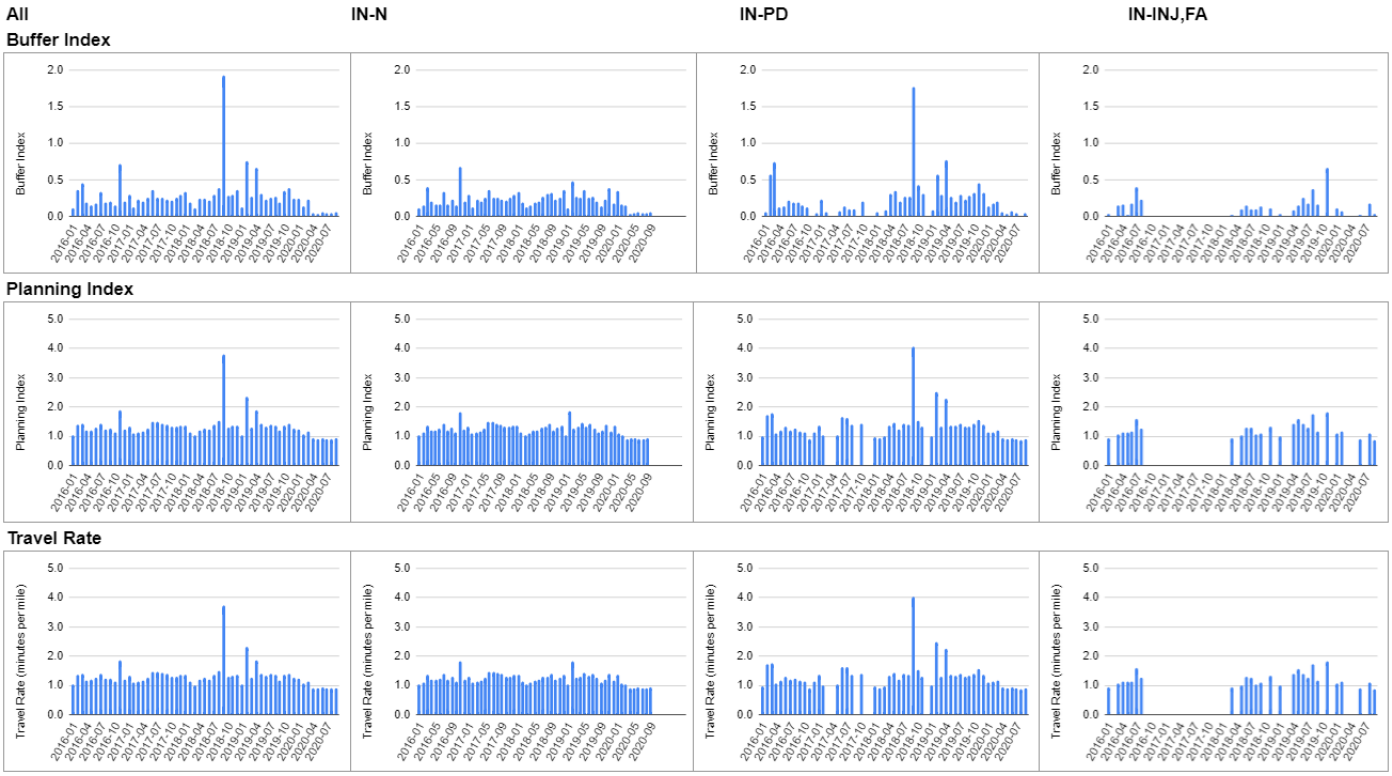
A.17 I-94 CORRIDOR 4 (STPL – WISC, EASTBOUND/WESTBOUND)

A.17.1 I-94 EASTBOUND Route 4 (STPL to WISC, Afternoon Peak)

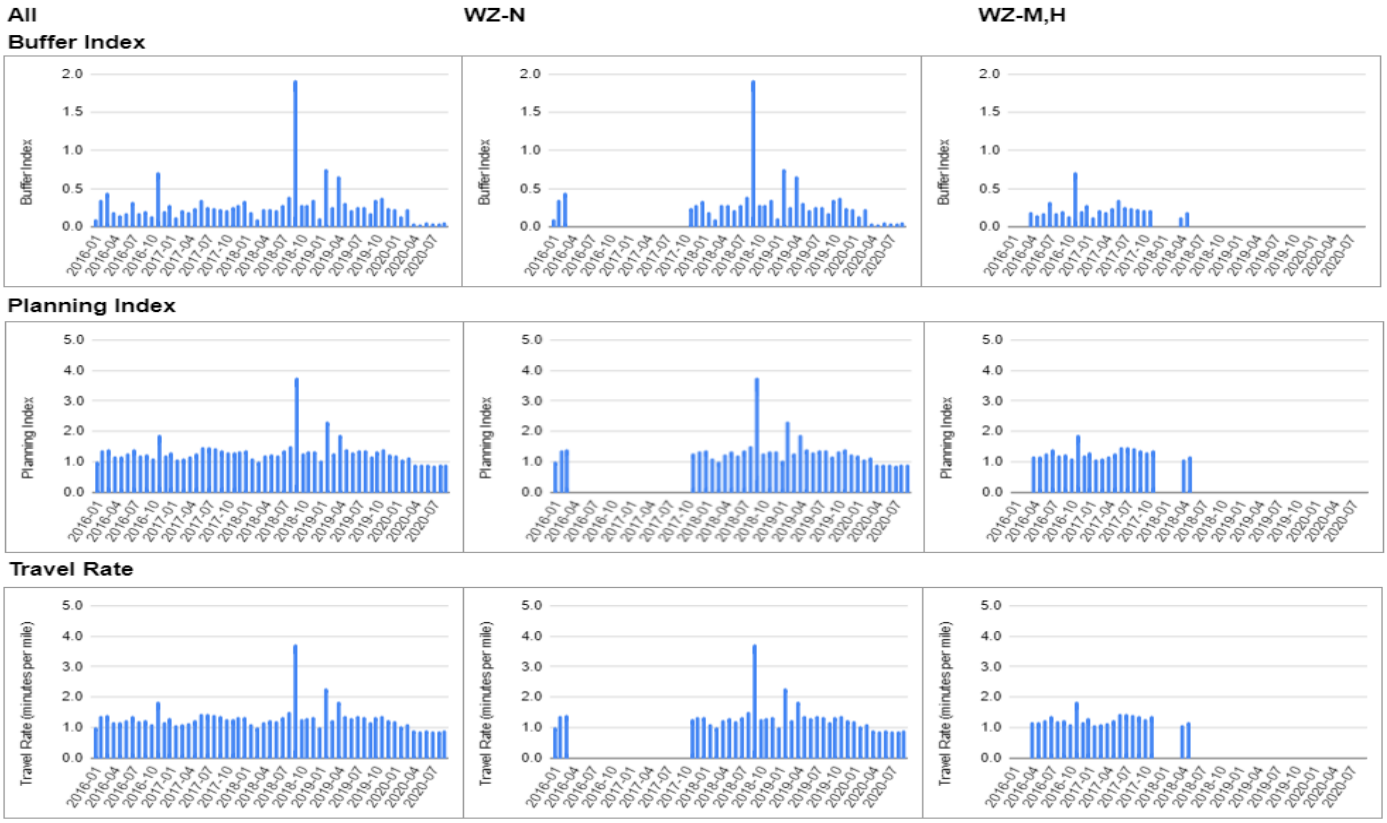
A.17.1.1 Effects of Weather



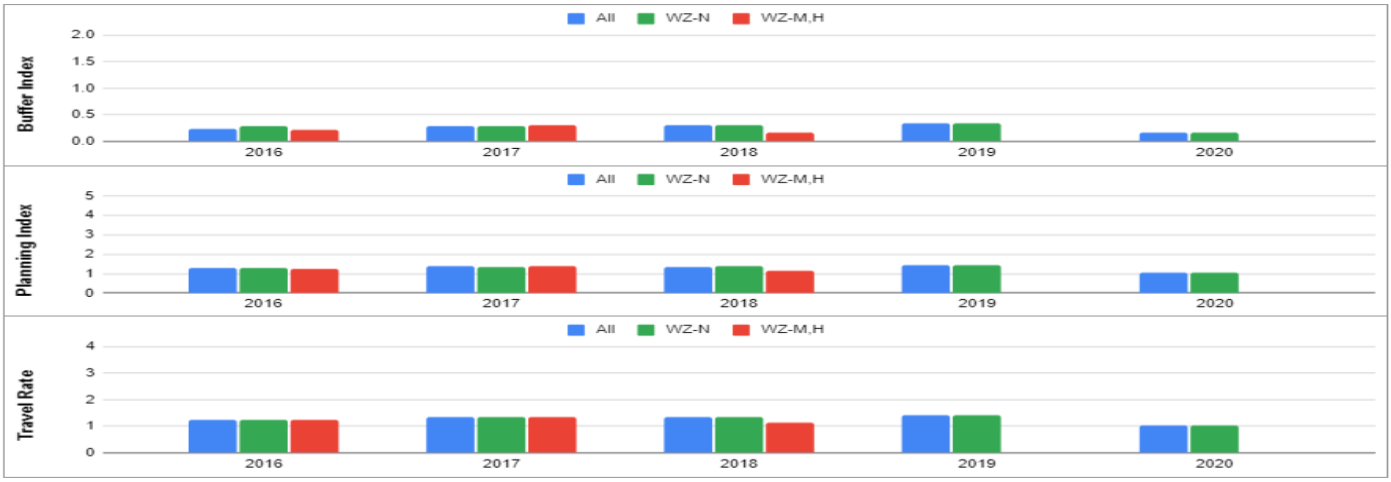
A.17.1.2 Effects of Incidents

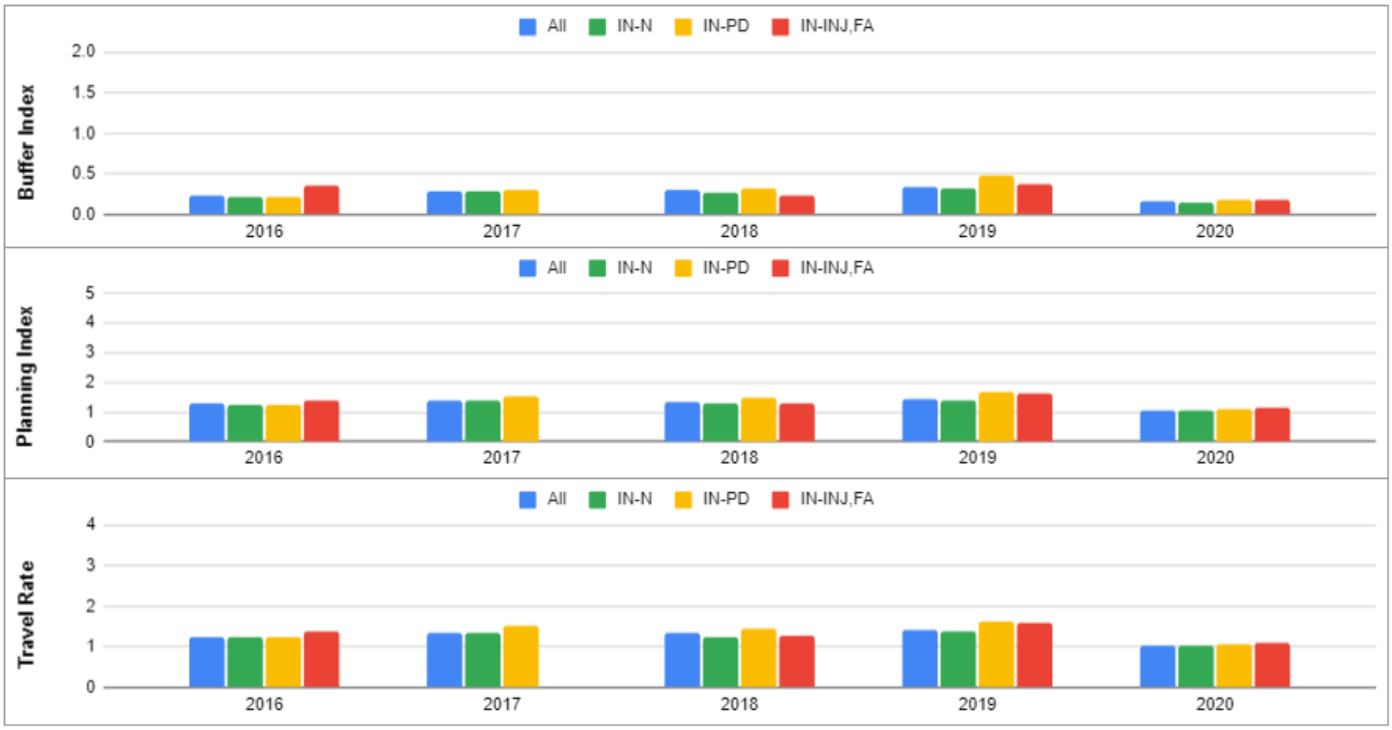


A.17.1.3 Effects of Work Zones

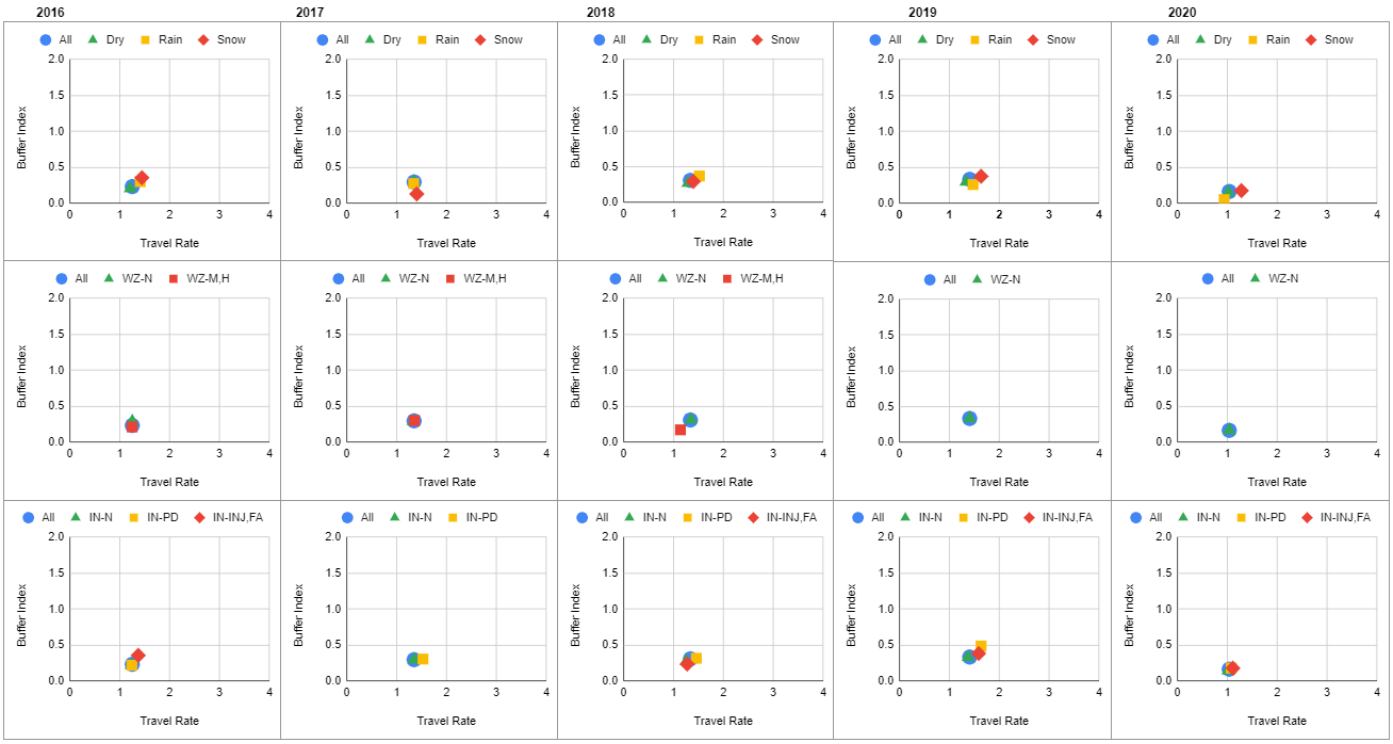


A.17.1.4 Yearly Variations

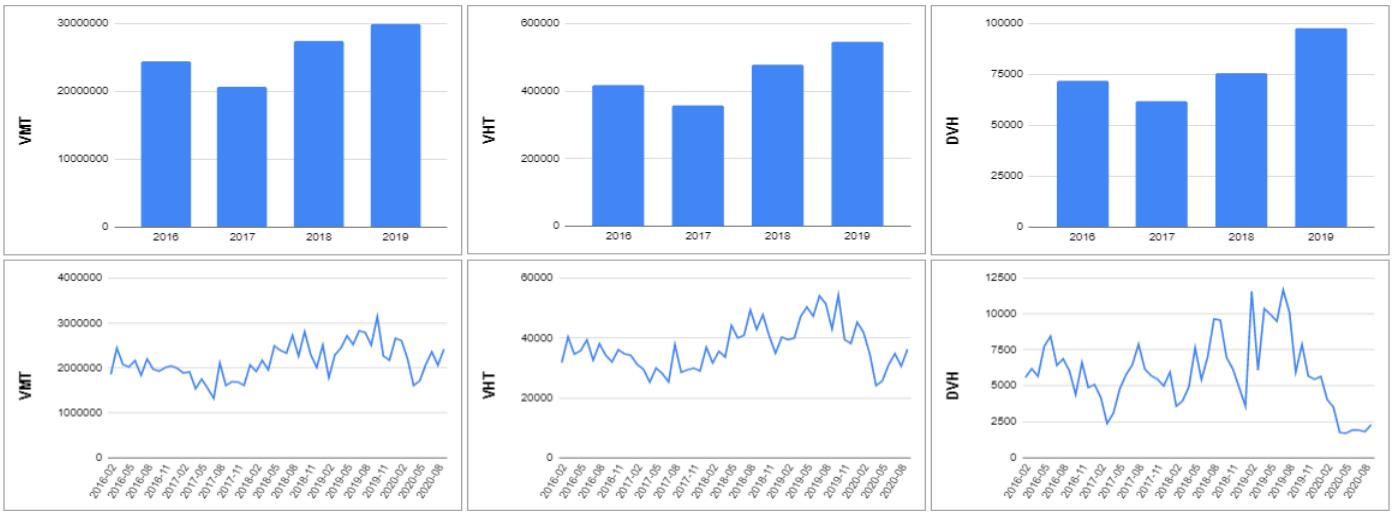

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.17.1.5 Yearly Variations of Combined Index



A.17.1.6 Variations of Traffic-Flow Measures

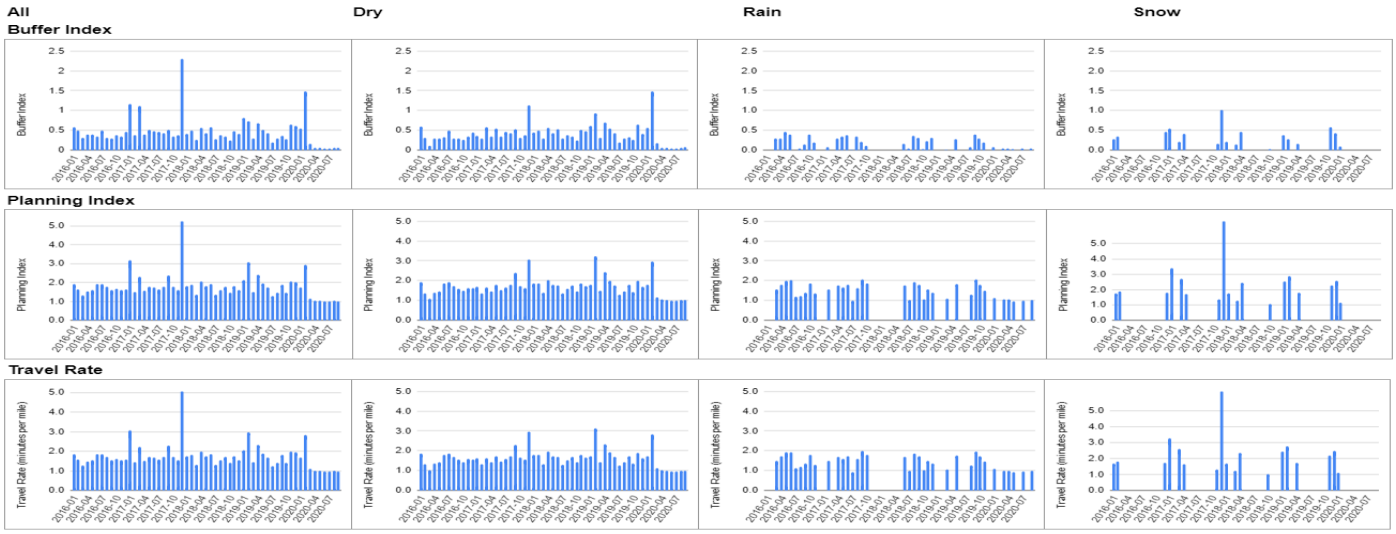


A.17.1.7 Trends Summary

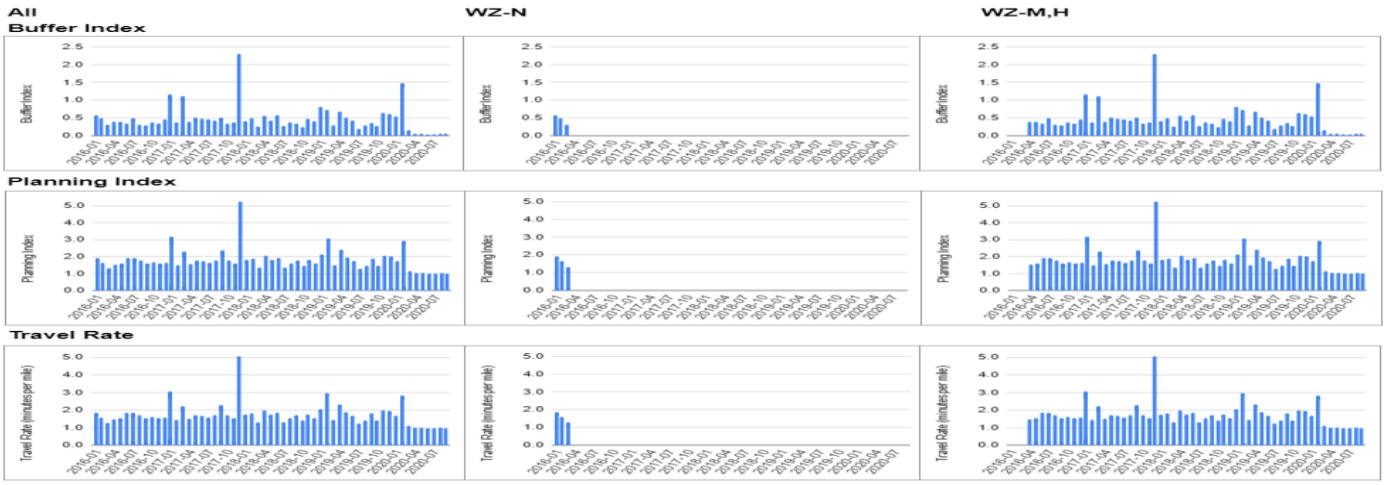
- Both VMT and DVH (delayed-vehicle hours) on this route have been continuously increasing since 2017, however, the monthly variations of the reliability measures have remained stable.
- Both weather and incidents have not significantly affected the reliability variations.

A.17.2 I-94 WESTBOUND Route 4 (WISC to STPL, Morning Peak)

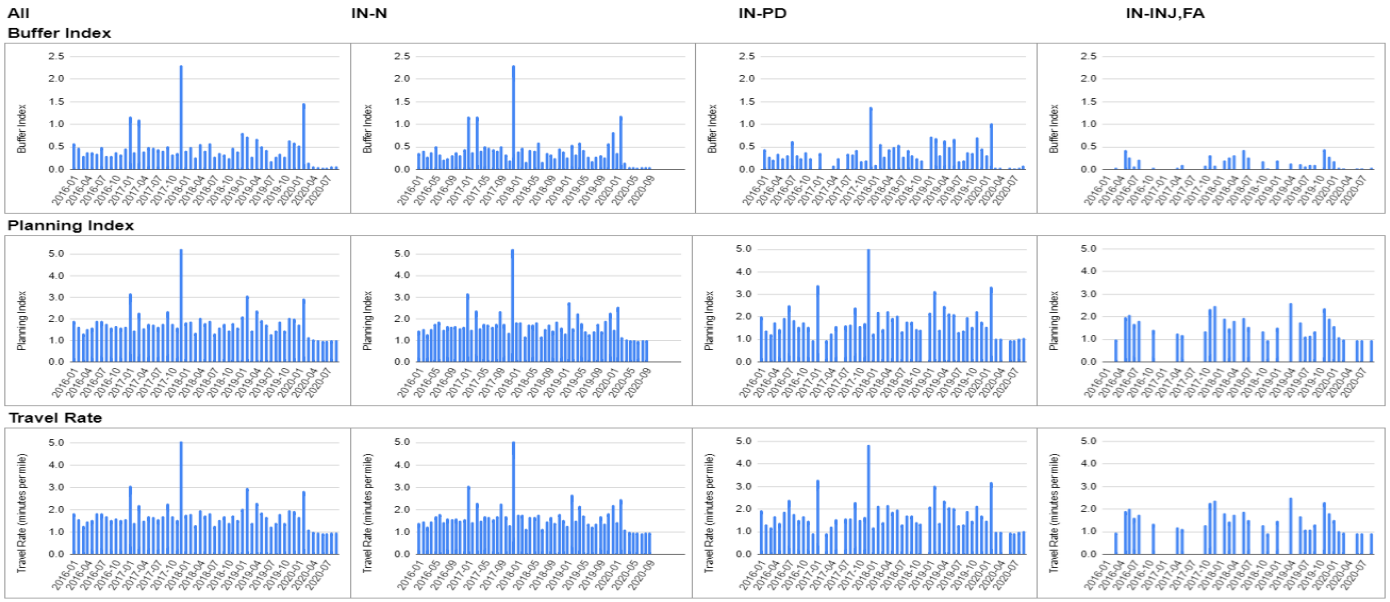
A.17.2.1 Effects of Weather



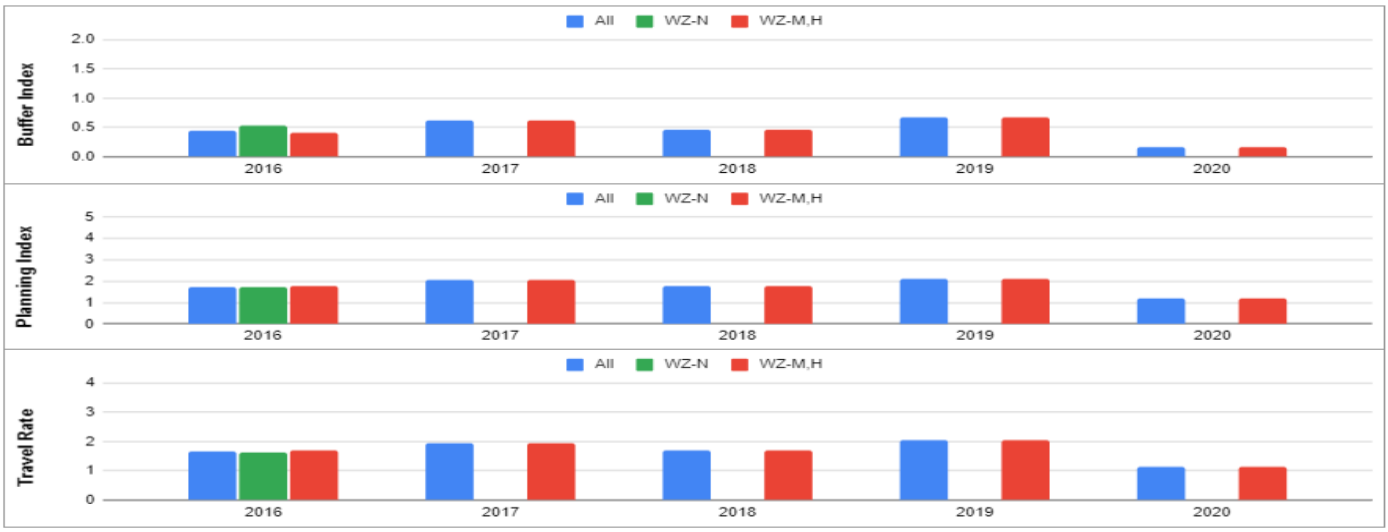
A.17.2.2 Effects of Work Zones

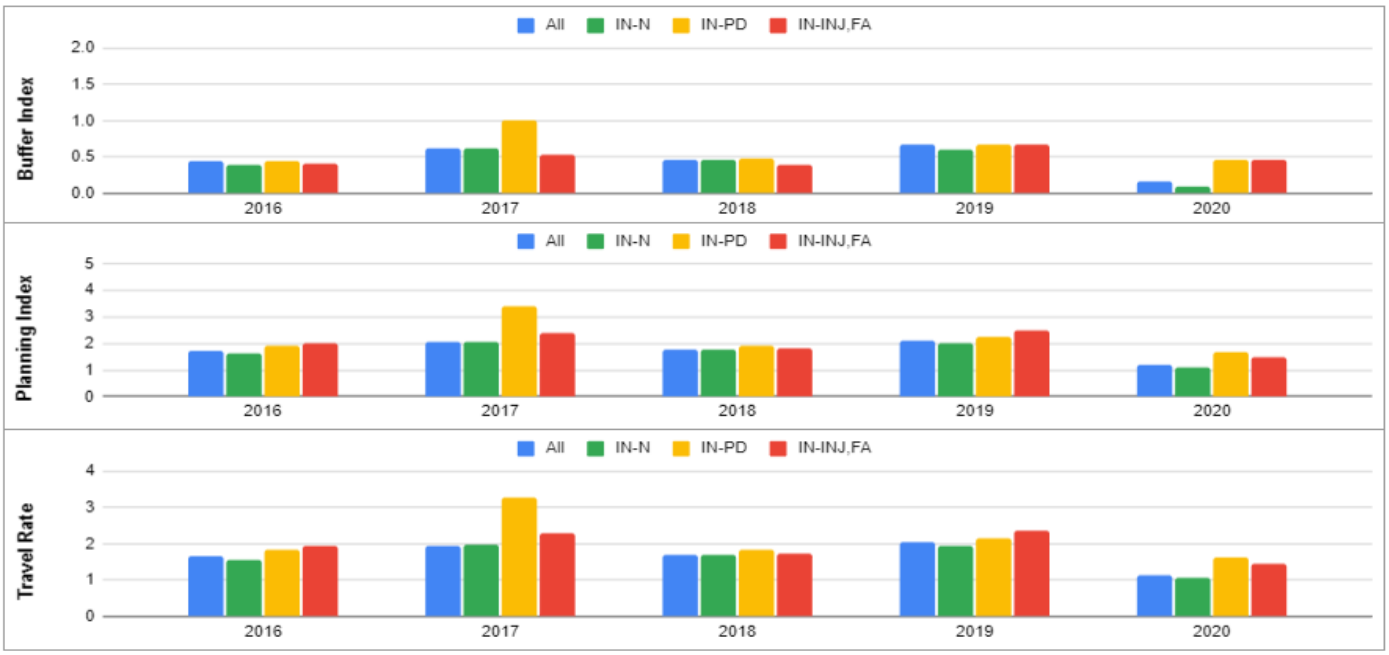


A.17.2.3 Effects of Incidents

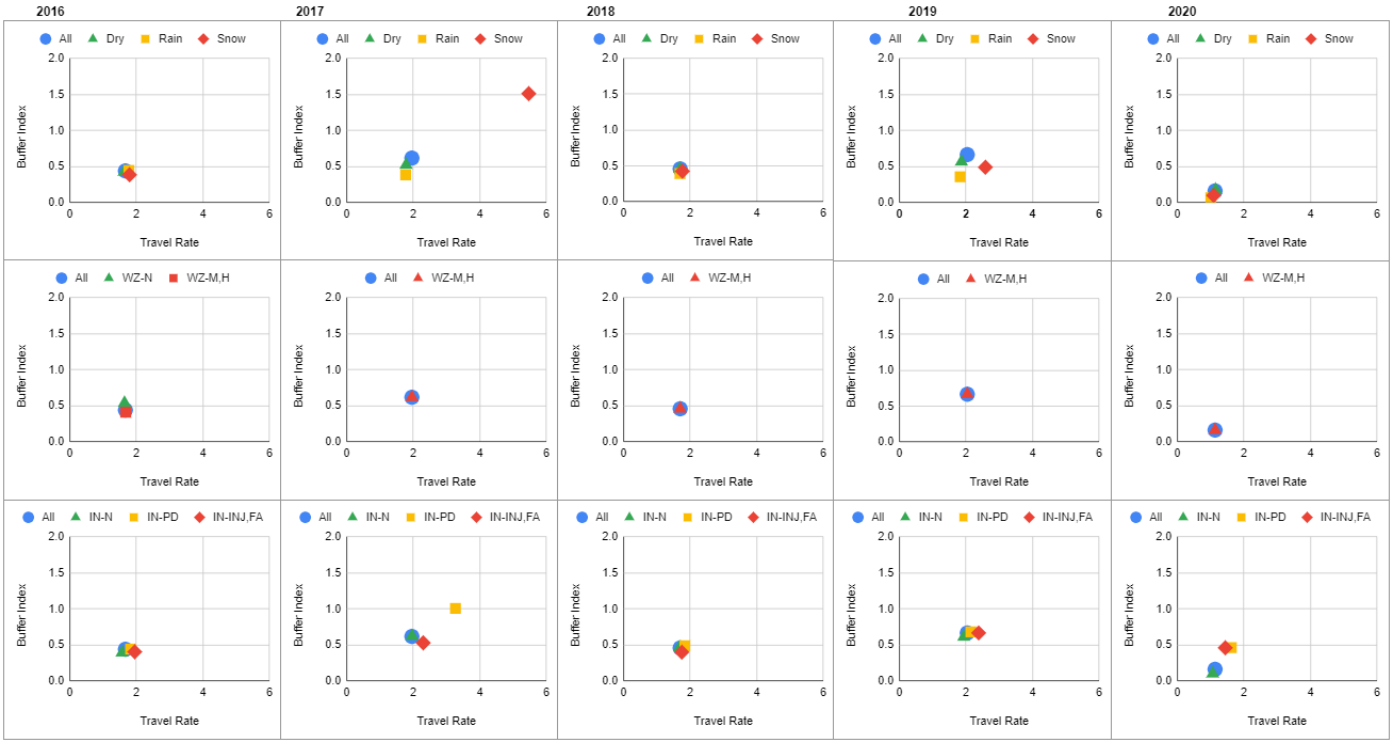


A.17.2.4 Yearly Variations

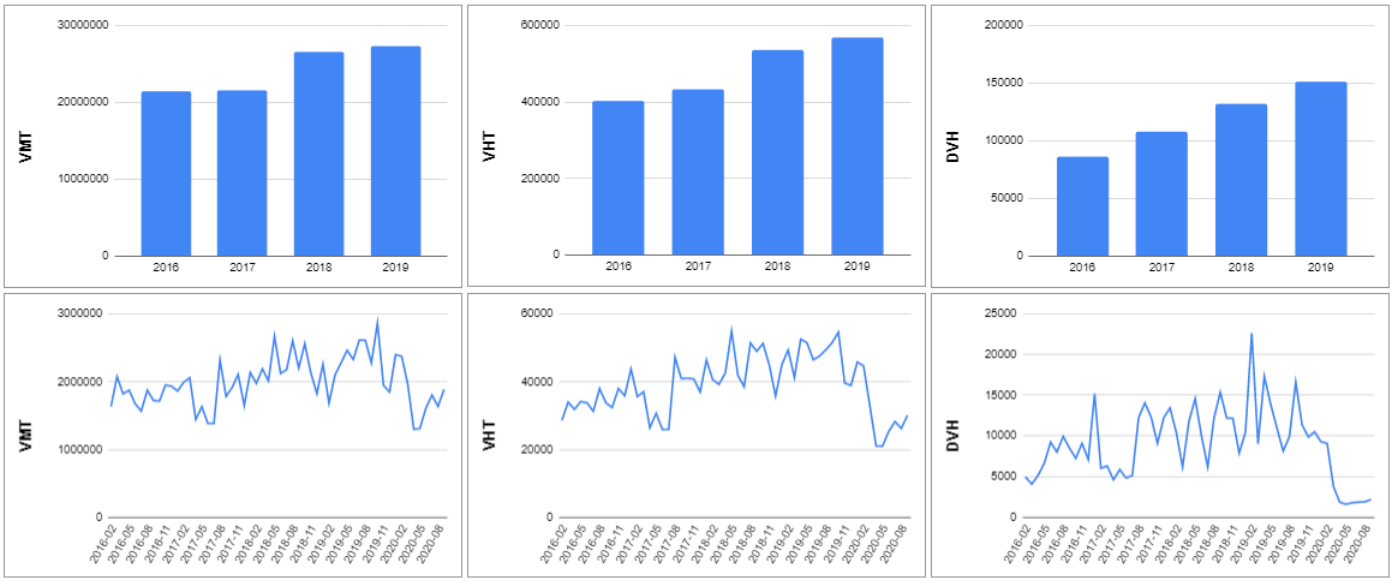

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.17.2.5 Yearly Variations of Combined Index



