Loop detectors: Accurate and Efficient?

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1 Introduction

The quality of the basic data is fundamental for the quality of modern traffic control and traffic management systems. In order to widen the data basis, it is very interesting to integrate data of already existing systems. Traffic actuated signal systems as part of modern traffic control and management systems provide good data sources because they use a lot of loops lying in the ground collecting information about the traffic volume on each lane. Using the supervising traffic control computer of the traffic signal system it is easy to get access to the data.

Because of financial, personnel and some technical restrictions it is not possible to implement a continuous and areawide quality control. Indeed there are algorithms promising automatic control and substitution of incorrect data, but hardly any comparison with real life data takes place.

This paper prepares a comparison of real life data with collected data and emphasizes the necessity of a continuous control for data that will be used for purposes it is not quality proofed for. It will be shown that there are a lot of different disturbing influences – especially within urban areas.

2 Methodology

The data of three representative intersections will be analysed in a detailed way by the comparison of the detected data with the real traffic volume. The design and the traffic conditions of these intersections vary but there is some equality nevertheless: For example all intersections are four way intersections and are fully traffic actuated with loop detectors in all lanes. Two of them are only 100 m away from each other. Because there are no origins or destinations in between, it is possible to compare the data in this relation. These two intersections will be named Intersection North and Intersection South. The third intersection differs from the others by a tramline, which is running parallel to the with-flow lane next to the roadside environment. Accordingly, this intersection will be named Intersection PT (Public Transport).

The first step of the method used is to check the data's plausibility. The aim is to get a first impression on the data's quality. This step includes the comparison of the absolute figures and a correlation analysis. Within the detailed analysis the profiles over time of the single streams and the respective rolling mean values (within 30 minutes) are examined. In this paper only some of the results of the study of Intersection PT will be shown as an example. This intersection is the one with the lowest accuracy. To get knowledge about the reason for very good and very bad exactness the results of the different streams will be compared.

Furthermore different possibilities to improve the data will be introduced and the influence of the inaccuracy on signal control and on OD-estimation will be shown.

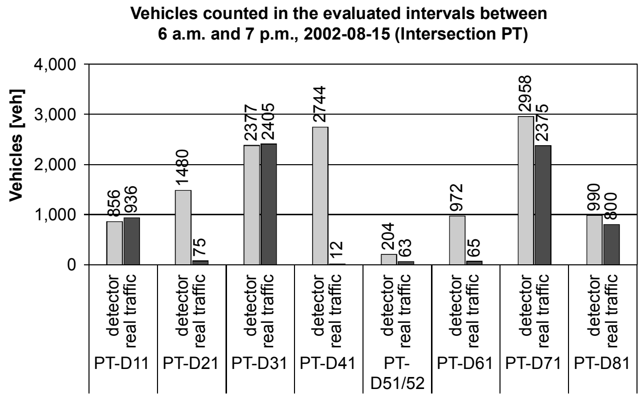
3 Data processing

The recorded signal plans include information about the state of the single signals in each second, about the current, the required stage and the aggregated traffic volumes (in minutes). If the data transfer is corrupt for one of these intervals the whole 5 minutes interval is discarded.

4 Detailed analysis - Intersection PT

Several of the loops at this intersection measure the multiple traffic volume. Two detectors count fewer vehicles than there actually are. These two detectors are the only ones that count with a deviation of less than 10 %. The other detectors overestimate the traffic on an average factor of 48! This value is strongly influenced by detector PT-D41, which counts more than 200 times the really existing traffic. After extracting this detector from the average the overestimation has still an approximate factor of 8.

The correlation analysis produces similar results: While the detectors PT-D11 and PT-D31 have a correlation coefficient of 0.88 and 0.89, the detectors PT-D21, PT-D41 and PT-D61 hardly show any correspondence to the real traffic data. The correlation coefficient of the detectors PT-D71 and PT-D81 is relatively high, even if more than 20 % of additional vehicles are counted.



