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The Impact of Hourly Measured Speed on Accident Risk in the Netherlands: Results from an Exploratory Study using GIS

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ABSTRACT

Several scholars have defined the urgent need for more research to identify the precise relationship between speed and crash involvement more fully. In this paper, we present the first results of an exploratory study carried out in the Brabant Southeast police region in the Netherlands. Hourly speed measurement data over a period of two years were collected from loop detectors on the municipal and provincial road network and were related to crashes. Different aspects of traffic intensity, speed and their impact on crashes were studied, including absolute speed, speed variation and the proportion of excessive speeders, both for vehicles under and over 5.2 meters long. The study also discusses a number of methodological aspects associated with this kind of analysis. The results show that although absolute speed plays a more important role on roads where speed limits are low, it is the variation in speed that correlates more with crashes when speed limits are higher. Given the limited study area, the results of this work cannot be generalized without risk. However, they offer interesting insights that deserve further investigation in a nationwide cross-sectional study.

1. INTRODUCTION

In a recent traffic safety bulletin issued by the Dutch Ministry of Transport, Public Works and Water Management, the total cost of road crashes to Dutch society was estimated at about 6 billion Euros (*1*). Furthermore, in the White Paper (*2*) on European Transport 2010, the European Commission claims that one person in three will be injured in an accident at some point in his or her life. As a result, it is not surprising that, in recent years, road safety has become a hot issue on the political and societal agenda.

In terms of contributing factors to crashes, previous research has revealed that human failure is the most important causal factor that may lead to an accident (*3*). It is in fact much more important than failures on the part of the vehicle or the infrastructure. Furthermore, and of particular relevance for this study, speeding or inappropriate speed has proven to be a major contributing factor in terms of car crashes. In 2001, for instance, the German Federal Statistical Office calculated that 25% of all crashes involved inappropriate speed as a contributing factor (*4*). It is assumed that a reduction in speed has an important potential with respect to reducing the number of severe crashes, including fatalities and severe injuries. However, it is believed that not only the absolute speed level is of importance, but also the relative speed differences (speed variance) between motor vehicles on a road segment. The underlying idea in this connection is that disruptive traffic conditions contribute to traffic accidents. Such disruptive traffic conditions, which are unstable and undesirable, can be represented by high temporal and spatial variations in traffic parameters, yet only a limited amount of research has been done in terms of relating the actual speed measured on a road segment to the number of crashes on that segment in order to verify whether indeed the *actual* speed driven or *differences* in speed between motor vehicles matters more as a contributing factor. The relationship between speed and accident risk is in fact complex, and several studies seem to report conflicting results. In this study, we therefore aim to contribute to the subject literature and shed more light on this complex relationship by linking hourly speed measurement data from loop detectors to crashes.

The paper is organized as follows. In the next section, we provide a concise overview of the existing literature on the relationship between speed and traffic safety, including the kind of data and methodologies that are being used. In Section 3, we elaborate on the data that have been used in this study. Section 4 provides the results of the analysis and discusses the main findings. Finally, Section 5 is reserved for conclusions, a discussion on the limitations of this study, and topics for future research.

2. LITERATURE REVIEW

There is a general consensus in the literature that speed plays an important role in crash risk. However, the precise relationship between speed and crash risk has been treated in several different ways in the literature, a fact which can make comparison across existing studies difficult. The reason is that studies differ with respect to how the variable speed is operationalized (i.e. how the operation used to measure the concept of "variable speed" through a specific observation or set of observations for research purposes is defined), how crash and speed data are collected, and which methods are adopted to relate speed to crash risk. Drawing conclusions about how exactly speed affects crash risk is therefore not by any means a straightforward process.

Firstly, with respect to the operationalization of the variable speed, some authors used the *posted* maximum speed and studied the effect of speed limit decreases/increases on the number and/or severity of crashes (*5*, *6*, *7*). These studies can be classified as "before and after studies." Others use *measured* (real time) vehicle speeds and use aspects of the speed distribution, such as the average speed, the 85th percentile speed, the standard deviation of speed, the percentage of vehicles exceeding the speed limit, or the ratio of standard deviation to mean speed (*8*). With respect to the absolute level of speed, most of the studies point towards an exponential relationship between speed and crash risk (*5, 9, 10*), while a number of more recent studies point towards the importance of speed variation in relation to crashes (*8, 11*).

Secondly, a large difference can be found in the literature on how speed and crash data are collected. Whereas some studies use surveys (*9, 10*), others use estimates or real measurements. Moreoever, while some studies use real accident records (road-based studies), many are based on driver-stated crash involvement (driver-based studies). The idea of using loop detector data to predict crashes, is relatively new, though there have been some efforts in this field in the recent past. In general, a distinction can be made with respect to the level of aggregation in time and space of the data. In aggregate studies, the unit of analysis is the number of crashes during a certain period of time (typically per month or per year) and for a specific region (typically a particular road or a larger geographical region). Traffic flow information is then typically presented at the same level of aggregation. Research has indicated, however, that interpretations of the relationship between speed and crashes should be carried out with great care due to the statistical problem of ecological fallacy (*12, 13*). Ecological fallacy means that a relationship that has been found between speed and crash risk on the aggregate level cannot necessarily be expected to exist at the individual level. This problem can be overcome by adopting disaggregate studies where individual crashes constitute the units of analysis and traffic flow information is related to the specific time and place where the crashes occurred.