A.17.2.6 Variations of Traffic-Flow Measures



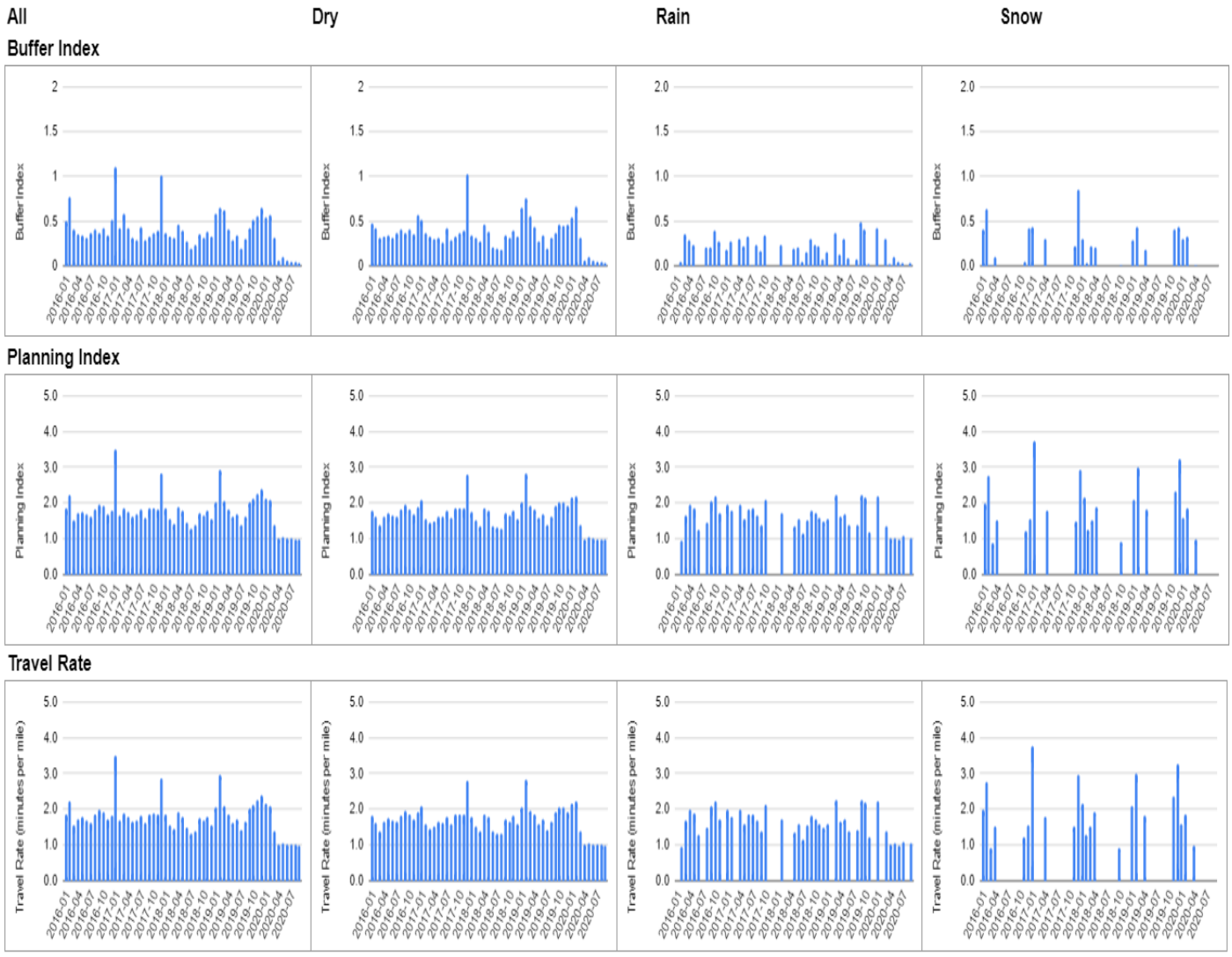
A.17.2.7 Trends Summary

- Both VMT and DVH have been increasing for a period of 2016 – 2019, however, the monthly variations of the travel-time reliability measures show relatively stable patterns except those months directly affected by snow and incidents.

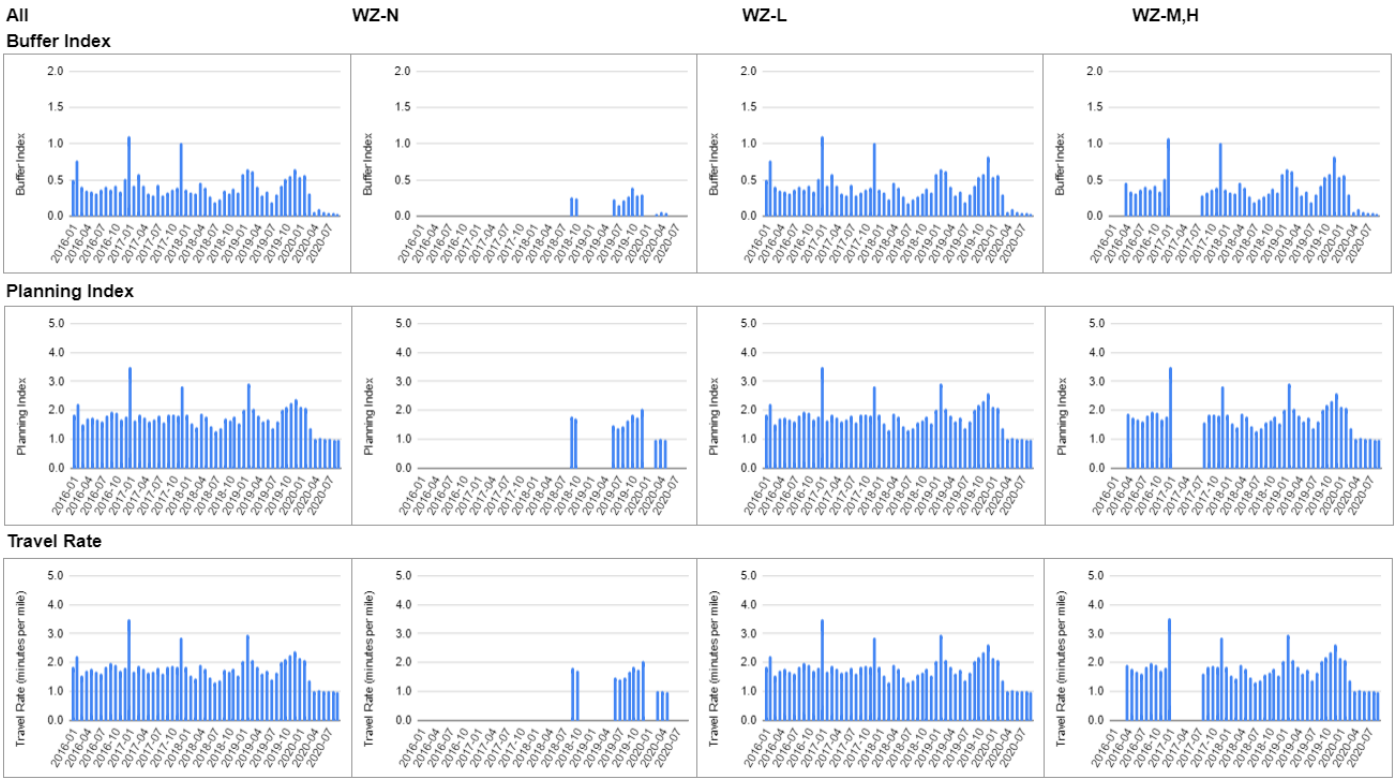
A.18 I-35W CORRIDOR 1 (SOUTH SPLIT – MPLS, NORTHBOUND/SOUTHBOUND)

A.18.1 I-35W NORTHBOUND Route 1 (South Split to MPLS, Morning Peak)

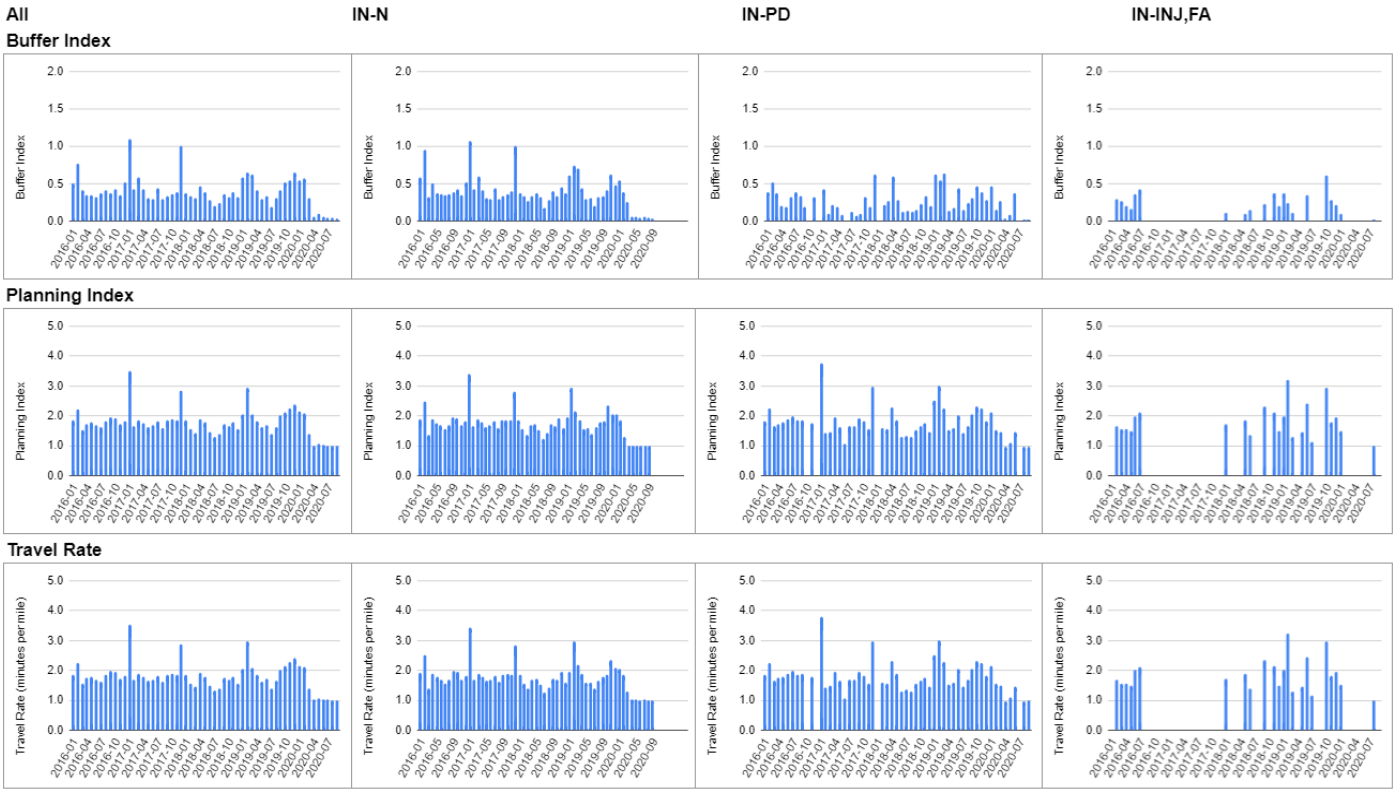
A.18.1.1 Effects of Weather



A.18.1.2 Effects of Work Zones

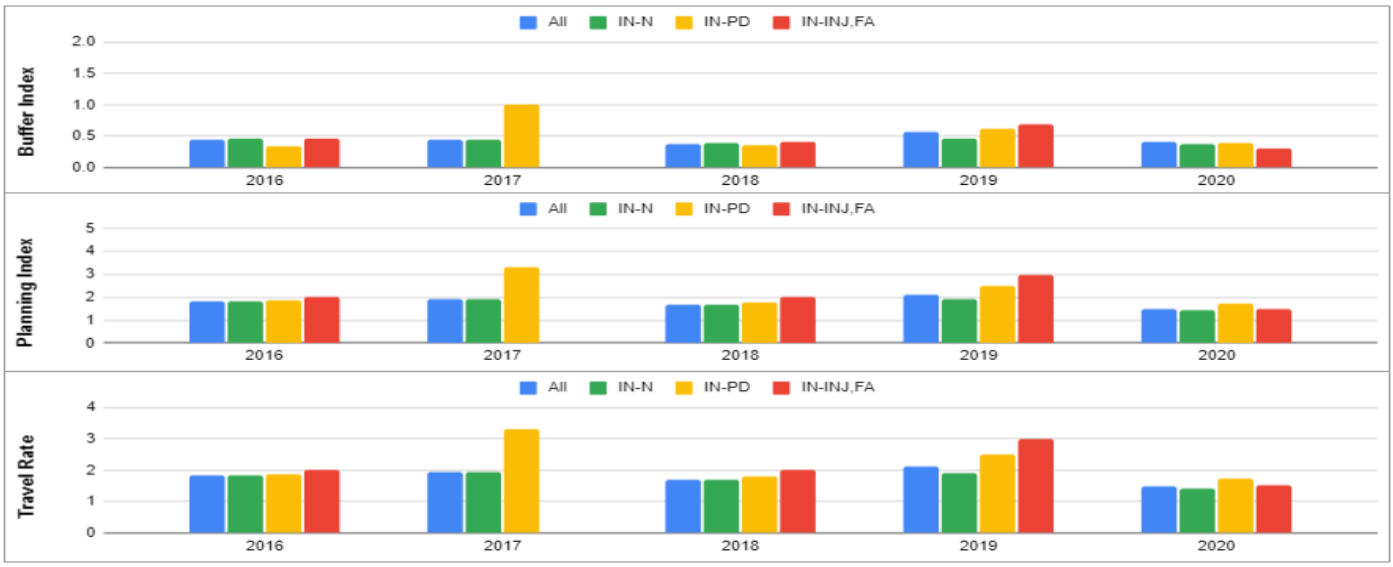


A.18.1.3 Effects of Incidents

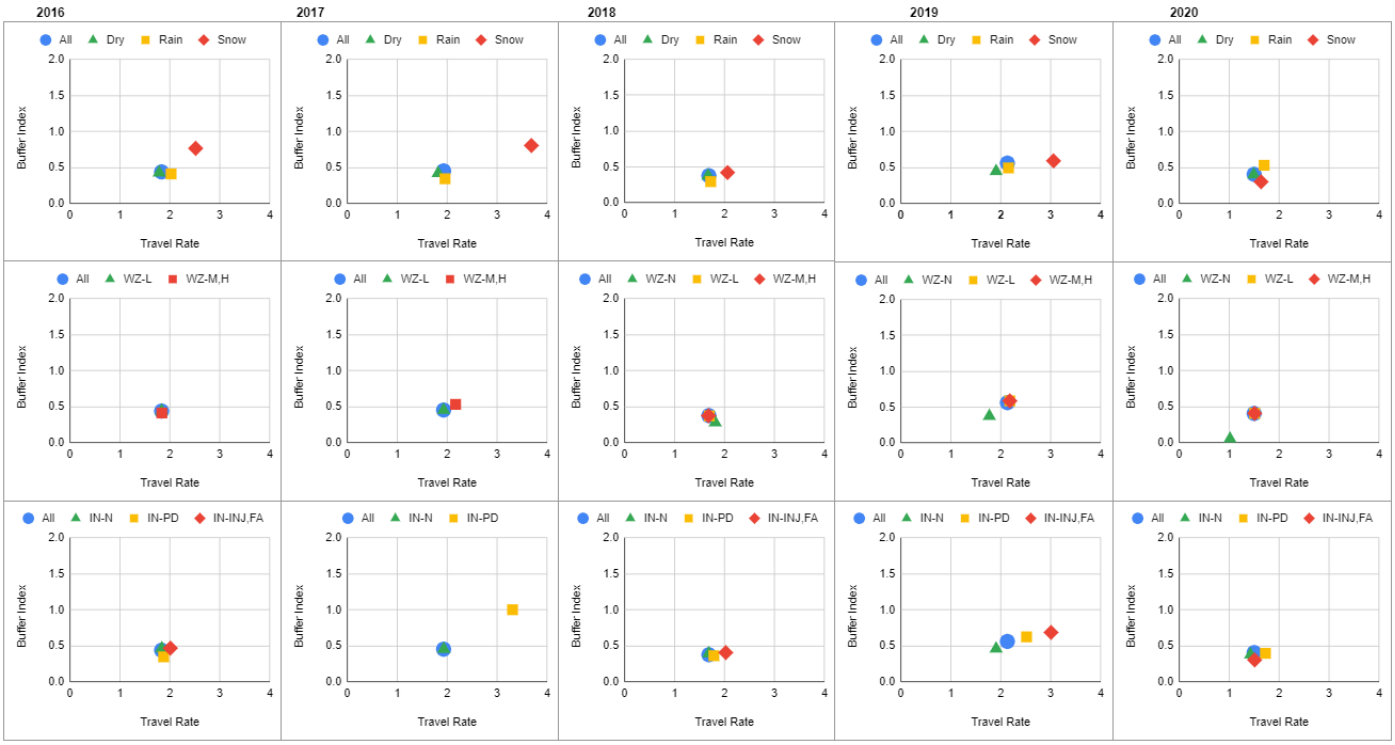


A.18.1.4 Yearly Variations

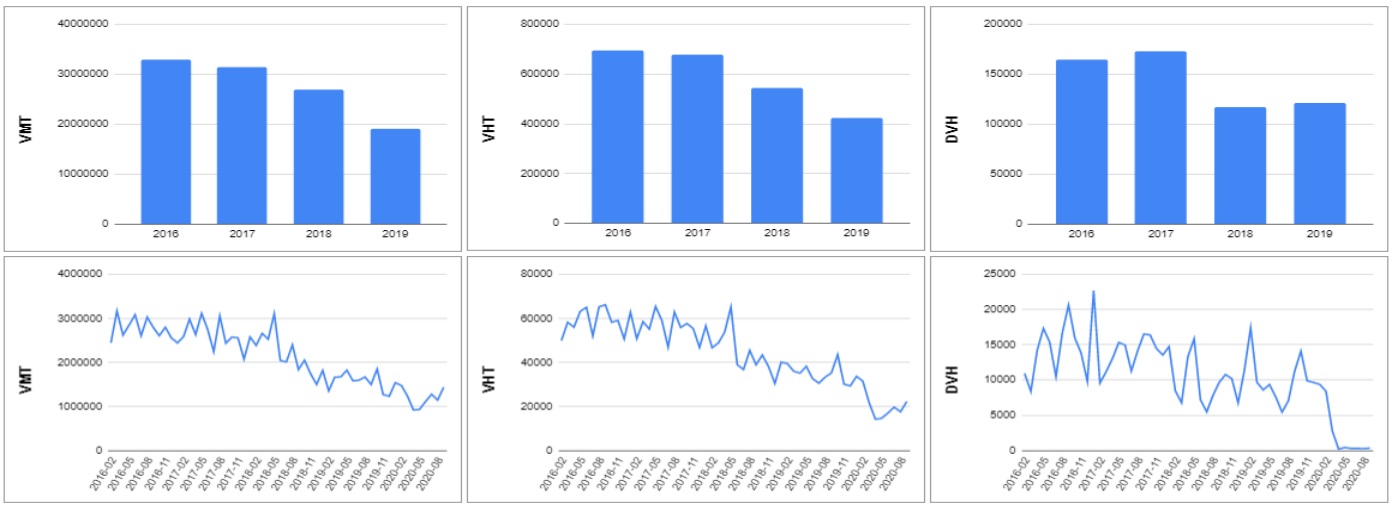

All
WZ-N
WZ-L
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
Planning Index
5
4
3
2
1
0
Travel Rate


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
Planning Index
5
4
3
2
1
0
Travel Rate

A.18.1.5 Yearly Variations of Combined Index



A.18.1.6 Variations of Traffic-Flow Measures

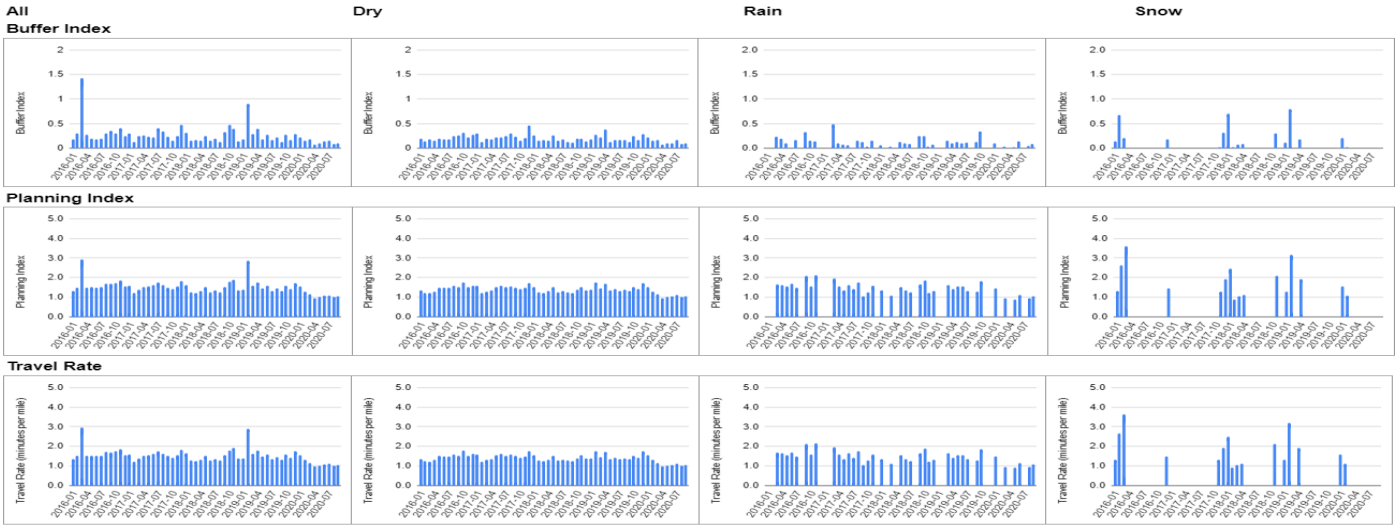


A.18.1.7 Trends Summary

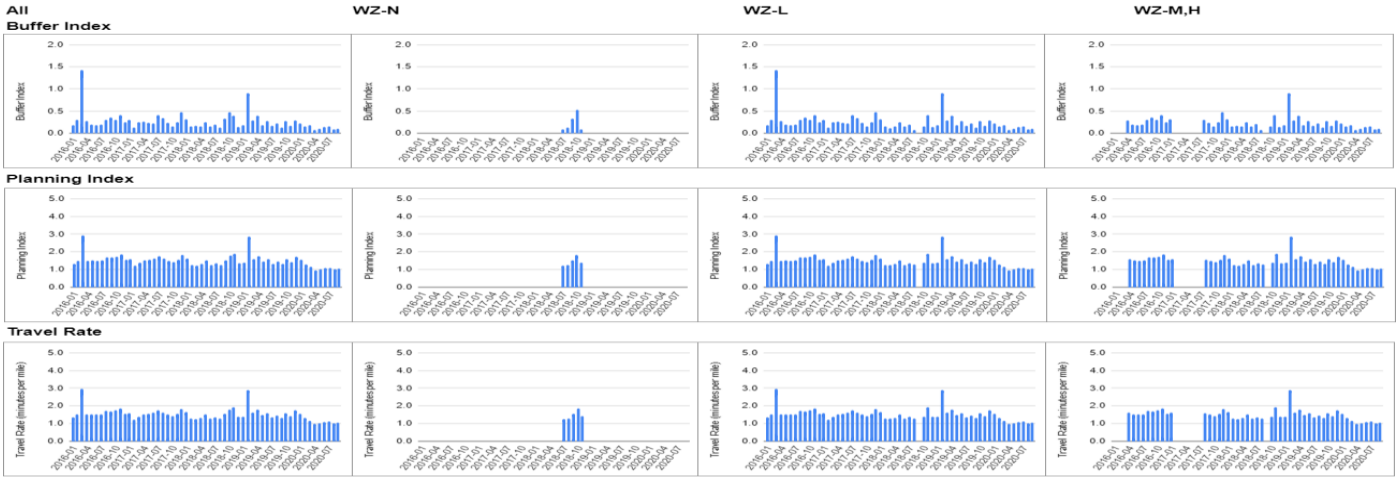
- Both VMT and DVH have been decreasing since 2016, while the monthly variation patters of the reliability measures have not shown any significant changes.
- Both snow and incidents have been consistently contributing to the increase in the travel-time variability and congestion level.

A.18.2 I-35W SOUTHBOUND Route 1 (MPLS to South Split, Afternoon Peak)

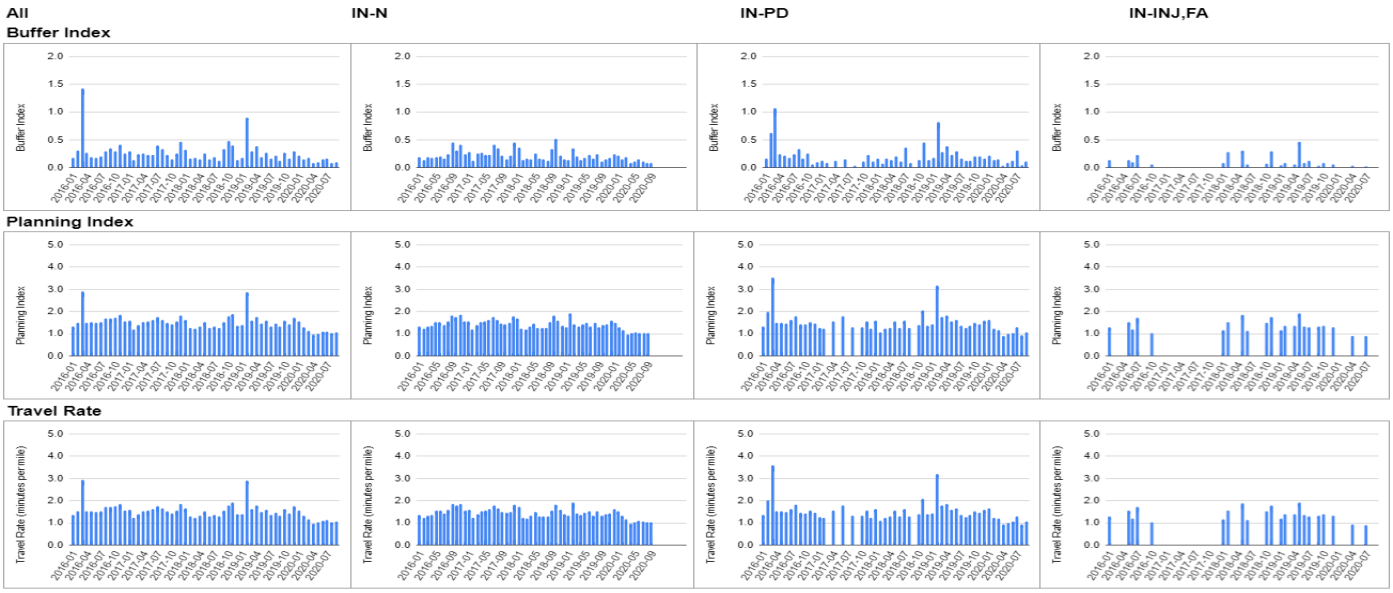
A.18.2.1 Effects of Weather



A.18.2.2 Effects of Work Zones

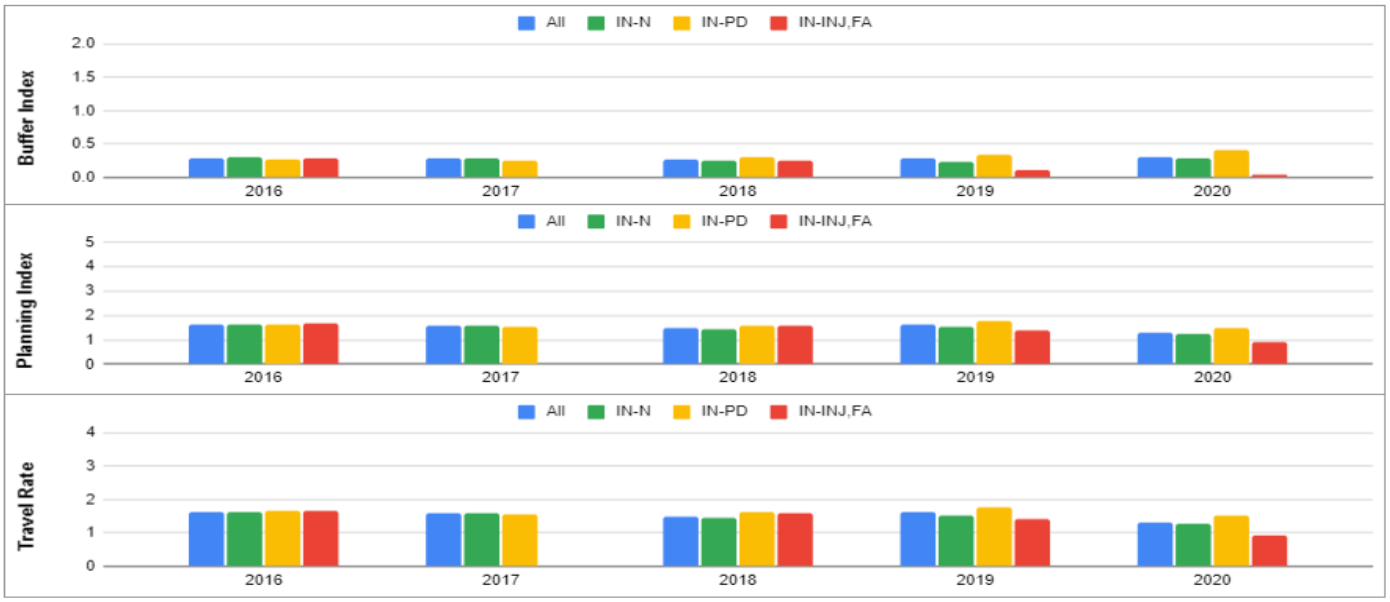


A.18.2.3 Effects of Incidents



A.18.2.4 Yearly Variations


All
WZ-N
WZ-L
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
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0.5
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2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
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2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
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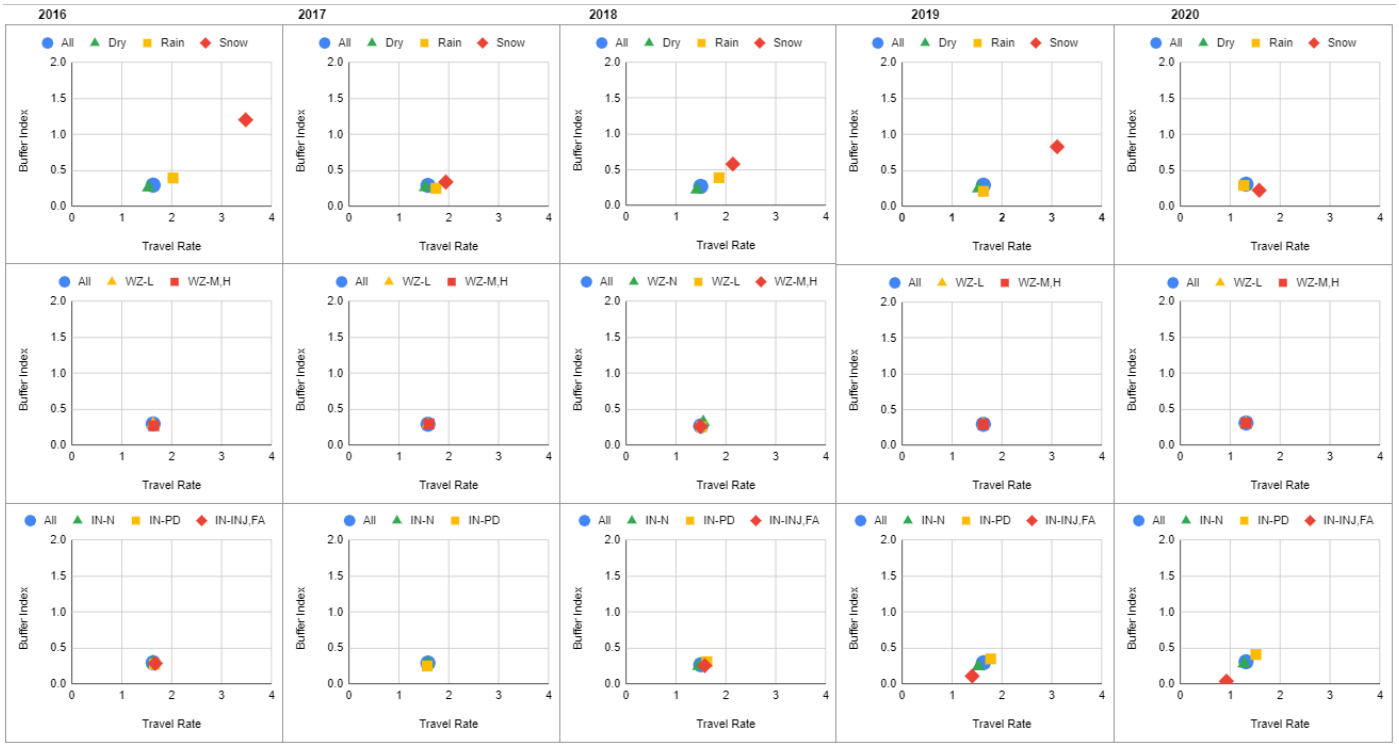
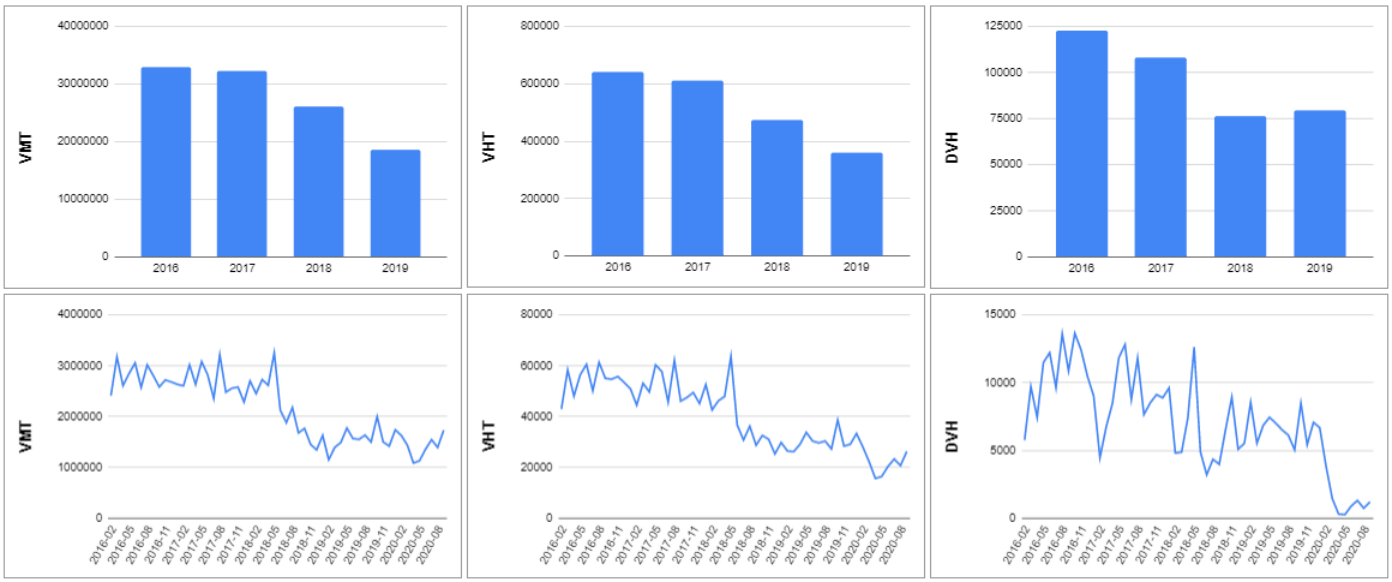
2016
2017
2018
2019
2020

