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Comparison of the Flow Rate and Speed of Vehicles on a Representative Road Section before and after the Implementation of Measures in Connection with COVID-19

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Abstract: Transport is an inseparable part of the life of all citizens. At the beginning of the year, the COVID-19 pandemic hit the world. Individual states have taken strict measures to prevent its spread among the population. Due to this fact, the government of the Slovak Republic has issued restrictions on the closure of public spaces (schools, shopping centres, restaurants, bars, etc.). These restrictions have had an impact not only on the economic activity of the population but also on their mobility in the form of reduced traffic. This is due to the drastically reduced mobility associated with the coronavirus, such as commuting trips and extremely limited leisure opportunities. Reduced mobility of the population (reduction of the number of vehicles in the traffic flow) can bring positive effects not only on overloaded road network (increased vehicle speed, lower flow) but also on the environment (reduction of noise, emissions, etc.). This article aims at finding out what effect the measures taken had on the quality of traffic flow. The quality of movement was examined in the form of the flow and speed of vehicles on one of the busiest first-class road sections. Descriptive statistics were used to examine the state of the restrictions. The results show that after the introduction of measures against the spread of coronavirus, the intensity and speed of vehicles in the measured section decreased.

Keywords: traffic flow; flow; speed; restriction; COVID-19

1. Introduction

Transportation is a complicated stochastic process. Nowadays, it is an inseparable part of each of us—whether when traveling to work, for relaxation, transportation of goods, etc. Rising living standards of the population as well as favourable conditions when travelling across countries are some of the key indicators reflected in the increase in demand for transport. The consumer lifestyle has also affected our society. The social trend in the automotive industry is particularly obvious. Previously, car ownership in our region was a sign of luxury, wealth and higher social status. Today, many more people can buy it. The fact that nowadays buying a vehicle is much easier than some years ago does not only affect the environmental aspect in the form of pollution (emissions), noise, vibration. This factor mainly affects the increase in the number of vehicles on the roads, which often causes congestions on the road network [1,2].

Due to increasing flows, especially on highways and first-class roads, the smoothness of traffic flow moves away from free traffic flow and the part of traffic flow with a load degree heading to 1 increases [3–5]. The time between the origin and the destination of the trip increases significantly. Travel time is considered one of the main indicators of road network permeability [6]. Travel time is affected by vehicle speed. Measurement of the speed of an individual vehicle requires observation over both time and space [7–10]. Overload makes the entire transport system inefficient. A significant negative effect on heavily overloaded roads is also the time loss resulting from congestions, which has an indirect impact on the economic activity of the population [11,12].

The reduction of the traffic flow of vehicles on the road network may be caused, for example, by a certain state of emergency. In our study, the coronavirus pandemic represented a state of emergency that reduced the traffic flow of vehicles on the road network. By March 2020, the WHO had declared COVID-19 a worldwide pandemic with 216 countries, areas or territories showing 10,719,646 cases and 517,337 deaths combined as of 2 July 2020 [13]. This pandemic led to a series of worldwide public health measures to contain and reduce its spread. In many countries, the measures included physical distancing measures, such as the "lockdown" of educational institutions, restaurants, bars, retail and other non-essential businesses, banning public events, such as sporting events, concerts, theatre shows and encouraging or requiring teleworking from home and staying at home [14]. As a result, travel demand decreases, and many countries have witnessed spectacular drops in public transport ridership and car traffic too (decreasing congestion and air pollution). The crisis has affected all modes of transport, from cars and public transport in cities to buses, trains and planes at the national and international levels. Of course, social distancing might also influence travel mode choice. Because of the reduced travel demand, a higher share of car use will probably not result in more kilometers travelled by car. In fact, less driving and lower amounts of congestion can be expected [14].

By the end of March 2020, global road transport activity was almost 50% lower than the average in 2019, and by mid-April 2020 it was almost 75% lower than in 2019 in commercial air transport [15–21]. In France, lockdown caused a 65% reduction in the countrywide number of displacements and was particularly effective in reducing work-related short-range mobility, especially during rush hours, and recreational long-range trips [22]. The coronavirus outbreak has brought Britain to a near standstill, with road travel plummeting by as much as 73% [23]. A satellite that detects emissions in the atmosphere linked to cars and trucks shows huge declines in pollution in cities across the United States [24]. In China, the air quality improved during the control period for COVID-19, and that apparently was mainly caused by reductions in emissions from the transportation and industrial sectors. The transportation sector was the major factor for the reduction of NO_2 mass concentrations, indicating the control measures greatly reduced the pollution emissions caused by the movement of people [25]. As in China, in São Paulo, researches have reported air quality improvements associated with social distancing measures, and consequent decrease of vehicle transit. In São Paulo road traffic accounts for approximately 68% of NO_x and 98% of CO emissions. During the partial lockdown, vehicle traffic considerably decreased in all analyzed areas, positively affecting the air quality. The NO_2 levels over the Metropolitan Area of São Paulo decreased during the partial lockdown: −27% compared to the four-week before the partial lockdown in São Paulo [26].

In the first quarter, the coronavirus pandemic also affected the Slovak Republic. Slovak Republic have enforced social distancing by imposing lockdowns (in the country as a whole), as some countries (e.g., China, Italy, Spain), while other countries (e.g., Netherlands, Sweden, UK, USA) have taken less stringent social distancing measures. The lockdowns have required a significant number of employees to work from home and most out-of-home (leisure) activities were cancelled. This has led to a reduction in the number of vehicles on the road and at the same time an improvement in local air quality due to less road traffic. As of 12 March 2020, coronavirus disease 2019 (COVID-19) has been confirmed in 125,048 people worldwide [27]. What makes the picture a little less gloomy is (perhaps even literally) that COVID-19 has given several countries clearer skies [28–30].

2. Traffic Flow

In theory, traffic flow can be understood as a flow composed of different types of vehicles that have specific attributes. These attributes distinguish it from similar phenomena (flows), known for example in physics. Therefore, it is necessary to examine it separately. Several factors affect the traffic flow. On the other hand, the traffic flow influences its surroundings through its behaviour, both in qualitative and quantitative ways [31,32]. The traffic flow is understood as the unity of temporal and spatial characteristics but also of the transport and motoric characteristics of vehicles on the road. The movement of vehicles in traffic flow is affected by other vehicles in the traffic and is therefore monitored as a whole and not as the movement of an individual vehicle [33–35].

2.1. Basic Characteristics of the Traffic Flow

Three interdependent variables are considered as these characteristics, namely speed v (d, t), flow q (d, t) and density k (d, t). All of these variables are dependent on place and time. The quantity of the traffic flow is its flow and the quality expresses the speed and fluency in the given conditions. The research and description of the relationships between these three variables is the basis of the traffic flow theory [33,35,36].

2.1.1. Speed

The speed v is dependent directly on the distance s and indirectly on the time t. It is most often stated in the basic units of the SI (The International System of Units), i.e., in m/s or km/h [37].

$$v(d,\ t) = \frac{\partial s}{\partial t}[\mathrm{km/h}], \tag{1}$$

where:

- v is the speed of the traffic flow [km/h],
- d is the distance of the monitored section of road [km],
- t is the time [s].

2.1.2. Flow

Flow is the most important characteristic of traffic flow because the largest flow that communication can transmit is the capacity of road communication. We define the flow rate as the number of vehicles passing a certain point in a given time period in one or both directions [33].

$$q(d,\ t) = \frac{N}{t}\ [\mathrm{veh/h}], \tag{2}$$

where:

- N is number of vehicles [veh].

