

# How does the rainfall influence the traffic parameters of the motorways?

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## 1. ABSTRACT SUMMARY

The relationship between traffic events and weather has been studied for over 60 years. During the last decades, several experts have analyzed the effects of weather on traffic and accidents in the world. The speed changes in traffic lanes (fast lane and slow lane) have been studied in different motorway cross sections with various traffic characteristics under heterogeneous traffic intensities and weather conditions.

## 2. INTRODUCTION

Different environmental impacts significantly influence the contact between road surface, vehicle and driver. Adverse weather events and conditions have an impact on the pavement-vehicle relationship. Drivers try to accommodate to the new situation by changing their driving style. Traffic and road safety parameters can change considerably depending on the dimension and the intensity of the event. Several studies have dealt with the effects of rain on traffic, accident risk and traffic demand changes: : *Codling* (1974); *Polvinen* (1985); *Peltola et al.* (1997); *Elvik et al.* (1997); *Chung et al.* (2005 a, b, 2006), *Keay and Simmonds* (2005), and *Alhassan and Johnnie* (2010).

Out of the weather events, the rainfall has the most significant impact on the traffic flow because of the (1) poor visibility conditions, (2) decreased adhesion coefficient between the road surface and vehicle and (3) increased risk of aquaplaning. In such cases drivers reduce their speed and increase headways, which results in a slowing traffic flow and increasing travel time. Due to the speed reduction speed-density functions, which describe the continuous traffic flow process are changing and stable-instable domain are shifting.

In this paper, the author presents his own, national study results about traffic changes due to rainfall. Currently only the effects of rainfall out of adverse weather conditions were investigated. Different cross-sections with different traffic loads were chosen on the M3 and M7 motorway for the study.

Several factors have been motivated the realization of the research:

- In Hungary until now it has not been conducted yet any research that investigates the effects of weather parameters on traffic flow;
- In the recent years, extreme weather events have been getting more and more frequent and intense (extreme precipitation, wind, etc.);
- The recognition of driver behaviour in adverse weather conditions can be utilizable in further researches as input data. (e.g. emergency traffic control);
- Drivers run with higher speed on the motorway networks and the configuration of the roads are different than the urban and main roads;

Drivers can be informed via the roadside collective information equipment and it can influence driving behaviour as well.

### 3. SHORT LITERATURE REVIEW

The beginning of scientific research of the effects of weather events on traffic went back to the early 1950's. *Tanner* (1952) had investigated the connections first, and later, from the mid 1970' the traffic meteorology researches have become more intensive. Among others *Codling* (1974), *Changnon* (1996), *Hogema* (1996), *Keay and Simmonds* (2005), *Chung et al.* (2005a, b) and *Alhassan and Johnnie* (2010, 2011) analyzed the connections between weather, traffic and road accidents data. It is not easy to compare the results, because (1) the applied traffic and weather data collecting methods; (2) the investigation spots and times; (3) the investigated sections and their configuration, (4) the traffic composition, (5) the technical quality of the applied equipment and several other factors were different. However, it can be declared that adverse weather conditions mitigate the travel demand, especially on weekends and holidays. Transportation mode choice is also affected by the weather. Those countries and regions where the proportion of cyclists and motorcyclists is high, in case of rainy weather the users switch from two-wheeled transportation method to closed-cabin vehicles. It can be individual motorized transport (especially cars) or public transport, depending on the degree of mobility.

Other researchers like *Hogema* (1996), *Alhassan* and *Johnnie* (2010) investigated the changes in headway time, while others have dealt with the accident risk *Polvinen* (1985), *Peltola et al.* (1997), *Elvik et al.* (1997), *Andrey* and *Yagar* (1993), *Satterthwaite* (1976), *Brodsky* and *Hakkert* (1988).

Several researchers *Khattak* and *Knapp* (2000), *Eldessouki, et al.* (2004), *Maze* and *Hans* (2007) have studied the effects of snow on traffic flow.

#### 4. METHODOLOGY

During the research five relevant cross-sections on two motorways were selected based on traffic considerations. At the selection of test sites it was important that the given cross-section is characterized by different traffic parameters (traffic volume, traffic composition, etc.) that the effects of weather events can be examined at different spots with various traffic parameters.