A.18.2.5 Yearly Variations of Combined Index



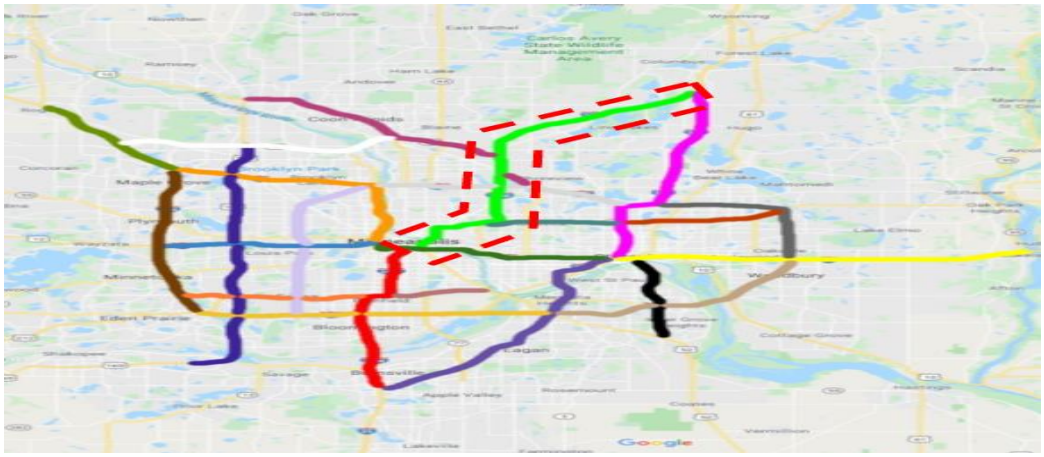
A.18.2.6 Variations of Traffic-Flow Measure



A.18.2.7 Trends Summary

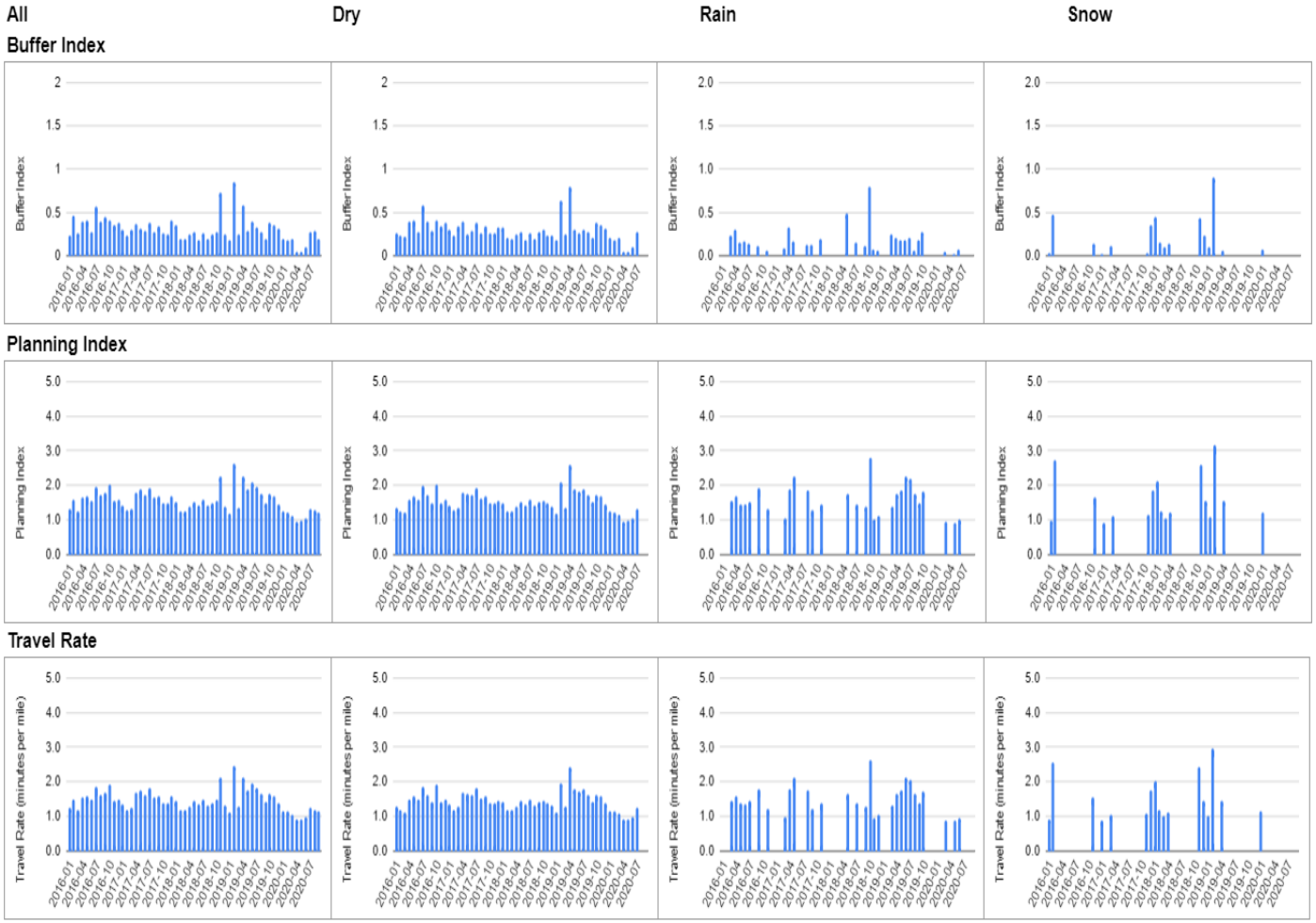
- Both VMT and DVH have been decreasing and the monthly variations of the reliability measures show stable patterns.
- Snow has been the main contributing factor to the increase in both travel-time variability and 95th %-ile travel time.

A.19 I-35W CORRIDOR 2 (MPLS – NORTH SPLIT, NORTHBOUND/SOUTHBOUND)

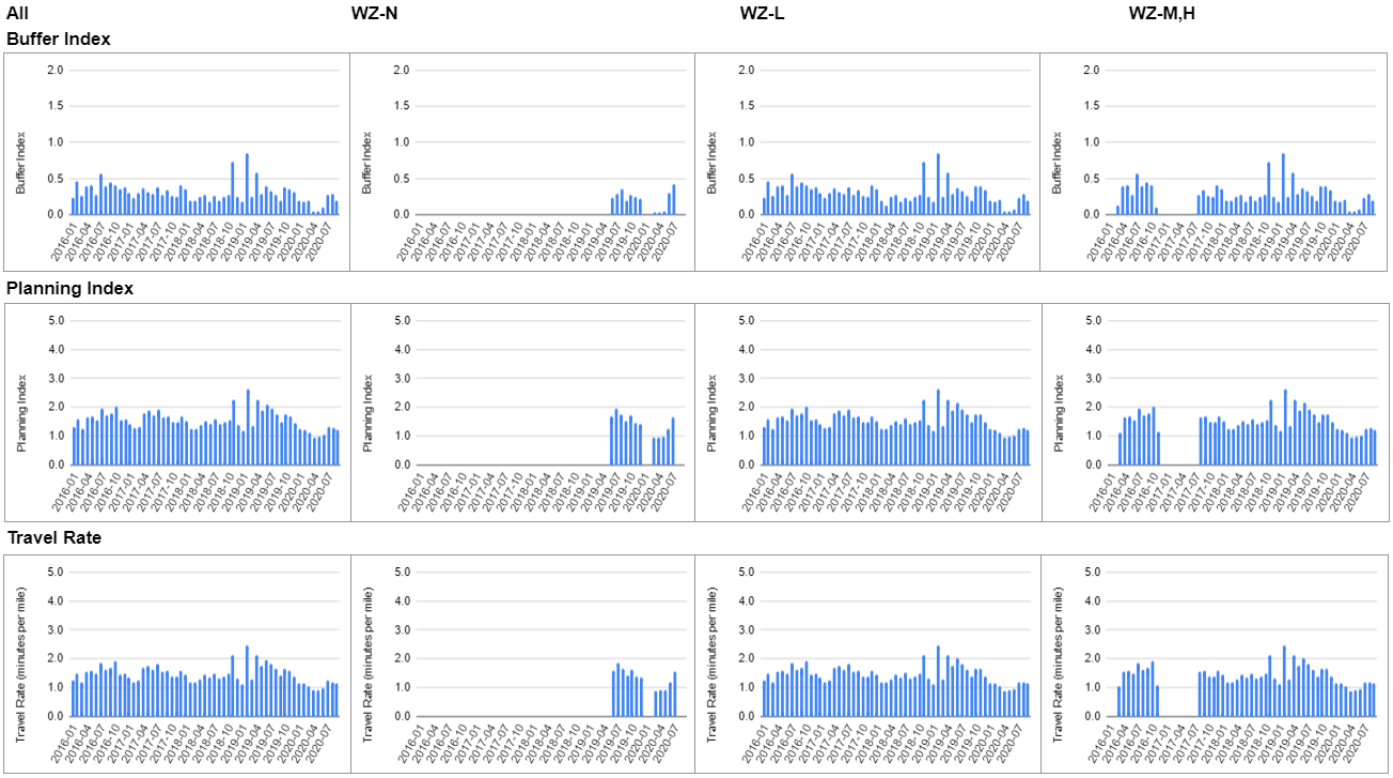


A.19.1 I-35W NORTHBOUND Route 2 (Mpls to North Split, Afternoon Peak)

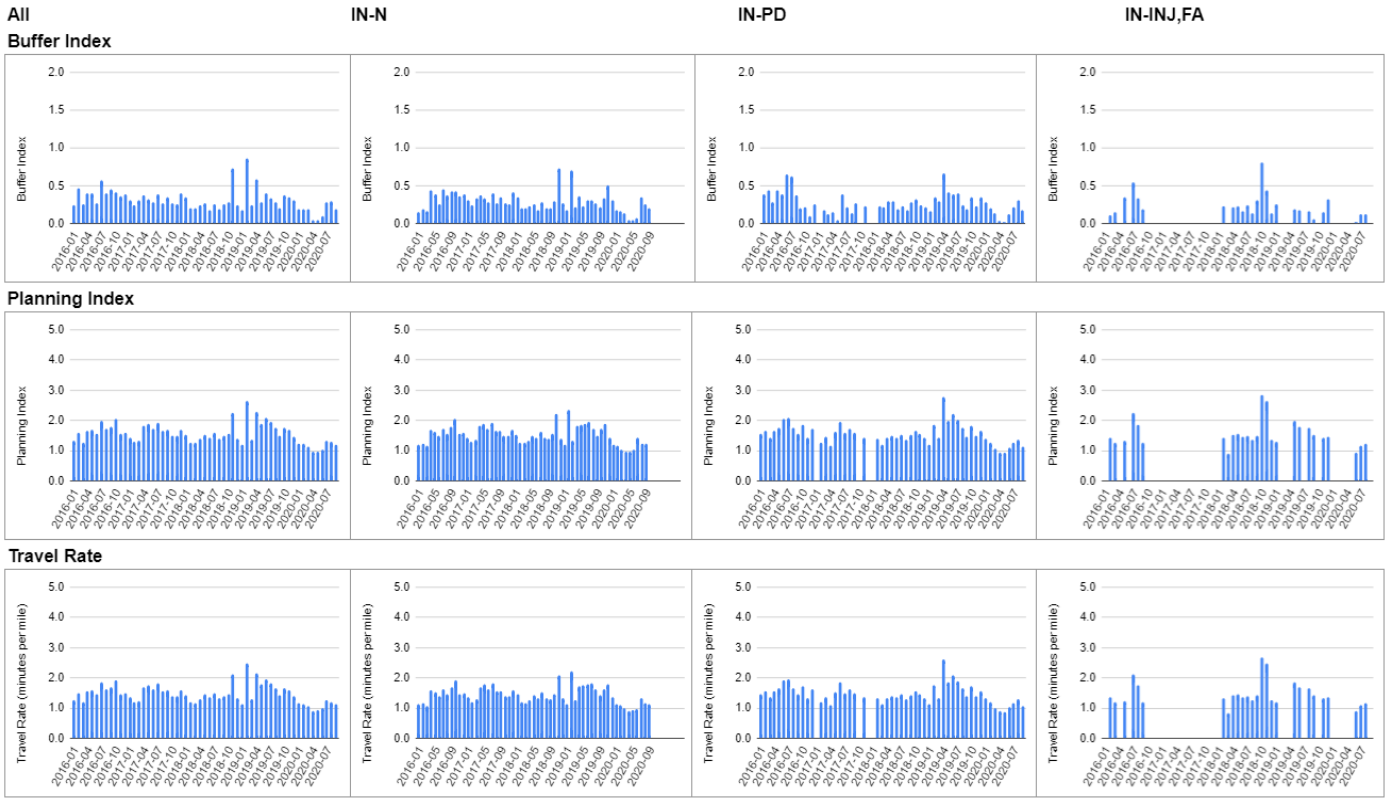
A.19.1.1 Effects of Weather



A.19.1.2 Effects of Work Zones



A.19.1.3 Effects of Incidents



A.19.1.4 Yearly Variations


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
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2016
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All
IN-N
IN-PD
IN-INJ,FA
Planning Index
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4
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All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
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All
WZ-N
WZ-L
WZ-M,H
Buffer Index
2.0
1.5
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2016
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All
WZ-N
WZ-L
WZ-M,H
Planning Index
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2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
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2016
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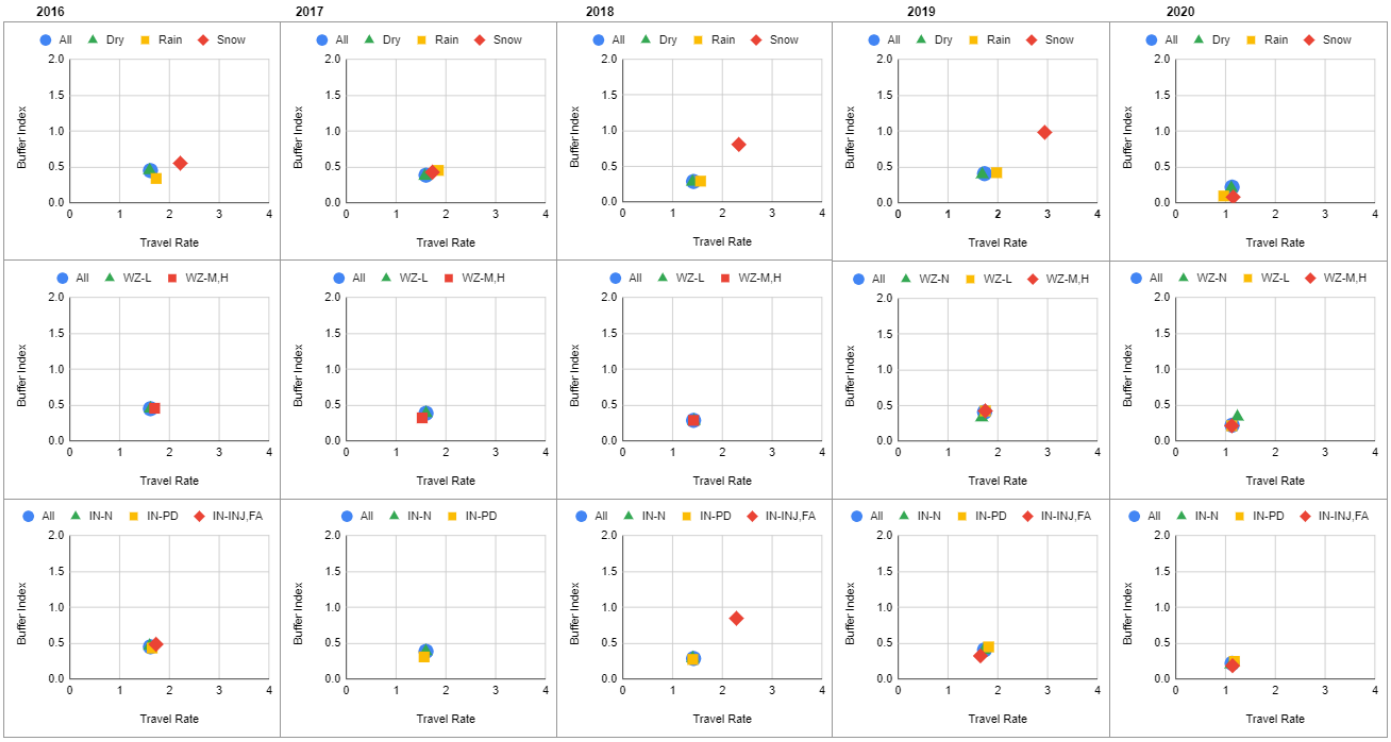
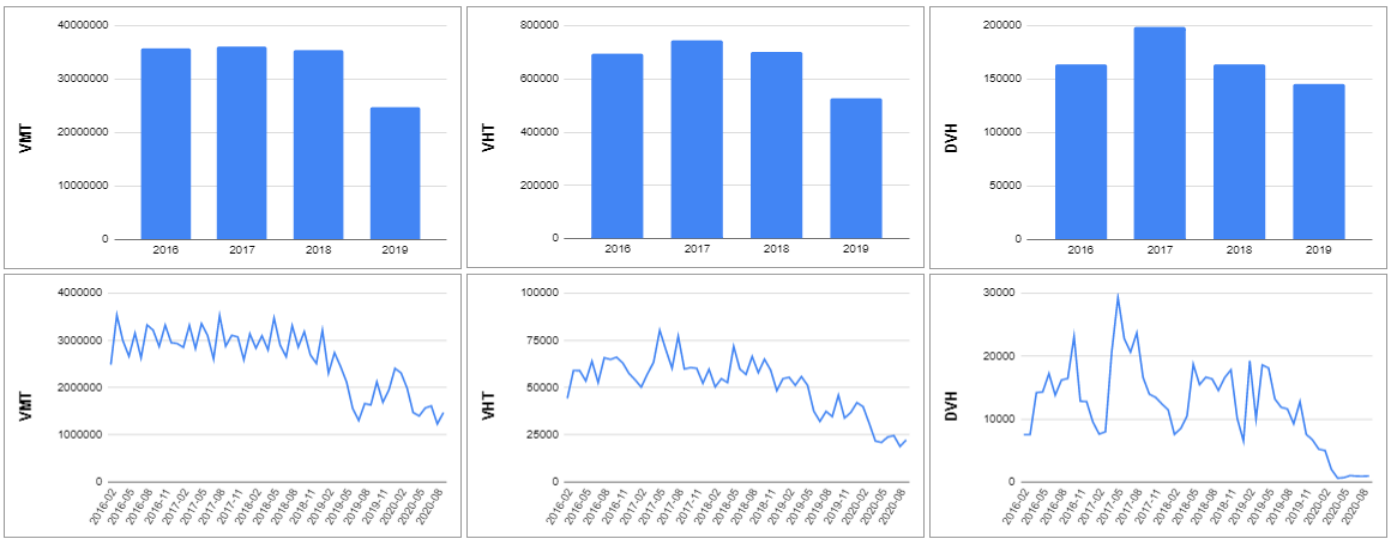
A.19.1.5 Yearly Variations of Combined Index



A.19.1.6 Variations of Traffic-Flow Measures

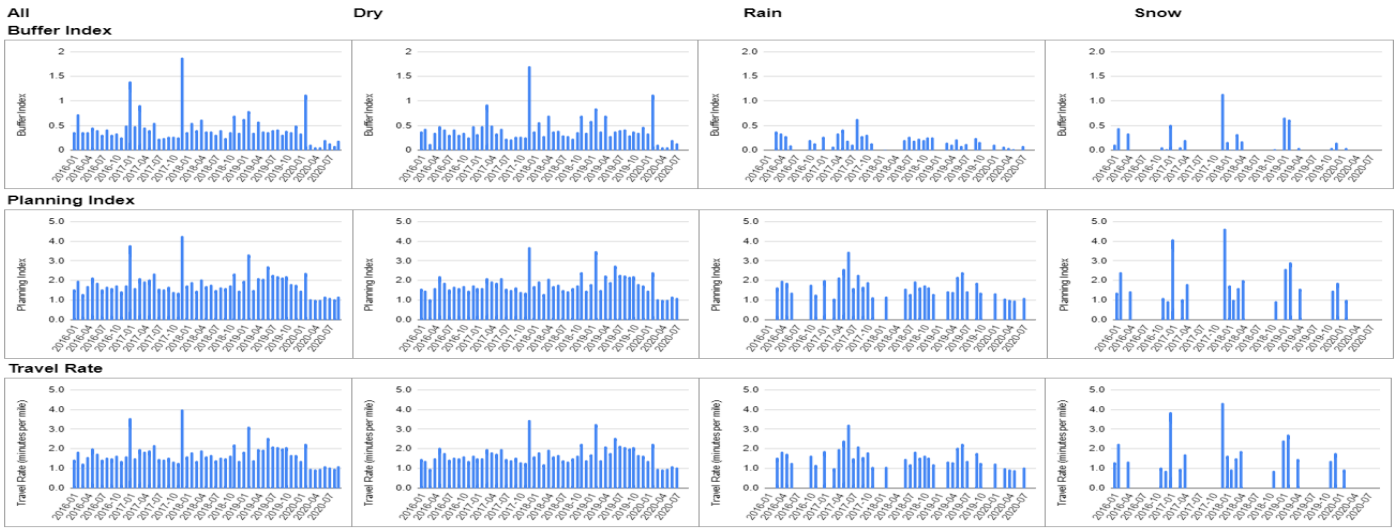


A.19.1.7 Trends Summary

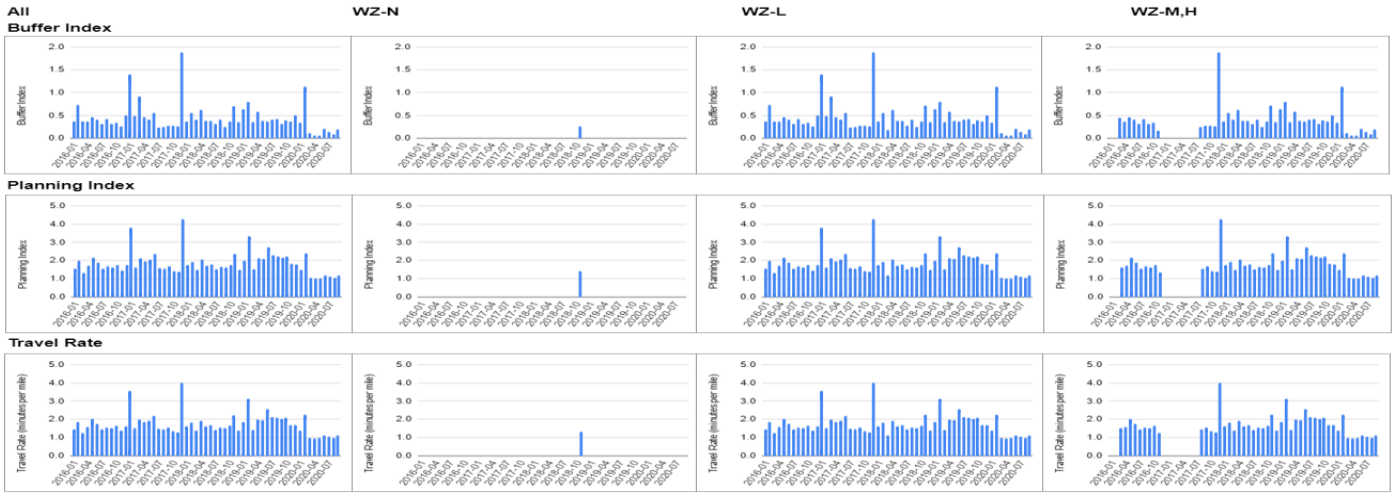
- The traffic flow on this route was significantly reduced in 2019, however, the reliability measures have not shown any improvements in 2019.
- Snow has been consistently affecting the reliability measures through time, and the injury/fatal incidents played a major role in increasing both travel-time variability and congestion level in 2018.

A.19.2 I-35W SOUTHBOUND Route 2 (North Split to MPLS, Morning Peak)

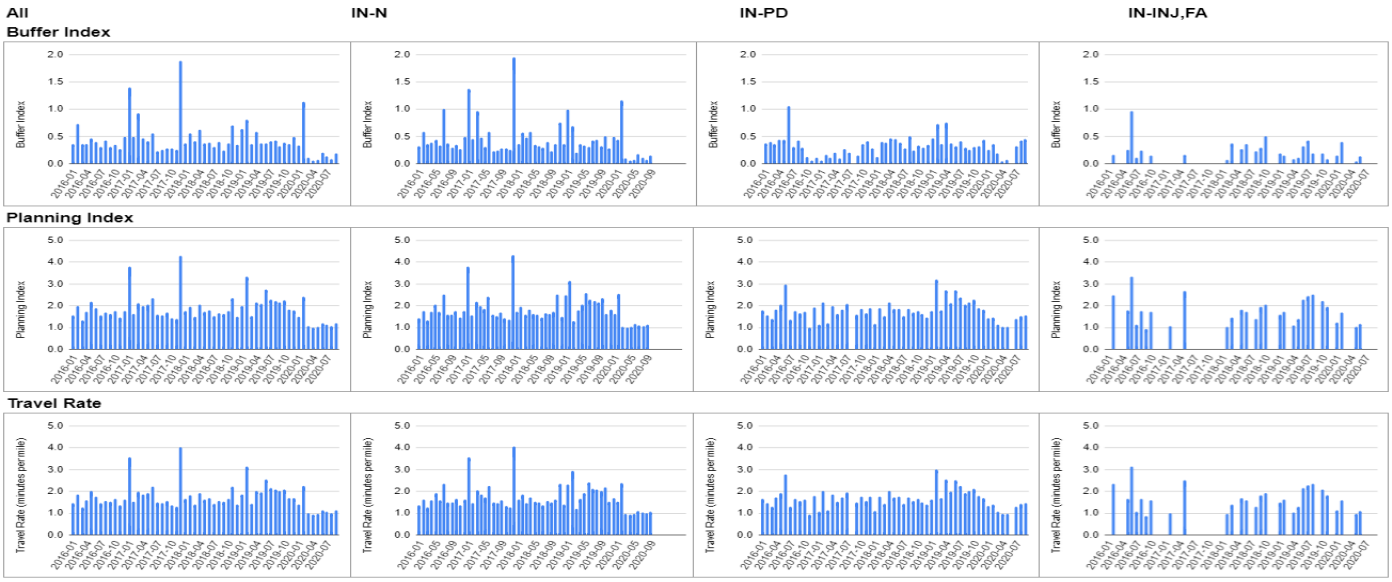
A.19.2.1 Effects of Weather



A.19.2.2 Effects of Work Zones



A.19.2.3 Effects of Incidents



A.19.2.4 Yearly Variations


All
WZ-N
WZ-L
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Buffer Index
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2020
All
WZ-N
WZ-L
WZ-M,H
Planning Index
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2018
2019
2020
All
WZ-N
WZ-L
WZ-M,H
Travel Rate
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2016
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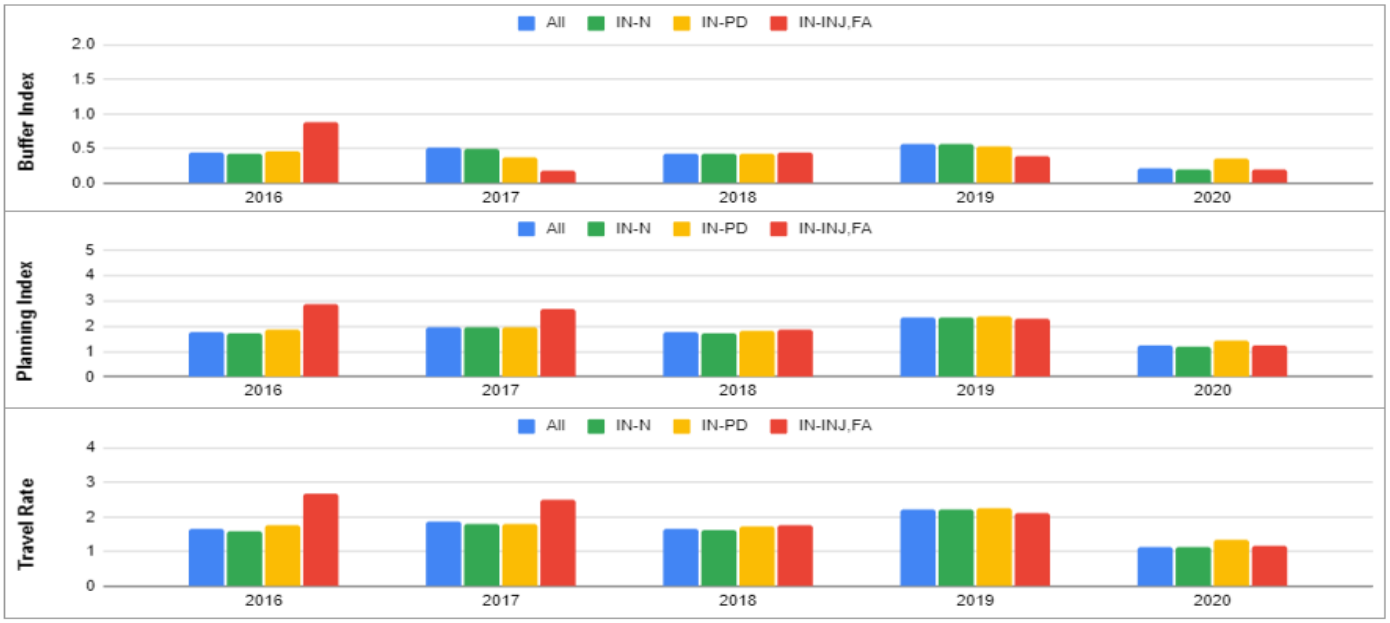
2020