2.1.3. Density

Density is the number of vehicles situated on a unit length of a roadway at a given time. At low density, vehicles are allowed to move freely, and drivers can choose the speed of their choice. On the contrary, at high density, the driver is influenced by other road users and congestion occurs [33].

$$k(d,\ t) = \frac{N}{l}\left[\frac{\mathrm{veh}}{\mathrm{km}}\right], \tag{3}$$

where:

- l is a monitored section of road [km].

2.1.4. Basic Equation between Traffic Flow Characteristics

There is a connection between the basic characteristics, and it is given by the continuity equation:

$$q = v{\cdot}k \tag{4}$$

Provided that these characteristics were obtained by spatial-temporal observation. Empirically, the natural dependence of speed on density is verified. There is a maximum speed at the minimum density and a maximum density at zero speed. It follows that density is also dependent on the flow [38].

The principles of descriptive statistics are most often used to evaluate the measured data from traffic surveys. Specifically, these are characteristics or measures of position. The most used characteristics of the position of one-dimensional distributions are the mean value (arithmetic mean), median, mode and quantiles [39,40].

- **The mean value** is the best-known characteristic of the position, it describes the place on the numerical axis around which the values of the random variable fluctuate randomly. It is also referred to as expected value or mathematical hope:

$$x = \frac{1}{n}\sum_{n=1}^{1} x_i, \tag{5}$$

where:

- x is random variable,
- n is number of variables.
- **The median** is a value that divides a series of ascending results into two equally numerous halves:

$$\widetilde{x} = a + h \cdot \frac{0.5 - \sum_{n=1}^{r-1} f_i}{f_{\widetilde{x}}} \tag{6}$$

where:

- a is lower limit of median class,
- h is range of median class,
- $\sum_{n=1}^{r-1} f_i$ is proceeding cumulative frequency from median class.
- $f_{\widetilde{x}}$ is frequency of median class.
- **The mode** is the most frequently occurring value in the statistics file.

3. Analysis of the Addressed Section of the Road I/11

Traffic flow monitoring was performed on the first-class road I/11, which is part of the European road E75. The first-class road I/11 connects northern and southern Europe [41]. It enters Slovakia via Svrčinovec border crossing and leads to the town of Žilina with a length of 36.8 km. It is relatively busy not only with individual passenger transport but also with freight transport, as it forms a significant transit junction to two neighbouring states. Long traffic jams (sometimes more than 10 km long) are an everyday part of this section of the road [42–44]. Traffic flow monitoring was performed at two points of the road in the Kysucké Nové Mesto district (Figure 1). This section was chosen due to the high volume of traffic. The intersection near Kysucké Nové Mesto plays a key role in the quality of the traffic flow. A few years ago, this intersection was changed from a roundabout to an intelligent light-controlled intersection.

A large number of people worked from home (home office) during the strict restrictions related to the spread of coronavirus. This has reduced the number of passengers in public transport, but also the number of vehicles on the road network. In public transport vehicles, the number of seats had been reduced and it had been and still is obligatory to have face protection. All cultural and sports events have been cancelled. Some sports matches were held but without the presence of spectators. This also had an impact on the number of vehicles on the roads and the number of passengers in public transport vehicles. In terms of reduced demand for transport, several connections in public transport were cancelled and the demand for freight transport was also reduced. Unfortunately, specific numbers are not yet available. During strict measures, state borders were closed, and it was not possible to travel abroad. However, freight vehicles were allowed to cross the border, but drivers were tested to see if they were infected. The survey was carried out online and it was necessary to monitor the individual measured values during the day and record them at 15-min intervals. Subsequently, graphs and tables were made.

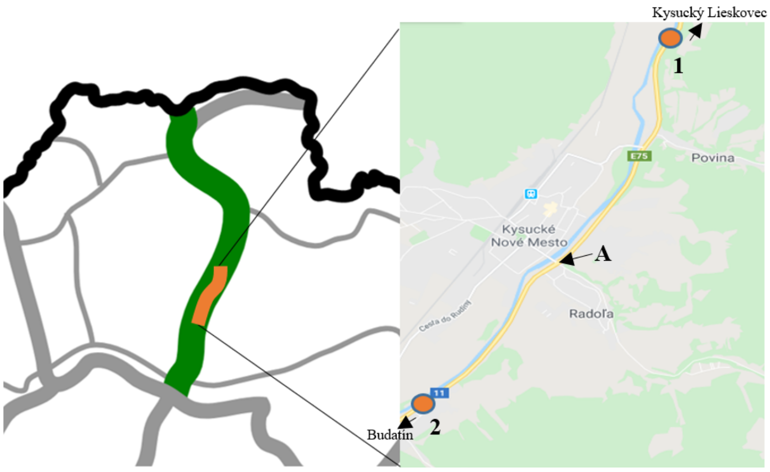

Figure 1. Marked monitored points on the addressed section of the road [author].

Traffic Data Collection

The monitored road section is one of the main road sections. Traffic detectors are located in two places (point 1 and 2—Figure 1), which record the average speed and flow (Figure 2) of the vehicles at 15-min intervals.

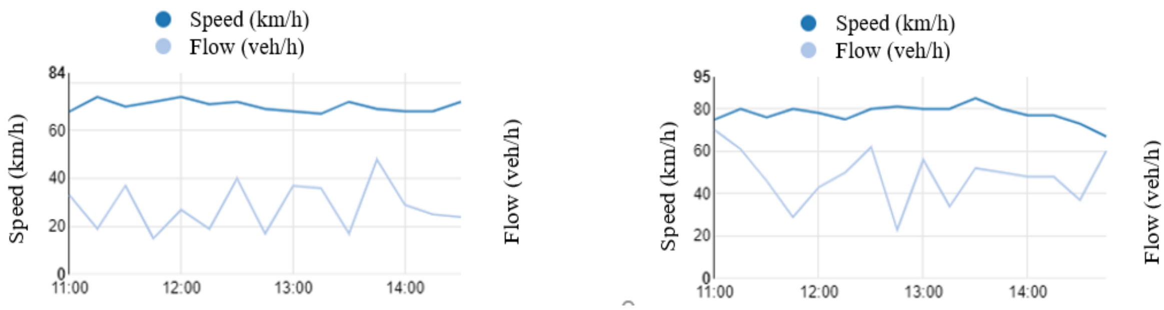

Figure 2. Flow and speed of vehicles from traffic detectors—odoprave.info.

The marked points in the picture are 6.5 km apart. Point 1 is 3.8 km from junction A and point 2 is 2.7 km away.

This traffic information is available 24 h a day and is processed by the National Traffic Information System. Then, they are published on the webpage odoprave.info. The National Traffic Information System (NSDI) is a comprehensive system environment for the obtaining, processing, provision, publication and distribution of traffic information and data on the current traffic situation on the whole road network in Slovakia [34,45]. The webpage provides comprehensive information on the current traffic situation, in particular on road traffic restrictions, traffic accidents and driving conditions. Records from this online traffic survey were used for analysis and subsequent comparison [31,45].