correlation analysis

Detector	Real traffic PT-D11	PT-D21	PT-D31	PT-D41	PT-D51/52	PT-D61	PT-D71	PT-D81
PT-D11	**0.88**	0.01	0.32	-0.10	-0.23	-0.07	0.11	0.19
PT-D21	**0.51**	-0.02	0.22	0.04	-0.03	0.13	0.17	**0.66**
PT-D31	0.33	0.10	**0.89**	-0.07	-0.02	-0.16	0.14	0.01
PT-D41	0.20	0.20	**0.51**	-0.11	-0.02	-0.16	**0.43**	0.12
PT-D51/52	-0.09	0.21	-0.11	0.27	**0.48**	**0.46**	0.16	0.20
PT-D61	0.17	-0.17	0.07	-0.19	-0.10	-0.16	-0.13	0.04
PT-D71	0.02	0.15	0.17	0.10	0.01	0.17	**0.74**	0.36
PT-D81	0.17	0.01	0.00	-0.02	-0.01	0.06	0.13	**0.74**

Figure 1: Plausibility check Intersection PT

The following paragraphs show the reasons for the very inaccurate measurements of detector PT-D21 and PT-D61. Detector PT-D21 counts 1480 veh/13 h even if there have been only 75 veh/13h. The correlation coefficient introduced in Figure 1 and re-enacted in Figure 2 shows a good correspondence of the detected values to the real traffic volume of PT-D81, which is running on the lane next to PT-D21. Adding all neighbouring streams leads to the comparison shown in the right diagram in Figure 2. It is evident that these two time series have many similarities, which is confirmed by the correlation coefficient of 0.75. In summary the detected traffic volume is about 80 % of the real traffic volume. As a result the conclusion is drawn that only large amounts of the neighbouring streams are detected but not the neighbouring streams as a whole.

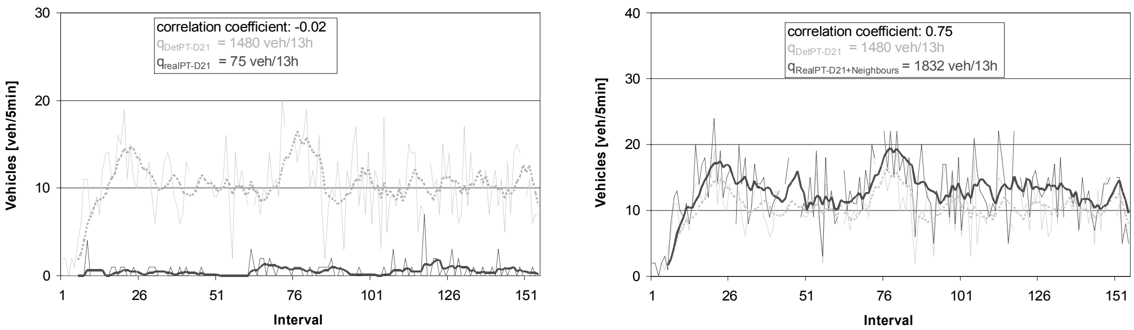


Figure 2: Analysing the measurement of PT-D21 (including the neighbouring streams)

Another detector with a very low traffic volume is PT-D61. During peak hour only 13 veh/h and between 6 a.m. and 7 p.m. only 65 veh/h use the intersection. In the same time period nearly 1000 vehicles are detected. Obviously, there are strong variations of the detected data. These deviations reach up to 20 veh/5min. Between peaks the detected traffic volume is not very different from the real one. The more detailed analysis shown in Figure 3 reveals a connection among the detected data and the tramline: Each passing tram is responsible for one of the peaks. Because the peaks are not uniform it is not possible to eliminate the error.

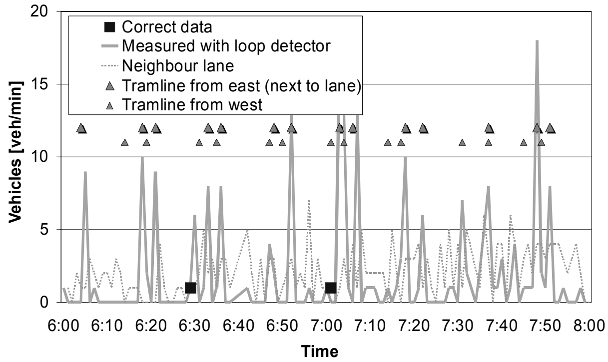


Figure 3: Influence of the tramline on PT-D61

5 Integrated analysis

There seems to be no proof for the influence of the detectors' design and their distance to the stop-line on the data quality of the detection process. Furthermore there is no connection between the share of the green time and the data quality as well. Instead of this Figure 4 shows that the data quality increases with higher traffic volumes. Especially detectors with very low loads tend to count their neighbouring streams additionally.

