Analysis of the effect of hard shoulder opening on motorway traffic

Master‘s Thesis of Mehfuz Rahman Shaikh

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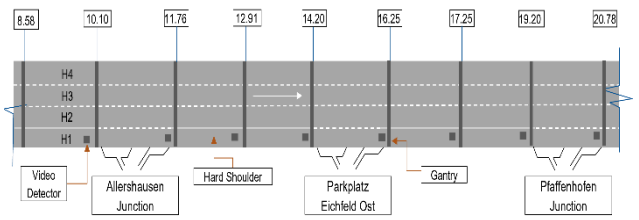


Figure 1: A9 Motorway Lane Configuration from Munich to Nuremberg

Background and Objective

Opening Hard shoulder lane for dense traffic flow is one of the important ATM strategies implemented in several countries to counter increasing traffic congestion during peak hours. It was first introduced in 1990 in Germany.

The objective of the paper is to investigate the impact of opening the hard shoulder lane on A9 motorway traffic through data analysis by traffic state estimation and visualization.

Methodology

The A9 motorway detector data has been considered for the day and length when the hard shoulder lane was open to perform a comparative analysis of the length one hour before it was opened, during its operation time and one hour after it closed. A detailed macroscopic and microscopic analysis of each lane is done. For this, the ETL process is applied to the data for cleaning, filtering and grouping effectively.

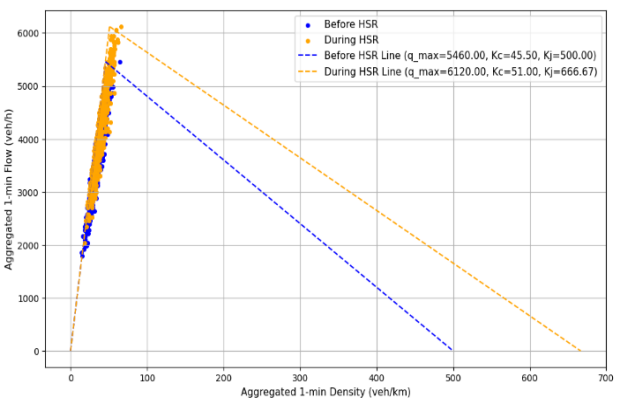


Figure 2: Fundamental Diagram of Flow-Density Relation

Analysis

With an increase in demand, the opening of the hard shoulder lane led to effective H1 lane utilization. The flow increased in adjacent lane H2 as well. It reduced flow in fast-moving lane H4. After closing, the speed drops in adjacent lane H2 due to the merging effect and increases further in H3 and H4. During the opening time, due to increased speed, the density fell in all lanes. It also increases the capacity threshold of the motorway. Hence, Traffic enters from recurring congestion to free flow condition

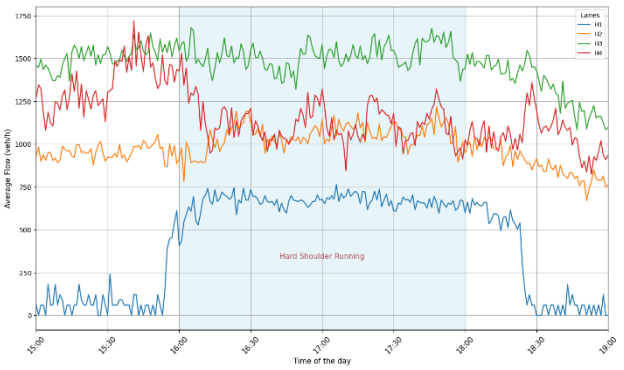


Figure 3: Average Flow in Each Lane Across Time

Occupancy data reveals that the occupancy reduced in H2 with an increase in H1 (hard shoulder) suggesting lane-changing behaviour. Speed difference experiment also shows lane shift possibility in adjacent lanes where most of the truck drivers shifted to the hard shoulder lane improving the flow of the cars in other lanes. Moreover, It also led to an increase in the net time gap with a small margin between vehicles proving drivers can maintain safe distances but can be a concern over time with an increase in flow. The opening also reduced travel time variability and travel time in all standard lanes.