4. Evaluation of Online Traffic Surveys

The surveys aimed to obtain information about traffic on the monitored section, then compare and evaluate it. Two traffic surveys were carried out. Both surveys lasted 12 h, from 6:00 to 18:00. The maximum speed at the monitoring point was 90 km/h. The first traffic survey was carried out on the

5th of March 2020, before the introduction of measures against the spread of coronavirus. The second was carried out four weeks later—the 2nd of April 2020. Clear to partly cloudy weather was during both surveys. The first survey was carried out spontaneously to obtain information about the traffic situation in the monitored section. However, after the introduction of the restrictions, a second survey was deliberately carried out and compared with the first one. The green columns in figures represent the peak hour.

4.1. The First Traffic Survey (5 March 2020)

The total number of monitored vehicles in 12 h in point 1 was 2906 vehicles in both directions, which represents an average of 242 vehicles per hour. The following figures show the daily variation of the flow and speed of vehicles at point 1 for both directions (Figure 3).

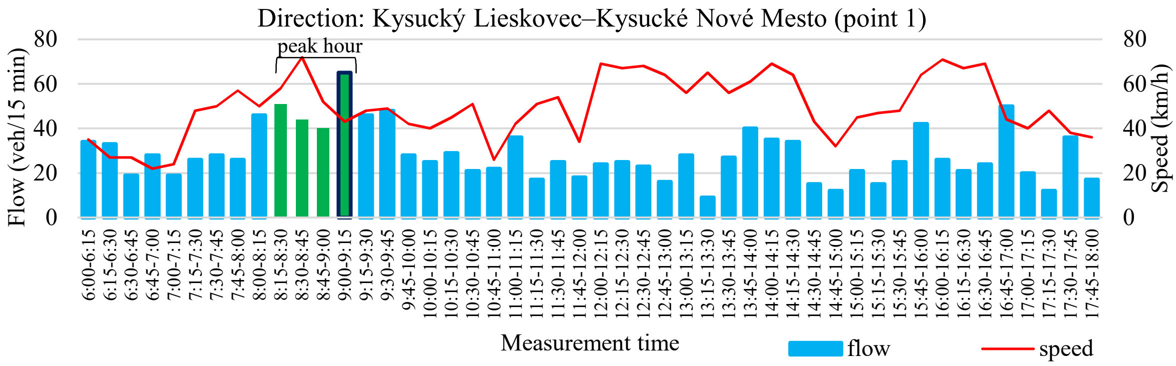

Figure 3. The flow and speed of vehicles for the direction Kysucký Lieskovec–Kysucké Nové Mesto (point 1).

Figure 3 shows the flow and speed of vehicles in 15-min intervals for the direction Kysucký Lieskovec–Kysucké Nové Mesto. The peak hour was from 8:15 to 9:15—200 vehicles. The highest number of vehicles that passed the monitored section in one interval (15 min) was between 9:00–9:15. The highest speed of 72 km/h was recorded in the interval 8:30–8:45. In the opposite direction (Kysucké Nové Mesto–Kysucký Lieskovec), the peak hour was from 6:45 to 7:45—184 vehicles. You can see it in Figure 4. The speed was around 70 km/h, but between 13:15 and 13:30, it decelerated to 47 km/h.

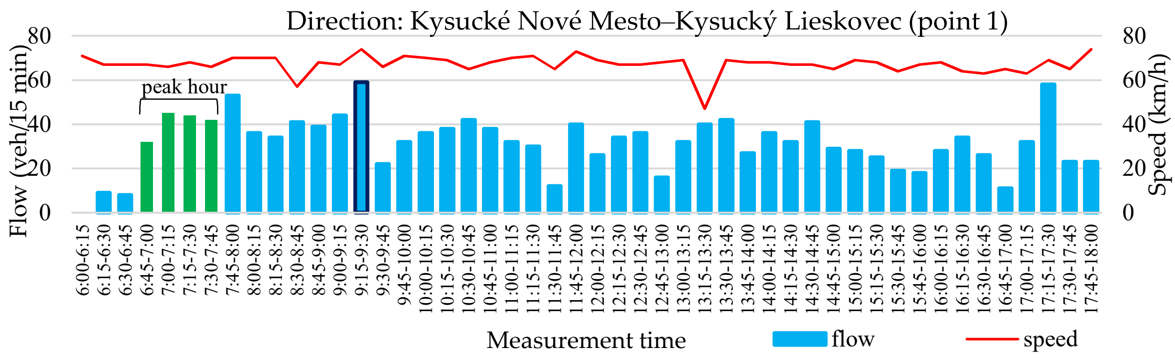

Figure 4. The flow and speed of vehicles for the direction Kysucké Nové Mesto–Kysucký Lieskovec (point 1).

A total of 4527 vehicles passed point 2 during the survey (377 veh/h). The following figures show the flow and speed of vehicles for both directions at this point.

In the first case (Figure 5), the peak hour was from 6:45 to 7:45—289 vehicles. The maximum number of vehicles in 15 min interval was between 7:15–7:30 (86 vehicles). The speed at the monitored point was about steady until 14:15 then there was a decrease. In the opposite direction (Figure 6), the peak hour was between 8:15 and 9:15—245 vehicles. The speed at the monitored point did not change significantly. The maximum number of vehicles in 15 min interval was from 6:15 to 6:30—92 vehicles.

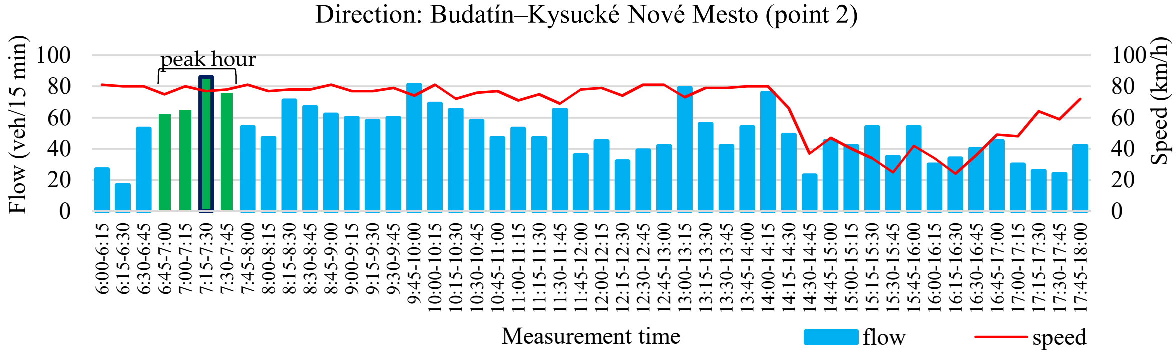

Figure 5. The flow and speed of vehicles for the direction Budatín–Kysucké Nové Mesto (point 2).

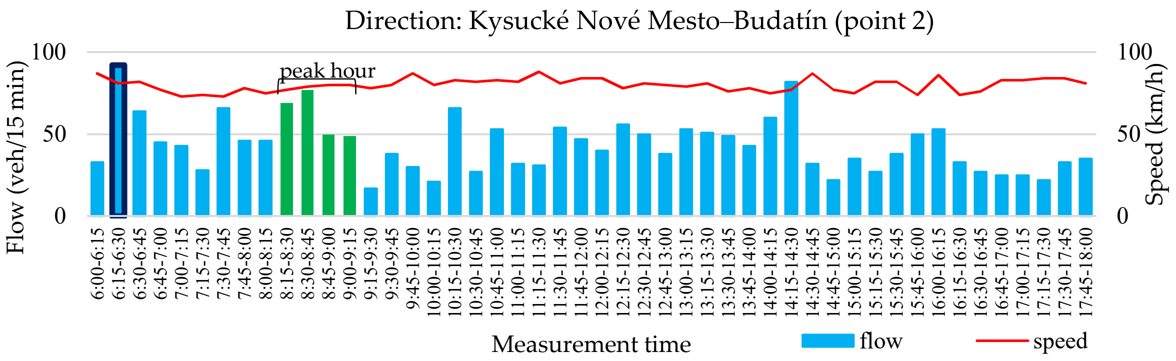

Figure 6. The flow and speed of vehicles for the direction Kysucké Nové Mesto–Budatín (point 2).