Some interesting disaggregate studies involve the work of Lee et al. (*14, 15*), who introduced the concept of "crash precursors" and hypothesized that the likelihood of a crash is significantly affected by short-term turbulence in traffic flow. Abdel-Aty et al. (*16*) adopted matched case-control logistic regression, with every crash being a case with corresponding non-crashes acting as controls. The five-minute average occupancy from dual loop detectors at the upstream station during the 5-10 minutes prior to the crash along with the five-minute coefficient of variation in speed at the downstream station during the same time have been found to affect the crash occurrence most significantly. Abdel-Aty and Abdalla (*17*) showed that the presence of an on-ramp increases the likelihood of a crash happening within half a mile downstream of the crash location. Bad pavement conditions and the presence of horizontal curvature increase the likelihood of a crash. High variability in speed for a period of 15 minutes in a certain location was shown to increase the likelihood of a crash occurring at half a mile downstream. Unlike speed, low variability in volume over 15 minutes was shown to increase the likelihood of a crash occurring at a mile downstream. Golob et al. (*18*) used data from single loop detectors to conduct multivariate analyses of 1,000 crashes on freeways in Southern California. Their analysis revealed ways in which differences in variances in speeds and volumes across lanes, as well as central tendencies of speeds and volumes, combine in complex ways to explain crash taxonomy.

The present study resembles closely, but not fully, a disaggregate approach in that real-time traffic flow data on a per-hour basis are used from loop detectors and related to crashes that occurred on the road segments where those detectors are located. Consequently, there is a close match in space (on the road segment level) and a relatively close match in time (on a per-hour basis) of the traffic flow and crash data. However, the study is not fully disaggregate, since the traffic flow and crash data per segment are aggregated per hour, whereas in most other disaggregate studies real-time traffic flow data are used from seconds before a crash happened. “Fully” disaggregate studies therefore tend to be more predictive in nature, i.e. tend towards prediction of individual crashes based on real-time traffic flow circumstances, whereas our approach aims at identifying correlations between traffic flow circumstances and crashes on a less disaggregate level in time.

3. DATA PREPARATION

The data for this study were collected from different sources for the period 2002-2003 in the Brabant Southeast police region in the Netherlands. Furthermore, we decided to focus the analysis on the provincial and municipal roads, since an analysis between observed vehicle speeds and crashes had not previously been carried out on this level of the road network in the Netherlands. Roads of this type in the Netherlands can be divided into different speed limits, i.e. 50 km/h, 60 km/h, 70 km/h and 80 km/h roads. The first data source in this study contains detailed information about vehicle speeds, traffic exposure and traffic composition for 29 loop detectors (see Figure 1), which was made available by the Bureau of Traffic Enforcement of the Public Prosecutor’s Office (BVOM).

< INSERT FIGURE 1 HERE>

More precisely, for each loop detector, data were provided on an hourly basis and grouped into 10 different speed categories, depending on the road segment’s legal speed limit (50-70-80 km/h, 60 km/h road segments were not present in the data source). Moreover, the data about speeds and traffic exposure were made available for vehicles with a length under and over 5.2 meters, i.e. light versus heavy vehicles.

The second data source in this study was made available by the AVV Transport Research Centre of the Dutch Ministry of Transport, Public Works and Water Management and constitutes a record of road crashes on provincial and municipal roads in the Brabant Southeast police region for the period 2002-2003. Crashes resulting from parking maneuvers were removed from the data, the reason being that we were interested in the relationship between (free flow) speed and crashes, and crashes resulting from parking maneuvers could therefore have biased our results.

Finally, the third data source, also made available by the AVV Transport Research Centre, contains detailed data from the digital road network, including the road segments of which each road is composed. Based on these three data sets, a spatial analysis was carried out in a GIS to allocate crashes to each loop detector based on the road segment ID which is the common identifier for both the loop detector position and the crash location (see Figure 2).

< INSERT FIGURE 2 HERE>

In other words, all the crashes in the period 2002-2003 that occurred on the road segment where the loop detector was located were allocated to that loop detector. Yet two problems naturally arise in this case. Firstly, multiple loop detector configurations are possible, depending on the number of directions, the number of lanes per direction, and whether or not different directions are each digitized with a different road segment ID. This problem is illustrated in Figure 3.

< INSERT FIGURE 3 HERE>

In Figure 3(a), the loop detector is located on a road with two lanes in opposite directions. In that case, if the two lanes each carry a different digitized road segment ID in the road network data file (as shown in the drawing), the speed measurement data from the two loop detectors is kept apart. In other words, the measurement data from the loop detector in the left direction is allocated to road segment A and the measurement data from the loop detector in the right direction is allocated to road segment B. If both opposite lanes carry the same road segment ID, the speed measurement data of both loops is aggregated and allocated to that road segment ID. In Figure 3(b), the loop detectors are located on a road with two lanes in the same direction. In that case, there is only one road segment ID and thus the speed measurement data of both loop detectors are aggregated for this one road segment ID (segment A in the figure). Finally, Figure 3(c) represents a loop detector configuration on a two-by-two road with two lanes in each direction and each direction possessing a separate road segment ID. In that case, the speed measurement data of the two loop detectors in the left direction are aggregated and allocated to segment A, and the speed measurement data of the two loop detectors in the right direction are aggregated and allocated to segment B. If the digital road network defines only one segment ID for both directions, then all the speed measurement data are aggregated and allocated to that single segment ID.

For example, Figure 4 illustrates a situation where a type S2 loop detector is present on a road with two lanes in opposite directions. However, since both opposite lanes carry the same road segment ID (363198026) in the digital road network file, the speed measurement data of loop detector 22R006 are aggregated and allocated to that road segment ID.

< INSERT FIGURE 4 HERE>

A second problem that arises when allocating crashes to loop detectors is the question of how to treat crashes that have occurred on neighbouring road segments, i.e next to or in the neighbourhood of the road segment on which the loop detector is located. In several cases we decided to allocate crashes from multiple neighbouring road segments to the respective loop detector. For instance, this was the case when the loop detector was located in between two intersections and where the characteristics (e.g. speed, number of lanes, etc.) of that stretch of road (consisting of different digital road segments) did not change in between those two intersections.