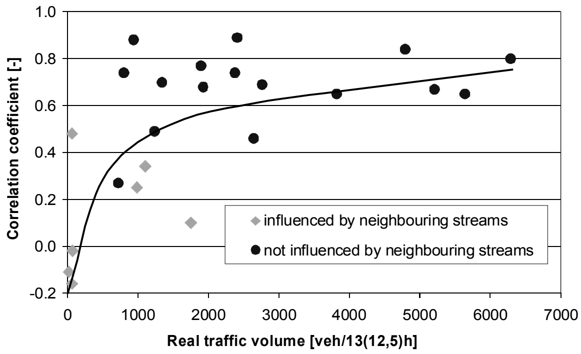


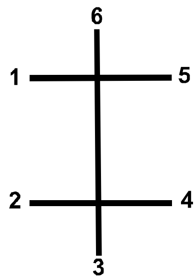
Figure 4: Influence of the traffic volume on the quality

6 Impact of the inaccuracy on signal control and OD-estimation

Detectors that are activated by different streams hardly influence the logic of the signal control system because claiming a stage change is registered only after 3s of non-interrupted demand. This threshold isn't reached by passing vehicles. The end of the stages will not be affected inaccurately as well because detectors are able to count too many vehicles only while being idle. This means that both streams are in their green period and that one of these streams still needs right of way. In summary, there are hardly any negative effects on the signal control system.

A comparison of the matrices obtained by the counted and the detected data points out the impact on OD estimation (see Figure 5). The OD-estimation is based on the algorithm of VAN ZUYLEN and WILLUMSEN, which allows changing an existing matrix by incomplete data. On the left side of the figure the arrangement of the districts is shown. On the right side the OD-Matrix estimated by the real traffic volume and the comparison with the matrix estimated by the detected traffic volume is shown. The change of the OD-Matrix shows that some of the relations are a lot overestimated and that the two matrices differ quite a lot.

Scheme of the intersections and the districts



OD-Matrix, estimated by real traffic volume [veh/12h]

	1	2	3	4	5	6
1	0	13	993	0	4067	9
2	0	0	44	7257	0	0
3	2010	472	0	986	1626	746
4	7	7548	173	0	94	10
5	5176	163	1088	0	0	83
6	28	4	1770	0	21	0

Change of OD-Matrix, due to estimation by detected traffic volume [%]

	1	2	3	4	5	6
1			- 36,3		+ 6,5	
2				+ 7,6		
3	- 18,6	+ 45,1		+ 45,0	- 18,6	- 18,5
4		+ 28,8	+ 28,3			
5	+ 5,4	- 36,8	- 36,9			
6			- 1,6			

Figure 5: Comparison of the two OD-Matrices

7 Possibilities of data examination and improvement

Usually, the analyses shown aren't available in real-world settings due to the large effort required to derive them. If no real traffic volumes are available there are two different principles for controlling the data. On the one hand, there is the longitudinal comparison of data, which means the resemblance of traffic volumes at adjacent junctions respectively at detectors lined up in another way. On the other hand there is the comparison with historical data.

The first step is the longitudinal comparison of detectors. In the examples considered this is possible in both directions between Intersection South and Intersection North. Because both junctions are very close to each other and origins and destinations between them are insignificant, cars that pass Intersection South in direction north should arrive at Intersection North and vice versa. The proximity of both intersections enables the neglect of an offset.

The measurement results at both observation points scarcely match. Furthermore, the whole detected traffic volume (particularly in south-north-direction) is less than the counted traffic volume. Thus, one risk of automated data equalisation is shown: Both the detectors at Intersection North and those at Intersection South measure with an error rate of 10 %. As these errors occur continuously, they cannot be noticed by an insufficient match of the time series, but suggest a faulty measurement of good quality. As a result it is stated that an algorithm to improve the quality must contain information about the real present traffic volume.

If this information is unavailable, an improvement is only suitable concerning the similarity of the two profiles over time. The quality of this improvement depends on the partition of the difference of cars measured at both junctions on these junctions. The first tested formula is based on the data directly received. For every interval the difference between both time series was divided up in the relation of the inverted percentage of the traffic volume (because it is shown that the quality of the data increases with the traffic volume) and subtracted respectively summed from/to the initial values. The success control for this calculation points to an improvement of the measurements quality. However, the fundamental assumption for this calculation is that the measurements' quality increases with the traffic volume. If this effect does not occur, this assumption invariably leads to an unsuitable result.