4.2. *The Second Traffic Survey (2 April 2020)*

A total number of 2356 of vehicles was recorded in point 1 during the survey. The flow and speed of the traffic flow for each direction are shown in Figures 7 and 8.

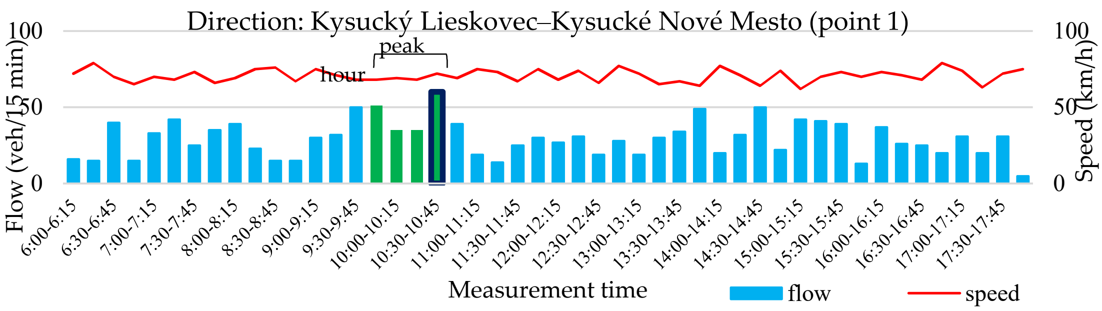

Figure 7. The flow and speed of vehicles for the direction Kysucký Lieskovec–Kysucké Nové Mesto (point 1).

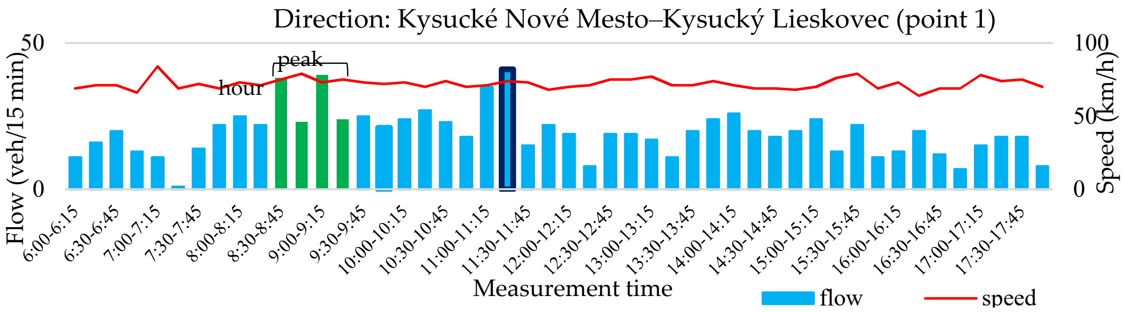

Figure 8. The flow and speed of vehicles for the direction Kysucké Nové Mesto–Kysucký Lieskovec (point 1).

In Figure 7, the peak hour was between 9:45 and 10:45—181 vehicles. The highest number of vehicles that passed the monitored section in one interval (15 min) was between 10:30–10:45. The highest speed was recorded in the interval 16:45–17:00—79 km/h. The peak hour for the opposite direction (Figure 8) was from 8:30 to 9:30—124 vehicles. The highest speed of vehicles (84 km/h) was recorded between 7:00–7:15.

The total number of 3354 vehicles was recorded in point 2 during the survey. The flow and speed of the traffic flow for each direction are shown in the following figures.

In the first case (Figure 9), the peak hour was from 8:00 to 9:00—235 vehicles. The maximum number of vehicles in 15 min interval was between 8:30–8:45 (70 vehicles). In the opposite direction (Figure 10), the peak hour was between 14:30 and 15:30—183 vehicles. The speed at the monitored point changed significantly in comparison with the direction Budatín–Kysucké Nové Mesto. The maximum number of vehicles in 15 min interval was from 15:00 to 15:15—64 vehicles.

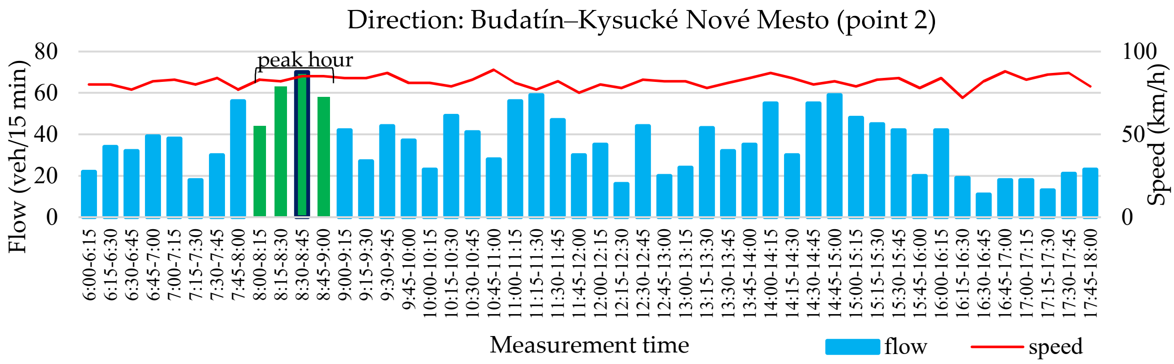

Figure 9. The flow and speed of vehicles for the direction Budatín–Kysucké Nové Mesto (point 2).

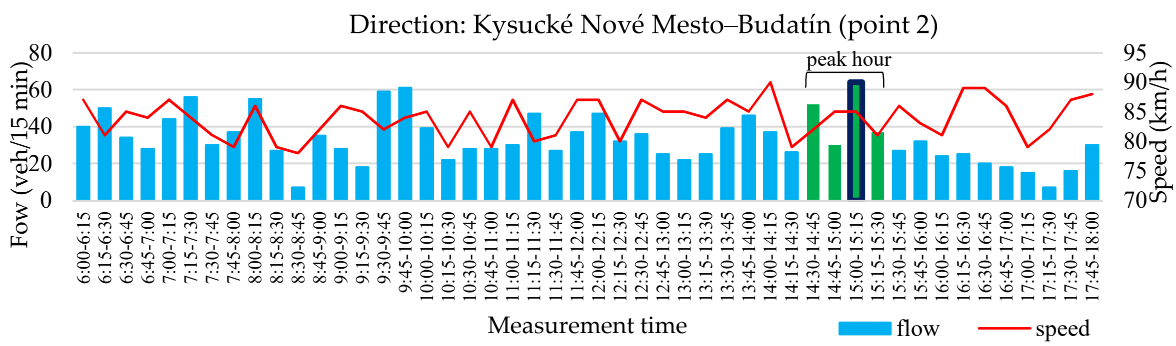

Figure 10. The flow and speed of vehicles for the direction Kysucké Nové Mesto–Budatín (point 2).