This is illustrated in Figure 5 for one particular stretch of road consisting of several road segments. The position of the loop detector (example 22R004) is shown on the picture and is associated with one road segment (road segment ID 305181001). However, since the total road stretch between the two intersections consists of multiple neighbouring road segments (road segment ID 305181001 and 303181020), which are very similar in terms of the above-mentioned characteristics, we decided to allocate all crashes of that complete road stretch to that loop detector.

< INSERT FIGURE 5 HERE>

The principal motivation behind this decision was and is the belief that the measured speed, traffic composition, and exposure do not change significantly in between both intersections. As a result, the measured speed and exposure data can be considered as representative for the entire road stretch instead of just the road segment on which the loop is located. The decision as to which crashes to allocate to each loop detector was made separately for each loop, depending on the characteristics of the environment (homogeneous land use, no dangerous curves, etc.). Note, however, that intersection-related crashes were not included, since crashes on these road segments could be more typical for the intersection itself rather than for the speed behavior. Intersection-related crashes are identified in the road crashes database based on expert judgement made by trained operators using information on the crash registration form, the collision diagram and the digital road information.

Since the literature clearly indicates that different aspects of speed may influence crash risk differently, we defined a number of speed characteristics for each loop detector and for each hour, both for vehicles under and over 5.2 meters in length, that could be derived from the loop detector data, i.e. mean speed, speed variation and percentage of vehicles travelling at excessive speeds. Both the mean speed and the speed variance can easily be calculated from the distribution of vehicle frequencies over the 10 different speed categories. Note that the speed variation was calculated as a standardized variance of speed, since, in absolute terms, a difference in speed of 10 km/h between the lowest and highest speed measurement is a larger difference on 50 km/h roads than on 80 km/h roads.

The standardized variance of speed will also enable a fair comparison of its impact on crashes across roads with different legal speed limits (see results section). The proportion of vehicles travelling at excessive speeds was defined as the proportion of vehicles that exceed the speed above which a fine is issued. This speed typically lies at 10% above the legal speed limit and thus depends on the road segment's legal speed limit at the location of the loop detector. Furthermore, the relationship between traffic composition and crash risk is also of particular interest. We therefore also calculated, for each hour, the ratio of vehicles under and over 5.2 meters in length on the particular road segment.

4. RESULTS

In order to study the effect of the speed-related variables on crash risk defined above, we compared the values of the above-mentioned speed variables at the hour of a crash (at least one crash allocated to the road segment of the loop detector) with the value observed under normal conditions (hours without crashes). In other words, we were interested in finding out, for each road segment, whether the speed behaviour at hours where a crash occurred deviated from the speed behaviour during hours without crashes.

If the speed behaviour is indeed different, we postulate that speed may be a contributing factor to crashes. Note that, consistent with earlier research (*19, 20*), we do not refer to causality in our study but, rather, a correlation between speed and crashes, since the former would require knowledge about the speed behaviour of a particular vehicle involved in a crash; that is, the so-called "case-control" study approach. An important issue, however, is also how we calculate speed behavior under so-called "normal conditions."

Indeed, it is not a good idea to calculate the mean speed, speed variation and the proportion of vehicles travelling at excessive speed simply over all hours of the year in which no crashes occurred. Obviously, traffic exposure differs significantly per hour and per day, and thus the overall mean speed over the past year at a particular segment would not be a good indicator for the expected mean speed at a particular hour of a particular day at which a crash occurred. Therefore, if a crash occurred on a Tuesday morning at 8 o'clock on a particular road segment, we compared the speed variables at that particular day, time and location with the average speed variables calculated for that location over all Tuesdays at 8 o'clock in the morning. In other words, we compared the values of each speed variable for a particular loop detector at the time of a crash with the average speed values calculated for that loop detector over the last year for the same day of the week, and at the same hour of the day when no crashes occurred. In addition, exactly the same analysis was carried out at the hour preceding the hour of the crash, since our expectation was that the crash itself would influence the measured speed during the hour in which the crash occurred due to ensuing congestion. The speed measured during the hour preceding the hour of the crash may therefore be more representative for the speed behavior of the vehicles at the actual time of the crash.

To rule out as many intervening effects as possible, the speed behavior analysis was carried out separately for road segments with different speed limits (50-70-80 km/h), for segments inside and outside the built-up area, and, finally, a distinction was also drawn between municipal and provincial road segments. This enables us to compare groups of road segments that are as homogeneous as possible with respect to other observable differences. Additionally, it offers the opportunity to compare the results between the different groups, which is important from a policy perspective; for instance, does speed behaviour correlate differently with crashes on 50, 70 and 80 km/h roads?

Table 1 shows a comparison of the results concerning the relationship between different aspects of speed, traffic intensity and crashes for the different groups of road segments at the hours when road crashes occurred. The table shows results both for vehicles under and over 5.2 meters in length. Some interesting conclusions can be drawn. Firstly, but not surprisingly, traffic intensity accounts for most of the variance in relation to crashes, and this is valid for the intensity of both small and large vehicles. Indeed, compared to the speed variables in the table, more crashes occurred at hours when the intensity of the traffic was above-average on the respective road segments where they took place. For example, 54.78% of the crashes (53 out of 115) inside the built-up area occurred during hours when the traffic intensity of vehicles under 5.2 meters in length was above-average on the respective road segments where they took place.

< INSERT TABLE 1 HERE>

Despite a few exceptions, this percentage is consistently higher than for the speed variables (e.g. 40.87% for absolute speed, 27.82% for excessive speeding and 46.09% for speed variance), which indicates that traffic intensity is certainly the largest contributing factor in terms of explaining crashes.