Days – when significant rain has fallen, which has made difficult to transport on the spots – have been collected from a meteorology database *Időkép* (2012). The State Motorway Company (ÁAK) has given free run of their own raw traffic data measured by company owned traffic counting stations ÁAK (2013). The analysis was performed with these data. During the study traffic parameters of advantageous (dry, rainless) and adverse (rainy) periods have been compared per lanes. Thus, it was possible to examine the effects of weather on traffic flow (especially effects on speed).

The weather database contained the rainy periods – with 10 minutes accuracy – and the amount of rainfall. According to the weather data it was possible to search specific periods in the traffic database. Data provided by ÁAK contained the number and average speed of recorded trucks and cars divided into six-minute intervals for each counting station per lanes.

During the study only the speed changes were analysed. Analyses of further data and parameters (like traffic density, headway time) were not possible from the available data, because these data are nowhere measured on the national road network. At the selected cross-sections “RAKTEL” measurement devices are operating which record the speeds and categories of the passing vehicles. Data that was collected by the traffic counting stations were handled in a simplified spreadsheet form from the Traffic Management System of ÁAK.

During the study from 2010 it was selected 180 days when significant rainfall fell from traffic aspect. The 180 days do means more than 180 weather events, because there were days when the total daily precipitation amount fell in more parts. Day and night, natural and artificial light conditions, low

and high traffic periods occurred in terms of the time of the test events. This study does not examine the effects of string wind, because the traffic counting and weather stations are not located on the same spots and on-site data were not available. In contrast to the precipitation, there can be significant differences in the wind speeds in a few hundred meters distance too. It is non-negligible that that wind sensor is installed on a mountaintop, in a valley or on a spot with special microclimate characteristic.

## 5. RESULTS

Based on the traffic data analyse it can be submitted that under 4-5 mm/h rainfall intensity the rain does not have any significant impact on the traffic, it does not influence the speed of vehicles. Over 5 mm/h intensity the rain can cause significant traffic speed reduction for cars. The degree of reduction depends on the intensity of rain, visibility conditions (day and night), actual traffic volume, tracing of the road and the lane (slow or fast lane). According to the intensity of rainfall four groups can be distinguished:

- 0–4 mm/h: no significant impact, alteration of speed is negligible (within the measurement margin of error);
- 5–10 mm/h: moderate impact, the speed decrease is up to 10-20 km/h;
- 10–20 mm/h: intense impact, the speed decrease is up to 15-40 km/h;
- Over 20 mm/h: extreme impact, the speed decrease may be greater than 40 km/h.

Based on the examination it is found that the speed decrease is not the same. The speed reduction on a given section can be caused by the drivers who temporally interrupt their journey (drive in the nearest parking facility or stop on the emergency lane) because of the inclement weather. Those who stop, they reckon the traffic conditions as not sufficient for the driving based on their own assessment. However in those situations, there can be drivers who undertake to continue their journeys. Really extreme weather is necessary for the full stop. Empirically in such case, an accident is the main cause that triggers the full stop.

Speed decrease is more significant on the fast lane in all circumstances. Trucks mainly use the slow lane (between 06-22 it is mandatory and at night because of the “keep right”), thus they reduce the average speed measured on the slow lane. (In dry conditions, the average speed difference is 15-30 km/h between the slow and fast lane. It depends on the time of day, light,

trace of the road and the applied speed limits too.) Speed changes of trucks were also examined in the analysis, but no effects were detectable due to rainfall activity. According to the Highway Code trucks must not go faster than 80 km/h on the motorways and in case of rainy weather the speed of cars usually fall down maximum to 80-85 km/h. Empirically it can be stated that the rainfall has less effect on the drivers of heavier vehicles. Its reason might be found in the driving dynamics features of vehicles: higher and more secure adhesion, advanced driving dynamics and emergency support systems. This phenomenon may be also observed in case of heavier (larger, better equipped and more expensive) passenger vehicles. These cars give a higher “sense of security” for the drivers, but often they are effectless, because the supporting systems are not able to rewrite the laws of physics.

Although based on the available data it is not, but empirically it can be declared that the trace of the road and road condition also has a significant impact on the speed change. Those spots where the precipitation can be lead off only through the road grooving, there the rainfall can accumulate on the road during a long-lasting and/or an intensive rain, thus there the speed decreases are more significant. It is caused by the coexistence of several factors:

- at those spots, the motorway operator places static warning or speed limit signs;
- drivers see the accumulated water on the pavement in case of adverse weather event;
- when the section is curved the intention to avoid aquaplaning is contribute to the speed decrease *Elvika* and *Greibeb* (2005); *Mayora* and *Pina* (2008); *Ahammed* (2009).