5. Result and Discussion

The previous figures show the recorded values in monitored points 1 and 2 separately for both days of the survey. Figures 11–16 show a comparison of the recorded values at the monitored points during 5 March 2020 and 2 April 2020.

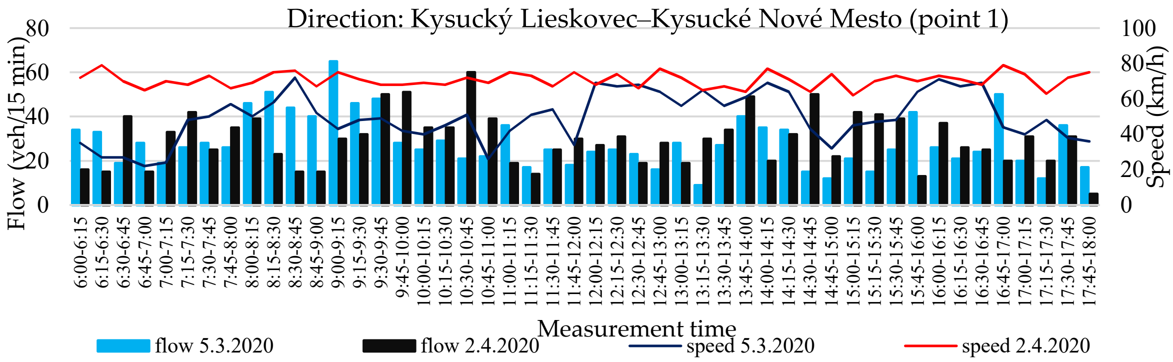

Figure 11. The comparison of the flow and speed for the direction Kysucký Lieskovec–Kysucké Nové Mesto (point 1).

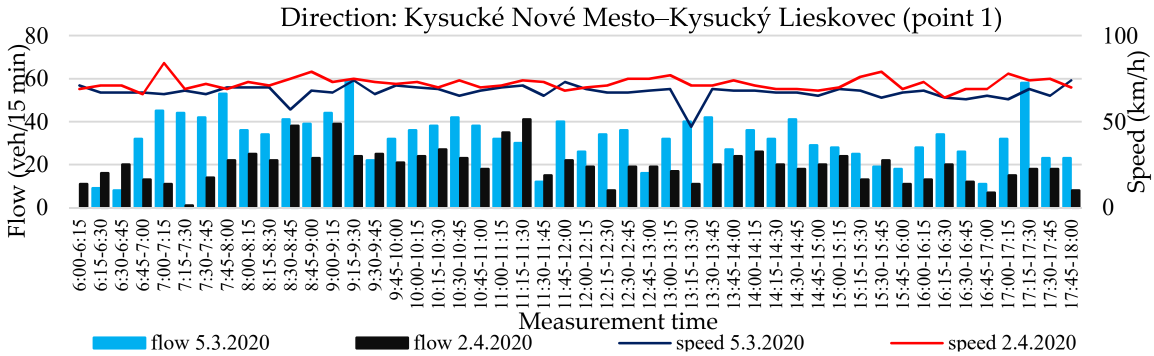

Figure 12. The comparison of the flow and speed for the direction Kysucké Nové Mesto–Kysucký Lieskovec (point 1).

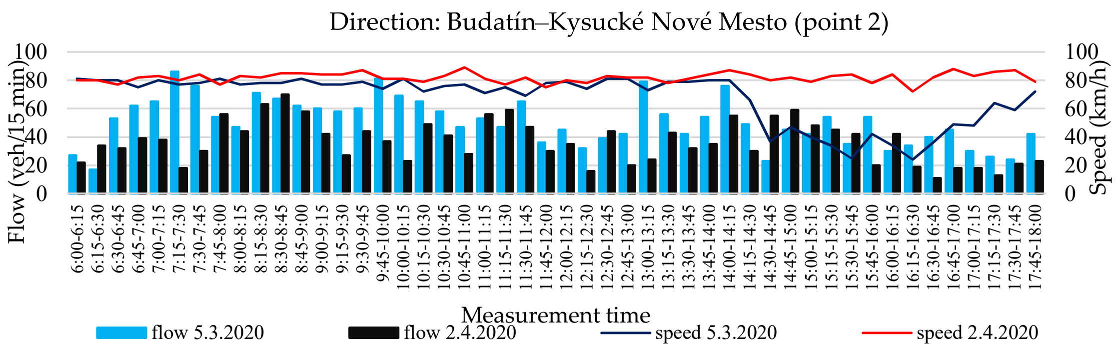

Figure 13. The comparison of the flow and speed for the direction Budatín–Kysucké Nové Mesto (point 2).

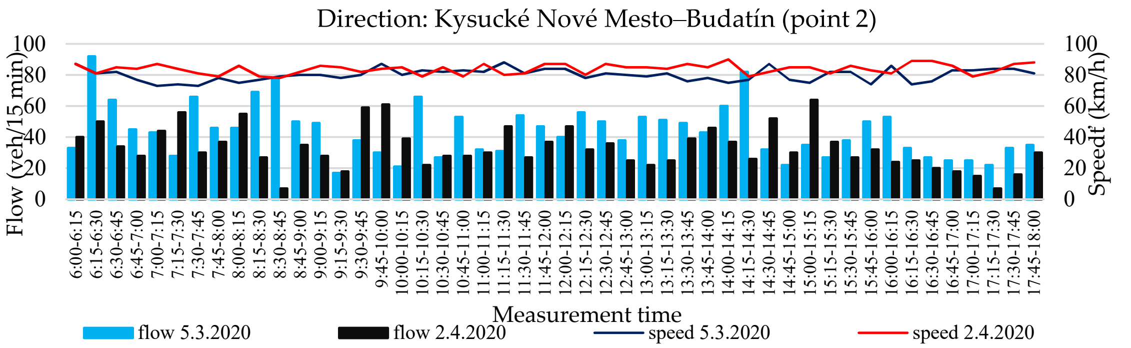

Figure 14. The comparison of the flow and speed for the direction Kysucké Nové Mesto–Budatín (point 2).

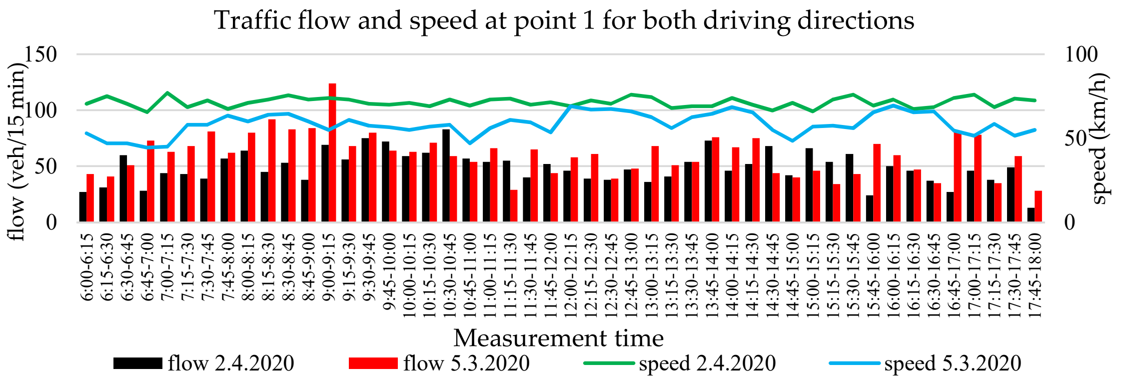

Figure 15. The comparison of the flow and speed of vehicles at point 1 for both driving directions.