With respect to the speed variables, analysis of the results in Table 1 shows that, on average, the variable speed variation between small vehicles is more dominant relative to the other speed-related variables (absolute speed and excessive speeding). Furthermore, speed variation becomes more important in explaining road crashes as the road’s legal speed limit increases. Indeed, when looking at the speed variation, crashes tend to occur more frequently when the variation in small vehicle speeds exceeds the normal speed variation on the respective road segments where the crashes occurred. For instance, on 50 km/h roads, 40.91% of the crashes occurred at hours when the variation in speeds between small vehicles exceeded the variation that is observed on average. This amount increases as the road’s legal speed limit increases: 49.35% on 70 km/h roads and 68.75% on 80 km/h roads. In other words, the results tend to support the conclusion that variations in speed between small vehicles are correlated more heavily with crashes on roads with higher speed limits. By contrast, the correlation between crashes and the actual speed as well as excessive speeding tends to decrease as the road’s legal speed limit increases. For instance, Table 1 shows that on 50 km/h roads 43.18% of the crashes tended to occur at hours when the average actual speed of small vehicles was above the overall average observed on those road segments. This number decreases as the road’s legal speed limit increases. Indeed, on 70 km/h roads, this number decreases to 37.66% and on 80 km/h roads it decreases further to 18.75%.

Somewhat similar results can be drawn for the variable that measures the proportion of small vehicles travelling at excessive speeds. Table 1 shows that on 50 km/h roads, 31.82% of the crashes occurred during hours when the proportion of vehicles travelling at excessive speeds was higher than average on those road segments where the crashes occurred. For 70 km/h roads and 80 km/h roads, one can observe a significant drop, namely 25.95% and 12.5% respectively. In other words, the proportion of vehicles travelling at excessive speeds seems less correlated with the number of crashes on 80 km/h roads than on 50 and 70 km/h roads.

In summary of the above findings, they tend to support the conclusion that it is not the absolute speed or the proportion of excessive speeders amongst small vehicles that correlates more with the number of crashes on roads with higher speed limits. Instead, the speed variation amongst the small vehicles plays a more important role. In fact, these conclusions are further supported when comparing roads inside and outside the built-up area. For small vehicles, 63.64% of the crashes outside the built-up area (mostly 70 and 80 km/h roads) occurred at hours when the speed variation was higher than average, whilst this is the case only for 46.09% of the crashes that occurred on road segments inside the built-up area (mostly 50 and 70 km/h roads). Again, the proportion of crashes occuring during hours with higher than average speeds or a higher proportion of vehicles travelling at excessive speeds amongst small vehicles is also lower outside the built-up area than inside the built-up area, which again confirms our earlier conclusions.

With respect to larger vehicles (over 5.2 meters in length), the analysis does not arrive at entirely the same conclusions. In fact, Table 1 shows that, with respect to heavy vehicles, traffic intensity correlates differently with crashes depending on the road's legal speed limit. Indeed, as the road's legal speed limit increases, a higher proportion of crashes tend to occur at hours when the intensity of heavy traffic is above average on the respective road segments where those crashes occurred. For instance, on 80 km/h roads, 62.5% of the crashes occurred at hours when the intensity of heavy traffic was higher than average, whilst for 50 and 70 km/h roads this proportion is only 50.0% and 49.35% respectively. Also, the absolute speed of heavy vehicles plays a rather different role in relation to crashes when looking at different road types. Indeed, where for small vehicles we found an inverse correlation between absolute speed and the road's legal speed limit, this is exactly the opposite for large vehicles. Inside the built-up area, 37.39% of the crashes occurred at hours when the absolute speed of large vehicles was higher than average, whereas this figure amounts to 54.54% on road segments outside the built-up area.

As mentioned earlier, in order to rule out the possible effect of traffic congestion due to a crash on the traffic intensity and speeds measured at the hour of the crash, we also calculated the same figures for the hour preceding the crashes, as we expect these measurements to be more representative to approximate the real circumstances before a crash. The results of this analysis are presented in Table 2.

< INSERT TABLE 2 HERE>

It is interesting to discover that the conclusions found for small vehicles in Table 1 also hold true for Table 2. Yet, the conclusions found for large vehicles in Table 1 are not always supported by Table 2. In fact, they are more consistent with the conclusions found for small vehicles. Conclusions with respect to large vehicles are therefore difficult to make.

At this point, we should emphasize that the above results are based on a relatively small sample of road segments, in a limited study area and with a limited number of crashes that are not equally dispersed across the different types of road segments. Especially for those types of road segments where only a small number of crashes occurred (e.g. provincial, 80 km/h roads), small changes in the number of crashes may lead to relatively large differences in the proportion of crashes reported in Tables 1 and 2. This may affect the significance of the quantitative differences found between the results of different road types. The external validity of the results should therefore be considered with great care. Nevertheless, based on the results in Tables 1 and 2, and by working closely with the data for a period of time, we believe that, qualitatively speaking, the correlations presented between traffic intensity, speed and crashes are quite consistent and hold considerable promise for further research.

5. CONCLUSION AND LIMITATIONS

Although this study is not exactly a cross-sectional study, it embodies several characteristics of one. Indeed, both real speed measurements and crashes are linked on the same road segment, whereas in many other studies this link cannot be made, for instance when interviewing drivers and linking their speed behavior to historical crash involvement. Furthermore, our study is based on a cross-section of road segments on different road types, i.e. inside and outside the built-up area, on municipal versus provincial roads, and for 50 km/h versus 70 km/h and 80 km/h roads. The foregoing having been said, however, it is not exactly a cross-sectional study in that only road segments on which at least one crash happened over the past two years were included. Future research efforts would therefore involve both segments with and without crashes within a larger geographical study area to contrast both groups in terms of speed behavior using a regression type of analysis.

In addition, we aim in our future work to draw distinctions between different crash types, i.e. crashes resulting in slight, serious or fatal injuries, or resulting only in material damage. As the objective of most government action with respect to traffic safety is in the first instance to reduce the number of serious injuries and fatalities, it is important to obtain a more detailed insight into the relationship between measured speeds and different crash types.