All
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IN-PD
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IN-N
IN-PD
IN-INJ,FA
Planning Index
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2020
All
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IN-PD
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Travel Rate
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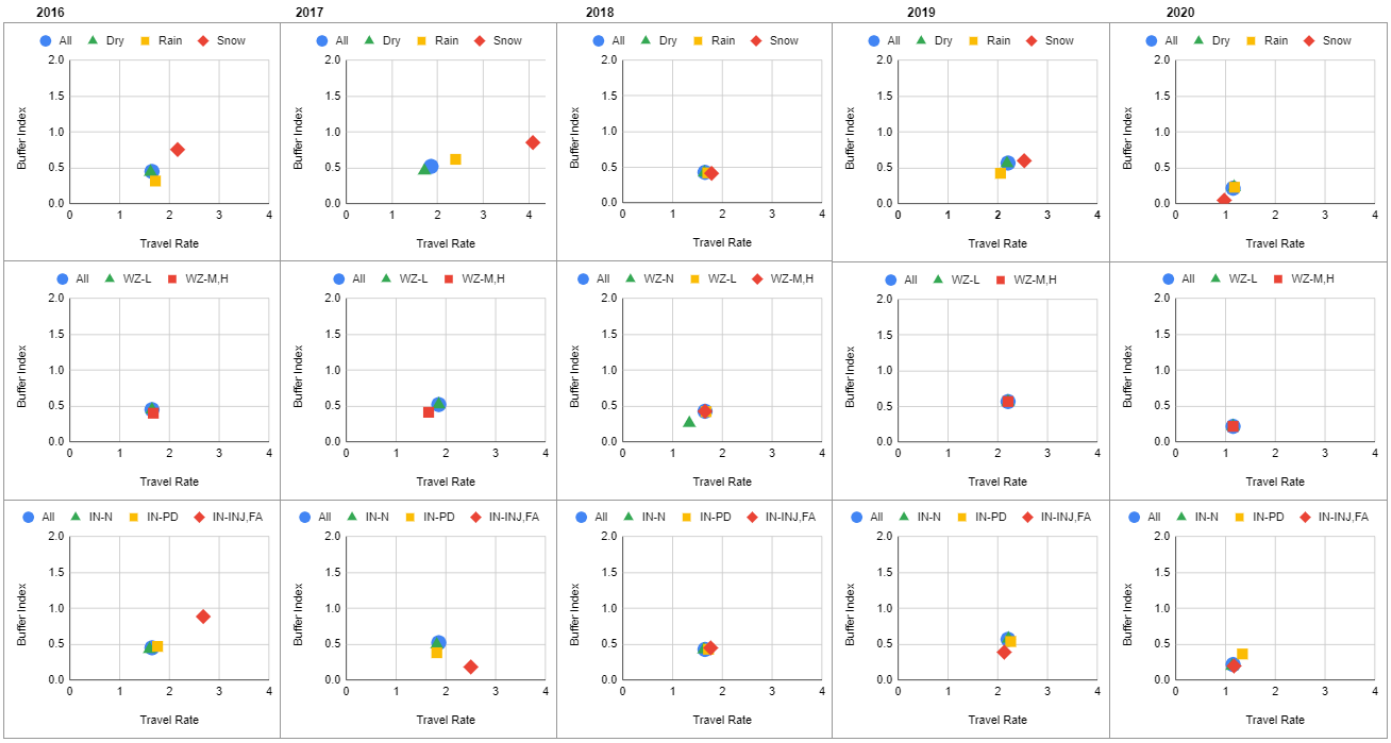
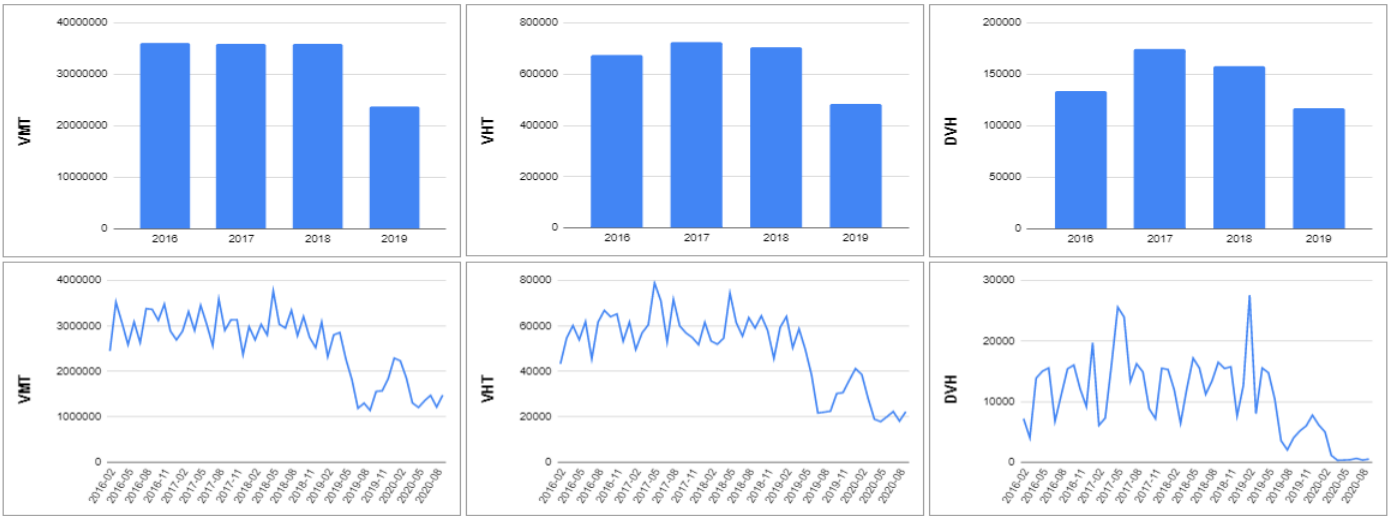
2020

A.19.2.5 Yearly Variations of Combined Index



A.19.2.6 Variations of Traffic-Flow Measures

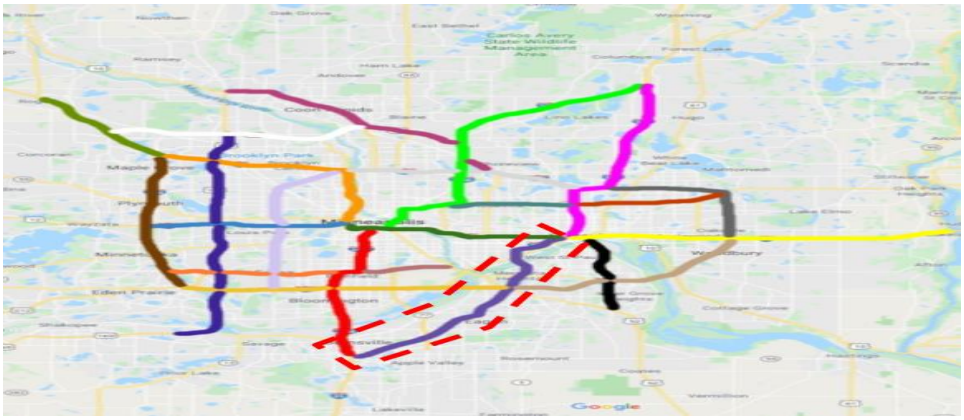


A.19.2.7 Trends Summary

- Similar to the afternoon peak period, the traffic flow in 2019 showed significant reduction in both VMT and DVH, however, the travel-time reliability measures have not improved during the same period.

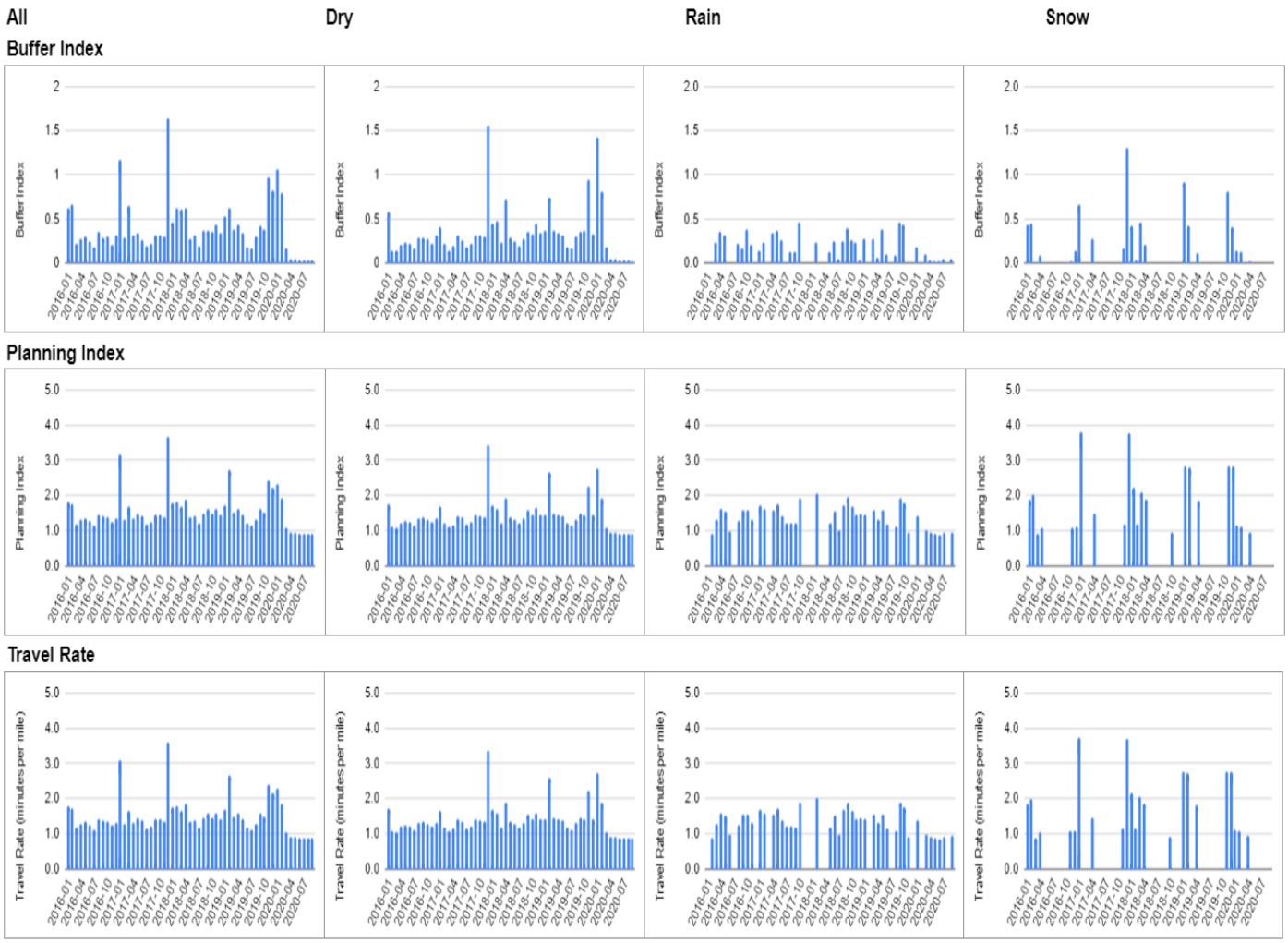
- Both snow and incidents have significantly affected the travel-time reliability until 2017, while their effects on the reliability have been substantially reduced from 2018.

A.20 I-35E CORRIDOR 1 (SOUTH SPLIT TO STPL, NORTHBOUND/SOUTHBOUND)

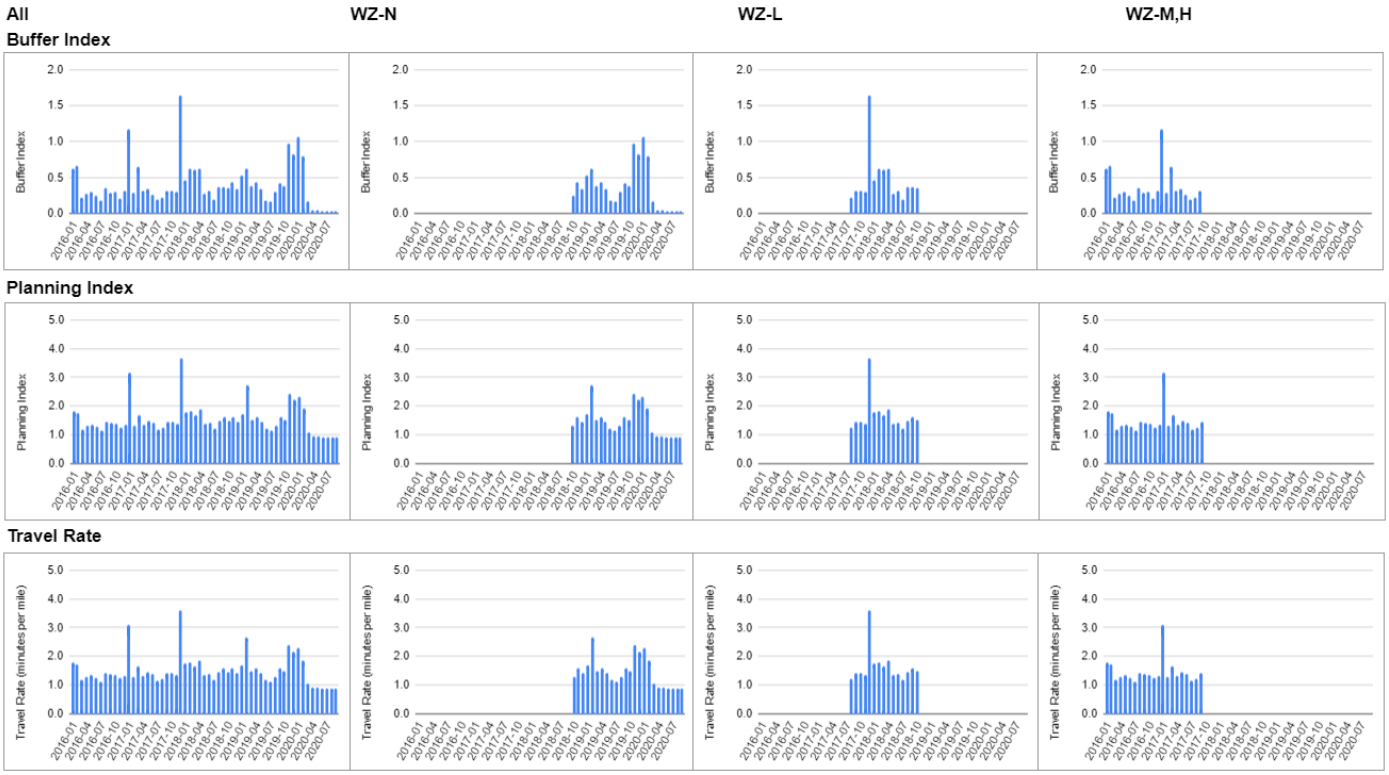


A.20.1 I-35E NORTHBOUND Route 1 (South Split to STPL, Morning Peak)

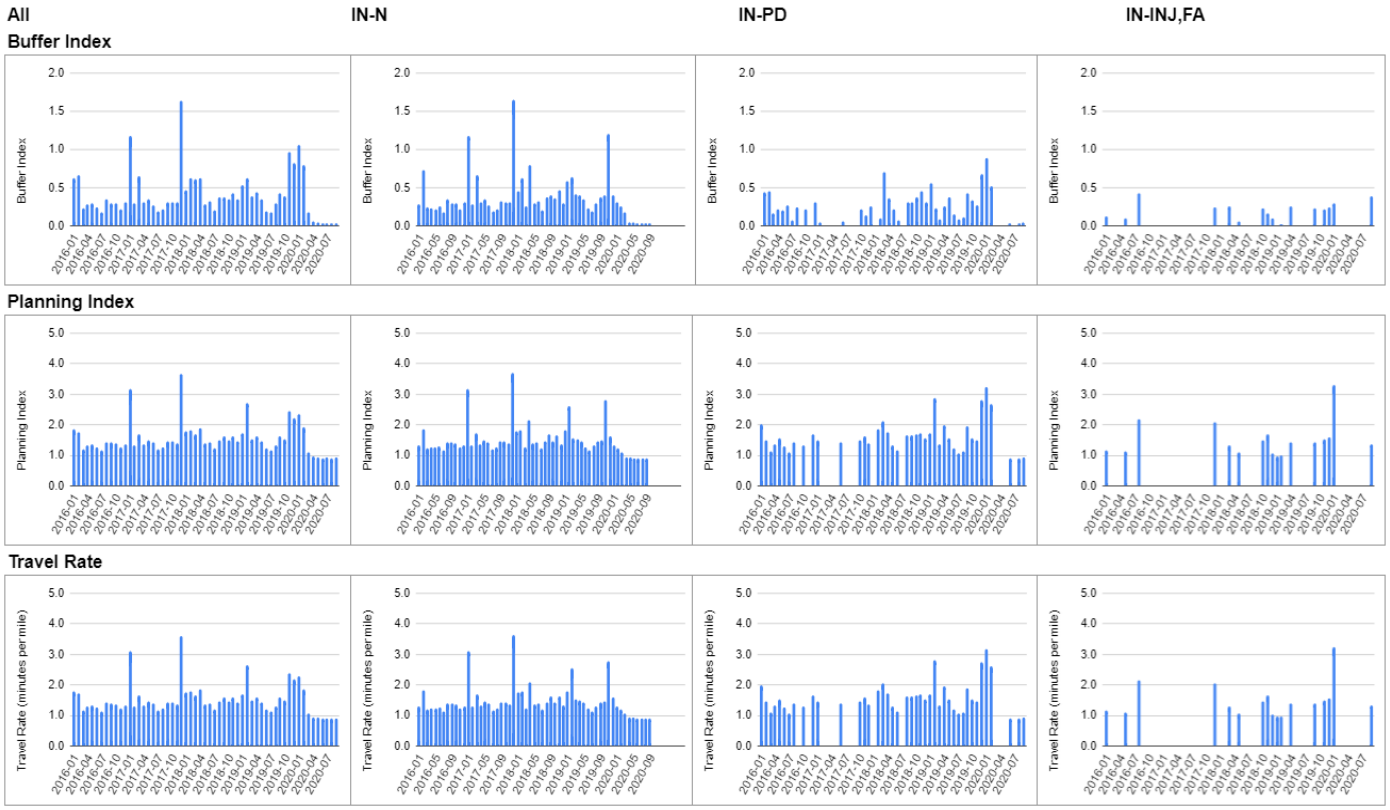
A.20.1.1 Effects of Weather



A.20.1.2 Effects of Work Zones



A.20.1.3 Effects of Incidents



A.20.1.4 Yearly Variations


All
WZ-N
WZ-L
WZ-M,H
Buffer Index
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2016
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All
WZ-N
WZ-L
WZ-M,H
Planning Index
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All
WZ-N
WZ-L
WZ-M,H
Travel Rate
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2016
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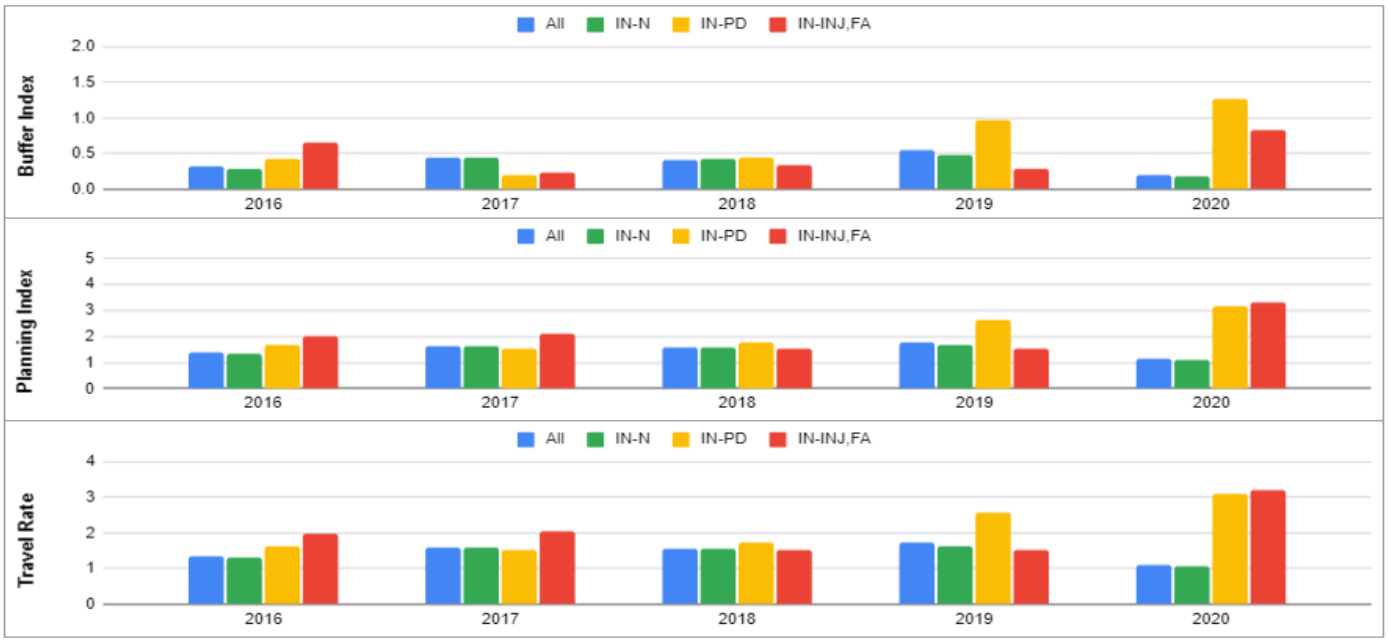
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
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2016
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All
IN-N
IN-PD
IN-INJ,FA
Planning Index
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2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
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2016
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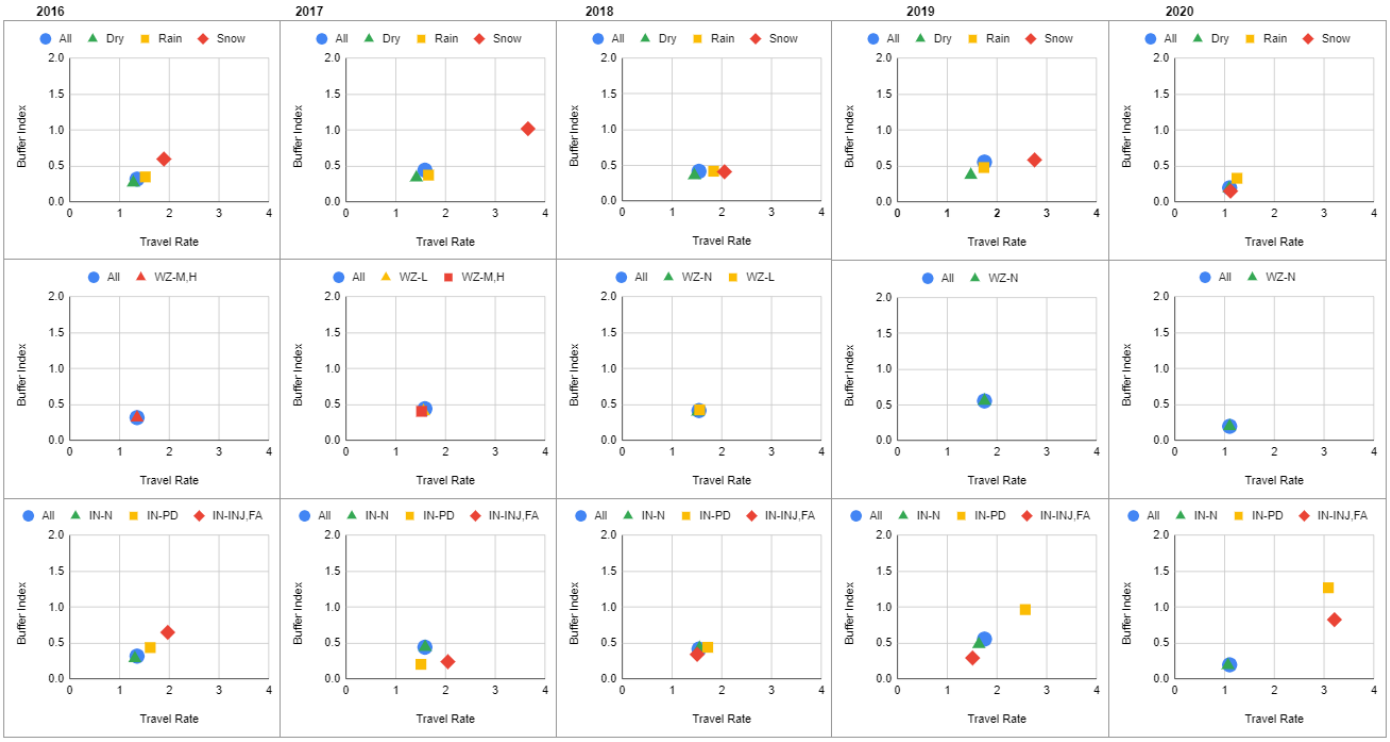
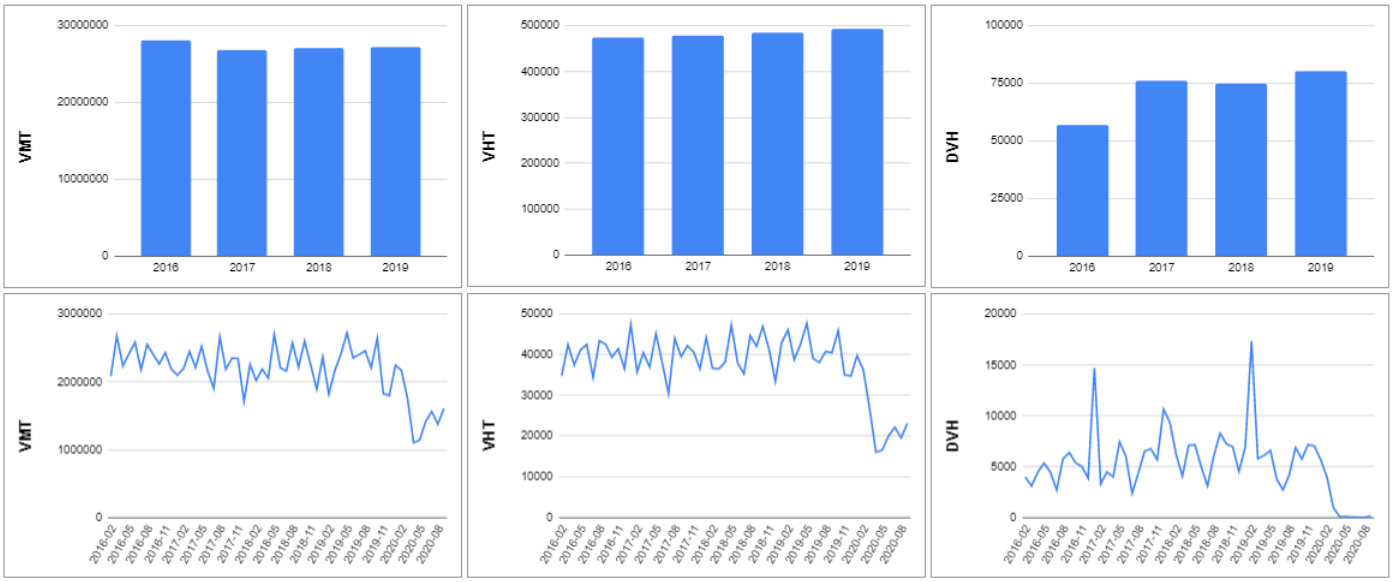
2018
2019
2020

A.20.1.5 Yearly Variations of Combined Index



A.20.1.6 Variations of Traffic-flow Measures



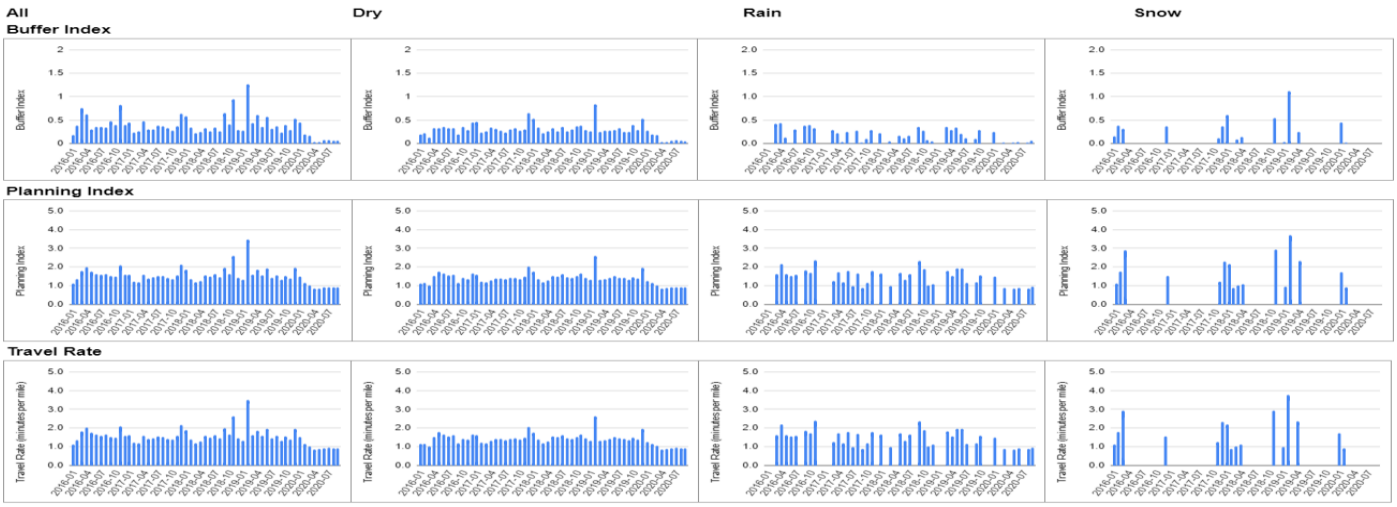
A.20.1.7 Trends Summary

- The traffic flow on this route has been stable as indicated by the variation patterns of VMT/DVH and also by those of the reliability measures.

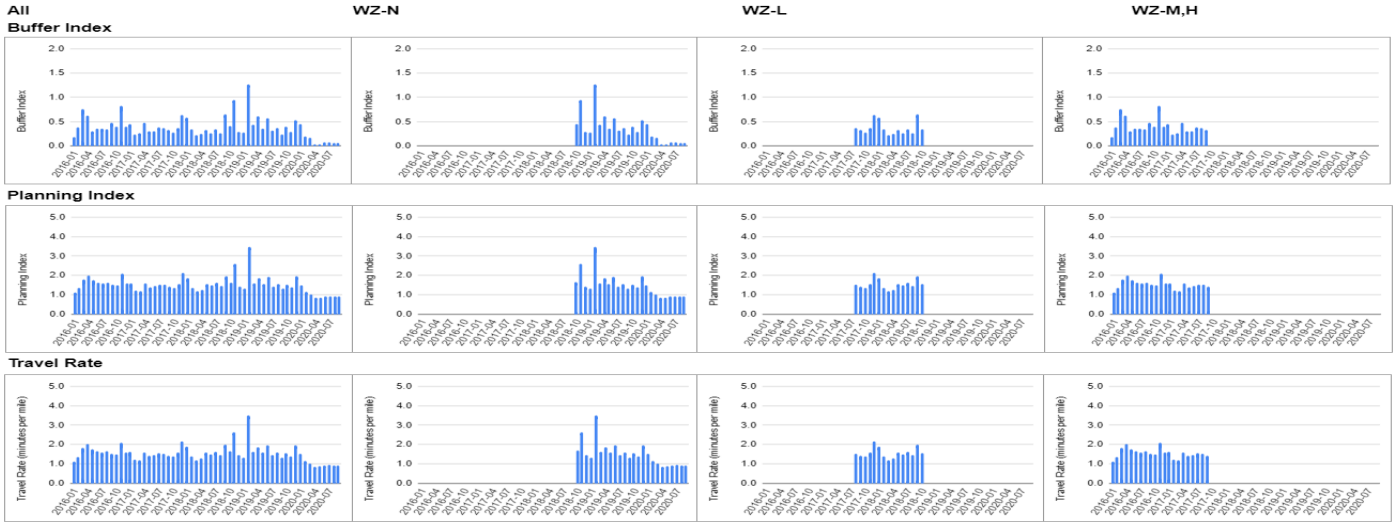
- Snow has been a consistent factor affecting the reliability measures, while incidents also have significant effects on the reliability variations.