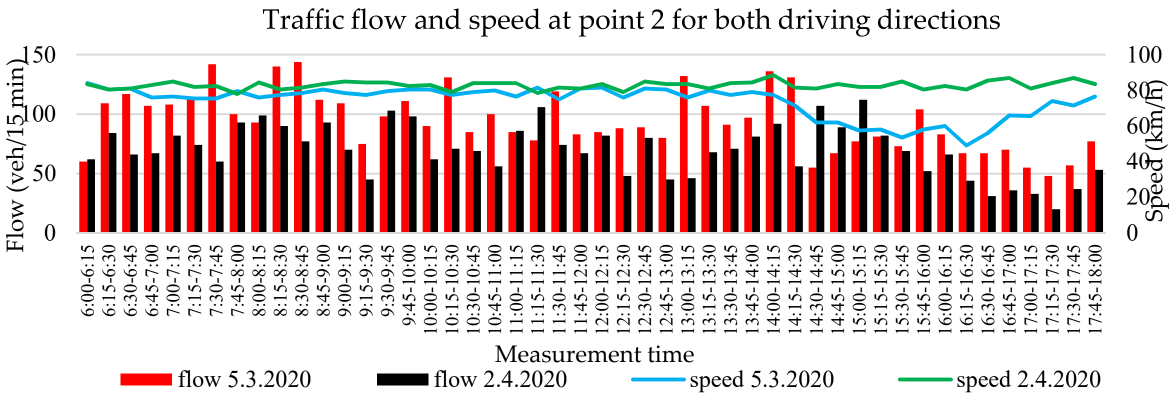

Figure 16. The comparison of the flow and speed of vehicles at point 2 for both driving directions.

In fact, it is a graphical comparison of the recorded intensity and speed at point 1, 2 separately according to the direction of the traffic flow. It is a combination of histograms (Figures 3–10).

In the first measurement (Figure 11), the flow reached a maximum value of 75 veh/15 min. However, in the second measurement, its maximum value was 20% lower (60 veh/15 min). In the first measurement, the speed of the vehicles had a fluctuating tendency during the day. During the morning, the lowest speed was 22 km/h. This was caused by regular traffic jams, which arise in front of the crossroads near Kysucké Nové Mesto. During the second measurement, due to the lower flow of the vehicles, the speed did not change significantly. The highest recorded value was 79 km/h, but in the first survey, the maximum speed was 73 km/h.

In the opposite direction (Figure 12), the decrease in the flow is also clearly visible in the second measurement. The maximum flow was 41 veh/15 min. It was approximately 30.5% higher (59 veh/15 min) during the first measurement. The speed did not change significantly during the second measurement. However, the difference in maximum speed between measurements is around 17%. In the second measurement, it reached a value of 84 km/h.

In conclusion, the flow has decreased after the introduction of measures against the spread of coronavirus. The same statement can be made with the achieved values in the second monitored point.

The flow measured during the first survey (blue colour) reached higher values than can be seen from the graphic processing. The maximum flow at the second measurement was reached in the interval 8:30–8:45 (70 veh/15 min—2.4.). At the first measurement, the maximum flow was almost 18% higher. The speed in both cases was around 80 km/h. However, the speed at the first measurement slowed down significantly after 14:00, which was caused by the formation of a traffic jam in front of the intersection.

In the opposite direction, the highest value of flow was 92 veh/15 min, recorded in the time interval 6:15–6:30. In the second survey, the maximum flow was 30% lower (64 veh/15 min). The speed of the vehicles in both measurements was around 80 km/h.

All of the above comparisons were table processed using descriptive statistics. For the flow and speed, the basic characteristics of the position (mean value, median and mode) were calculated. The final values and their comparison are shown in the following tables. Table 1 shows the average flow for both measurements and their subsequent comparison and evaluation.

Table 1. The basic characteristics of the position of the average flow in 15-min intervals.

	Direction	**5 March 2020 Flow [veh/15 min]**			**2 April 2020 Flow [veh/15 min]**			**Comparison [%]**	
		Average	**Median**	**Mode**	**Average**	**Median**	**Mode**	**Average**	**Median**
Point 1	Kysucký Lieskovec–Kysucké Nové Mesto	29	26	28	30	30	15	**3.87**	**15.38**
	Kysucké Nové Mesto–Kysucký Lieskovec	32	32	32	19	20	20	**−39.28**	**−39.06**
Point 2	Budatín–Kysucké Nové Mesto	51	51	54	37	36	18	**−27.60**	**−29.41**
	Kysucké Nové Mesto–Budatín	44	43	33	33	30	28	**−23.97**	**−30.23**

The average flow value at the first measurement in point 1 reached 29 veh/15 min. The median was 26 veh/15 min. After the introduction of measures against the spread of coronavirus, the second survey found out that the average flow value increased by one. The average and median reached the same values, 30 veh/15 min. Only in this case, the flow did not decrease, but on the contrary, increased by 3.87%. This may be because, in the first measurement, more intervals were recorded with the lower flow but large variance. On the contrary, in the second survey, most of the intervals reached lower values but with smaller variance. In contrast to the average values, the mode reached a lower value in the second measurement. The most frequently recurring flow value for the 15-min interval was 28 veh/15 min in the first measurement, and 15 veh/15 min in the second measurement.

In other directions, the average flow of vehicles decreased after the introduction of restrictions. In relative terms, this decrease represented a variance of 24%–40%.

The previous Table 2 shows the average speed values for the individual directions. The average speed of vehicles increased, which caused a decrease in the flow. The number of vehicles on the road decreased, which led to an increase in the quality of traffic flow in the form of increased speed. The relative decrease in the average speed between the surveys is shown in Table 2. The highest increase in speed was found in the direction Kysucký Lieskovec–Kysucké Nové Mesto, up to 42.51%. The highest average value of speed during the first measurement was 80 km/h and the second measurement was 84 km/h in the direction Kysucké Nové Mesto–Budatín.

Table 2. The basic characteristics of the position of the average speed in 15-min intervals.

	Direction	5 March 2020			2 April 2020			Comparison [%]	
		Speed [km/h]			Speed [km/h]				
		Average	Median	Mode	Average	Median	Mode	Average	Median
Point 1	Kysucký Lieskovec–Kysucké Nové Mesto	50	49	48	71	71	68	**42.51**	**45.36**
	Kysucké Nové Mesto–Kysucký Lieskovec	67	68	67	72	71	69	**7.32**	**4.41**
Point 2	Budatín–Kysucké Nové Mesto	67	77	81	82	82	82	**21.39**	**7.19**
	Kysucké Nové Mesto–Budatín	80	80	81	84	85	85	**4.79**	**6.25**

Comparison of the Flow and Speed at Monitored Points

Figures 15 and 16 show a graphical course of the flow and speed recorded during the surveys at the monitored points for both lanes. It can be seen from the figures that the flow at both monitored points reached higher values during the first measurement. Following the introduction of measures against the spread of coronavirus, the flow decreased. On the contrary, due to the decrease in the flow, the speed of vehicles has increased.