Finally, our results are also affected by the practices of placing and operating loop detectors. For instance, in the case of two-way roads with single segment identities, differences in crash and traffic counts cannot be separated for each driving direction, and are therefore aggregated in our study. This may limit the validity of the results found.

Nevertheless, we believe that our work contributes to the existing literature in several ways. Firstly, the results in this work make clear that the relationship between measured speed and crashes is influenced by road characteristics; for example, the same magnitude of difference in measured speed or traffic intensity has a different effect on crashes depending on the road's legal speed limit. Secondly, different aspects of speed correlate differently with regard to the occurrence of crashes, again depending on the road type. For instance, the results in this study tend to support the view that the variation in respective vehicle speeds correlates more strongly on roads with higher legal speed limits, whereas crashes on roads with lower legal speed limits occur more frequently at hours when vehicles drive faster than usual. Although this study is based on a limited number of data points in time, space and quantity of road segments, we believe that the results hold considerable promise in terms of supporting government decision-making if the findings can be confirmed in a larger study. For instance, government action aimed at increasing traffic safety on higher speed roads could then be targeted towards reducing the variation in speed of vehicles and harmonizing traffic flows. On the other hand, the findings in this study also tend to suggest that government action with respect to low-speed roads should focus more on reducing the number of vehicles travelling at excessive speeds and higher than average speeds by, for example, (automatic) speed enforcement.

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LIST OF TABLES AND FIGURES

FIGURE 1 Overview of loop detector positions (dots) on provincial and municipal roads in the Brabant southeast police region in the Netherlands.

FIGURE 2 Data architecture and relationship structure between data sources.

FIGURE 3 Loop detector configurations and allocation to road segments.

FIGURE 4 Loop detector configuration linked with the digital road network.

FIGURE 5 Location of a loop detector allocated to multiple road segments.

TABLE 1 Results with Respect to Traffic Intensity and Speed Compared for Different Groups of Road Segments at the Hour of a Crash

TABLE 2 Results with Respect to Traffic Intensity and Speed Compared for Different Groups of Road Segments at the Hour Preceding a Crash

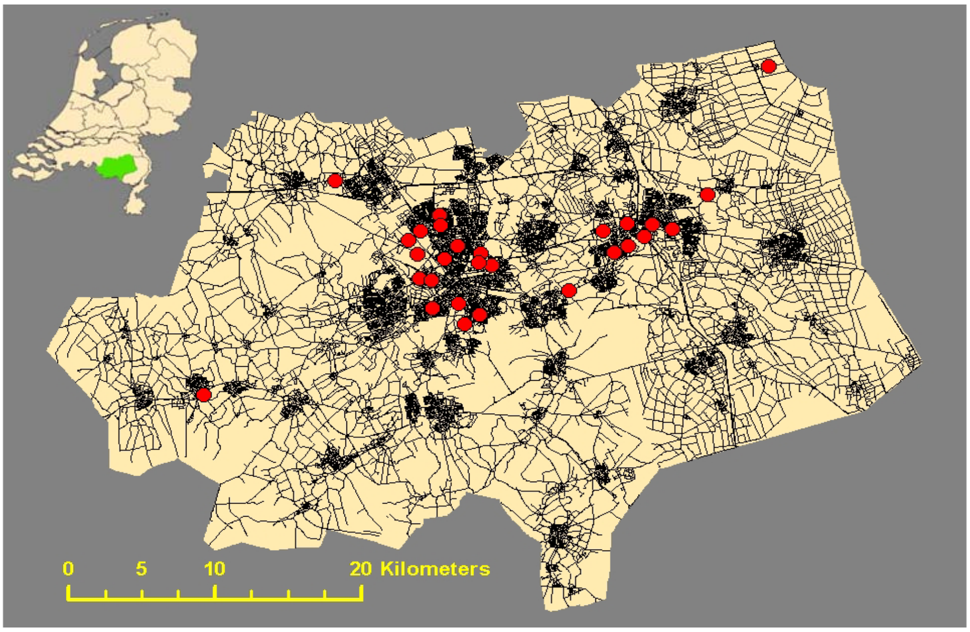

FIGURE 1 Overview of loop detector positions (dots) on provincial and municipal roads in the Brabant southeast police region in the Netherlands.

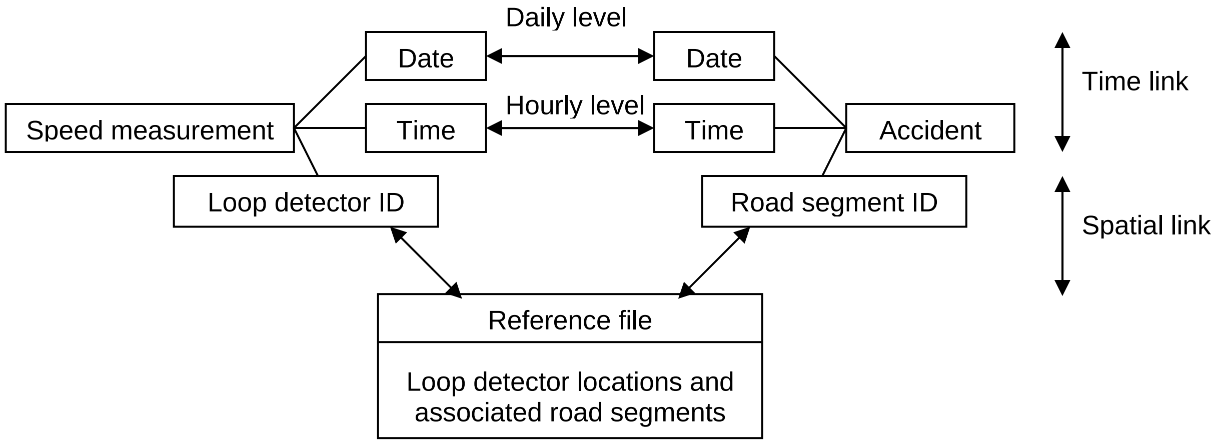

FIGURE 2 Data architecture and relationship structure between data sources.