A.20.2 I-35E SOUTHBOUND Route 1 (STPL to South Split, Afternoon Peak)

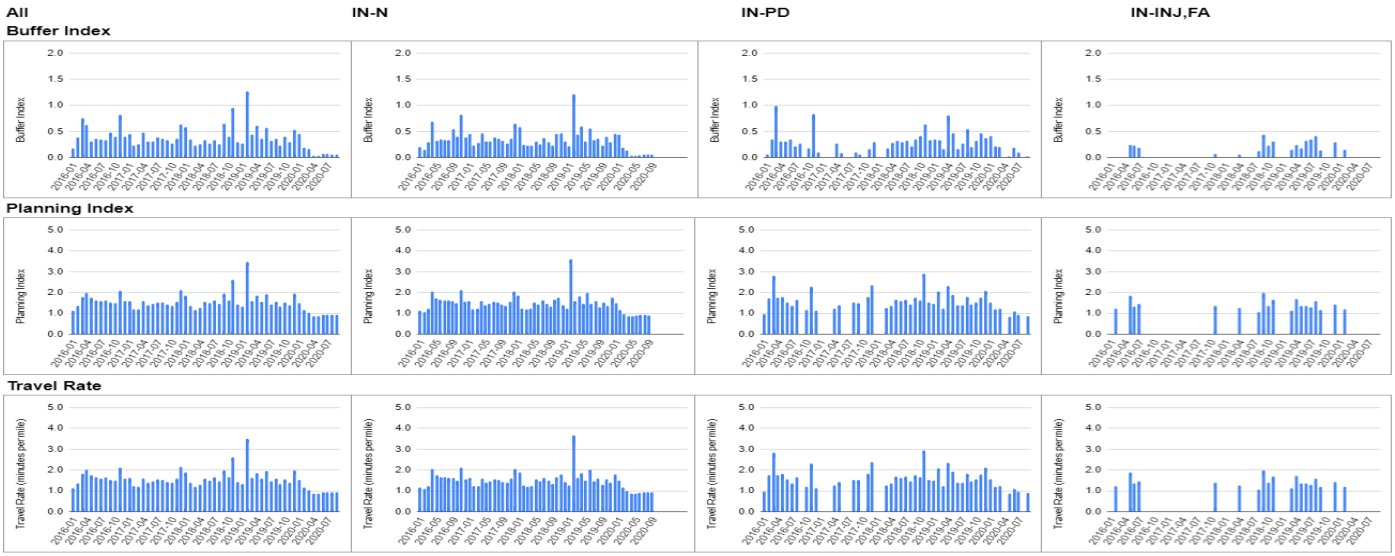
A.20.2.1 Effects of Weather



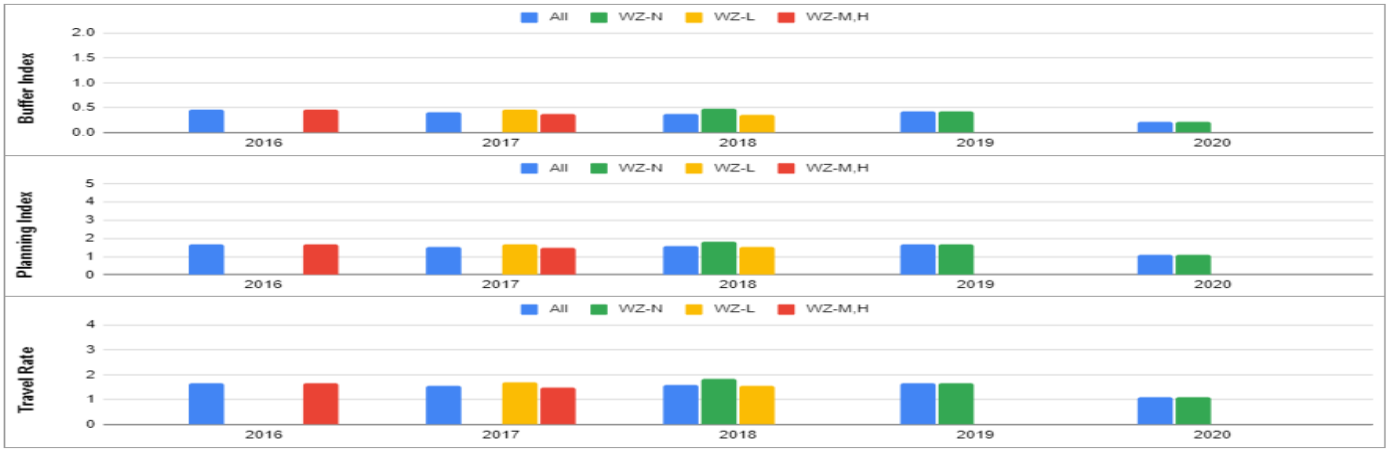
A.20.2.2 Effects of Work Zones



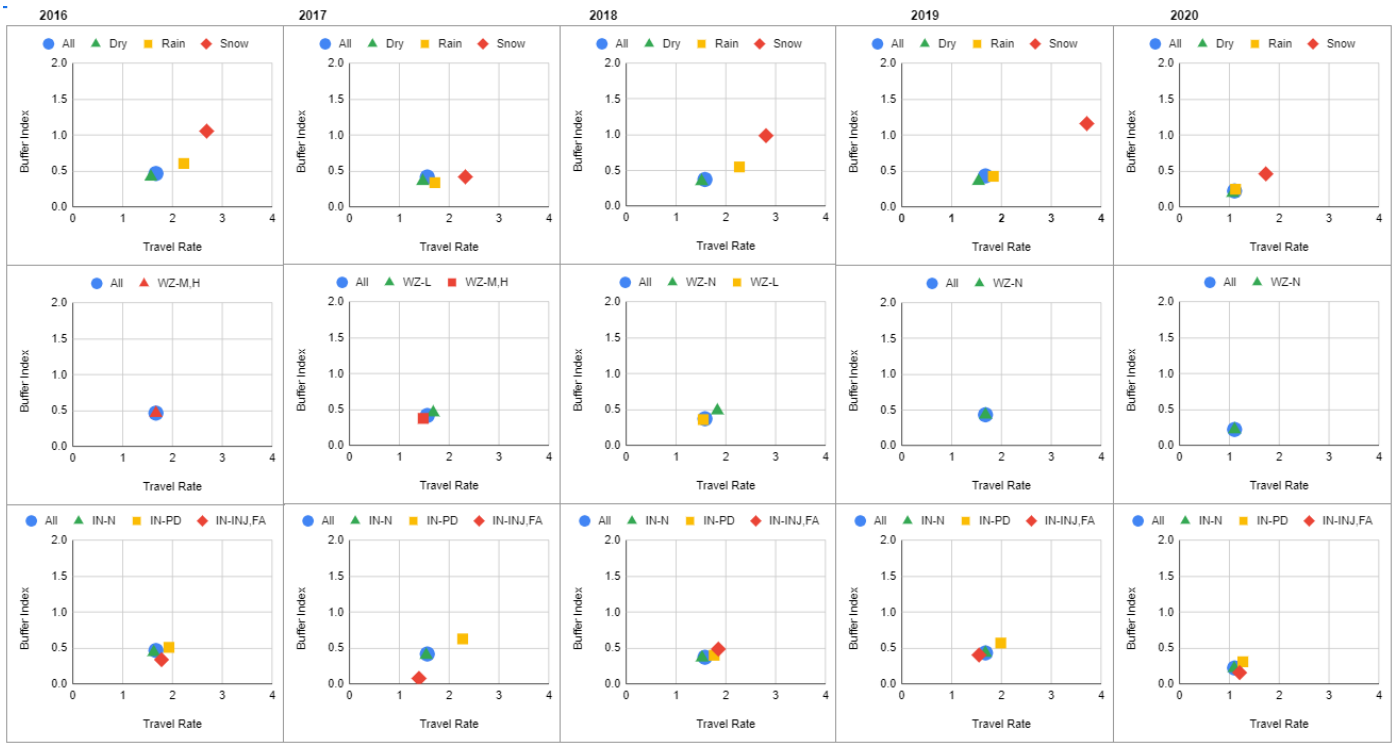
A.20.2.3 Effects of Incidents



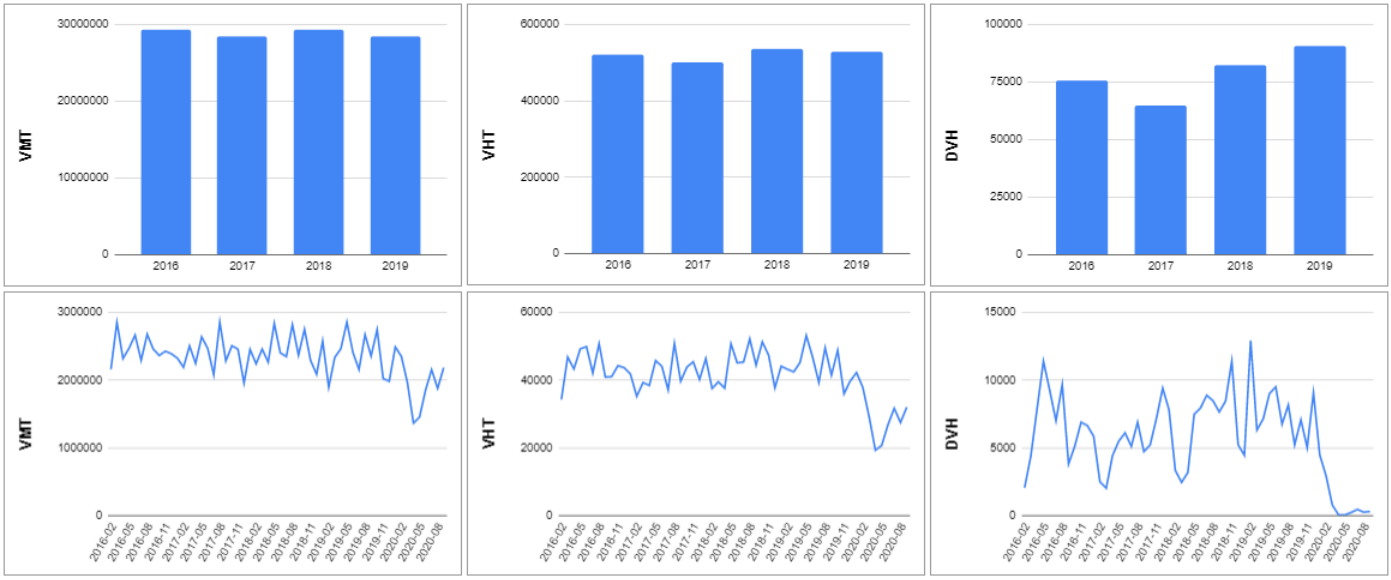
A.20.2.4 Yearly Variations



A.20.2.5 Yearly Variations



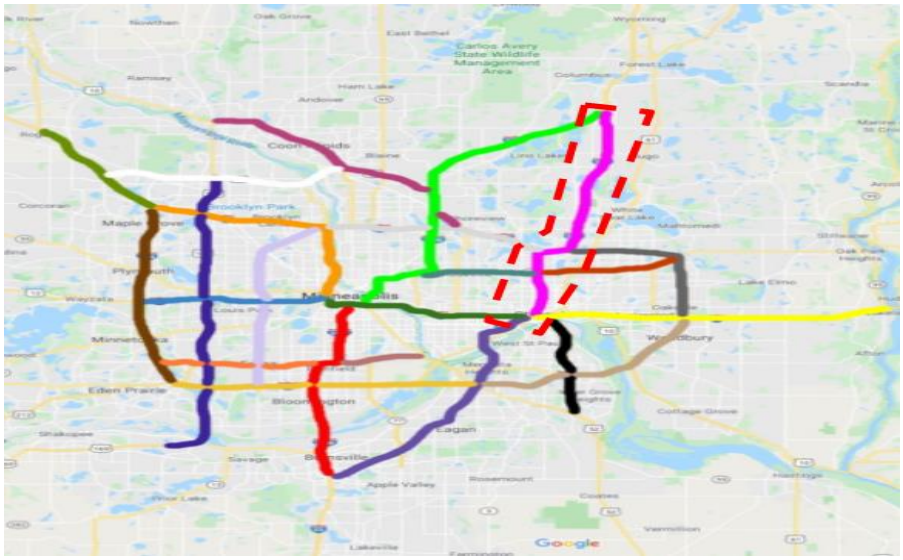
A.20.2.6 Variations of Traffic-Flow Measures



A.20.2.7 Trends Summary

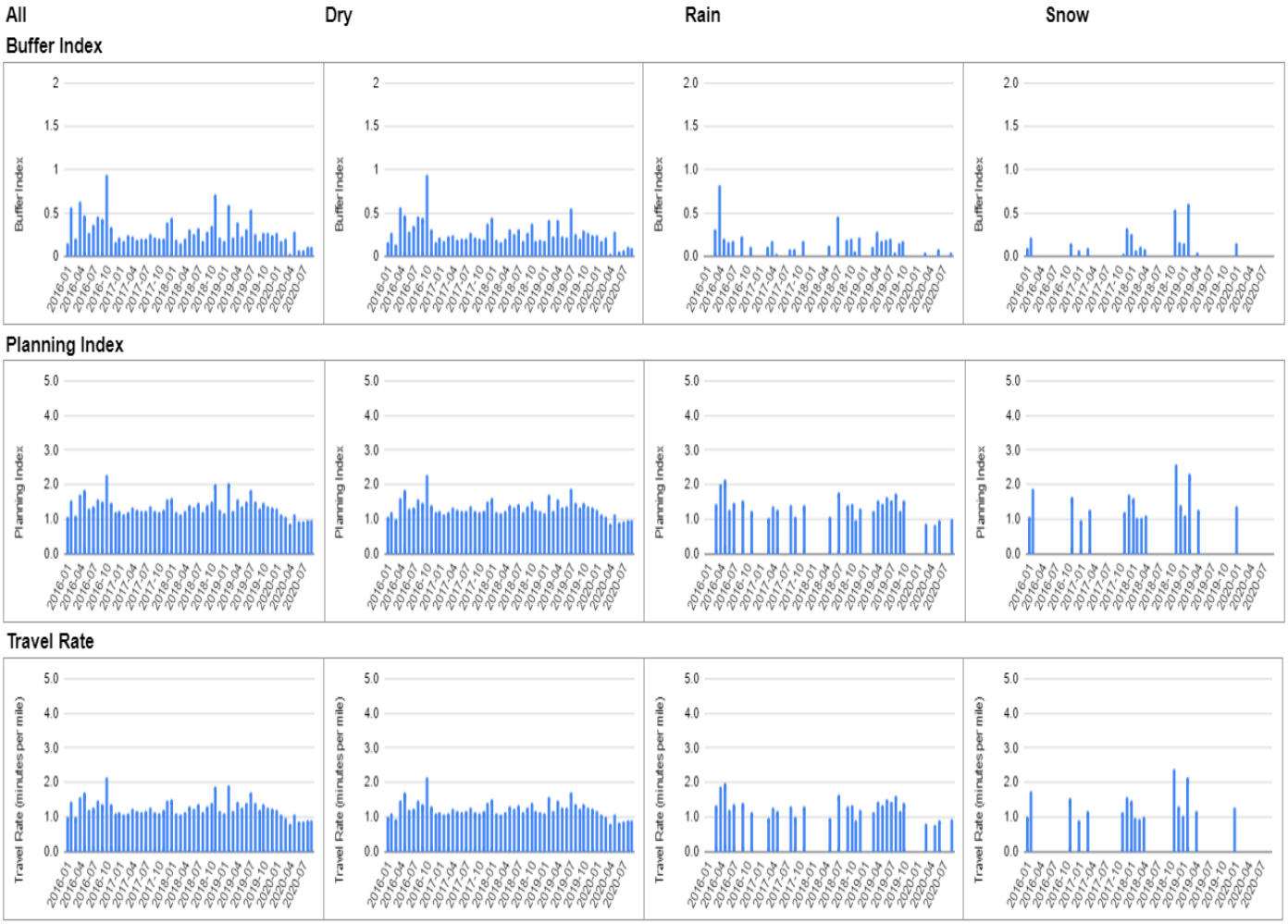
- Both traffic flow and reliability measures show stable patterns through time.
- Snow has consistently been a major factor affecting both travel-time variability and variations in 95th %-ile travel times, while the effects of incidents have not been significant.

A.21 I-35E CORRIDOR 2 (STPL – NORTH SPLIT, NORTHBOUND/SOUTHBOUND)

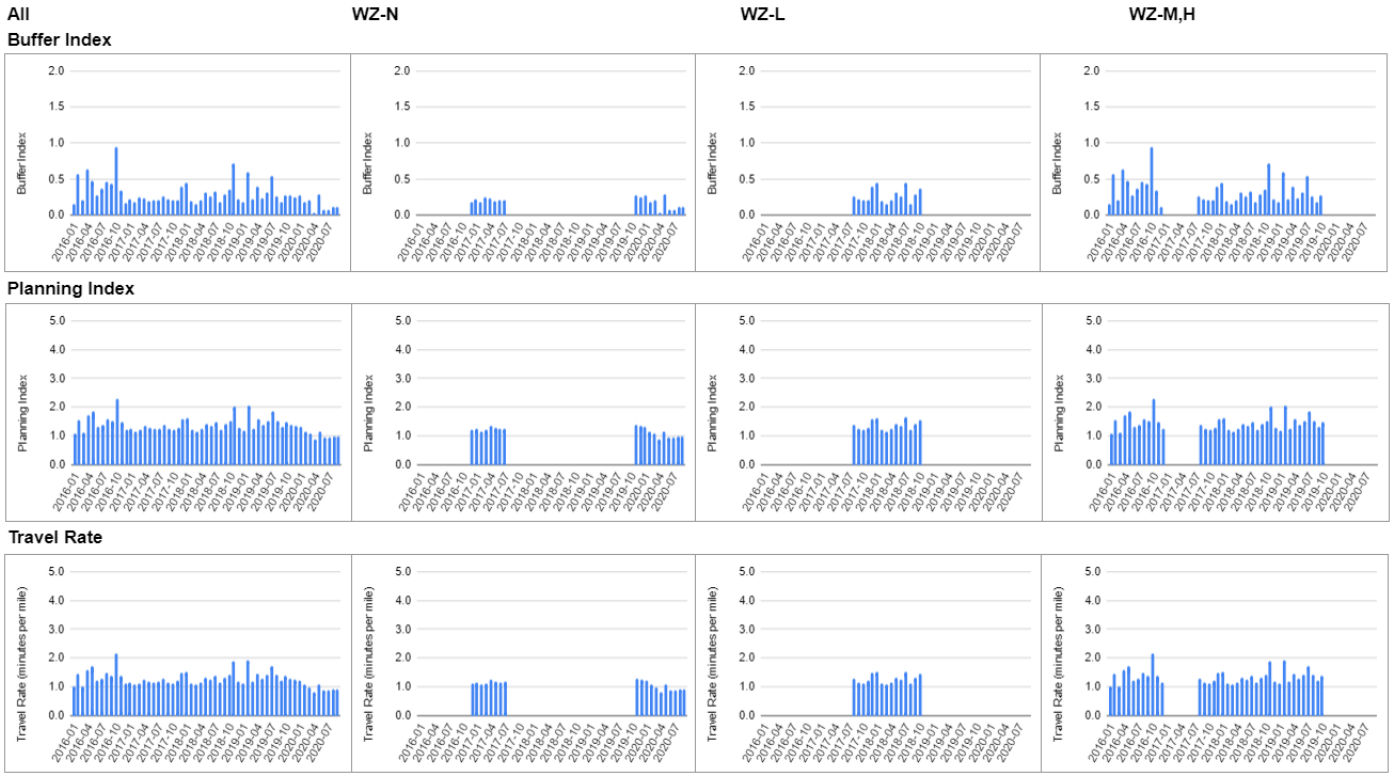


A.21.1 I-35E NORTHBOUND Route 2 (STPL to North Split, Afternoon Peak)

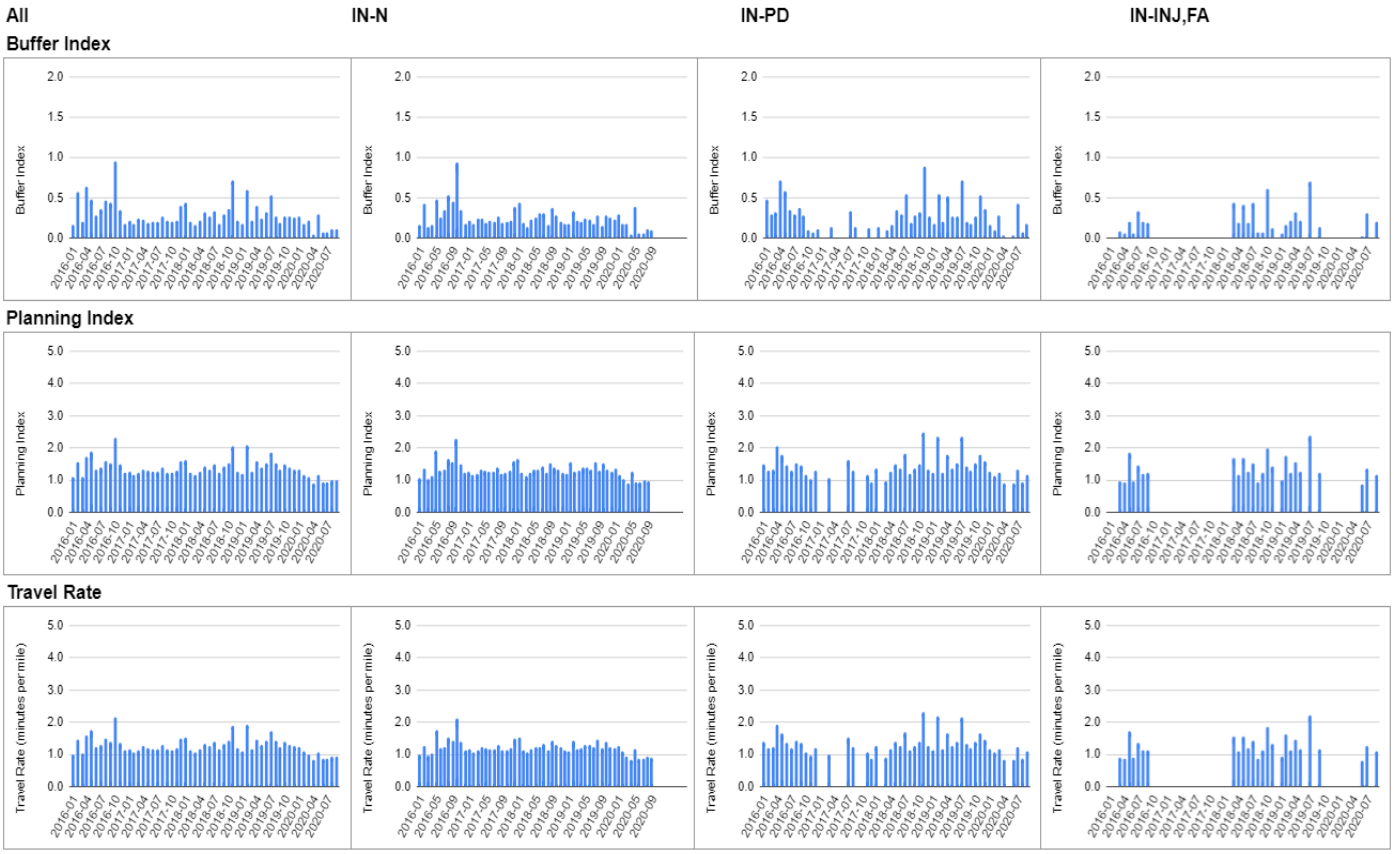
A.21.1.1 Effects of Weather



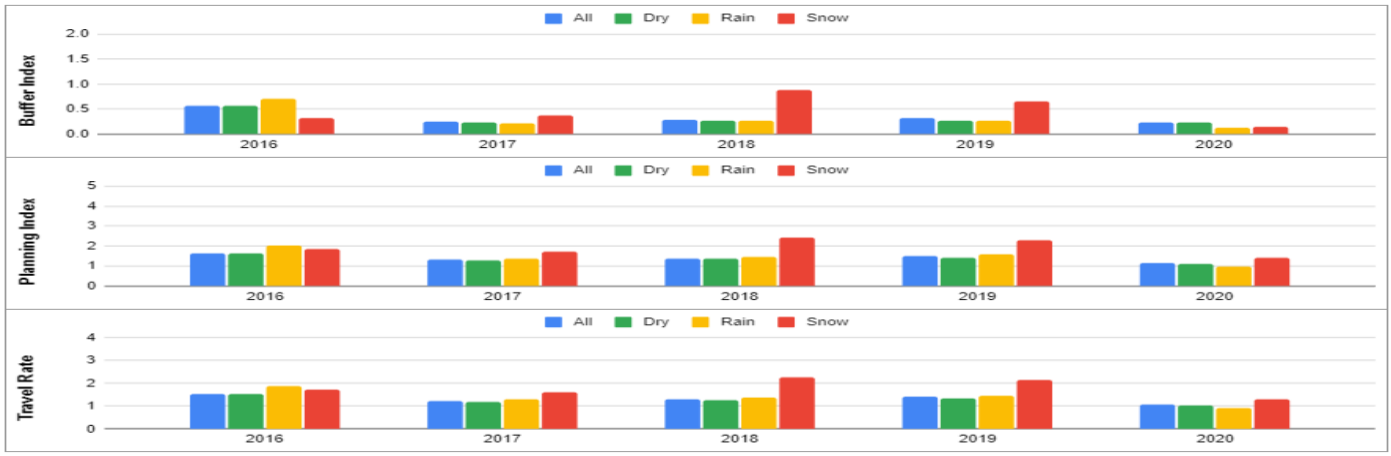
A.21.1.2 Effects of Work Zones

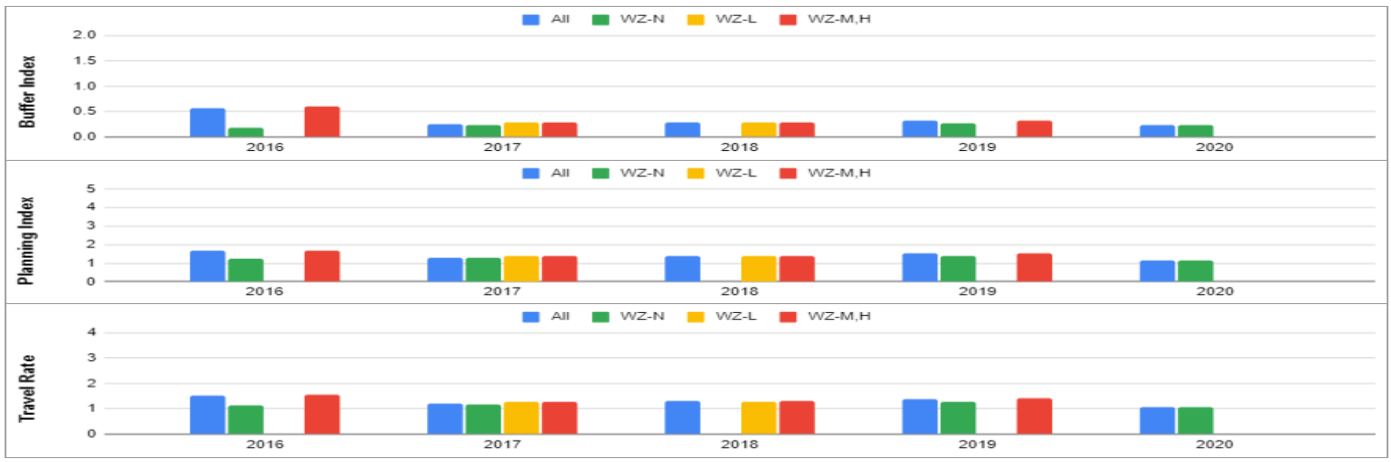


A.21.1.3 Effects of Incidents



A.21.1.4 Yearly Variations




All
WZ-N
WZ-L
WZ-M,H
Buffer Index
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Planning Index
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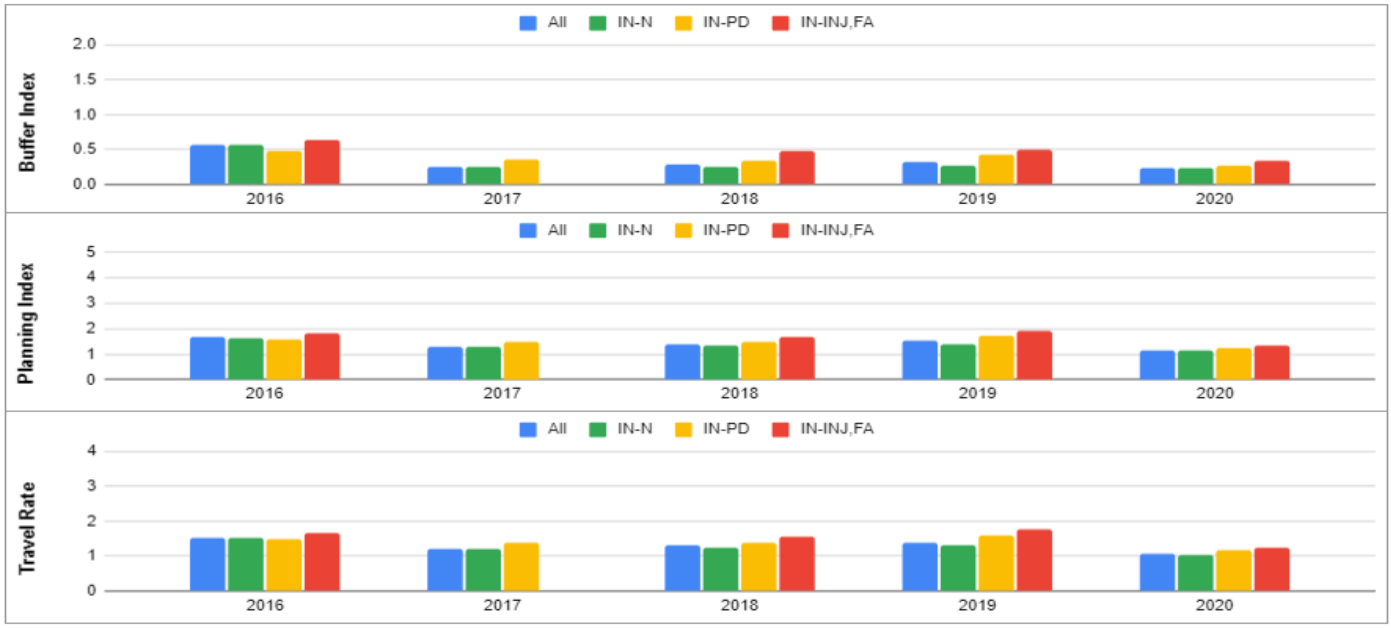
Travel Rate


All
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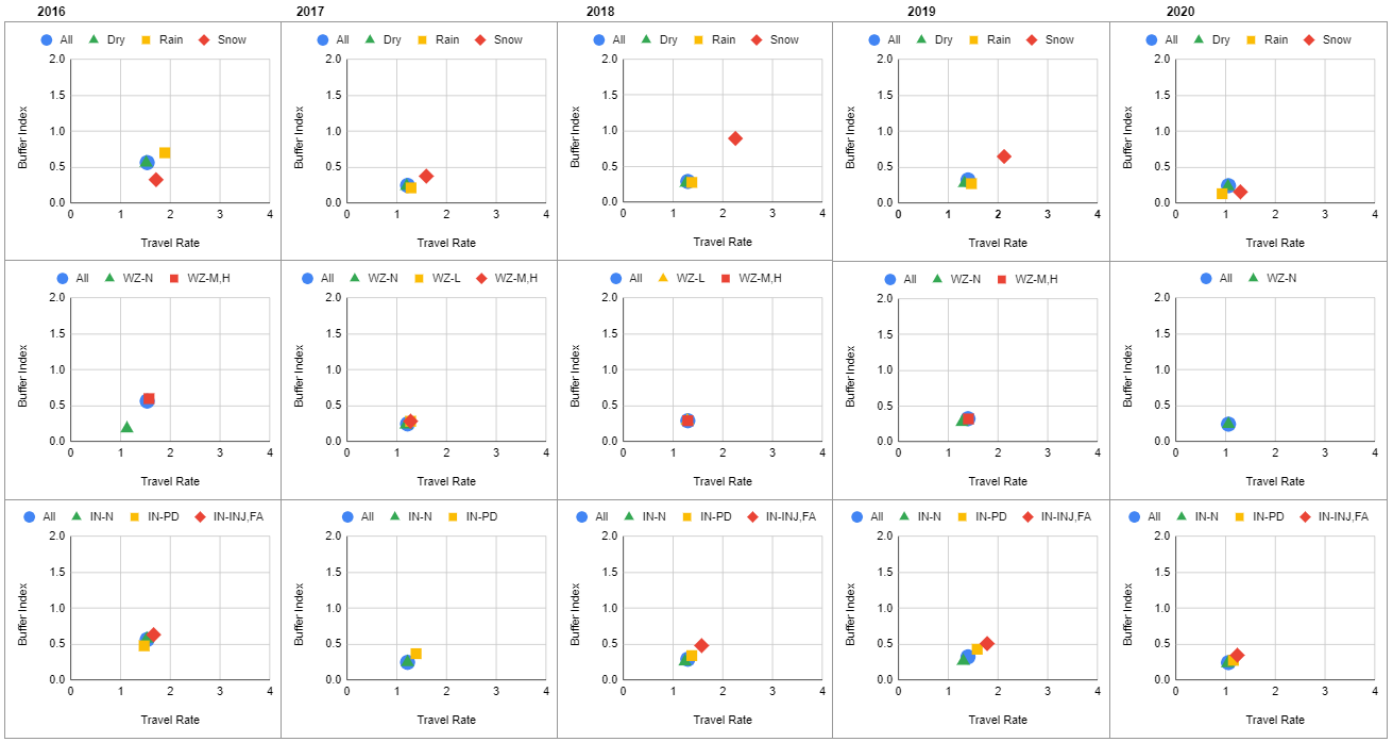
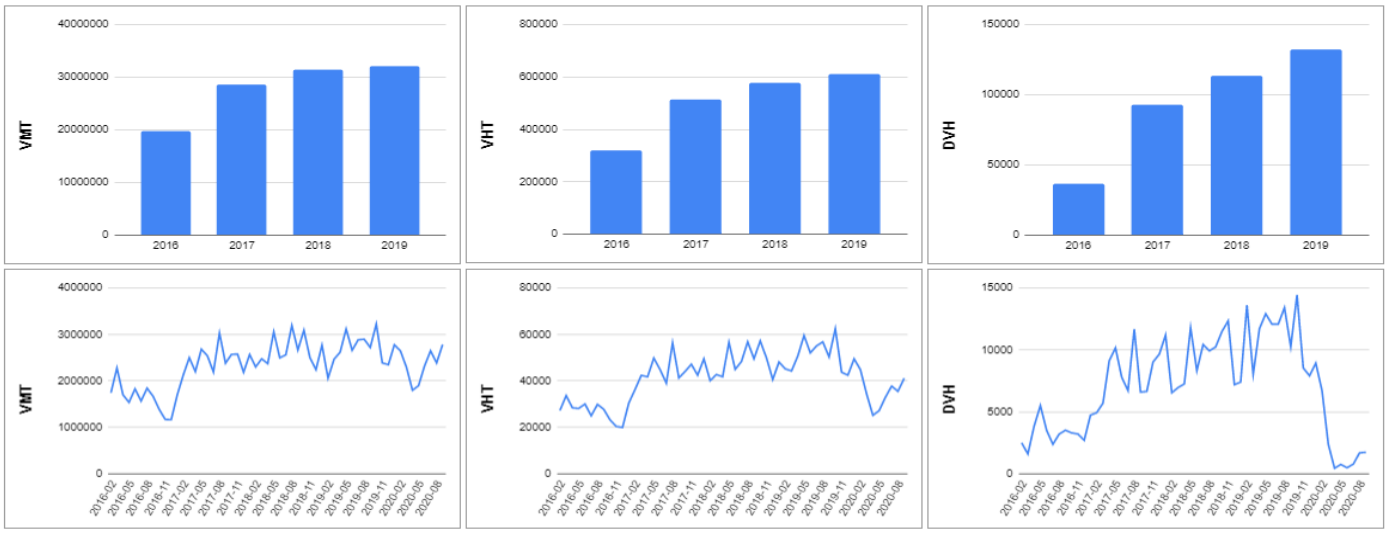
Travel Rate

A.21.1.5 Yearly Variations of Combined Index



A.21.1.6 Variations of Traffic-Flow Measures

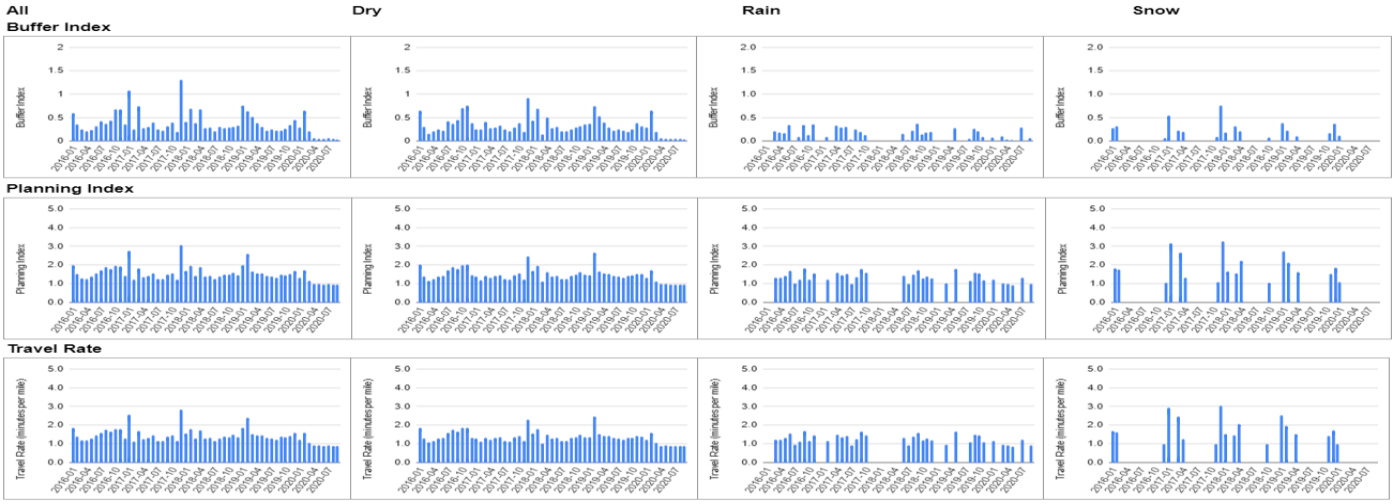


A.21.1.7 Trends Summary

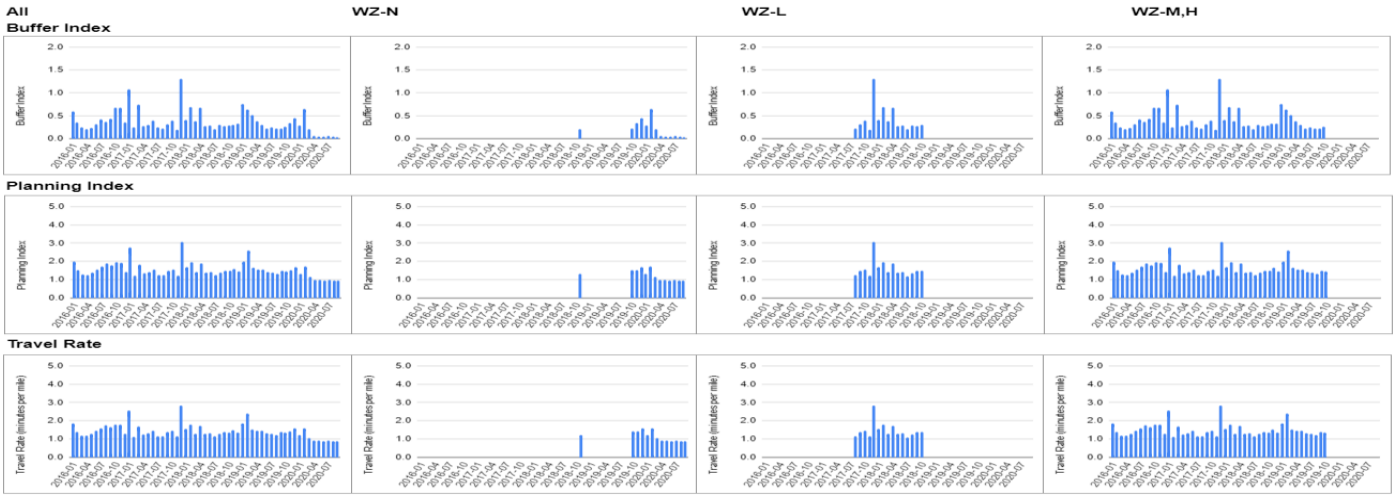
- Both VMT and DVH have been continuously increasing on this route, however, the monthly variations of the reliability measures show stable patterns without excessive congestion.
- Snow has been the main factor affecting the reliability, while the effects of incidents also have been continuously growing.