The highest value in point 1 was 124 veh/15 min (5 March 2020). In the second measurement (2 April 2020) it was 83 veh/15 min (it is 41 veh/15 min less (−33%)). The vehicle speed during the first measurement did not exceed 70 km/h. On the contrary, in the second measurement, its value is mostly above the level of 70 km/h.

The highest value in point 2 was 144 veh/15 min (5 March 2020). In the second measurement, it was 112 veh/15 min (2 April 2020). This represents 32 veh/15 min (22.2%) less. The speed reached a value of about 80 km/h, but after 14:15 it decreased significantly. This decrease could be caused by some restrictions on the road, e.g., traffic jam.

The average differences from the data shown in the graphs are shown in Tables 3 and 4. The following tables show the average flow and speed for both directions at the monitored points and their subsequent comparison and evaluation.

Table 3. The basic characteristics of the position of the average flow in 15-min intervals.

Direction	5 March 2020			2 April 2020			Comparison [%]	
	Flow [veh/h]							
	Average	Median	Mode	Average	Median	Modus	Average	Median
Point 1	61	62	68	49	48	46	**−18.87**	**−21.95**
Point 2	94	91	85	70	70	82	**−25.90**	**−23.20**
Direction	**Speed [km/h]**							
	Average	**Median**	**Mode**	**Average**	**Median**	**Mode**	**Average**	**Median**
Point 1	58.4	58.0	55.0	71.4	71.0	73.0	**22.25**	**22.41**
Point 2	73.7	77.0	80.5	82.8	83.3	83.5	**12.38**	**8.12**

Table 4. Comparison of traffic flow and speed in 2019 and 2020.

	2 April 2019			2 April 2020			Comparison [%]	
			Flow [veh/15 min]					
Direction	**Average**	**Median**	**Mode**	**Average**	**Median**	**Modus**	**Average**	**Median**
Point 1	158	154	149	49	48	46	**−68.98**	**−68.83**
Point 2	186	191	197	70	70	82	**−62.36**	**−63.35**
			Speed [km/h]					
Direction	**Average**	**Median**	**Mode**	**Average**	**Median**	**Mode**	**Average**	**Median**
Point 1	55.1	48.0	46.0	71.4	71.0	73.0	**22.83**	**22.39**
Point 2	75.8	78.5	80.0	82.8	83.3	83.5	**9.23**	**5.76**

The average flow of vehicles in the first survey reached the value of 61 veh/15min in point 1. In the second survey, it reached a value of 49 veh/15min, it is a decrease of about 19%. In point 2, there was a decrease of almost 26% between the two surveys. The mode of flow in the first measurement reached 68 veh/15min and in the second measurement, it decreased to 46 veh/15min. Due to the decrease in the intensity of vehicles at the monitored points, the average speed increased on average by 12.38% in point 2, and by as much as 22.25% in point 1.

The following figures (Figures 17 and 18) show a graphical course of the flow and speed between 2019 and 2020, specifically 2 April recorded at the monitored points for both lanes a comparison made.

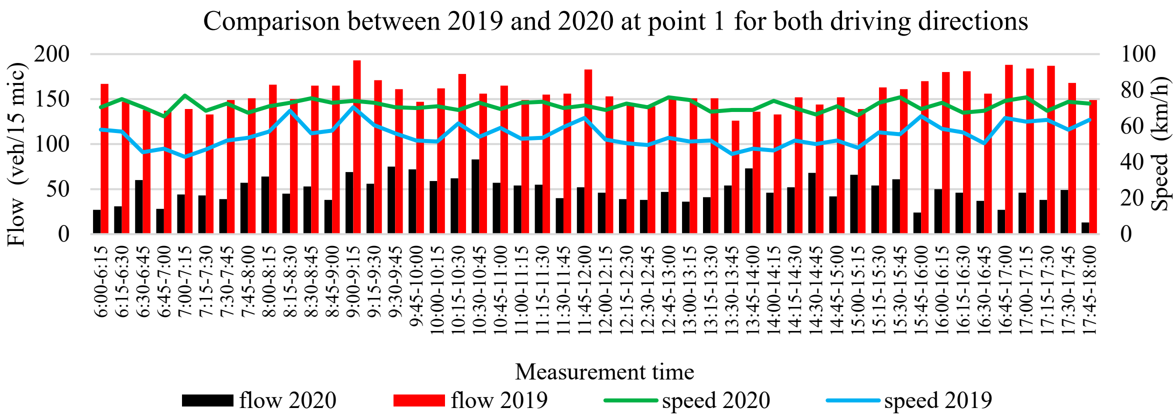

Figure 17. The comparison of the flow and speed of vehicles at point 1 for both driving directions between 2020 and 2019.

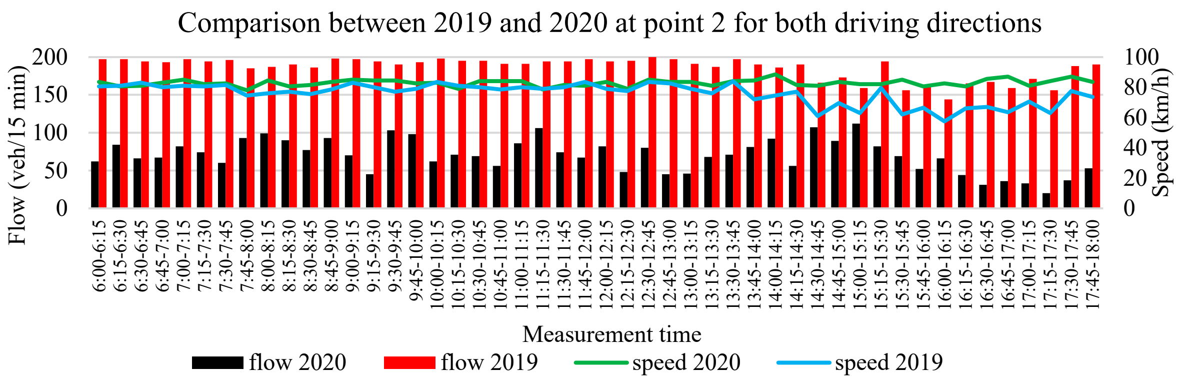

Figure 18. The comparison of the flow and speed of vehicles at point 2 for both driving directions between 2020 and 2019.

The highest value in point 1 was 198 veh/15min (2.4.2019). In the 2020, it was only 83 veh/15 min. This represents 116 veh/15 min (58,1%) less. The speed oscillated around 70 km / h in 2020, but in 2019 a larger dispersion is visible, while the average speed this year reached around 55 km/h.

In point 2, the traffic flow for 2019 did not change significantly during the day. The decline was not recorded until the afternoon. In this case, the highest number of vehicles was captured at 12: 30-12: 45, namely 200 veh/15 min. while in 2020 it reached a value of only 112 veh/15 min. In this comparison, however, the difference between the speeds of the vehicles is not as large as in point 1. The average speed in 2019 was lower by 6 km/h compared to 202, when it reached 76 km/h. All compared values are given in summary Table 4, as in the previous case.

The average value of the traffic flow in 2019 reached in point 1. 158 veh/15min and in point 2. to 186 veh/15 min.The last comparison shows a huge decrease in the flow of vehicles in 2020 compared to 2019. This decrease represents almost by 70% fewer vehicles in 2020 than on the same day in 2019. However, the average speed in point 2 did not show a very large difference of 9.23%, on the contrary in point 1 it increased by more than 20%.