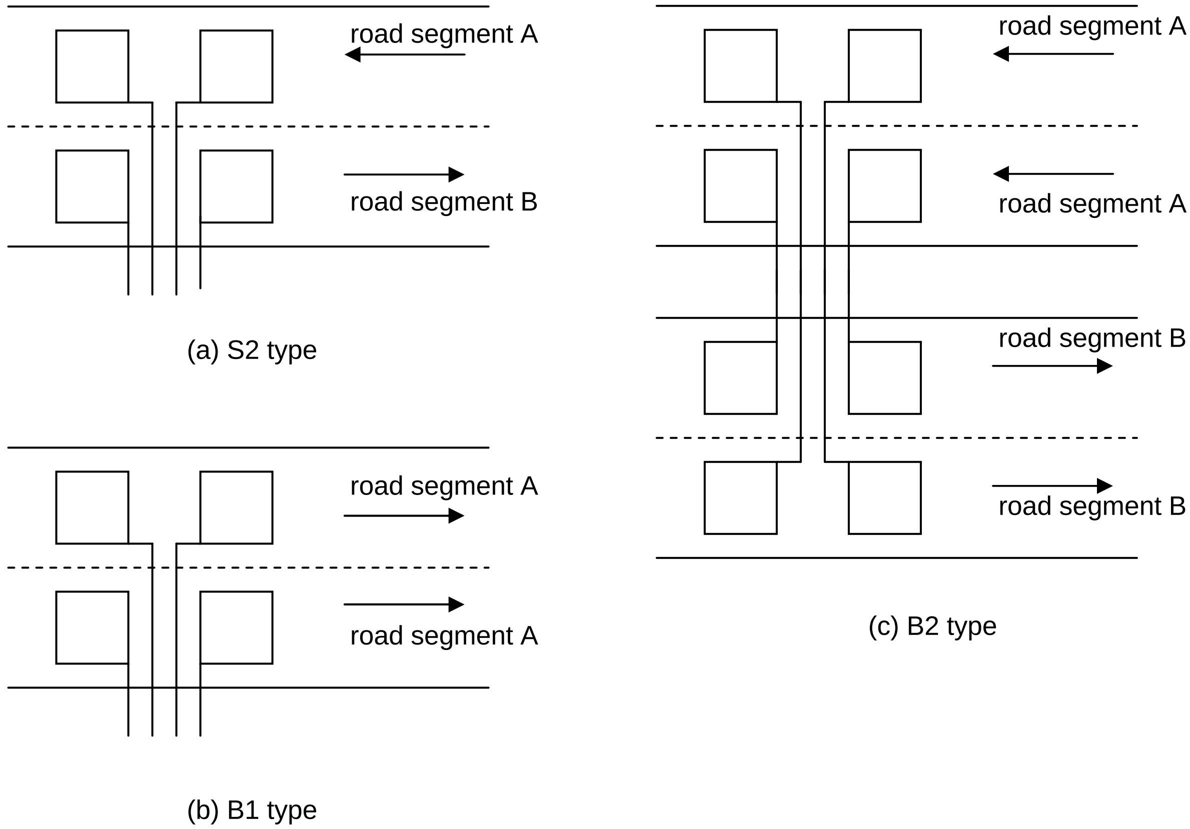

FIGURE 3 Loop detector configurations and allocation to road segments.