Therefore, a more qualified partition of the difference is needed. If there is more information available about the usual quality of the detection, for example the correlation coefficient, this information can be used instead of the traffic volume. Figure 6 shows the success control for this calculation. An explicit improvement of the correlation coefficients, the detector values and the counting data is eminent. It becomes clear that even simple methods of longitudinal alignment improve the data significantly. Even though the time series of the adjacent intersections fit better after this calculation, no larger similarities with the detected traffic volume are guaranteed.

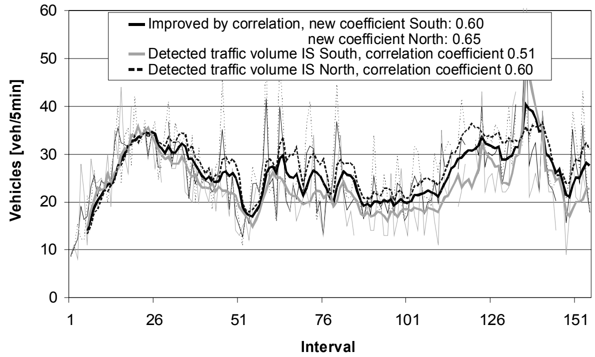


Figure 6: Result of the improvement of the detected data by using the correlation coefficient (from north to south)

As mentioned above, comparing detected with historical data is another analysis method. Using Intersection PT as example again, both detector data for the day of the manual counting and for the same weekday, but one respectively two weeks before, are available. The comparison of the absolute traffic volume is shown in Figure 7. It is easy to see that the particular errors of the measurement discussed above occur in each of the three weeks. If one would therefore compare the automatically raised data with those of the preceding weeks, no discrepancy would be recognized. For example, on August 1st three of the detectors determine a relatively strong deviation compared to the other days. A reason for this error cannot be derived from the available database. In this case merely a view on adjacent junctions helps to determine if on these particular days an increased traffic volume occurred.

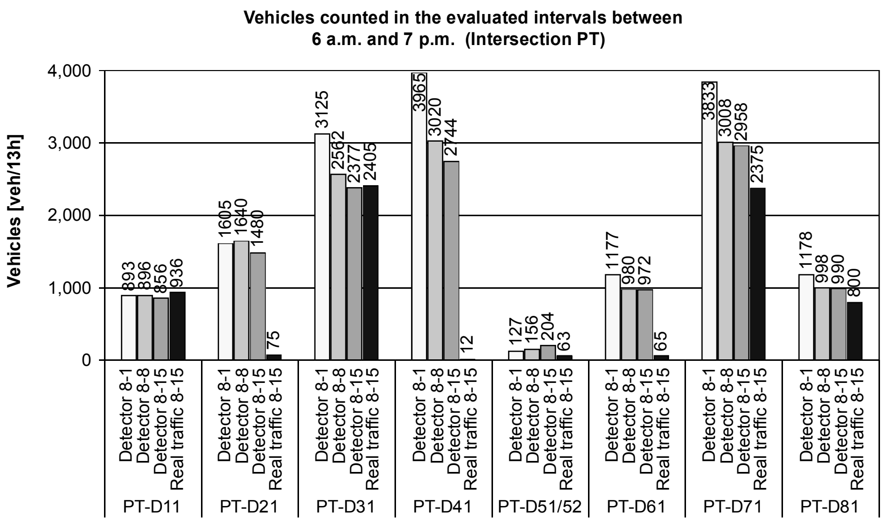


Figure 7: Comparison with historical data (Intersection PT)

8 Conclusions

This paper proves that using detector data without quality control will most probably lead to false results. Without the integration of real traffic data it is hardly possible to get reliable estimations because occurring errors might be systematic and systematic errors cannot be determined by longitudinal comparisons or by comparison with historical data.

For using data resulting from loop detectors some conditions have to be considered:

- The data should be compared with real traffic volumes and time series. Someone who knows the real traffic conditions should make the analysis in order to recognise apparent errors.
- Detectors shall not be situated within the conflict area of the intersections but in the intersection arms so that they are clearly attached to one stream only.
- If detectors are arranged on turning lanes one has to make sure that no neighbouring streams are detected in addition. For example a second loop for recognising the direction of the passing vehicles can be installed.
- Trams tend to influence the detectors (at least up to a distance of 10 m). A sign of such unwanted influence is the data’s periodical staggering.

If all these requirements are fulfilled, automatically detected data can be a useful and effective part of modern traffic management systems.

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