A.21.2 I-35E SOUTHBOUND Route 2 (North Split to STPL, Morning Peak)

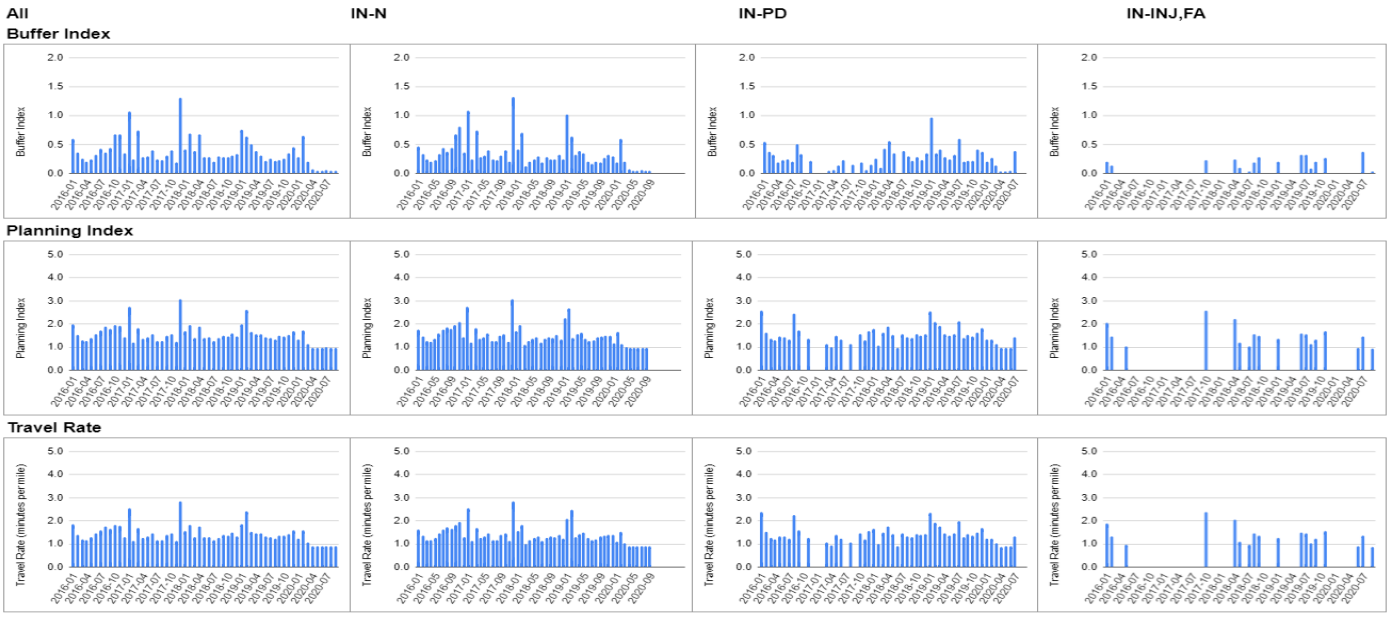
A.21.2.1 Effects of Weather



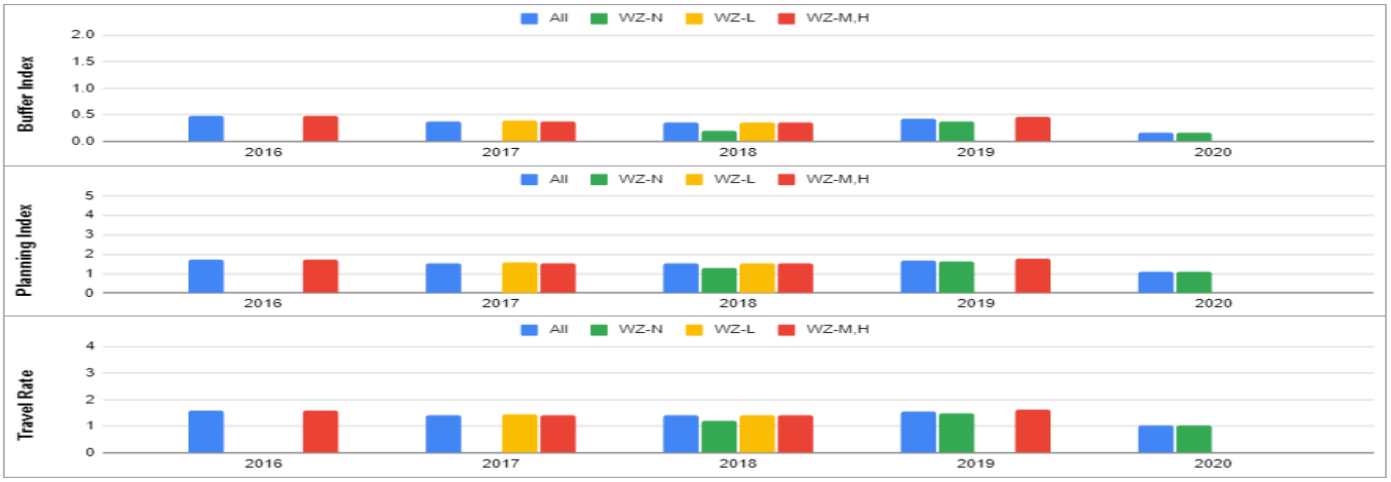
A.21.2.2 Effects of Work Zones



A.21.2.3 Effects of Incidents



A.21.2.4 Yearly Variations


All
WZ-N
WZ-L
WZ-M,H
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Planning Index
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Travel Rate


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IN-PD
IN-INJ,FA
Buffer Index
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2020
Planning Index
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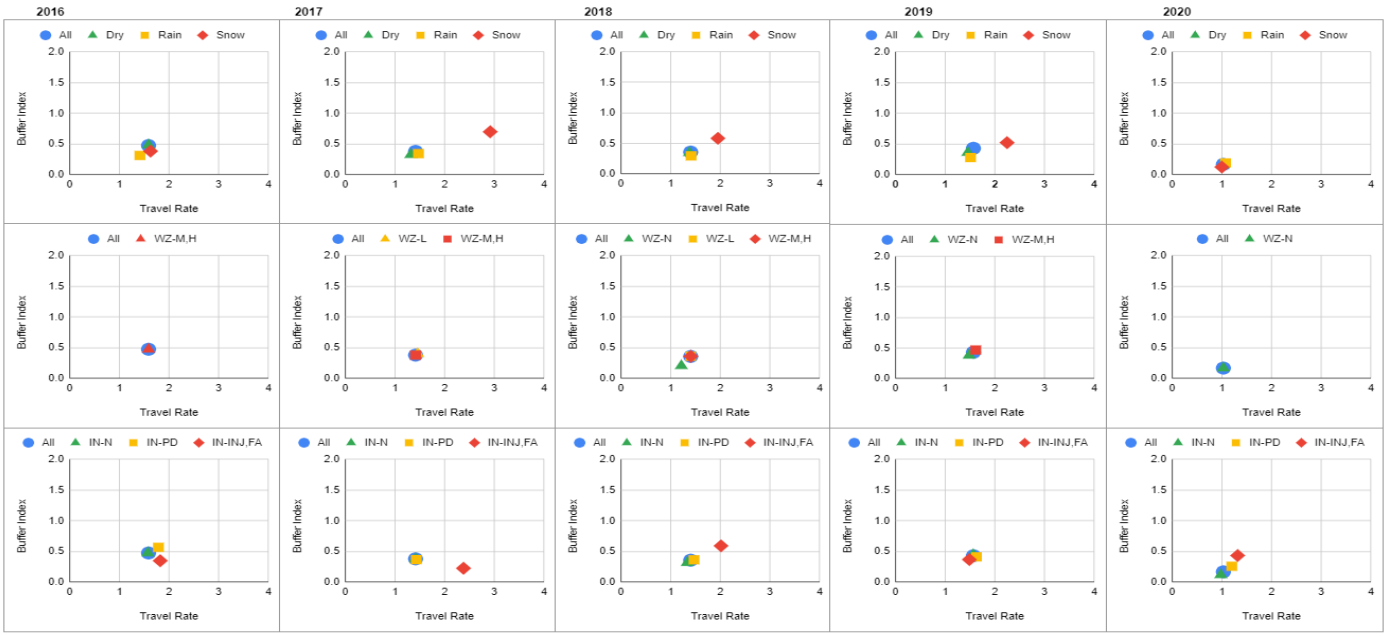
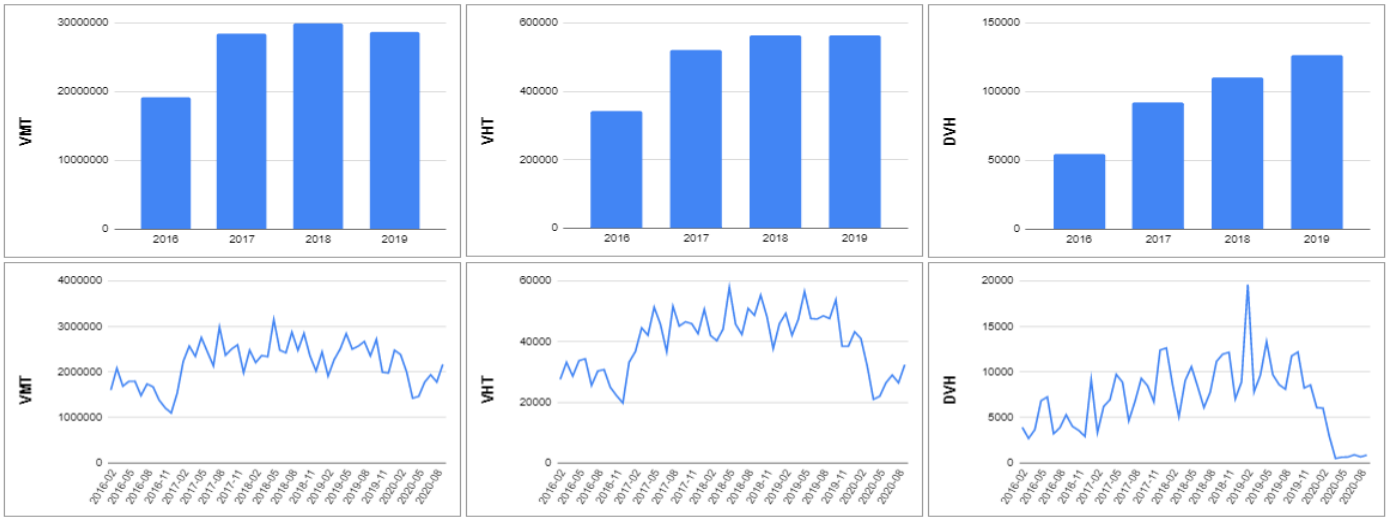
Travel Rate

A.21.2.5 Yearly Variations of Combined Index



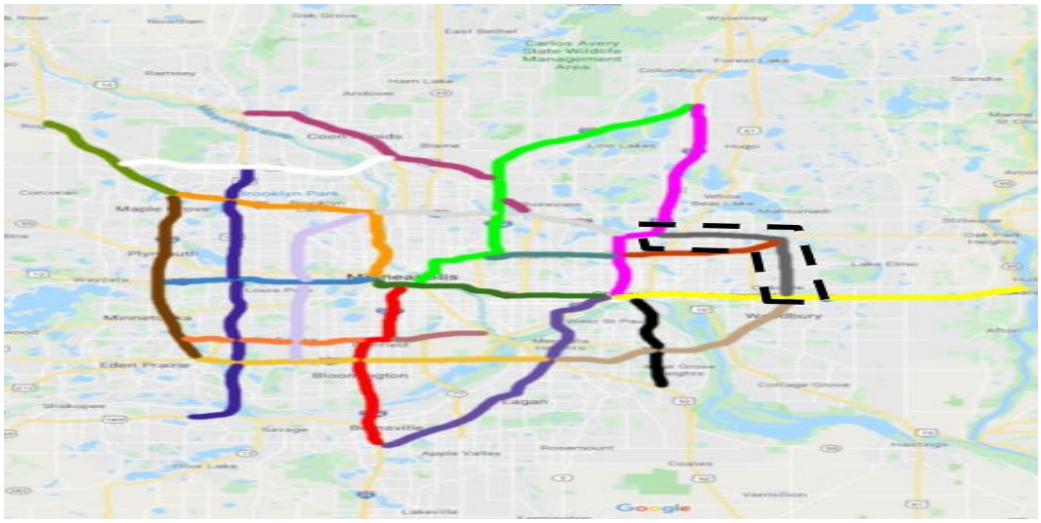
A.21.2.6 Variations of Traffic-Flow Measures



A.21.2.7 Trends Summary

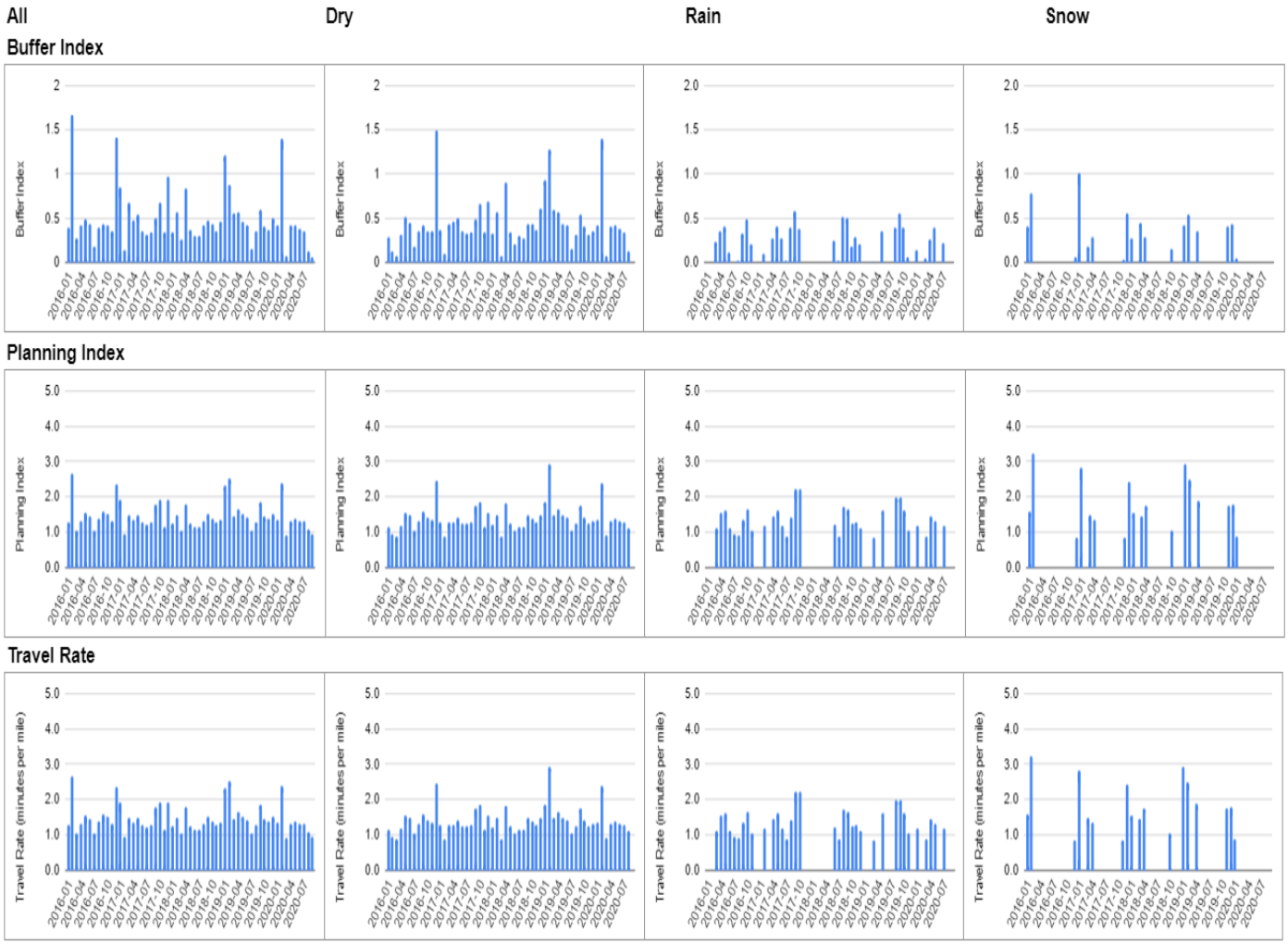
- The VMT has been reduced in 2019, while DVH remained at the same level as in 2018.
- The monthly buffer-index values, i.e., travel-time variability, show seasonal variations mostly attributed to snow.
- Snow also has been the major contributing factor to the increase and variations of the 95th %-ile travel times.
- The injury/fatal incidents have been mostly affecting the planning index and travel rates, i.e., the magnitude and variations of the 95th %-ile travel times.

A.22 I-694 CORRIDOR 1 (I-94 – I-35E, EASTBOUND/WESTBOUND)

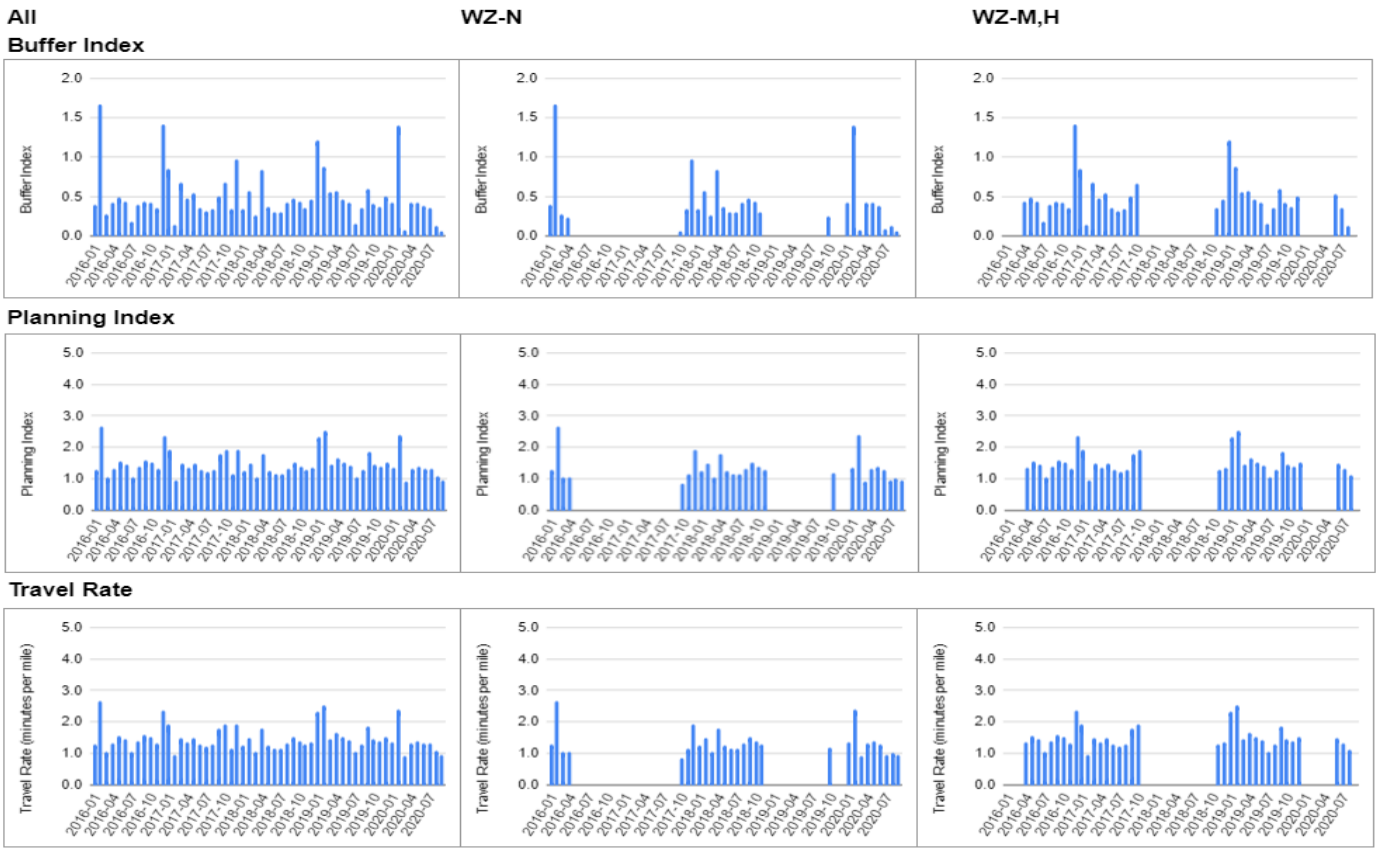


A.22.1 I-694 WESTBOUND Route 1 (I-94 to I-35E, Morning Peak)

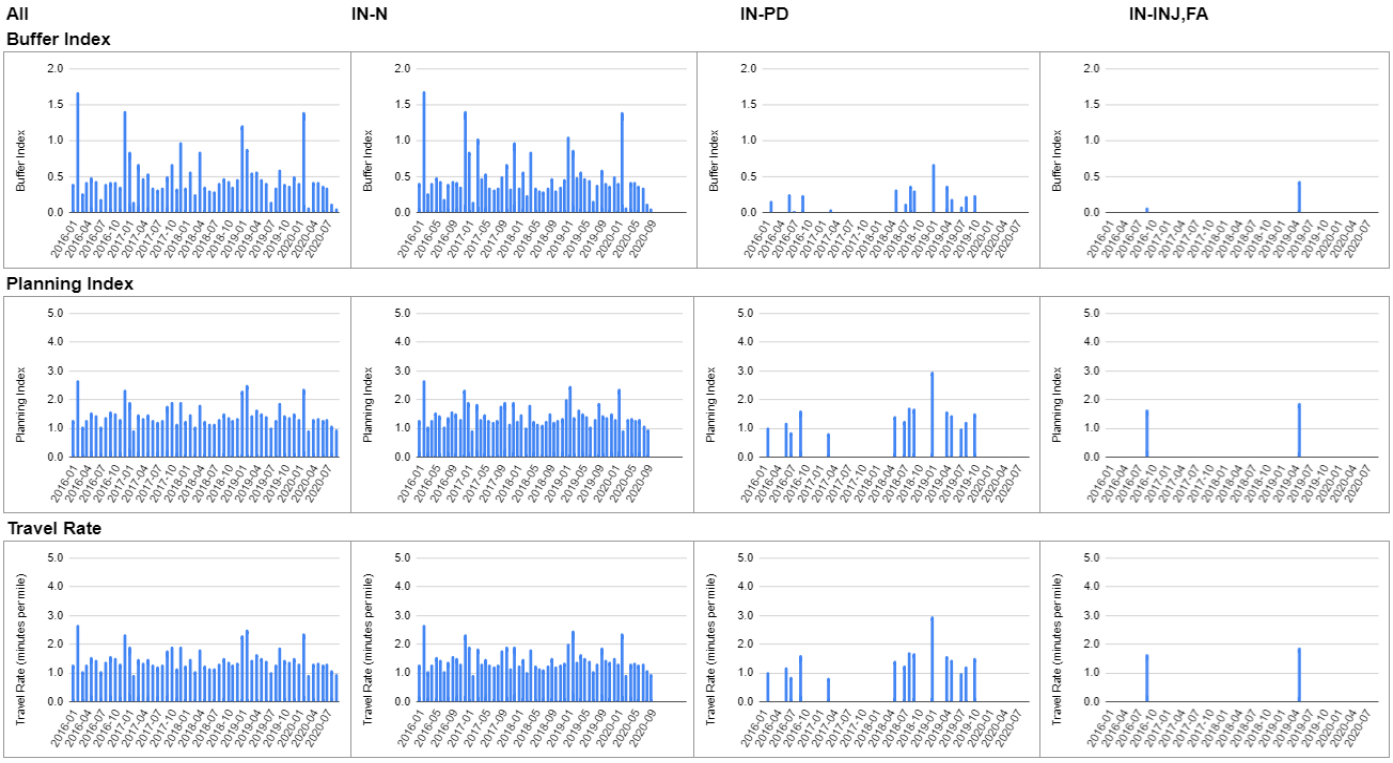
A.22.1.1 Effects of Weather



A.22.1.2 Effects of Work Zones



A.22.1.3 Effects of Incidents

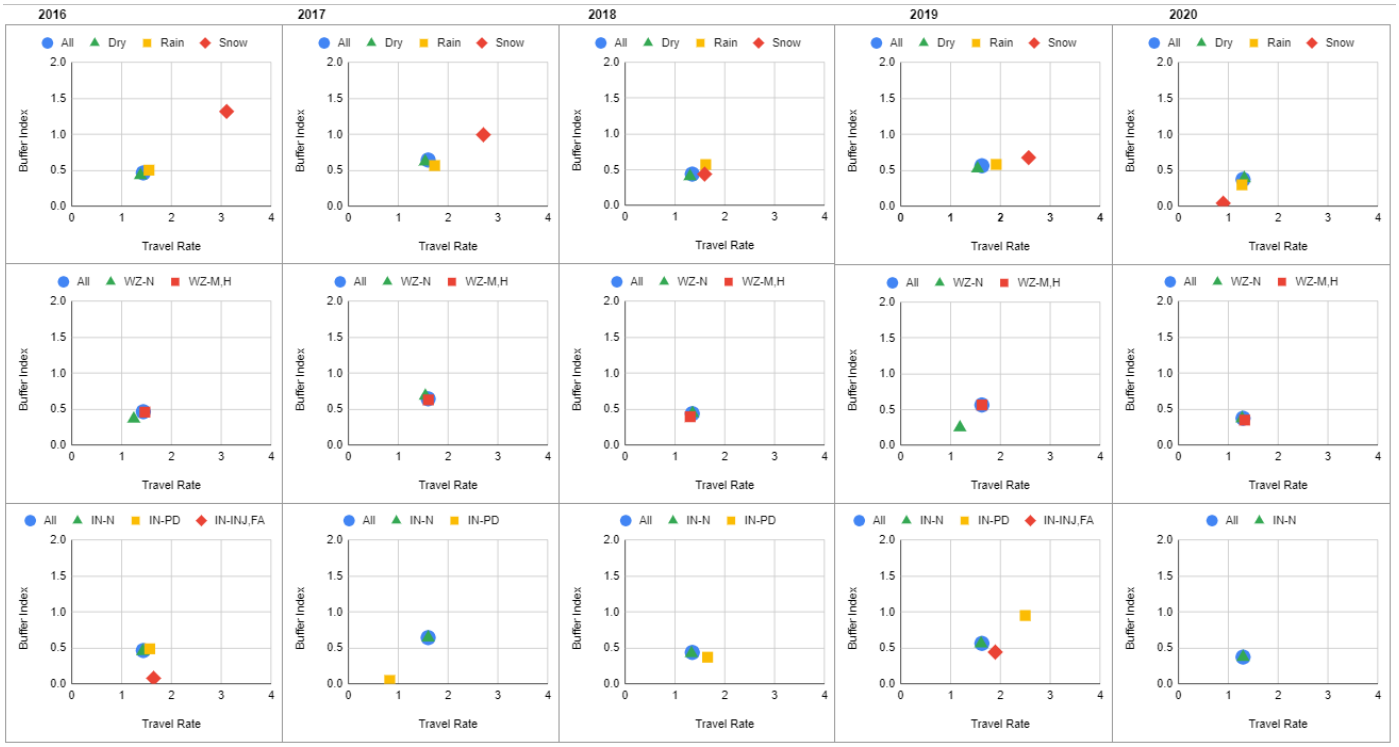


A.22.1.4 Yearly Variations

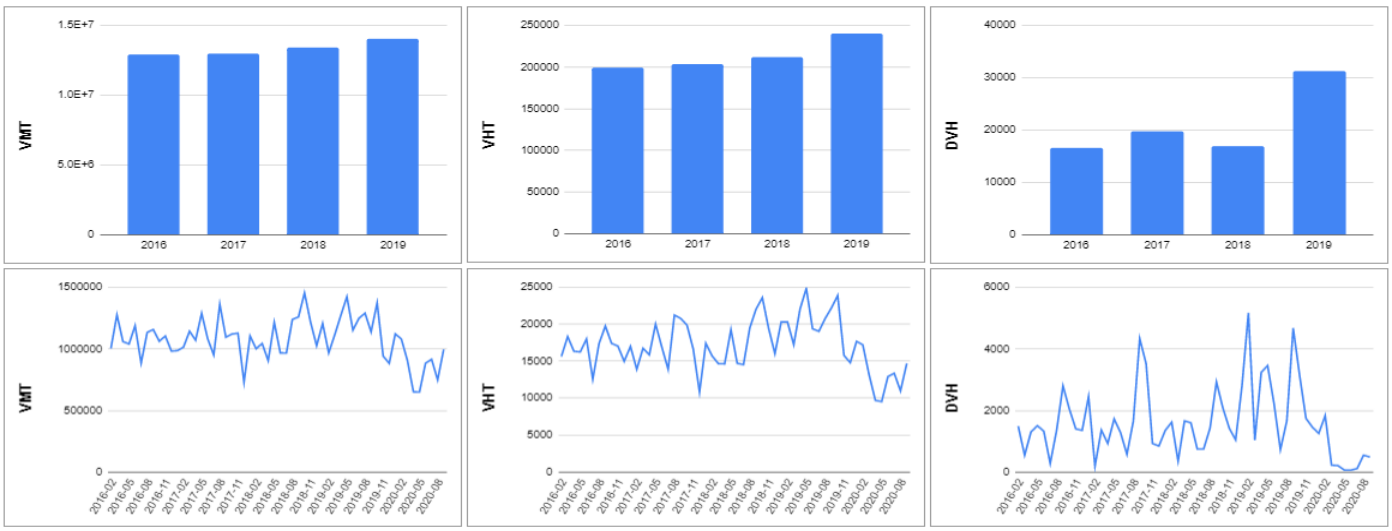

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.22.1.5 Yearly Variations of Combined Index



A.22.1.6 Variations of Traffic-Flow Measures

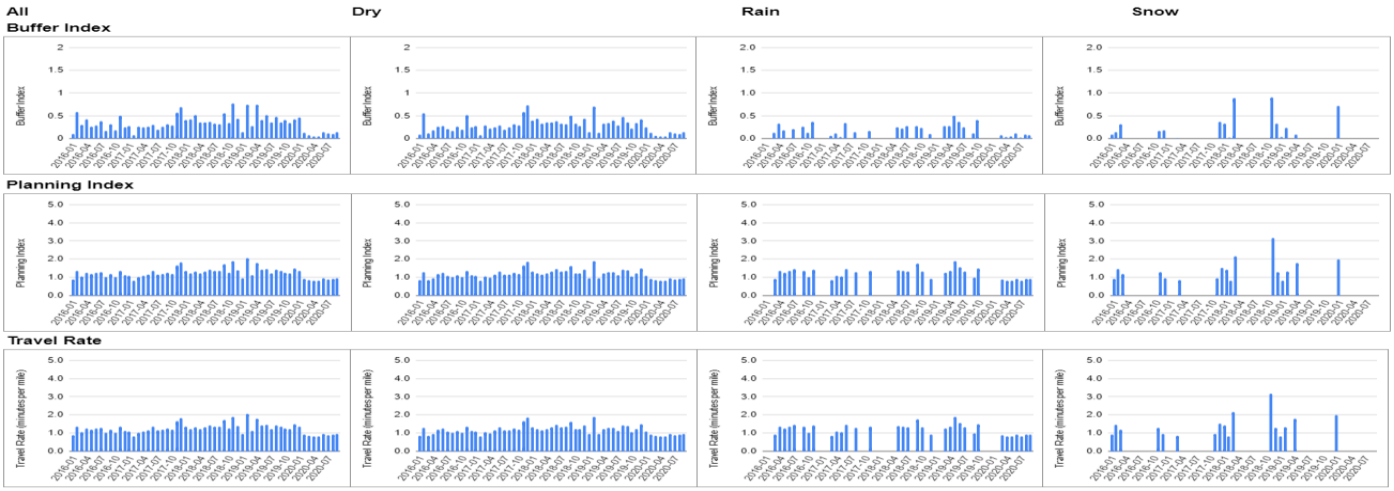


A.22.1.7 Trends Summary

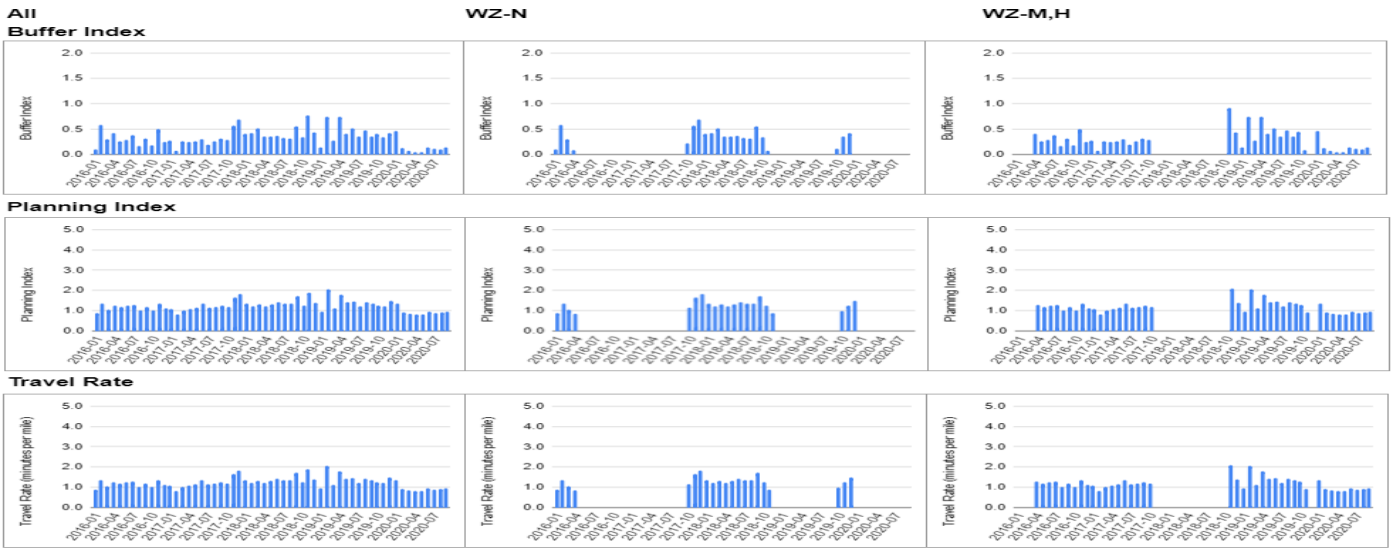
- Both VMT and DVH show a slightly increasing pattern from 2016 to 2019.
- The monthly buffer index values indicate significant seasonal variability in travel times mostly affected by snow.
- Both planning indices and travel rates also exhibit seasonal patterns, indicating the effects of snow on increasing 95th %-ile travel times.
- Incidents have also been a contributing factor to the increase in 95th %-ile travel times in most years.