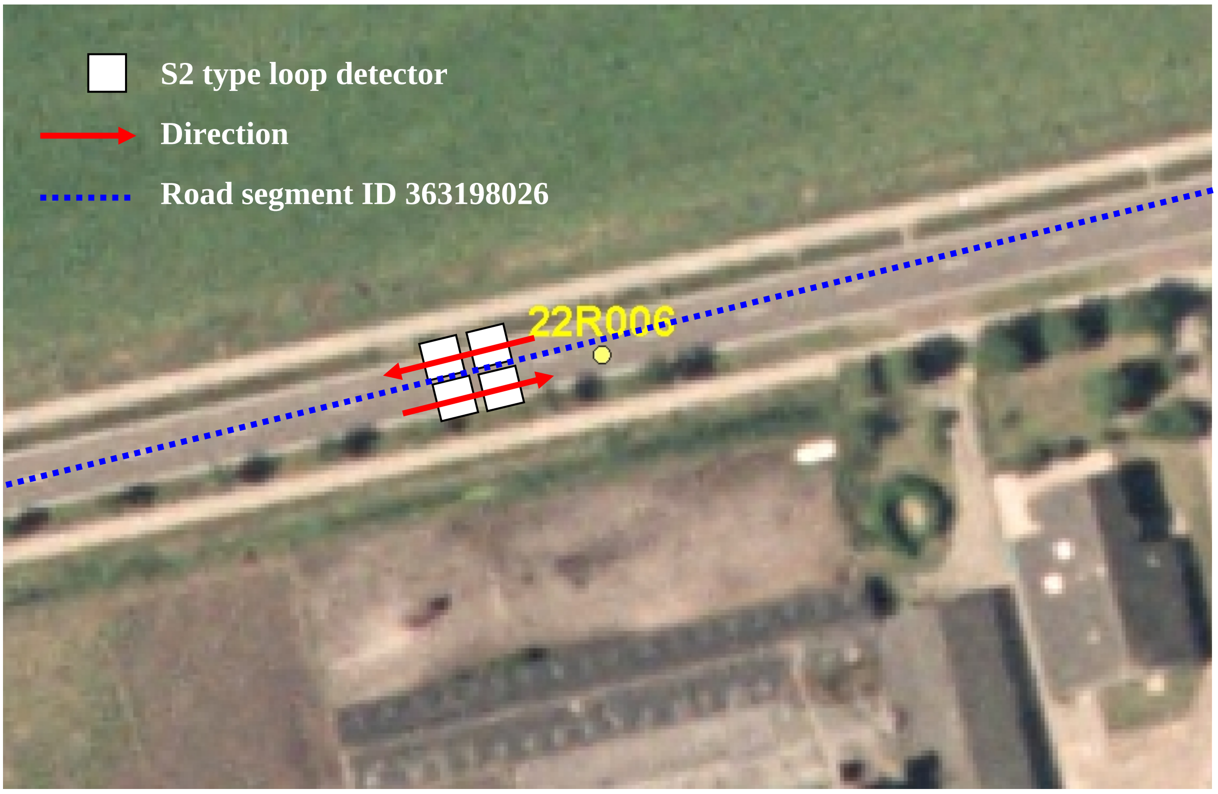

FIGURE 4 Loop detector configuration linked with the digital road network.

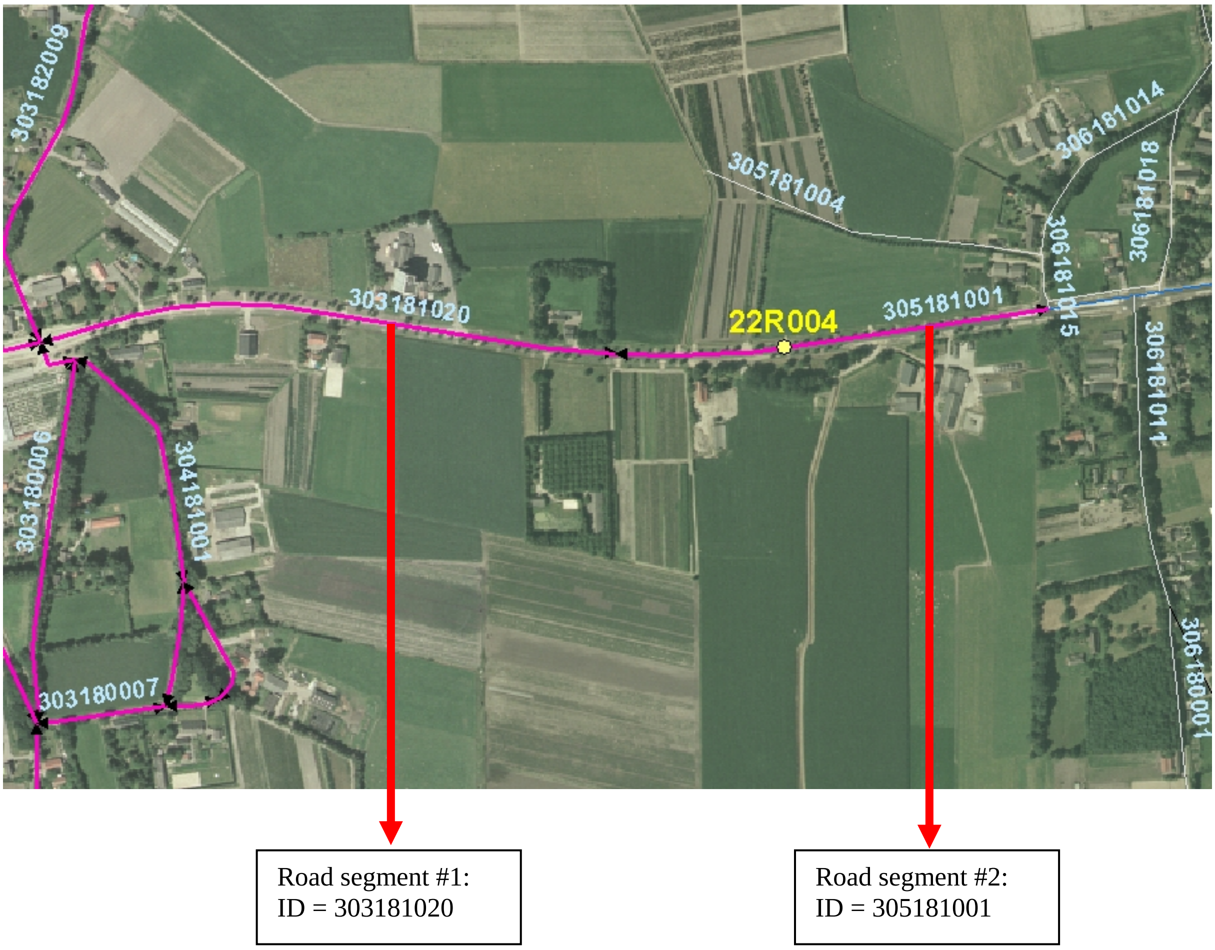

FIGURE 5 Location of a loop detector allocated to multiple road segments.

TABLE 1 Results with Respect to Traffic Intensity and Speed Compared for Different Groups of Road Segments at the Hour of a Crash