Besides the analysis of traffic parameters, the development of accident data was analyzed during the research. The Hungarian statistical data collection does not enable to examine the effects of weather events on traffic and accidents based on the accident report forms. Only the number and proportion of personal injury accidents occurred on wet pavement are available. It is not possible to draw accurate conclusions whether the accident occurred due to weather conditions or not. It can be determined only in the exact view of the circumstances of the accident, in the possession of police reports.

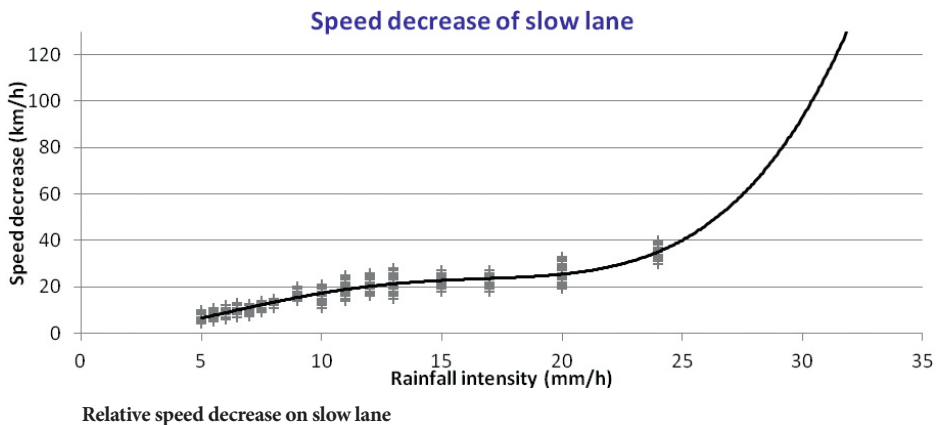
It is important to emphasize that values in the figures are average values that are significantly influenced by the traffic volume, trace of the road, sudden change of road conditions (friction, visibility, etc.). Thus, these values provide

guidance on the scale and rate of changes in the function of the rainfall intensity. Furthermore on those sections where the traffic volume reaches the maximum of capacity (e.g. during the morning rush hours on sections around Budapest), even more intense effects are expected. Heavy traffic cause slower progress and adverse effects of precipitation (decrease of visibility and road friction coefficient) contributes to these situations.

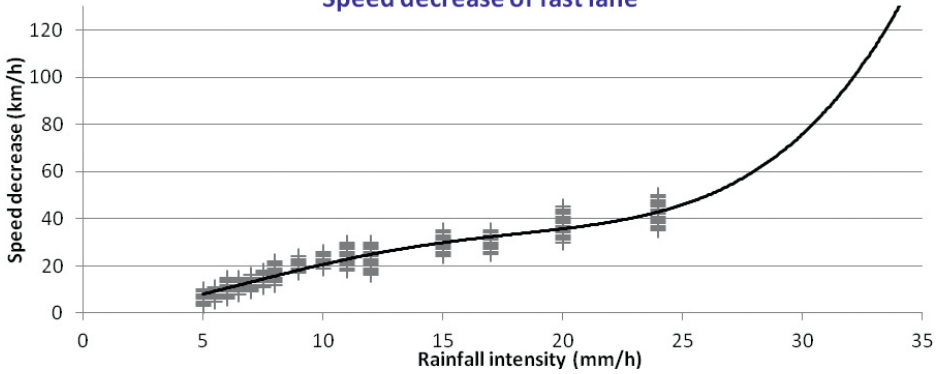
Fitting a polynomial to the measured value figure 1 and 2 illustrate the relative speed decrease on the slow and fast lanes. Figure 3 and 4 illustrate the absolute changes with 20% confidence intervals. Determination of the initial speeds – that are necessary for absolute values – were determined by averaging ( $v_0$ ), with the examination of the average speeds in dry (rainless) weather at the examined cross-sections.

- **AVERAGE SPEED OF FAST LANE:** 125 km/h, standard deviation 2,5 km/h
- **AVERAGE SPEED OF SLOW LANE:** 106 km/h, standard deviation 3,4 km/h

By the help of the fitted fourth-degree polynomial, it is able to forecast the speed decrease (with uncertainty) over 25 mm/h rainfall intensity. The results are in line with international trends, which indicate a total stop at ~ 30-50 mm/h rainfall intensity.