A.22.2 I-694 EASTBOUND Route 1 (I35E to I94, Afternoon Peak)

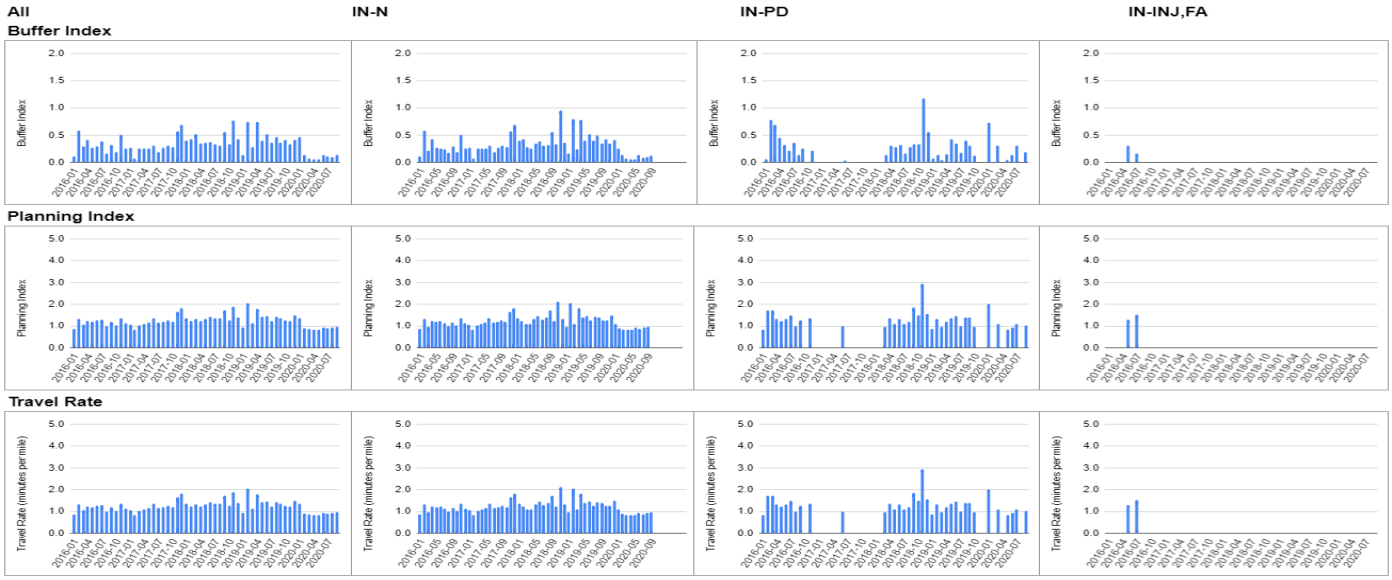
A.22.2.1 Effects of Weather



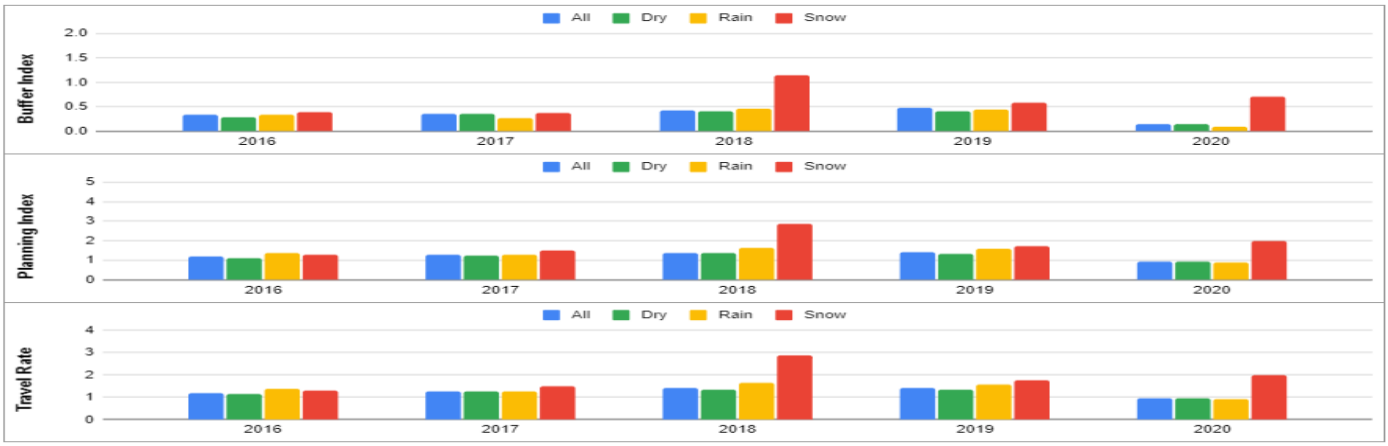
A.22.2.2 Effects of Work Zones

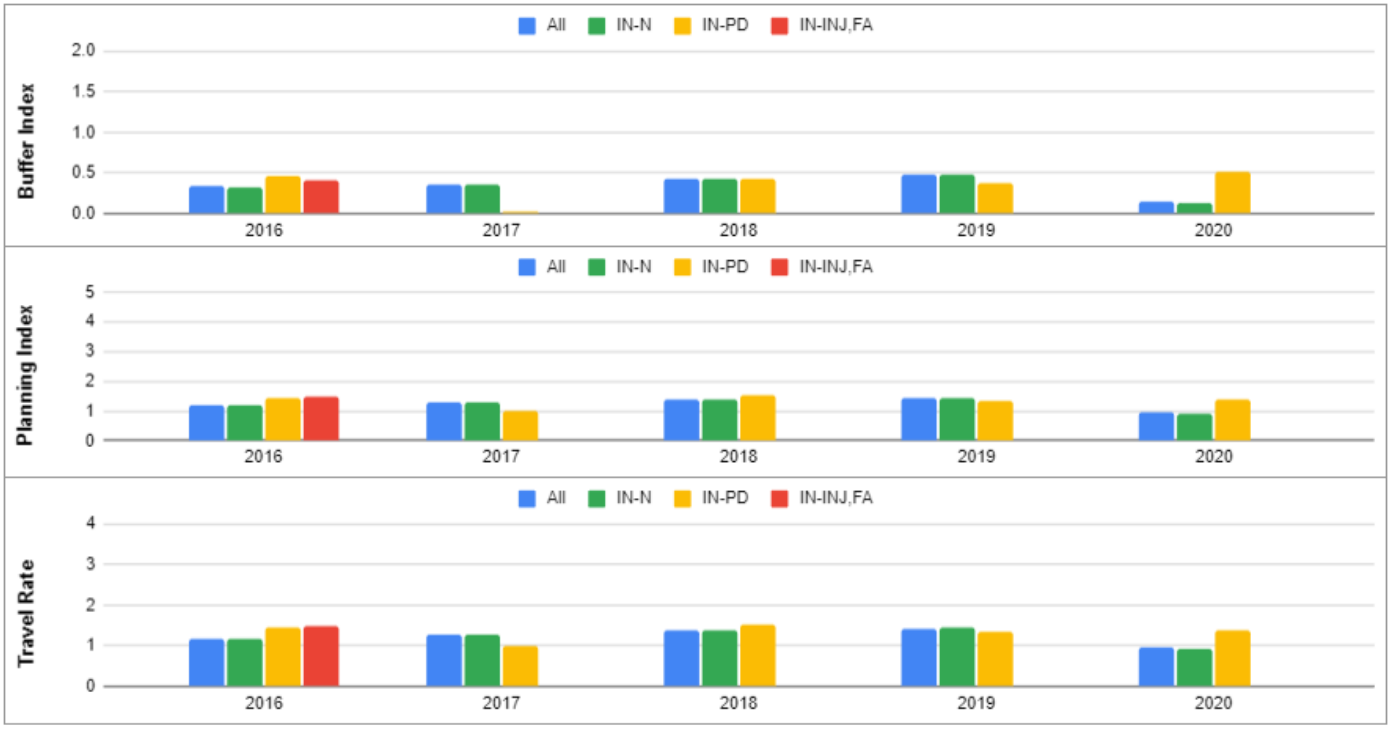


A.22.2.3 Effects of Incidents

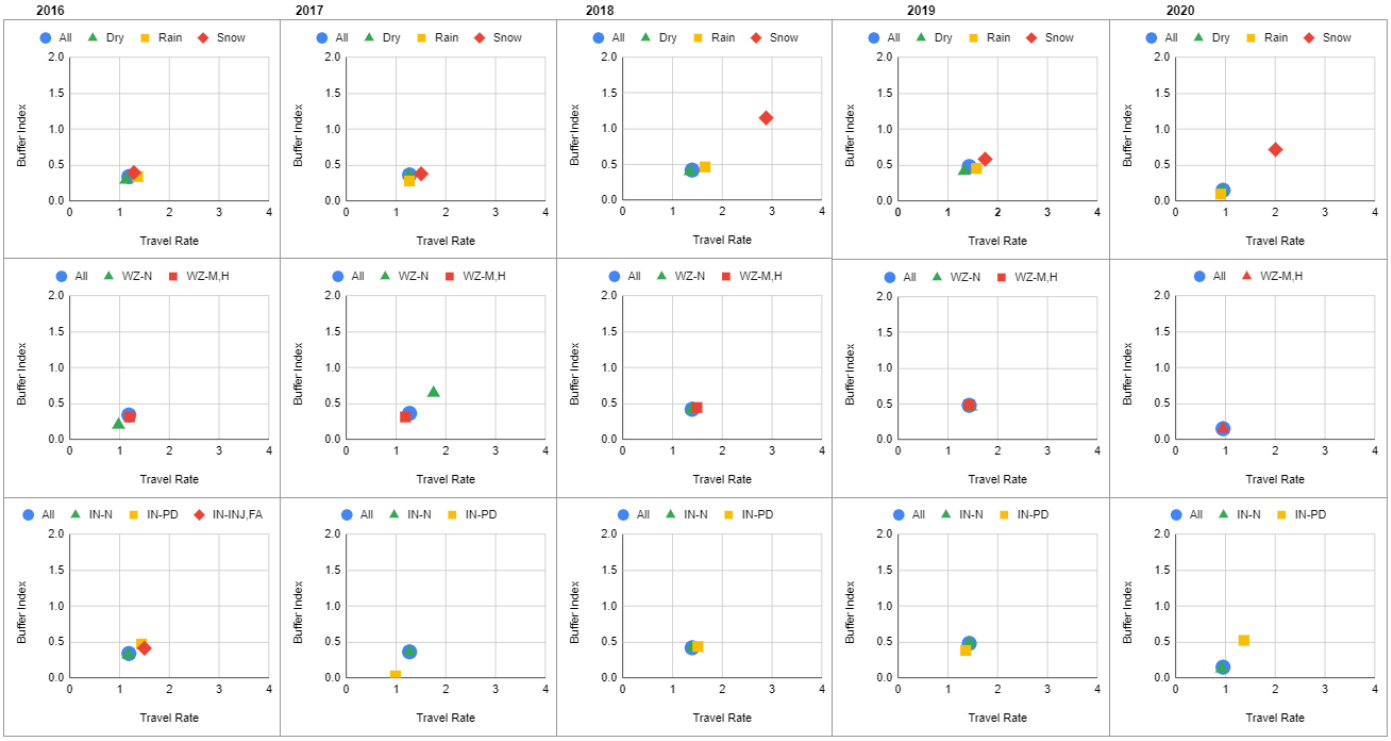


A.22.2.4 Yearly Variations

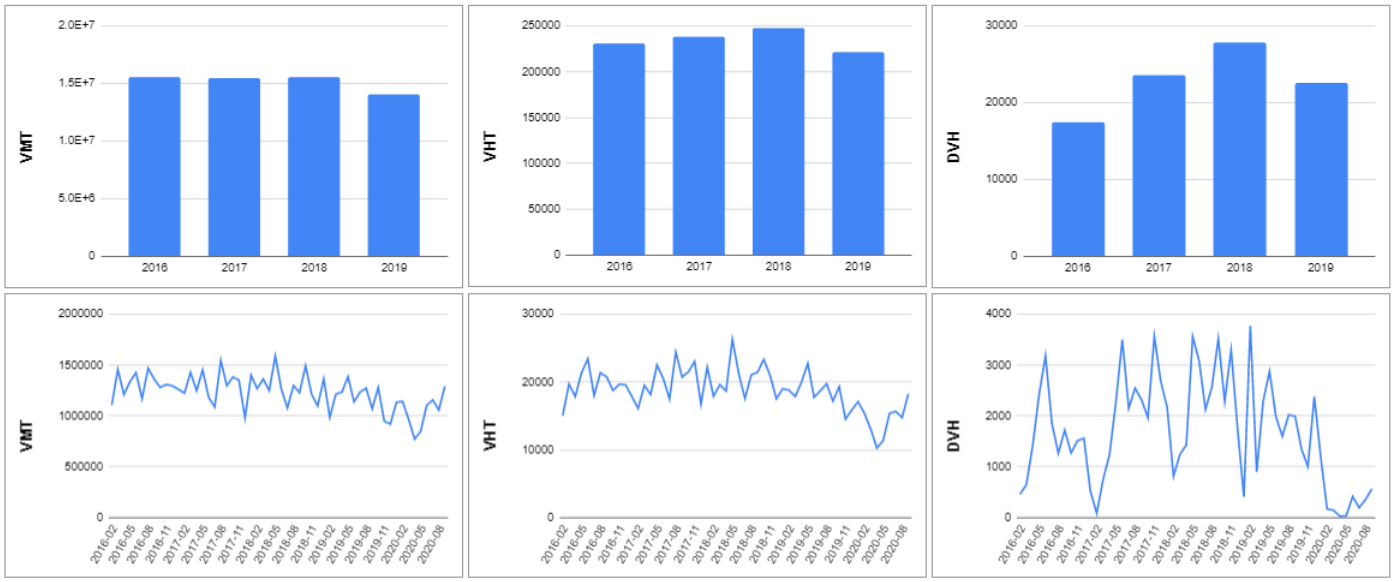




A.22.2.5 Yearly Variations of Combined Index



A.22.2.6 Variations of Traffic-Flow Measures



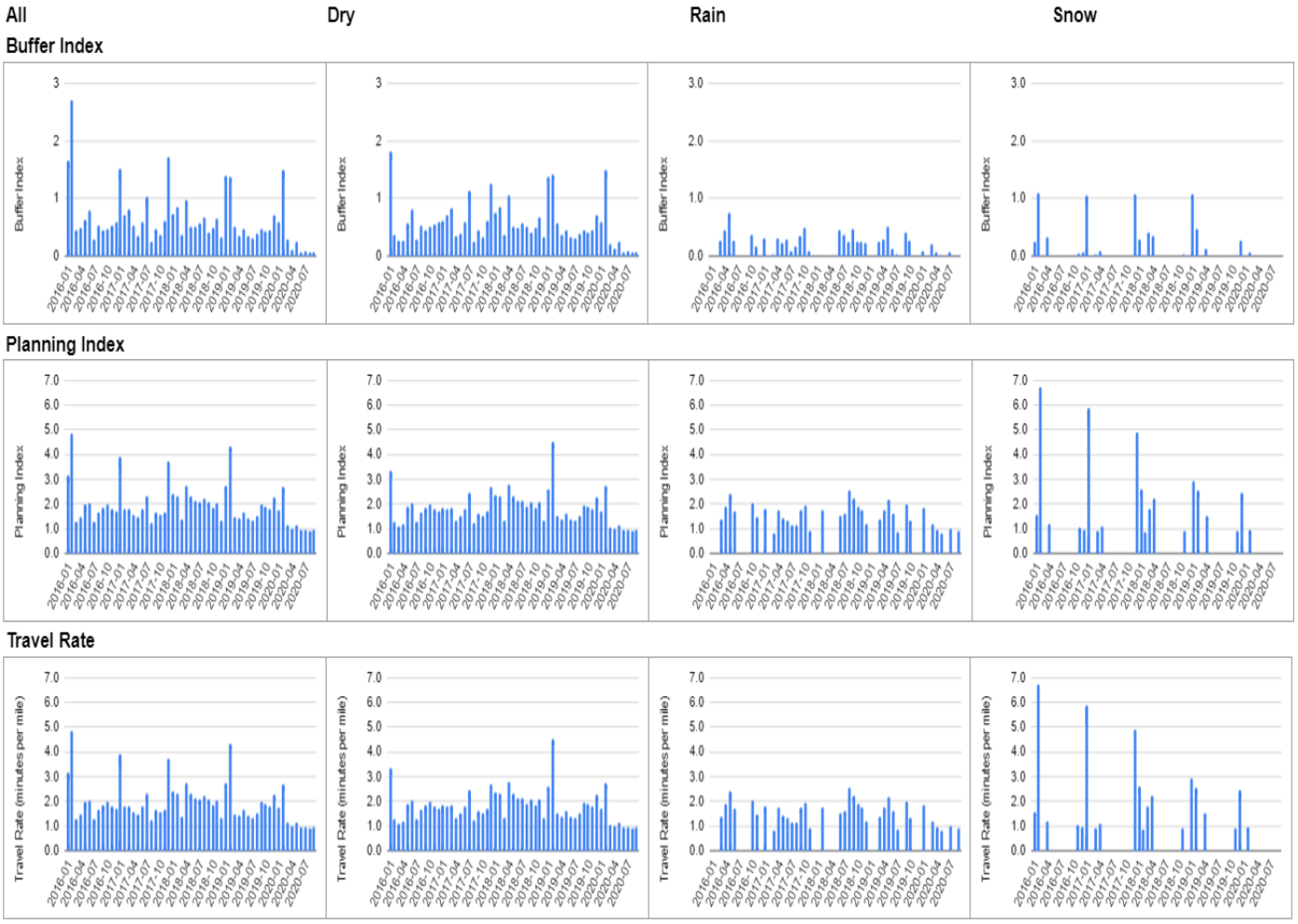
A.22.2.7 Trends Summary

- Both traffic-flow and travel-time reliability measures show stable patterns through time.
- Weather is still the main factor affecting the reliability values and incidents do not appear to have significant effects.

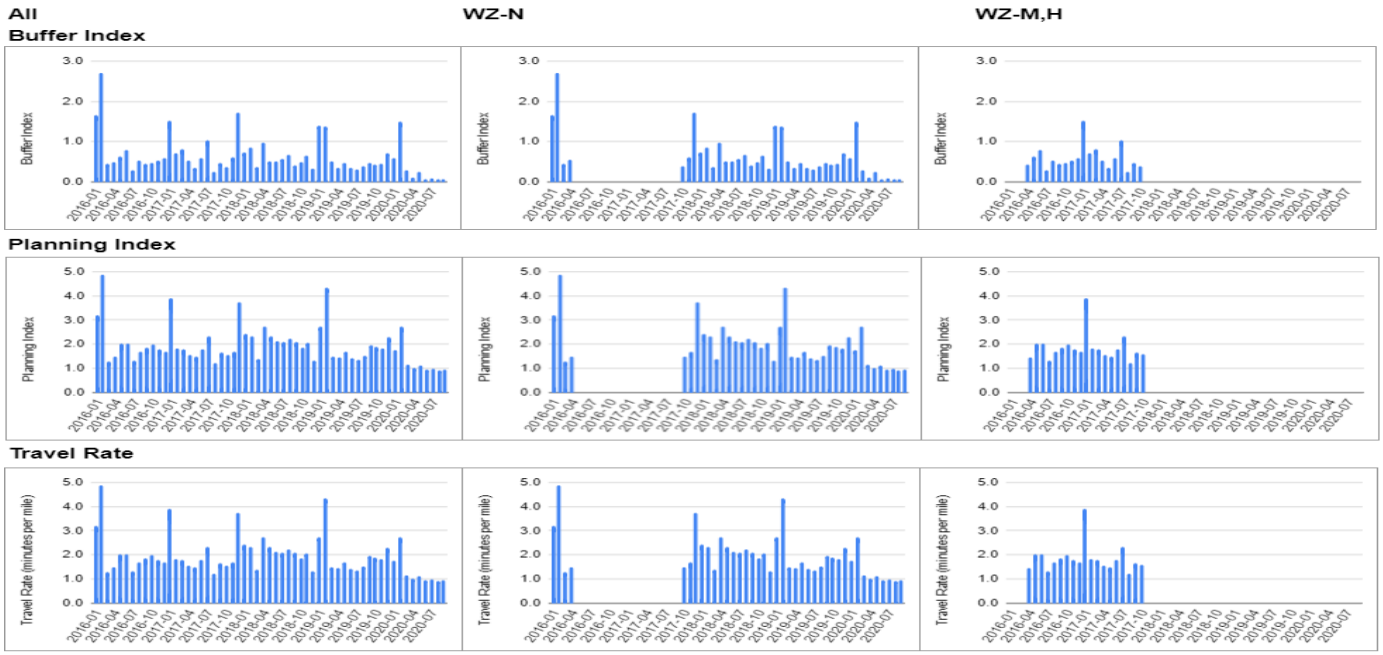
A.23 I-694 CORRIDOR 2 (I-35E – TH 252, EASTBOUND/WESTBOUND)

A.23.1 I-694 WESTBOUND Route 2 (I-35E to TH 252, Morning Peak)