Due to the fact that there was an increased fluency of the traffic flow (increased speed and a decrease in the flow of vehicles), it is possible to state a positive effect of the restrictions on the quality of movement at the monitored points. However, the crisis has also shown that it is possible for governments can take measures that have a great impact that also have the support of the people. This is important: The people are the ones who experience the benefits of clean air and the disappearance of congestion [46].

Already in the graphical comparison of surveys, a decrease in the flow of vehicles, and an increase in the speed of the current traffic flow can be seen. Using descriptive statistics, the positions of the monitored quantities were calculated and compared with each other. These comparisons were made in two ways: separately for each direction and together for both directions. The analysis and comparison of individual directions showed that in one case the number of vehicles increased on average by 3.87%. In other cases, there was a strong decrease in the average flow of vehicles in the range of 23.97% to 39.28%. The highest decrease (39.28%) was found in the direction Kysucké Nové Mesto–Kysucký Lieskovec (point 1). In our case, however, there is a decrease in the number of vehicles on one road. But, for example, when comparing 2019 and 2020, the decrease in traffic flow reached almost 70% at both points, similar to [15,22,23,25].

The traffic flow has decreased in cities around the world. Somewhere traffic flow drops by more than 80% [47]. In China, for example, there has been a dramatic reduction in road traffic during the control period. The flow of commercial vehicles and buses in the Beijing–Tianjin–Hebei region and its surrounding areas decreased by 77% and 39%, respectively, during the control period [25]. In the UK, data shows motor traffic dropped by 73% on 29 March [23] compared with pre-outbreak levels. The analysis shows the number of road miles travelled has not been this low since 1955. Bucsky states that mobility was severely reduced, at least by 51% and maximally by 64%, and the middle estimate suggests a reduction of 57% in Budapest for the second half of March [48]. In our study, we did not look at the reduction of traffic throughout the Slovak Republic, but we focused on one path. Therefore, it can be assumed that the decrease in the flow of vehicles in road transport could be even lower, as reported by other studies.

The decrease in the average flow of vehicles caused an increase in the average speed in the range of 4.8–42.5%. It is interesting that in the direction Kysucký Lieskovec–Kysucké Nové Mesto, where the flow rate increased, there was the largest increase in speed. In the case of the analysis of the average values of the traffic flow in both directions, there was a decrease in the flow rate and an increase in speed in the monitored points 1 and 2. In point 1, the average flow rate decreased by almost 19%, in the second point by almost 26%. This fact and the interaction between the monitored variables caused an increase in the speed of 12.38% in point 2 and 22.25% in point 1. Several studies [13,49–51] also confirm an increase in speed on the roads in response to a reduction in traffic flow but also points to an increase in average speeds between 2019 and 2020.

In addition to the decrease in the flow rate, air quality records in the Slovak Republic also showed a decrease in pollutants. In cities, changes in NO_2 concentrations from the 10-year average range from −6 to −41%, with the average for all stations at −24%. Changes in NO_x concentrations from the 10-year average are more pronounced from +29% to −53%, with an average of −25%. The observed trends are less pronounced compared to 2019, where the average decrease from all stations is at −23% for NO_2 and −21% for NO_x. PM10 concentrations in the considered period of 2020 compared to the average of 2010–2019 decreased, on average, by −14% and compared to 2019 increased by +1% [52]. Results from the study [53] given at a resolution of 20 km show decreases in NO_2 concentrations ranging from −30% to −50% in all Western European countries. The reduction in NO_2 concentrations in Madrid (Spain), under COVID-19 lockdown during March 2020 were 50% and 62%, respectively [54]. Others authors in Barcelona (Spain) assessed air quality changes during the lockdown in the city of Barcelona and observed a 31% and 51% reduction of particulate matter (PM10) and nitrogen dioxide (NO_2), respectively, during the lockdown compared to the month before the lockdown [55]. The NO_2 levels of São Paulo decreased during the partial lockdown: −45% compared to the same period in 2019 [26] and e.g., in Almaty (Kazakhstan), CO and NO_2 concentrations reduced by 49% and 35%, respectively [56]. In one study from Morocco, it was found that during social distance, NO_2 levels fell by up to 96% and −75% for PM10 [57]. Sharma et al. [58] observed a 31% reduction of particulate matter (PM10), respectively, during the lockdown compared to the same time period of the past four years in India.

In the Slovak Republic, the decrease in NO_x and NO_2 concentrations in the urban area could be due to two factors over the period considered—favourable dispersion conditions or a decrease in emissions due to the measures under consideration, in particular in transport and to a lesser extent in industry. For PM10, the situation is more complicated. These concentrations are more affected by cross-border transmission (significant cross-border transmission was observed at the beginning of measures with a likely source of dust in the Karakum Desert and around the Caspian Sea) and the most significant source of their household emissions—over 60%, followed by agriculture, transport (around 9%) and industry.

During the COVID-19 epidemic, various public health measures, such as encouraging social distancing, lockdown of cities, and travel restrictions. This could be explained by the fact that the emergency measures (lockdowns), related to the cessation of industrial and transportation activities, had as a consequence a limitation in NO_2 emission from both industrial production and vehicle exhaust, which has implicated a decrease in NO_2 concentrations during this period. Air quality also improves with the reduction of production activities and human mobility. At the same time, the lockdowns during COVID-19 are stricter, and the compliance of residents is better than usual. Reduced traffic in cities is also a major benefit in terms of reducing pollution in NO_2 and other local pollutants. Therefore, the air quality index decreases more after the private vehicles are restricted during this period. Comparing the air quality in 2019 and 2020, Cadotte [59] found that governments can improve air quality through policy change. Hepburn et al. consider the possible positive and negative effects of COVID-19 on climate change and tend to be very optimistic [60].

6. Conclusions

Currently, transport is a basic and very important part of society. In general, increasing the flow of vehicles increases the load on the road network to unfavourable values and the use of roads reaches the maximum capacity. However, an important task is to design and build roads that will suit the current as well as the future flow of vehicles.

The article aimed to point out how the measures against the spread of COVID-19 limited the quality of the traffic flow on the selected section of the road. Specifically, it was the first-class road I/11, which connects the cities of Žilina and Čadca. It is one of the most congested road sections in Slovakia. The flow and speed data from the National Traffic Information System were used as a basis for analysis and evaluation. The flow and speed of the traffic flow were monitored at two points in both directions during two surveys (before and after the introduction of measures). In addition to traffic surveys, a comparison was made between 2019 and 2020 for the same day, 2 April. In this case, there was a significant decrease in the number of vehicles. Based on our results, it can be argued that the lockdown and social distancing had a great impact on the decline in traffic not only in our country but also around the world, as describe in other studies.

Based on the findings, it can be argued that the measures related to COVID-19 had a positive effect on improving the quality of traffic flow in the monitored road section. In addition to reducing the flow of traffic on roads and in cities around the world, there has been a reduction in air pollutants in the Slovak Republic and other countries. However, several scientific studies have shown that this state of emergency has affected not only road transport but all modes of transport worldwide. In this way, the negative effects of traffic and industry such as particulate matter such as emissions, noise, etc. have been reduced. Although the partial lockdown has contributed to a positive impact on air quality, reducing the number of vehicles and our planet has become "greener and healthier" for a while. It is important to consider the negative impacts on social aspects, considering the deaths caused by COVID-19 and also the economic effects.

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