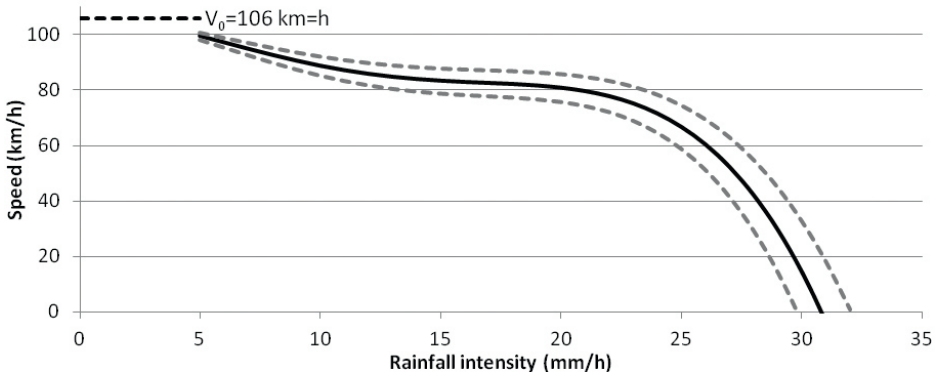


### Speed decrease of fast lane



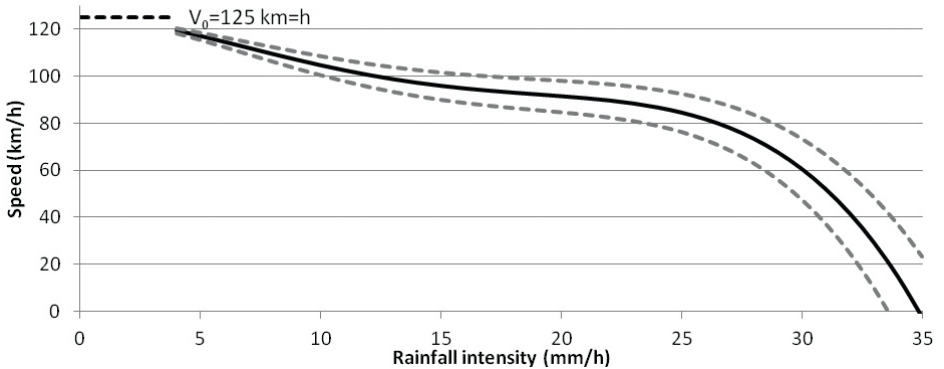
Relative speed decrease on fast lane

### Average speed of slow lane for different rainfall intensities



Absolute speed change for different rainfall intensities on the slow lane

### Average speed of fast lane for different rainfall intensities



Absolute speed change for different rainfall intensities on the fast lane

## 6. SUMMARY

The relationship between traffic events and weather has been studied for more than half a century. Researchers have highlighted for several connections, that are valid only in their particular test environment, in the view of the given mobility culture. In this research a context was set up between the motorway speed and rainfall intensity for the Hungarian motorway network, based on Hungarian data. The study has proved that rainfall has a significant impact on the speed and it depends on the intensity of rainfall. Based on the traffic data analyse it can be declare that under 5 mm/h rainfall intensity the rain does not have any significant impact on the traffic. Over 5 mm/h, the higher intensity causes the more significant speed reduction, which can be 30-40 km/h. On the slow lane the speed reduction is always smaller. The results of the research are average values. Trace of the road, traffic volume, natural and artificial light, time of day, seasons influence the measurable values of a specific site.

## 7. ACKNOWLEDGEMENT

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## 8. REFERENCES

- [1] AHAMMED, M. A.(2009) Safe, Quiet and Durable Pavement Surfaces. Master Thesis, University of Waterloo, Ontario, Canada.
- [2] ALHASSAN, H. M., and JOHNNIE, B. E. (2010). Effect of Rainfall on Microscopic Traffic Flow Parameters. Proceeding of Malaysian Universities Transportation Research Forum and Conferences 2010 (MUTRFC2010), 21 December 2010, Universiti Tenaga Nasional. ISBN 978-967-5770-08-1
- [3] ALHASSAN, H. M., and JOHNNIE, B. E. (2011). Effect of Rainfall Intensity Variability on Highway Capacity. European Journal of Scientific Research. ISSN 1450-216X Vol.49 No.1 (2011), pp.18-27, <http://www.eurojournals.com/ejsr.htm>
- [4] ANDREY, J. and YAGAR, S. (1993). A Temporal Analysis of Rain-Related Crash Risk. University of Waterloo, Ontario, Canada; Accident Analysis and Prevention, Vol. 25, No. 4, pp. 465-472.
- [5] BRODSKY, H. and HAKKERT, A. S. (1988). Risk of a Road Accident in Rainy Weather. University of Maryland at College Park, U.S.A. & Technion,



Road Safety Center, Haifa, Israel; Accident Analysis and Prevention, Vol. 20, No. 3, pp. 161-176.