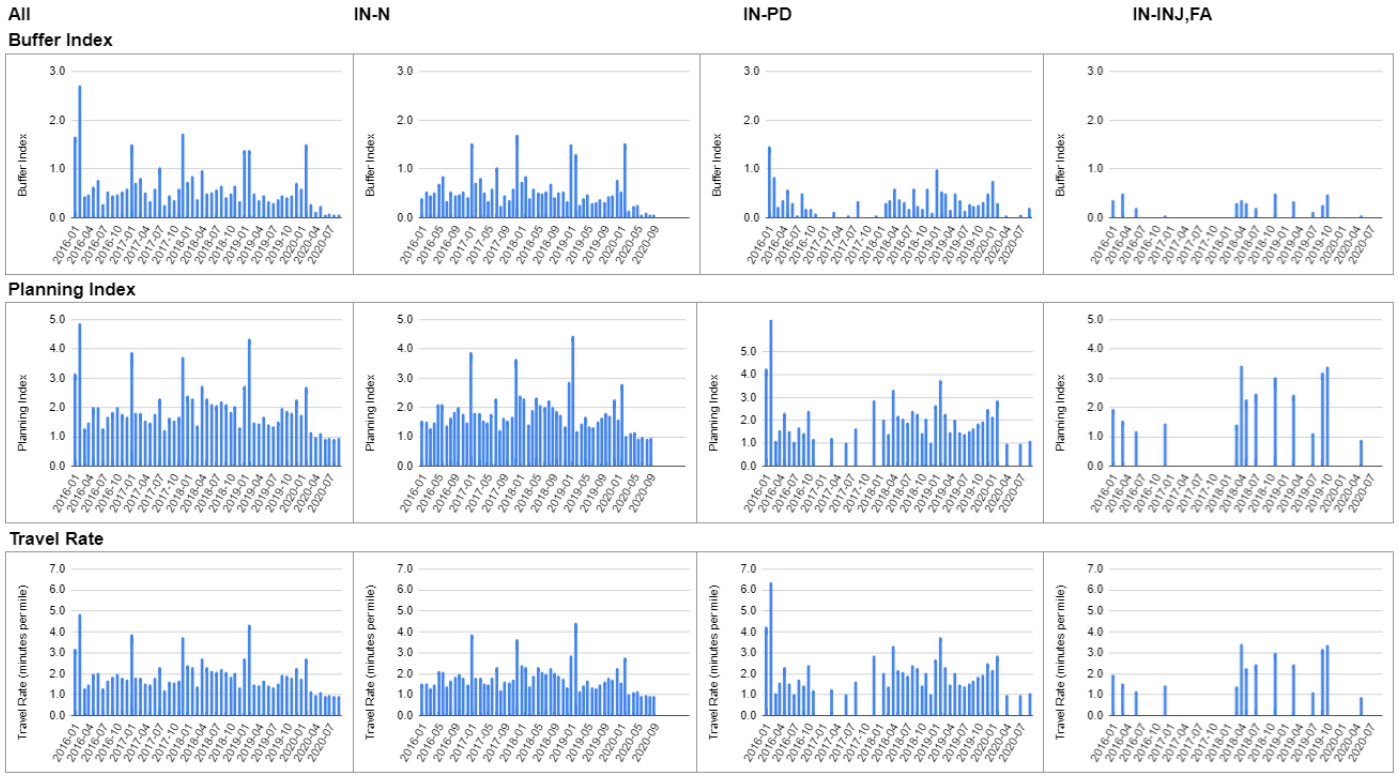
A.23.1.1 Effects of Weather



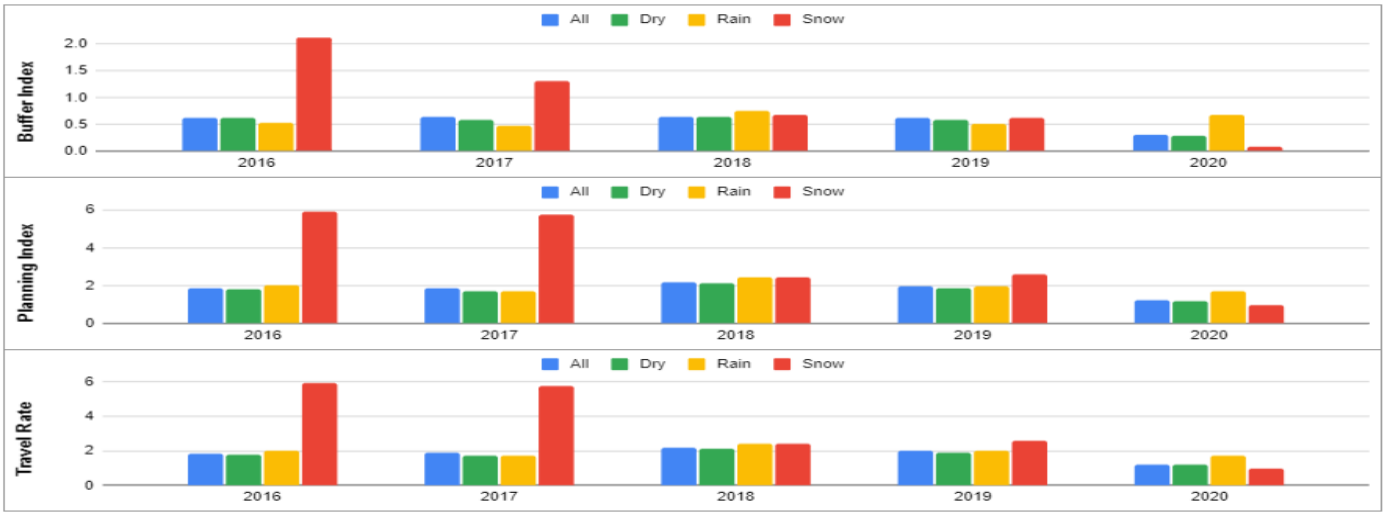
A.23.1.2 Effects of Work Zones



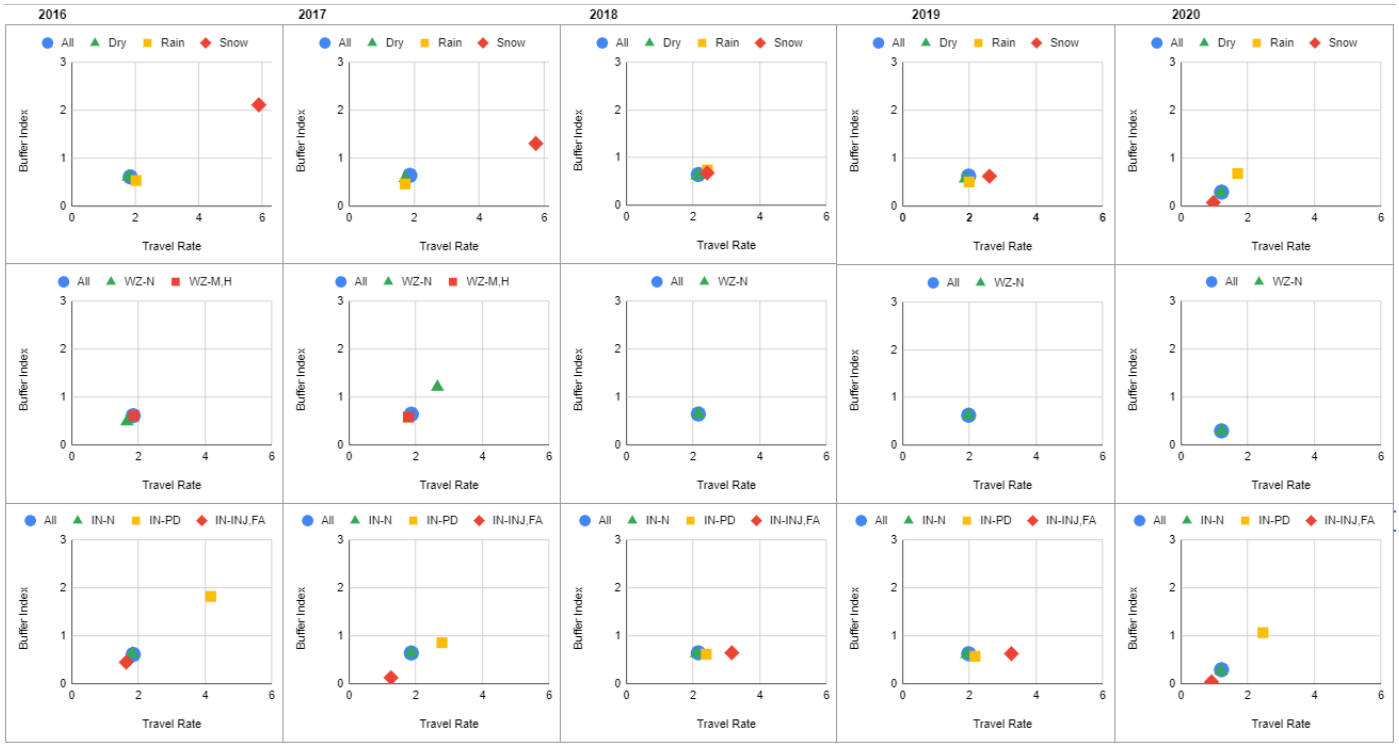
A.23.1.3 Effects of Incidents



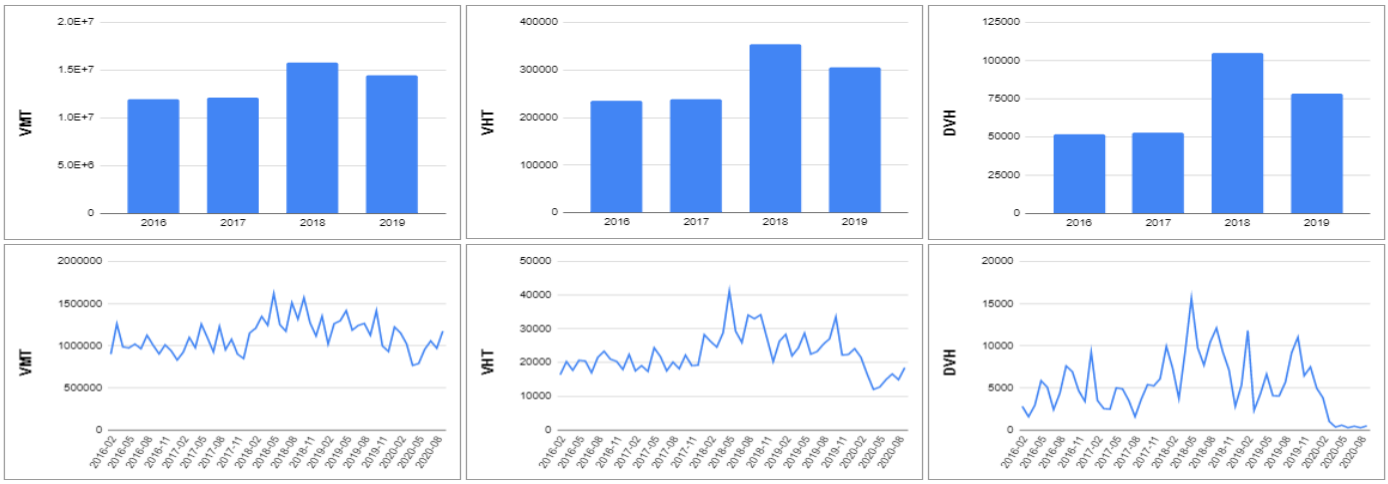
A.23.1.4 Yearly Variations



A.23.1.5 Yearly Variations of Combined Index



A.23.1.6 Variations of Traffic-Flow Measures

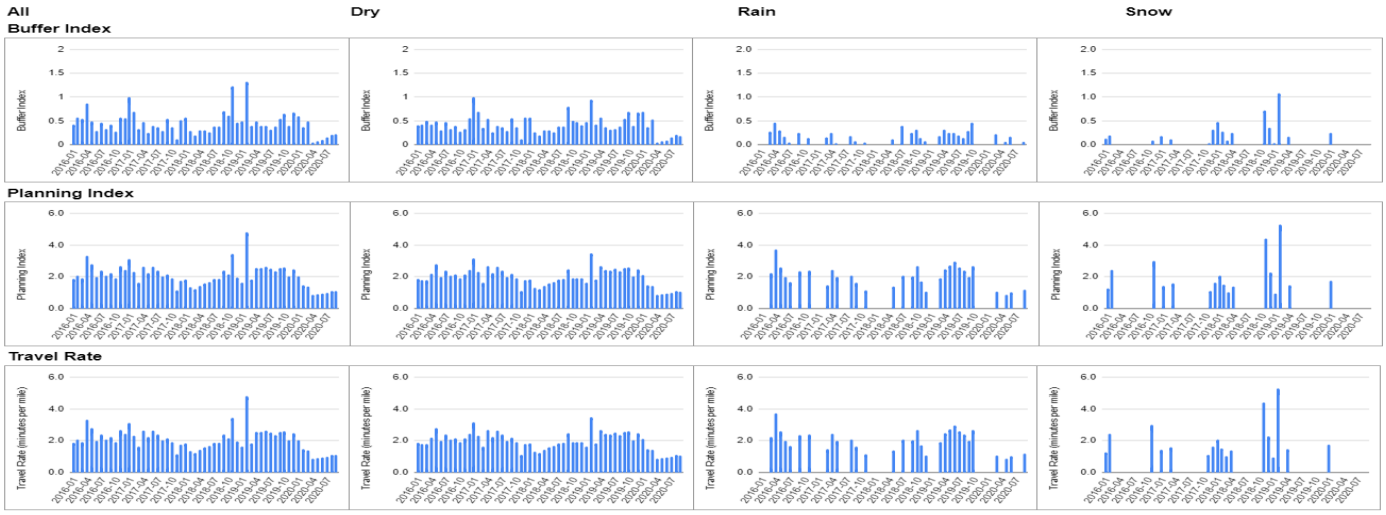


A.23.1.7 Trends Summary

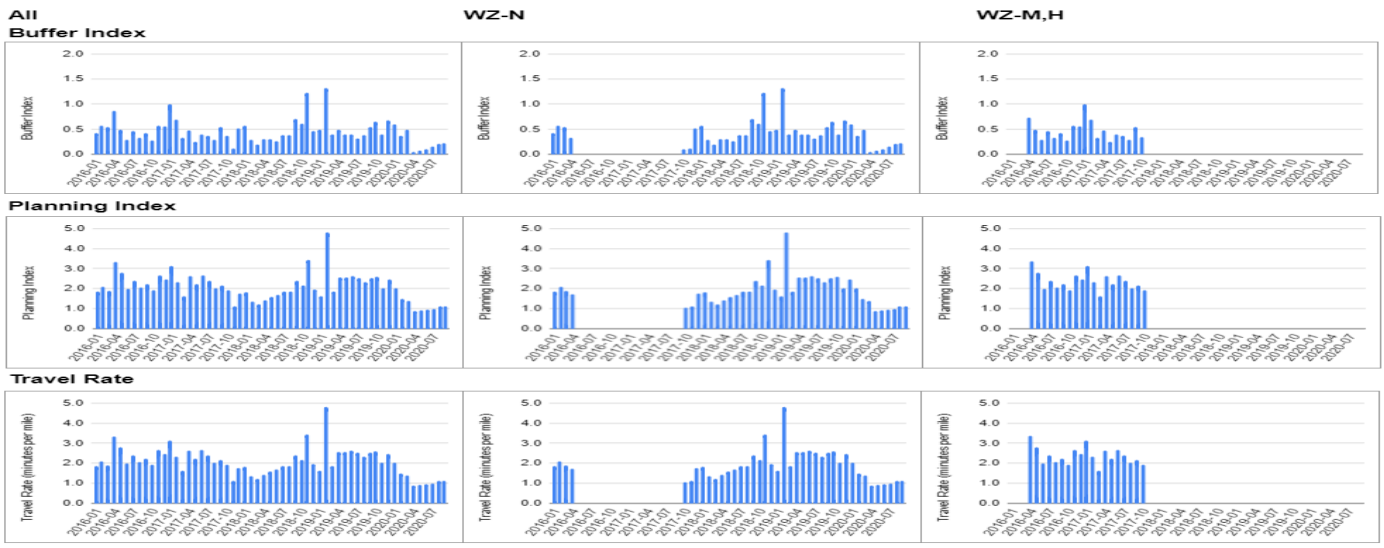
- Both VMT and DVH have been increasing from 2016 to 2019, while the travel-time reliability measures show relatively consistent patterns during the same period.
- The monthly variations of all the reliability measures exhibit clear seasonal patterns, i.e., increased travel-time variability with high 95th %-ile travel times during winter months.
- Incidents have been consistently a significant contributing factor to the increase in the 95th %-ile travel times.

A.23.2 I-694 EASTBOUND Route 2 (TH 252 to I-35E, Afternoon Peak)

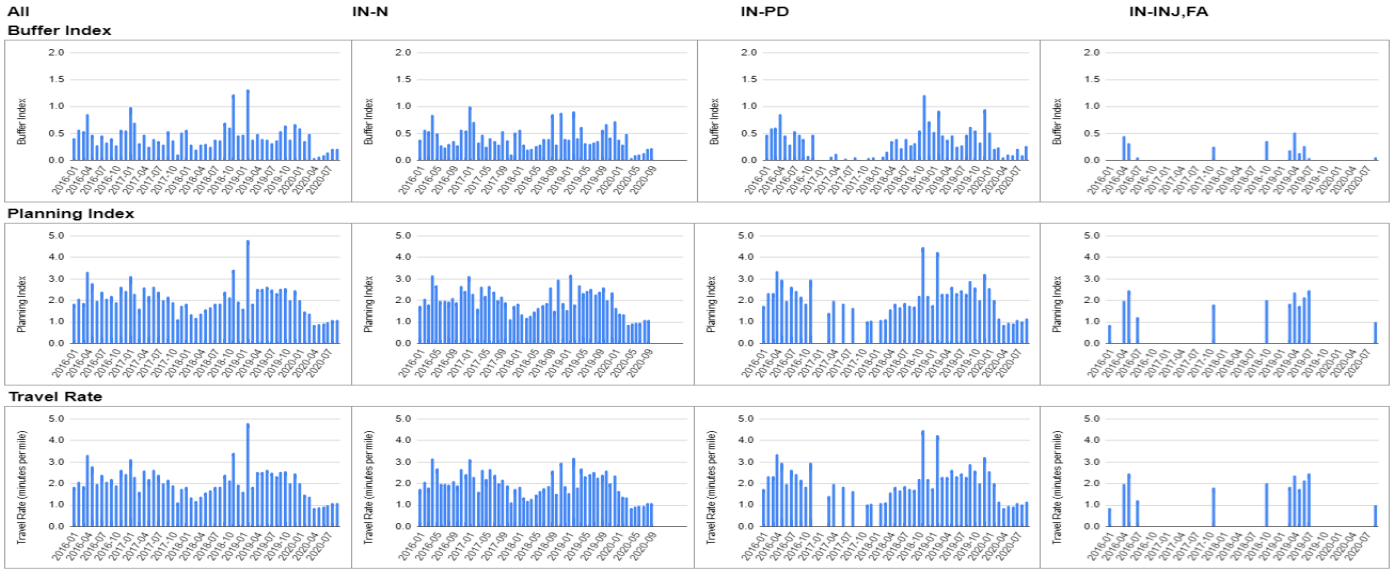
A.23.2.1 Effects of Weather



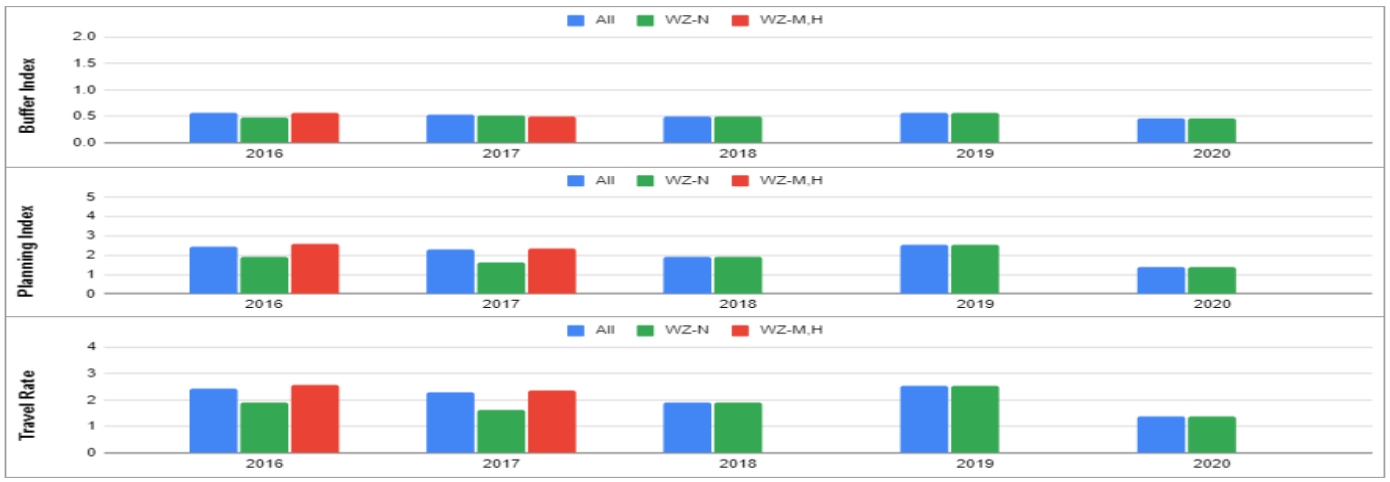
A.23.2.2 Effects of Work Zones



A.23.2.3 Effects of Incidents

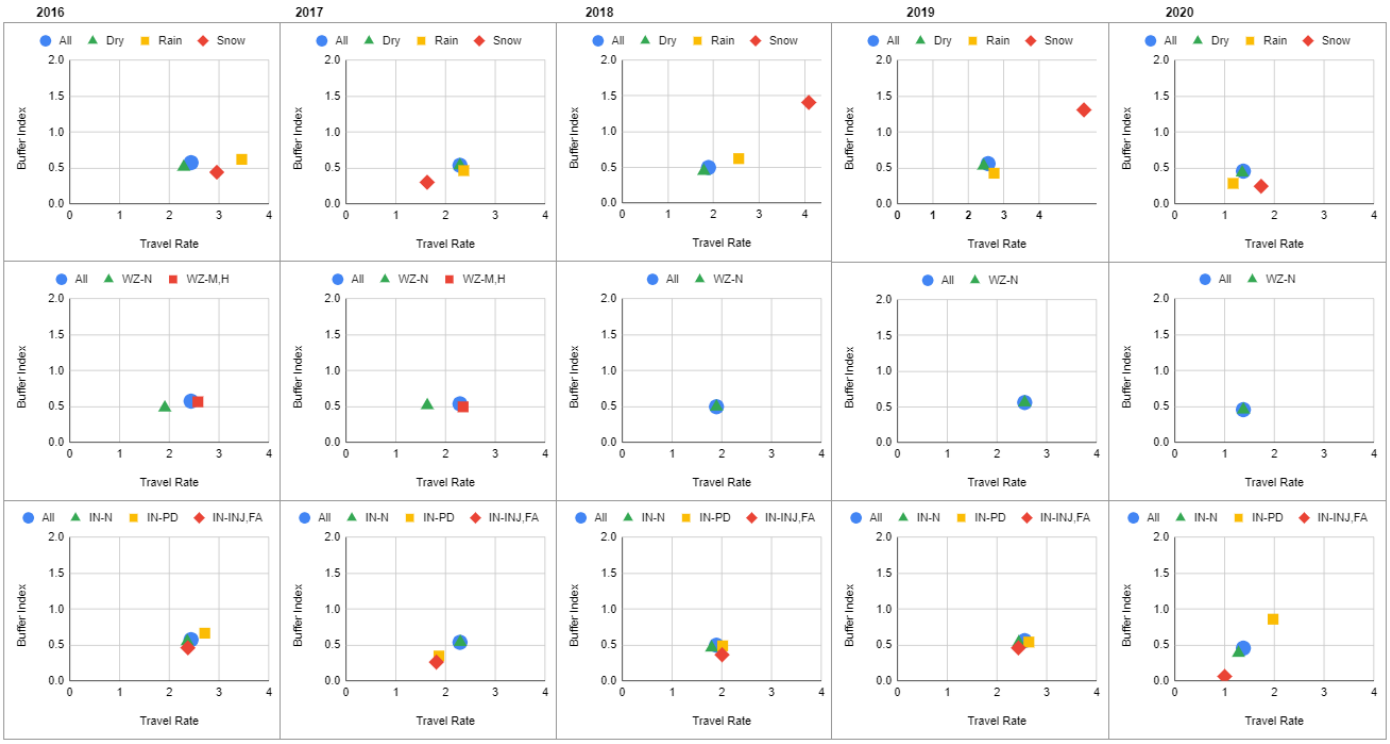


A.23.2.4 Yearly Variations

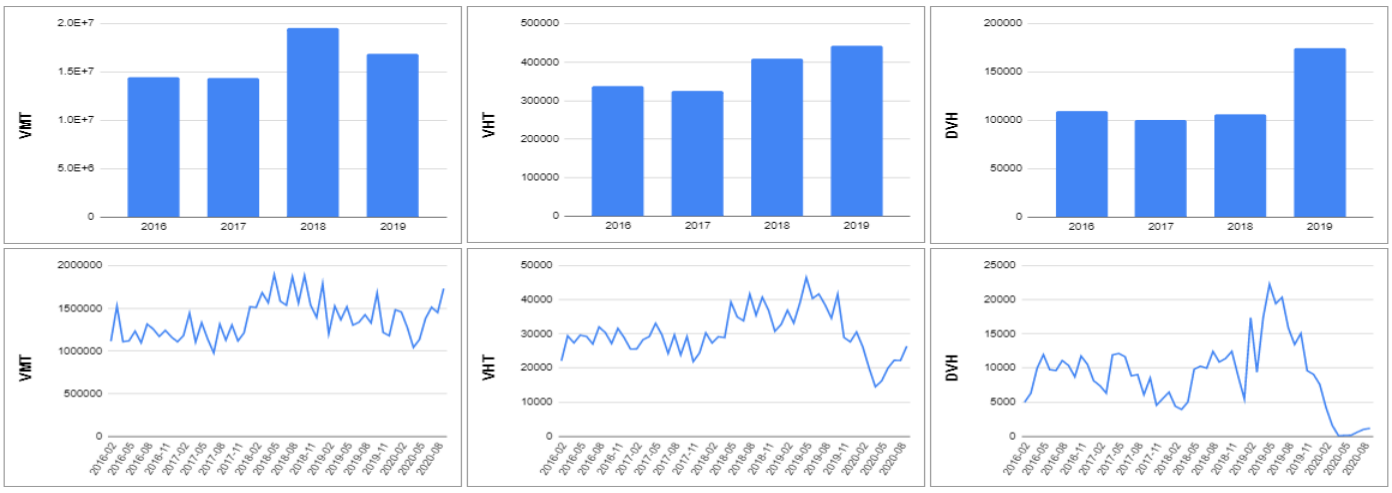

All
WZ-N
WZ-M,H
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
WZ-N
WZ-M,H
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020


All
IN-N
IN-PD
IN-INJ,FA
Buffer Index
2.0
1.5
1.0
0.5
0.0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Planning Index
5
4
3
2
1
0
2016
2017
2018
2019
2020
All
IN-N
IN-PD
IN-INJ,FA
Travel Rate
4
3
2
1
0
2016
2017
2018
2019
2020

A.23.2.5 Yearly Variations of Combined Index



A.23.2.6 Variations of Traffic-Flow Measures



A.23.2.7 Trends Summary

- The monthly/yearly variations of the traffic-flow measures indicate that congestion on this route has been continuously increasing. The monthly variations of both planning index and travel rates also show consistently high values of the 95th %-ile travel times through time.

- The monthly variations of the buffer index show relatively stable patterns, while the seasonal variations can still be observed, indicating the significant effects of snow on the travel-time variability on this route.
- Incidents do not appear to have substantial effects on the reliability values.

APPENDIX B: CODE SNIPPETS FOR CALCULATING TRAFFIC-FLOW MEASURES OF EFFECTIVENESS

B.1 CODE SNIPPET FOR “CALCULATE_TT_MOE_A_ROUTE” FUNCTION

```
def calculate_tt_moe_a_route(prd, ttri, **kwargs):
    """

    :type prd: pyticas.ttypes.Period
    :type ttri: pyticas_tetres.ttypes.TTRouteInfo
    """
    logger = getLogger(__name__)
    dbsession = kwargs.get('dbsession', None)
    create_or_update = kwargs.get("create_or_update", True)
    rw_moe_param_json = kwargs.get("rw_moe_param_json")
    if rw_moe_param_json:
        moe_param_config = RouteWiseMOEParametersInfo()
        moe_param_config.moe_lane_capacity = rw_moe_param_json.get('rw_moe_lane_capacity')
        moe_param_config.moe_critical_density = rw_moe_param_json.get('rw_moe_critical_density')
        moe_param_config.moe_congestion_threshold_speed = rw_moe_param_json.get('rw_moe_congestion_threshold_speed')
    else:
        moe_param_config = get_system_config_info()

    if dbsession:
        da_tt = TravelTimeDataAccess(prd.start_date.year, session=dbsession)
    else:
        da_tt = TravelTimeDataAccess(prd.start_date.year)
    creatable_list = list()
    updatable_dict = {}
    existing_data_dict = {}
    if create_or_update:
        existing_data_list = da_tt.list_by_period(ttri.id, prd)
        for existing_data in existing_data_list:
            existing_data_dict[(existing_data.route_id, existing_data.time)] = existing_data
    lock = kwargs.get('lock', nonop_with())
    if not create_or_update:
        # delete data to avoid duplicated data
        with lock:
            is_deleted = da_tt.delete_range(ttri.id, prd.start_date, prd.end_date, print_exception=True)
            if not is_deleted or not da_tt.commit():
                logger.warning('fail to delete the existing travel time data')
                if not dbsession:
                    da_tt.close_session()
                return False

    print(f"{Fore.GREEN}CALCULATING TRAVEL-TIME FOR ROUTE[{ttri.name}]")
    res_dict = _calculate_tt_moe(ttri.route, prd)

    if not res_dict:
        logger.warning('fail to calculate travel time')
        return False
```

```
    flow_data, raw_flow_data = res_dict["flow_data"]
    density_data, raw_density_data = res_dict['density_data']
    speed_data_without_virtual_node, speed_data, raw_speed_data = res_dict["speed_data"]
    travel_time_results = res_dict['tt']
    res_mrf = res_dict["mrf"]
    travel_time = travel_time_results[-1].data
    avg_speeds = _route_avgs(speed_data_without_virtual_node)
    accelerator_data = _raw_route_avgs(_calculate_accel(speed_data_without_virtual_node, prd.interval, **kwargs), prd)
    timeline = prd.get_timeline(as_datetime=False, with_date=True)
    print(f"{Fore.CYAN}Start[{timeline[0]}] End[{timeline[-1]}] TimelineLength[{len(timeline)}]")
    for index, dateTimeStamp in enumerate(timeline):
        meta_data = generate_meta_data(raw_flow_data, raw_speed_data, raw_density_data,
                                       flow_data, speed_data, density_data, speed_data_without_virtual_node, res_mrf,
                                       moe_param_config,
                                       index)
        meta_data_string = json.dumps(meta_data)
        interval = TT_DATA_INTERVAL
        moe_critical_density = moe_param_config.moe_critical_density
        moe_lane_capacity = moe_param_config.moe_lane_capacity
        moe_congestion_threshold_speed = moe_param_config.moe_congestion_threshold_speed
        vmt = calculate_vmt_dynamically(meta_data, interval)
        vht = calculate_vht_dynamically(meta_data, interval)
        dvh = calculate_dvh_dynamically(meta_data, interval)
        lvmt = calculate_lvmt_dynamically(meta_data, interval, moe_critical_density, moe_lane_capacity)
        uvmt = calculate_uvmt_dynamically(meta_data, interval, moe_critical_density, moe_lane_capacity)
        cm = calculate_cm_dynamically(meta_data, moe_congestion_threshold_speed)
        cmh = calculate_cmh_dynamically(meta_data, interval, moe_congestion_threshold_speed)
        tt_data = {
            'route_id': ttri.id,
            'time': dateTimeStamp,
            'tt': travel_time[index],
            'speed': avg_speeds[index],
            'vmt': vmt,
            'vht': vht,
            'dvh': dvh,
            'lvmt': lvmt,
            'uvmt': uvmt,
            'cm': cm,
            'cmh': cmh,
            'acceleration': accelerator_data[index],
            'meta_data': meta_data_string,

        }
        if create_or_update:
            existing_data = existing_data_dict.get((tt_data['route_id'], tt_data['time']))
            if existing_data:
                updatable_dict[existing_data.id] = tt_data
            else:
                creatable_list.append(tt_data)
        else:
            creatable_list.append(tt_data)
    inserted_ids = list()
    if creatable_list:
        with lock:
            inserted_ids = da_tt.bulk_insert(creatable_list)
            if not inserted_ids or not da_tt.commit():
                logger.warning('fail to insert the calculated travel time into database')
    if not inserted_ids:
        inserted_ids = list()
    if updatable_dict:
        with lock:
            for id, tt_data in updatable_dict.items():
                da_tt.update(id, generate_updatable_moe_dict(tt_data))
                inserted_ids.append(id)
            da_tt.commit()
    if not dbsession:
        da_tt.close_session()
    return inserted_ids
```

```
def _calculate_tt_moe(r, prd, **kwargs):
    """

    :type r: pyticas.ttypes.Route
    :type prd: pyticas.ttypes.Period
    """
    # 1. update lane configuration according to work zone
    cloned_route = r.clone()
    updated_route = cloned_route
    if not kwargs.get('nowz', False):
        try:
            cloned_route.cfg = route_config.create_route_config(cloned_route.rnodes)
            updated_route = cloned_route
        except Exception as e:
            getLogger(__name__).warning(
                'Exception occurred while creating route config for route: {}. Error: {}'.format(r, tb.traceback(e, f_print=False)))
    try:
        return {
            "flow_data": total_flow_with_virtual_nodes.run(updated_route, prd),
            "speed_data": speed_with_virtual_nodes.run(updated_route, prd),
            "density_data": density_with_virtual_nodes.run(updated_route, prd),
            "tt": moe.travel_time(updated_route, prd),
            "mrf": moe.mrf(updated_route, prd)
        }

    except Exception as ex:
        getLogger(__name__).warning(tb.traceback(ex))
```

B.2 “GENERATE_META_DATA” FUNCTION CALCULATING DIFFERENT META INFORMATION

```
def generate_meta_data(raw_flow_data, raw_speed_data, raw_density_data,
                       flow_data, speed_data, density_data, speed_data_without_virtual_node, mrf_data,
                       moe_param_config,
                       time_index):
    logger = getLogger(__name__)
    raw_meta_data = {
        "flow": [],
        "speed": [],
        "density": [],
        "lanes": [],
        "speed_limit": [],
        "speed_average": 0,
        "speed_variance": 0,
        "speed_max_u": 0,
        "speed_min_u": 0,
        "speed_difference": 0,
        "number_of_vehicles_entered": 0,
        "number_of_vehicles_exited": 0,
        "moe_lane_capacity": moe_param_config.moe_lane_capacity,
        "moe_critical_density": moe_param_config.moe_critical_density,
        "moe_congestion_threshold_speed": moe_param_config.moe_congestion_threshold_speed}
    for flow, speed, flow_object, density in zip(raw_flow_data, raw_speed_data, flow_data, raw_density_data):
        raw_meta_data['flow'].append(flow[time_index])
        raw_meta_data['speed'].append(speed[time_index])
        raw_meta_data['density'].append(density[time_index])
        raw_meta_data['lanes'].append(flow_object.lanes)
        raw_meta_data['speed_limit'].append(flow_object.speed_limit)
    speed_meta_data = list()
    for speed_rnode_data in speed_data_without_virtual_node:
        if speed_rnode_data and speed_rnode_data.data:
            speed_data = speed_rnode_data.data
            if speed_data[time_index] and speed_data[time_index] != MISSING_VALUE:
                speed_meta_data.append(speed_data[time_index])
```

```
    if mrf_data:
        try:
            ent_data = [rnd.data[time_index] for rnd in mrf_data
                        if rnd.data[time_index] > 0 and not isinstance(rnd.rnode, str) and rnd.rnode.is_entrance()]
            ent_total = sum(ent_data)
            raw_meta_data["number_of_vehicles_entered"] = ent_total
        except Exception as e:
            logger.warning('fail to calculate number of vehicles entered. Error: {}'.format(e))
        try:
            ext_data = [rnd.data[time_index] for rnd in mrf_data
                        if rnd.data[time_index] > 0 and not isinstance(rnd.rnode, str) and rnd.rnode.is_exit()]

            ext_total = sum(ext_data)
            raw_meta_data["number_of_vehicles_exited"] = ext_total
        except Exception as e:
            logger.warning('fail to calculate number of vehicles exited. Error: {}'.format(e))
    try:
        avg = statistics.mean(speed_meta_data)
        raw_meta_data["speed_average"] = avg
    except Exception as e:
        logger.warning('fail to calculate speed average. Error: {}'.format(e))
    try:
        variance = statistics.variance(speed_meta_data)
        raw_meta_data["speed_variance"] = variance
    except Exception as e:
        logger.warning('fail to calculate speed variance. Error: {}'.format(e))
    try:
        max_u = max(speed_meta_data)
        raw_meta_data["speed_max_u"] = max_u
    except Exception as e:
        logger.warning('fail to calculate speed max. Error: {}'.format(e))
    try:
        min_u = min(speed_meta_data)
        raw_meta_data["speed_min_u"] = min_u
    except Exception as e:
        logger.warning('fail to calculate speed min. Error: {}'.format(e))
    try:
        raw_meta_data["speed_difference"] = max_u - min_u
    except Exception:
        pass
    return raw_meta_data
```

B.3 FUNCTIONS CALCULATING INDIVIDUAL MOES

```
def calculate_vmt_dynamically(meta_data, interval, **kwargs):
    """
    Vehicle Miles Traveled (Trips per vehicle X miles per trip)
    Equation : VMT = total flow of station(v/h) * interval(hour) * 0.1(distance in mile);

    :param data: list of speed data list for each rnode.
                 e.g. data = [ [ u(i,t), u(i,t+1), u(i,t+2) .. ], [ u(i+1,t), u(i+1,t+1), u(i+1,t+2) .. ],
                 [ u(i+2,t), u(i+2,t+1), u(i+2,t+2) .. ],,,]
    :type data: list[list[float]]
    :param interval: data interval in second
    :type interval: int
    :type kwargs: dict
    :return:
    """
    data = meta_data.get('flow')
    missing_data = kwargs.get('missing_data', cfg.MISSING_VALUE)
    vd = moe_helper.VIRTUAL_RNODE_DISTANCE
    seconds_per_hour = 3600
    vmt_data = []
    for value in data:
        vmt = value * interval / seconds_per_hour * vd
        if value == missing_data:
            vmt = missing_data
        vmt_data.append(vmt)
    return sum(vmt_data)
```

```python
def calculate_vht_dynamically(meta_data, interval, **kwargs):
    """
    Vehicle Miles Traveled (Trips per vehicle X miles per trip)
    Equation : VMT = total flow of station(v/h) * interval(hour) * 0.1(distance in mile);

    :param data: list of speed data list for each rnode.
                 e.g. data = [ [ u(i,t), u(i,t+1), u(i,t+2) .. ], [ u(i+1,t), u(i+1,t+1), u(i+1,t+2) .. ],
                 [ u(i+2,t), u(i+2,t+1), u(i+2,t+2) .. ],,,]
    :type data: list[list[float]]
    :param interval: data interval in second
    :type interval: int
    :type kwargs: dict
    :return:
    """
    flow_data = meta_data.get('flow')
    speed_data = meta_data.get('speed')
    missing_data = kwargs.get('missing_data', cfg.MISSING_VALUE)
    vd = moe_helper.VIRTUAL_RNODE_DISTANCE
    seconds_per_hour = 3600
    vht_data = []
    for flow, speed in zip(flow_data, speed_data):
        if flow == missing_data or speed == missing_data:
            vht = missing_data
        elif flow and speed:
            vht = flow / speed * interval / seconds_per_hour * vd
        else:
            vht = missing_data
        vht_data.append(vht)
    return sum(vht_data)
```

```python
def calculate_dvh_dynamically(meta_data, interval, **kwargs):
    """
    Vehicle Miles Traveled (Trips per vehicle X miles per trip)
    Equation : VMT = total flow of station(v/h) * interval(hour) * 0.1(distance in mile);

    :param data: list of speed data list for each rnode.
                 e.g. data = [ [ u(i,t), u(i,t+1), u(i,t+2) .. ], [ u(i+1,t), u(i+1,t+1), u(i+1,t+2) .. ],
                 [ u(i+2,t), u(i+2,t+1), u(i+2,t+2) .. ],,,]
    :type data: list[list[float]]
    :param interval: data interval in second
    :type interval: int
    :type kwargs: dict
    :return:
    """
    flow_data = meta_data.get('flow')
    speed_data = meta_data.get('speed')
    speed_limit_data = meta_data.get('speed_limit')
    missing_data = kwargs.get('missing_data', cfg.MISSING_VALUE)
    vd = moe_helper.VIRTUAL_RNODE_DISTANCE
    seconds_per_hour = 3600
    dvh_data = []
    for flow, speed, speed_limit in zip(flow_data, speed_data, speed_limit_data):
        try:
            dvh = ((vd / speed) - (vd / speed_limit)) * flow * interval / seconds_per_hour
            if dvh < 0 or missing_data in [flow, speed_data]:
                dvh = 0
        except Exception as e:
            print(e)
            dvh = 0
        dvh_data.append(dvh)
    return sum(dvh_data)


def calculate_lvmt_dynamically(data, interval, critical_denisty, lane_capacity):
    try:
        vd = moe_helper.VIRTUAL_RNODE_DISTANCE
        seconds_per_hour = 3600
        lvmt_data = []
        density_data = data['density']
        flow_data = data['flow']
        lane_data = data['lanes']
        for flow, density, lanes in zip(flow_data, density_data, lane_data):
            if critical_denisty < density:
                lvmt = max(lane_capacity * lanes - flow, 0)
                lvmt = (lvmt * interval / seconds_per_hour * vd)
            else:
                lvmt = 0

            lvmt_data.append(lvmt)
        return sum(lvmt_data)
    except Exception as e:
        from pyticas_tetres.logger import getLogger
        logger = getLogger(__name__)
        logger.warning('fail to calculate calculate lvmt dynamically. Error: {}'.format(e))
        return 0
```

```python
def calculate_uvmt_dynamically(data, interval, critical_denisty, lane_capacity):
    try:
        vd = moe_helper.VIRTUAL_RNODE_DISTANCE
        seconds_per_hour = 3600
        density_data = data['density']
        flow_data = data['flow']
        lane_data = data['lanes']
        uvmt_data = []
        for flow, density, lanes in zip(flow_data, density_data, lane_data):
            if density <= critical_denisty:
                uvmt = max(lane_capacity * lanes - flow, 0)
                uvmt = (uvmt * interval / seconds_per_hour * vd)
            else:
                uvmt = 0

            uvmt_data.append(uvmt)
        return sum(uvmt_data)
    except Exception as e:
        from pyticas_tetres.logger import getLogger
        logger = getLogger(__name__)
        logger.warning('fail to calculate calculate uvmt dynamically. Error: {}'.format(e))
        return 0


def calculate_cm_dynamically(data, moe_congestion_threshold_speed, **kwargs):
    try:
        vd = moe_helper.VIRTUAL_RNODE_DISTANCE
        cm_data = []
        for index, each_station_speed_data in enumerate(data['speed']):
            value = 0 if each_station_speed_data >= moe_congestion_threshold_speed or each_station_speed_data < 0 else vd
            cm_data.append(value)
        cm_data[-1] = 0

        return sum(cm_data)
    except Exception as e:
        from pyticas_tetres.logger import getLogger
        logger = getLogger(__name__)
        logger.warning('fail to calculate calculate cm dynamically. Error: {}'.format(e))
        return 0
```

```python
def calculate_cmh_dynamically(data, interval, moe_congestion_threshold_speed, **kwargs):
    try:
        vd = moe_helper.VIRTUAL_RNODE_DISTANCE
        cmh_unit = (interval / 3600.0) * vd
        cmh_data = []
        for index, each_station_speed_data in enumerate(data['speed']):
            value = 0 if each_station_speed_data >= moe_congestion_threshold_speed or each_station_speed_data < 0 else cmh_unit
            cmh_data.append(value)
        cmh_data[-1] = 0

        return sum(cmh_data)
    except Exception as e:
        from pyticas_tetres.logger import getLogger
        logger = getLogger(__name__)
        logger.warning('fail to calculate calculate cmh dynamically. Error: {}'.format(e))
        return 0
```

```python
def _calculate_accel(speed_results, interval, **kwargs):
    """

    :type speed_results: list[RNodeData]
    :param interval: data interval in second
    :type interval: int
    :type kwargs: dict
    :return:
    """
    missing_data = kwargs.get('missing_data', cfg.MISSING_VALUE)
    us_data = [res.data for res in speed_results]
    accel_data = copy.deepcopy(us_data)
    accel_data[0] = [0] * len(accel_data[0])
    for ridx, rnode_data in enumerate(us_data):
        if not ridx: continue
        for tidx, value in enumerate(rnode_data):
            u1 = us_data[ridx - 1][tidx]
            u2 = value
            if missing_data in [u1, u2]:
                a = missing_data
            else:
                d = distance_in_mile(speed_results[ridx].rnode, speed_results[ridx - 1].rnode)
                a = calculate_acceleration(u1, u2, d)

            accel_data[ridx][tidx] = a

    return accel_data


def calculate_acceleration(u1, u2, mileDistance):
    return (u2 * u2 - u1 * u1) / (2 * mileDistance)
```