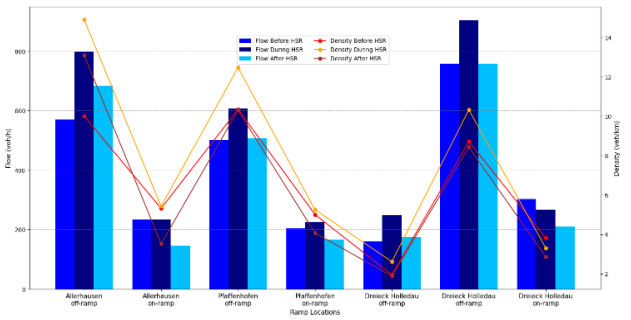


Figure 4: On-Ramp and Off-Ramp at Junctions

Ramp analysis shows a high exit rate during opening time which led to the usage of the hard shoulder lane as flow increased before the ramp exit and declined specifically after the Allershausen and Pfaffenhofen junction.

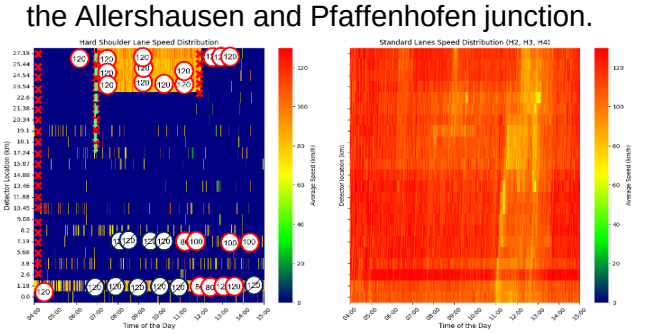
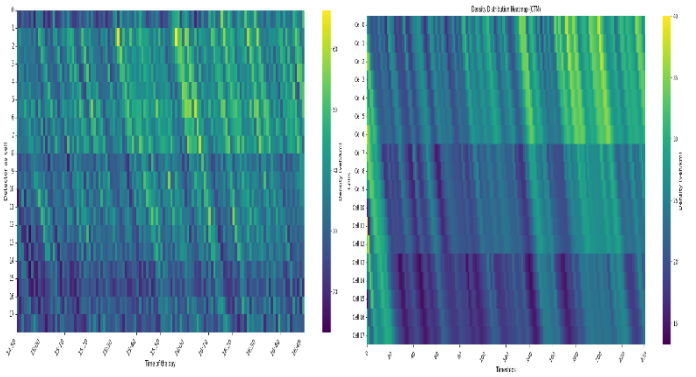


Figure 5: Speed Distribution and Signals Across Time and Detector Locations

The analysis also studied the day with technical issues which determined that vehicles reacted positively to variable speed limit signs than suddenly closed hard shoulder use signals for five hours until a properly closed signal was displayed. However, sudden close has affected the speed of other standard lanes and can increase the risk of collision.



a) b)

Figure 6: Density Distribution Across Cells and Time a) Real-Time Data b) CTM Generated Data

The cell Transmission model was developed to observe the traffic trend due to hard shoulder lane opening. The model depicts more system-wide effects than localized effects. The gradual fall and change in density pattern can be observed at the ramp location and upstream and downstream of the network. The model requires more modification to capture accurate and detailed results.

Limitation

The missing data hold the potential to affect the analysis as the study avoids any assumptions and interpolation keeping it realistic. Lane-changing behaviour can be better observed using visual data. Further, crash or conflict data can support safety analysis. The CTM analysis can be affected due to geometric challenges, fewer cell divisions, weather conditions and driver behaviour. In CTM, a larger difference in density can also lead to large fluctuations. Further, Heavy congestion data for longer periods can give accurate results.

Future Scope

CAV (connected autonomous vehicles) can have more benefits when information is communicated to drivers. It can improve safety and lane shifts. Research can be done on hybrid network environments and a combination of ATM strategies. CTM can be developed for hybrid traffic state to determine its potential. Lane-changing behaviour can also be incorporated into CTM. Furthermore, traffic emission, noise and cost impact analysis can also be done to find the impact of the hard shoulder lane opening.

Conclusion

The hard shoulder lane attracted 14.3 % of vehicle flow. It led to the redistribution of traffic, meeting the increasing demand on the fast-moving lane and improving the performance of the H2 and H3 lanes. It also influenced lane shifts and improved travel time by 2 minutes in the adjacent lane. It increased capacity flow over one hour by 11.86 % and over two hours by 23.09 %.