[6] CHANGNON, S.A. (1996). Effects of summer precipitation on urban transportation. *Climatic Change* 32 pp 481-494.

[7] CHUNG, E., OHTANI, O. and KUWAHARA, M. (2005a). Effect of rainfall on travel time and travel demand. 5th ITS European Congress, Hannover, Germany.

[8] CHUNG, E., OHTANI, O., KUWAHARA, M. and MORITA, H. (2006). Does Weather Affect Highway Capacity? Proceedings of the 5th International Symposium on Highway Capacity and Quality of Service. Vol. 1, p. 139-146. Yokohama, Japan 2006.

[9] CHUNG, E., OHTANI, O., WARITA, H., KUWAHARA, M. and MORITA, H. (2005b). Effect of rain on travel demand and traffic accident. 8th IEEE Intelligent Transportation Systems Conference, Vienna, Austria.

[10] CODLING, P.J. (1974). Weather and Road Accidents. In: ed. Taylor, J.A. *Climatic resources and economic activity: a symposium*, pp 205-222, Newton Abbot, UK.

[11] ELDESSOUKI, et al (2004). Using Relative Risk Analysis to Improve Connecticut Freeway Traffic Safety under Adverse Weather Conditions. University of Connecticut.

[12] ELVIK, R., MYSEN, A.B. and VAA, T. (1997). *Trafikksikkerhetshandbok (Traffic safety manual)*. Oslo: Transportøkonomisk Institut.

[13] ELVIKA, R. and GREIBEB, P. (2005). Road safety effects of porous asphalt: a systematic review of evaluation studies. *Accident Analysis & Prevention*, Volume 37, Issue 3, May 2005, Pages 515–522

[14] HOGEMA, J.H. (1996) Effects of rain on daily traffic volume and on driving behaviour. TNO report TM-96-B019, TNO Human Factors Research Institute, Soesterberg, the Netherlands.

[15] Időkép Ltd. (2012) Official supplying of data, weather data

[16] KEAY, K. and SIMMONDS, I. (2005). The association of rainfall and other weather variables with road traffic volume in Melbourne, Australia. *Accident Analysis and Prevention*, 37 pp 109-124.

[17] KHATTAK, A. and KNAPP, K. (2000). Interstate Highway Crash Injuries during Winter Snow and Non-Snow Events, 2001 Transportation Research Board (TRB) Annual Meeting, [www.topslab.wisc.edu/resources/publications/knapp\\_2001\\_0543.pdf](http://www.topslab.wisc.edu/resources/publications/knapp_2001_0543.pdf)

[18] LAMM, R., CHOUERI, E.M. and MAILAENDER, T. (1990).

Comparison of Operating Speeds on Dry and Wet Pavements of Two-Lane Rural Highways, Transportation Research Record 1280.

[19] MALMIVUO, M. and PELTOLA, H. (1997). Traffic safety at wintertime - a statistical investigation. Helsinki: Tielaitos. (Tielaitoksen selvityksia 6/1997).

[20] MAYORA, P. and PINA J. (2008). Effects of Pavement friction improvement on crash rates on Spanish two lane rural roads. Proceedings of the 87th Annual Meeting of Transportation Research Board (TRB), Washington D.C

[21] MAZE and HANS (2006). Crash Analysis to Improve Winter Weather Traffic Safety, Iowa State University, Center for Weather Impacts on Safety and Mobility, presented at the 2007 Transportation Research Board Annual Meeting.

[22] POLVINEN, P. (1985). Accident risks in winter road conditions. Helsinki: Tie- ja vesirakennushallitus, Ins. tsto Pentti Polvinen Ky. (TVH 741822)

[23] SATTERTHWAITTE, S. (1976). An Assessment of Seasonal and Weather Effects on the Frequency of Road Accidents in California. University College London, Traffic Studies Group; Accident Analysis and Prevention, Vol. 8, No. 2, pp. 87-96.

[24] State Motorway Management Company (ÁAK) 2013. Official supplying of data; raw traffic data before processing

[25] TANNER, J.C. (1952) Effect of Weather on Traffic Flow.