At the hour of a crash		Vehicles < 5.2 meters in length				Vehicles > 5.2 meters in length				
		Absolute speed above average	Excessive speeding above average	Speed variance above average	Traffic intensity above average	Absolute speed above average	Excessive speeding above average	Speed variance above average	Traffic intensity above average	Crashes
Inside/outside built-up area	**Inside**	47 *40.87%*	32 *27.82%*	53 *46.09%*	63 *54.78%*	43 *37.39%*	44 *38.26%*	52 *45.22%*	57 *49.56%*	115
	Outside	4 *18.18%*	4 *18.18%*	14 *63.64%*	12 *54.54%*	12 *54.54%*	6 *27.27%*	9 *40.91%*	13 *59.09%*	22
	Difference	**22.69%**	**9.64%**	**-17.55%**	**-0.24%**	**-17.15%**	**10.99%**	**4.31%**	**-9.53%**	
Road authority	**Municipalit y**	49 *38.28%*	34 *26.56%*	61 *47.66%*	71 *55.47%*	52 *40.62%*	48 *37.5%*	57 *44.53%*	64 *50%*	128
	Province	2 *22.22%*	2 *22.22%*	6 *66.67%*	4 *44.44%*	3 *33.33%*	2 *22.22%*	4 *44.44%*	6 *66.67%*	9
	Difference	**16.06%**	**4.34%**	**-19.01%**	**11.03%**	**7.29%**	**15.28%**	**0.09%**	**-16.67%**	
Legal speed limit	**50 km/h**	19 *43.18%*	14 *31.82%*	18 *40.91%*	25 *56.82%*	16 *36.36%*	19 *43.18%*	22 *50.00%*	22 *50.00%*	44
	70 km/h	29 *37.66%*	20 *25.97%*	38 *49.35%*	41 *53.25%*	32 *41.56%*	26 *33.77%*	32 *41.56%*	38 *49.35%*	77
	Difference	**5.52%**	**5.85%**	**-8.44%**	**3.57%**	**-5.2%**	**9.41%**	**8.44%**	**0.65%**	
	50 km/h	19 *43.18%*	14 *31.82%*	18 *40.91%*	25 *56.82%*	16 *36.36%*	19 *43.18%*	22 *50.00%*	22 *50.00%*	44
	80 km/h	3 *18.75%*	2 *12.5%*	11 *68.75%*	9 *56.25%*	7 *43.75%*	5 *31.25%*	7 *43.75%*	10 *62.5%*	16
	Difference	**24.43%**	**19.32%**	**-27.84%**	**0.57%**	**-7.39%**	**11.93%**	**6.25%**	**-12.5%**	
	70 km/h	29 *37.66%*	20 *25.97%*	38 *49.35%*	41 *53.25%*	32 *41.56%*	26 *33.77%*	32 *41.56%*	38 *49.35%*	77
	80 km/h	3 *18.75%*	2 *12.5%*	11 *68.75%*	9 *56.25%*	7 *43.75%*	5 *31.25%*	7 *43.75%*	10 *62.5%*	16
	Difference	**18.91%**	**13.47%**	**-19.40%**	**-3.00%**	**-2.19%**	**2.52%**	**-2.19%**	**-13.15%**	

TABLE 2 Results with Respect to Traffic Intensity and Speed Compared for Different Groups of Road Segments at the Hour Preceding a Crash

At the hour preceding a crash		Vehicles < 5.2 meters in length				Vehicles > 5.2 meters in length				
		Absolute speed above average	**Excessive speeding above average**	**Speed variance above average**	**Traffic intensity above average**	**Absolute speed above average**	**Excessive speeding above average**	**Speed variance above average**	**Traffic intensity above average**	**Crashes**
Inside/outside built-up area	**Inside**	46 *40.0%*	43 *37.39%*	42 *36.52%*	73 *63.48%*	63 *54.78%*	38 *33.04%*	43 *37.39%*	64 *55.65%*	115
	Outside	8 *36.36%*	2 *9.09%*	10 *45.45%*	14 *63.64%*	8 *36.36%*	7 *31.82%*	8 *36.36%*	13 *59.09%*	22
	Difference	**3.64%**	**28.3%**	**-8.93%**	**-0.16%**	**18.42%**	**1.22%**	**1.03%**	**-3.44%**	
Road authority	**Municipality**	49 *38.28%*	44 *34.37%*	47 *36.72%*	81 *63.28%*	66 *51.56%*	42 *32.81%*	48 *37.5%*	72 *56.25%*	128
	Province	5 *55.55%*	1 *11.11%*	5 *55.55%*	6 *66.67%*	5 *55.55%*	3 *33.33%*	3 *33.33%*	5 *55.55%*	9
	Difference	**-17.27%**	**23.26%**	**-18.83%**	**-3.39%**	**-3.99%**	**-0.52%**	**4.17%**	**0.7%**	
Legal speed limit	**50 km/h**	21 *47.73%*	18 *40.91%*	14 *31.82%*	30 *68.18%*	23 *52.27%*	17 *38.64%*	19 *43.18%*	31 *70.45%*	44
	70 km/h	27 *35.06%*	26 *33.77%*	29 *37.66%*	46 *59.74%*	42 *54.54%*	25 *32.47%*	27 *35.06%*	37 *48.05%*	77
	Difference	**12.67%**	**7.14%**	**-5.84%**	**8.44%**	**-2.27%**	**6.17%**	**8.12%**	**22.4%**	
	50 km/h	21 *47.73%*	18 *40.91%*	14 *31.82%*	30 *68.18%*	23 *52.27%*	17 *38.64%*	19 *43.18%*	31 *70.45%*	44
	80 km/h	6 *37.5%*	1 *6.25%*	9 *56.25%*	11 *68.75%*	6 *37.5%*	3 *18.75%*	5 *31.25%*	9 *56.25%*	16
	Difference	**10.23%**	**34.66%**	**-24.43%**	**-0.57%**	**14.77%**	**19.89%**	**11.93%**	**14.2%**	
	70 km/h	27 *35.06%*	26 *33.77%*	29 *37.66%*	46 *59.74%*	42 *54.54%*	25 *32.47%*	27 *35.06%*	37 *48.05%*	77
	80 km/h	6 *37.5%*	1 *6.25%*	9 *56.25%*	11 *68.75%*	6 *37.5%*	3 *18.75%*	5 *31.25%*	9 *56.25%*	16
	Difference	**-2.44%**	**27.52%**	**-18.59%**	**-9.01%**	**17.04%**	**13.72%**	**3.81%**	**-8.2%**	